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EUROPEAN COMMISSION
Innovation and Networks Executive Agency

Director

GRANT AGREEMENT

NUMBER 814945 — SolBio-Rev

This **Agreement** ('the Agreement') is **between** the following parties:

on the one part,

the **Innovation and Networks Executive Agency (INEA)** ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

represented for the purposes of signature of this Agreement by Head of Department H2020, Innovation and Networks Executive Agency, H2020 Department for all technical projects and grant agreements , Alan HAIGH,

and

on the other part,

1. 'the coordinator':

NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA (NTUA), established in HEROON POLYTECHNIOU 9 ZOGRAPHOU CAMPUS, ATHINA 15780, Greece, VAT number: EL099793475, represented for the purposes of signing the Agreement by Vice - Rector for Financial Planning and Development, Ioannis PASPALIARIS

and the following other beneficiaries, if they sign their 'Accession Form' (see Annex 3 and Article 56):

2. **FRIEDRICH-ALEXANDER-UNIVERSITAET ERLANGEN NUERNBERG (FAU)**, established in SCHLOSSPLATZ 4, ERLANGEN 91054, Germany, VAT number: DE132507686,

3. **FAHRENHEIT GMBH (FAHREN)**, established in SIEGFRIEDSTR 19, MUNCHEN 80803, Germany, VAT number: DE221337150,

4. **CONSIGLIO NAZIONALE DELLE RICERCHE (ITAE)**, established in PIAZZALE ALDO MORO 7, ROMA 00185, Italy, VAT number: IT02118311006,

5. **T.E.A.V.E LTD (TEAVE)**, established in 16, TAXIARCHON STR., PALEO FALIRO 17563, Greece, VAT number: EL095304865,

6. **AKOTEC PRODUKTIONSGESELLSCHAFT MBH (AKOTEC)**, established in GRUNDMUHLENWEG 3, ANGERMUNDE 16278, Germany, VAT number: DE258392653,

7. **UNIVERSIDAD DE LLEIDA (UDL)**, established in Placa Victor Siurana 1 1, LLEIDA 25003, Spain, VAT number: ESQ7550001G,

8. **DAIKIN AIRCONDITIONING HELLAS SA (Daikin)**, established in AGIOU KONSTANTINOU 50, MAROUSI 15124, Greece, VAT number: EL999211196,

9. **THE UNIVERSITY OF SUSSEX (UOS)**, established in SUSSEX HOUSE FALMER, BRIGHTON BN1 9RH, United Kingdom, VAT number: GB692712320,

10. **DBC EUROPE (DBC)**, established in ROND POINT ROBERT SCHUMAN 6, BRUXELLES 1040, Belgium, VAT number: BE0631731009,

11. **TECHLINK ASBL (TECH)**, established in JOSEPH CHANTRAINEPLANTSOEN 1, KORTENBERG 3070, Belgium, VAT number: BE0682796163,

12. **KARLSRUHER INSTITUT FUER TECHNOLOGIE (KIT)**, established in KAISERSTRASSE 12, KARLSRUHE 76131, Germany, VAT number: DE266749428,

13. **OKOFEN FORSCHUNGS-UND ENTWICKLUNGSG (OKOFEN)**, established in GEWERBEPARK 1, NIEDERKAPPEL 4133, Austria, VAT number: ATU23808501,

14. **STRABAG BELGIUM (STRABAG)**, established in NOORDERLAAN 139, ANTWERPEN 2030, Belgium, VAT number: BE0472028526,

15. **UNIVERSITA DEGLI STUDI DI MESSINA (UNIME)**, established in PIAZZA PUGLIATTI 1, MESSINA 98122, Italy, VAT number: IT00724160833,

Unless otherwise specified, references to ‘beneficiary’ or ‘beneficiaries’ include the coordinator.

The parties referred to above have agreed to enter into the Agreement under the terms and conditions below.

By signing the Agreement or the Accession Form, the beneficiaries accept the grant and agree to implement it under their own responsibility and in accordance with the Agreement, with all the obligations and conditions it sets out.

The Agreement is composed of:

Terms and Conditions

Annex 1 Description of the action

Annex 2 Estimated budget for the action

2a Additional information on the estimated budget

Annex 3 Accession Forms

Annex 4 Model for the financial statements

Annex 5 Model for the certificate on the financial statements

Annex 6 Model for the certificate on the methodology

TERMS AND CONDITIONS

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CHAPTER 1 GENERAL

ARTICLE 1 — SUBJECT OF THE AGREEMENT

This Agreement sets out the rights and obligations and the terms and conditions applicable to the grant awarded to the beneficiaries for implementing the action set out in Chapter 2.

CHAPTER 2 ACTION

ARTICLE 2 — ACTION TO BE IMPLEMENTED

The grant is awarded for the action entitled '**Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings**' — '**SolBio-Rev**' **('action')**, as described in Annex 1.

ARTICLE 3 — DURATION AND STARTING DATE OF THE ACTION

The duration of the action will be **48 months** as of 1 May 2019 ('**starting date of the action**').

ARTICLE 4 — ESTIMATED BUDGET AND BUDGET TRANSFERS

4.1 Estimated budget

The '**estimated budget**' for the action is set out in Annex 2.

It contains the estimated eligible costs and the forms of costs, broken down by beneficiary and budget category (see Articles 5, 6).

4.2 Budget transfers

The estimated budget breakdown indicated in Annex 2 may be adjusted — without an amendment (see Article 55) — by transfers of amounts between beneficiaries, budget categories and/or forms of costs set out in Annex 2, if the action is implemented as described in Annex 1.

However, the beneficiaries may not add costs relating to subcontracts not provided for in Annex 1, unless such additional subcontracts are approved by an amendment or in accordance with Article 13.

CHAPTER 3 GRANT

ARTICLE 5 — GRANT AMOUNT, FORM OF GRANT, REIMBURSEMENT RATES AND FORMS OF COSTS

5.1 Maximum grant amount

The '**maximum grant amount**' is **EUR 4 790 536.25** (four million seven hundred and ninety thousand five hundred and thirty six EURO and twenty five eurocents).

5.2 Form of grant, reimbursement rates and forms of costs

The grant reimburses **100% of the action's eligible costs** (see Article 6) ('**reimbursement of eligible costs grant**') (see Annex 2).

The estimated eligible costs of the action are EUR **4 790 536.25** (four million seven hundred and ninety thousand five hundred and thirty six EURO and twenty five eurocents).

Eligible costs (see Article 6) must be declared under the following forms ('**forms of costs**'):

(a) for **direct personnel costs**:

- as actually incurred costs ('**actual costs**') or
- on the basis of an amount per unit calculated by the beneficiary in accordance with its usual cost accounting practices ('**unit costs**').

Personnel **costs for SME owners** or **beneficiaries that are natural persons** not receiving a salary (see Article 6.2, Points A.4 and A.5) must be declared on the basis of the amount per unit set out in Annex 2a (**unit costs**);

(b) for **direct costs for subcontracting**: as actually incurred costs (**actual costs**);

(c) for **direct costs of providing financial support to third parties**: not applicable;

(d) for **other direct costs**:

- for costs of internally invoiced goods and services: on the basis of an amount per unit calculated by the beneficiary in accordance with its usual cost accounting practices ('**unit costs**');
- for all other costs: as actually incurred costs (**actual costs**);

(e) for **indirect costs**: on the basis of a flat-rate applied as set out in Article 6.2, Point E ('**flat-rate costs**');

(f) **specific cost category(ies):** not applicable.

5.3 Final grant amount — Calculation

The '**final grant amount**' depends on the actual extent to which the action is implemented in accordance with the Agreement's terms and conditions.

This amount is calculated by the Agency — when the payment of the balance is made (see Article 21.4) — in the following steps:

Step 1 — Application of the reimbursement rates to the eligible costs

Step 2 — Limit to the maximum grant amount

Step 3 — Reduction due to the no-profit rule

Step 4 — Reduction due to substantial errors, irregularities or fraud or serious breach of obligations

5.3.1 Step 1 — Application of the reimbursement rates to the eligible costs

The reimbursement rate(s) (see Article 5.2) are applied to the eligible costs (actual costs, unit costs and flat-rate costs; see Article 6) declared by the beneficiaries (see Article 20) and approved by the Agency (see Article 21).

5.3.2 Step 2 — Limit to the maximum grant amount

If the amount obtained following Step 1 is higher than the maximum grant amount set out in Article 5.1, it will be limited to the latter.

5.3.3 Step 3 — Reduction due to the no-profit rule

The grant must not produce a profit.

'**Profit**' means the surplus of the amount obtained following Steps 1 and 2 plus the action's total receipts, over the action's total eligible costs.

The '**action's total eligible costs**' are the consolidated total eligible costs approved by the Agency.

The '**action's total receipts**' are the consolidated total receipts generated during its duration (see Article 3).

The following are considered **receipts**:

(a) income generated by the action; if the income is generated from selling equipment or other assets purchased under the Agreement, the receipt is up to the amount declared as eligible under the Agreement;

(b) financial contributions given by third parties to the beneficiary specifically to be used for the action, and

(c) in-kind contributions provided by third parties free of charge and specifically to be used for the action, if they have been declared as eligible costs.

The following are however not considered receipts:

(a) income generated by exploiting the action's results (see Article 28);

(b) financial contributions by third parties, if they may be used to cover costs other than the eligible costs (see Article 6);

(c) financial contributions by third parties with no obligation to repay any amount unused at the end of the period set out in Article 3.

If there is a profit, it will be deducted from the amount obtained following Steps 1 and 2.

5.3.4 Step 4 — Reduction due to substantial errors, irregularities or fraud or serious breach of obligations — Reduced grant amount — Calculation

If the grant is reduced (see Article 43), the Agency will calculate the reduced grant amount by deducting the amount of the reduction (calculated in proportion to the seriousness of the errors,

irregularities or fraud or breach of obligations, in accordance with Article 43.2) from the maximum grant amount set out in Article 5.1.

The final grant amount will be the lower of the following two:

- the amount obtained following Steps 1 to 3 or
- the reduced grant amount following Step 4.

5.4 Revised final grant amount — Calculation

If — after the payment of the balance (in particular, after checks, reviews, audits or investigations; see Article 22) — the Agency rejects costs (see Article 42) or reduces the grant (see Article 43), it will calculate the '**revised final grant amount**' for the beneficiary concerned by the findings.

This amount is calculated by the Agency on the basis of the findings, as follows:

- in case of **rejection of costs**: by applying the reimbursement rate to the revised eligible costs approved by the Agency for the beneficiary concerned;
- in case of **reduction of the grant**: by calculating the concerned beneficiary's share in the grant amount reduced in proportion to the seriousness of the errors, irregularities or fraud or breach of obligations (see Article 43.2).

In case of **rejection of costs and reduction of the grant**, the revised final grant amount for the beneficiary concerned will be the lower of the two amounts above.

ARTICLE 6 — ELIGIBLE AND INELIGIBLE COSTS

6.1 General conditions for costs to be eligible

'**Eligible costs**' are costs that meet the following criteria:

(a) for **actual costs**:

(i) they must be actually incurred by the beneficiary;

(ii) they must be incurred in the period set out in Article 3, with the exception of costs relating to the submission of the periodic report for the last reporting period and the final report (see Article 20);

(iii) they must be indicated in the estimated budget set out in Annex 2;

(iv) they must be incurred in connection with the action as described in Annex 1 and necessary for its implementation;

(v) they must be identifiable and verifiable, in particular recorded in the beneficiary's accounts in accordance with the accounting standards applicable in the country where the beneficiary is established and with the beneficiary's usual cost accounting practices;

(vi) they must comply with the applicable national law on taxes, labour and social security, and

(vii) they must be reasonable, justified and must comply with the principle of sound financial management, in particular regarding economy and efficiency;

(b) for **unit costs**:

(i) they must be calculated as follows:

{amounts per unit set out in Annex 2a or calculated by the beneficiary in accordance with its usual cost accounting practices (see Article 6.2, Point A and Article 6.2.D.5)

multiplied by

the number of actual units};

(ii) the number of actual units must comply with the following conditions:

- the units must be actually used or produced in the period set out in Article 3;
- the units must be necessary for implementing the action or produced by it, and
- the number of units must be identifiable and verifiable, in particular supported by records and documentation (see Article 18);

(c) for **flat-rate costs**:

(i) they must be calculated by applying the flat-rate set out in Annex 2, and

(ii) the costs (actual costs or unit costs) to which the flat-rate is applied must comply with the conditions for eligibility set out in this Article.

6.2 Specific conditions for costs to be eligible

Costs are eligible if they comply with the general conditions (see above) and the specific conditions set out below for each of the following budget categories:

A. direct personnel costs;
B. direct costs of subcontracting;
C. not applicable;
D. other direct costs;
E. indirect costs;
F. not applicable.

'Direct costs' are costs that are directly linked to the action implementation and can therefore be attributed to it directly. They must not include any indirect costs (see Point E below).

'Indirect costs' are costs that are not directly linked to the action implementation and therefore cannot be attributed directly to it.

A. Direct personnel costs

<u>Types of eligible personnel costs</u>

A.1 Personnel costs are eligible, if they are related to personnel working for the beneficiary under an employment contract (or equivalent appointing act) and assigned to the action ('**costs for employees (or equivalent)**'). They must be limited to salaries (including during parental leave), social security contributions, taxes and other costs included in the **remuneration**, if they arise from national law or the employment contract (or equivalent appointing act).

Beneficiaries that are non-profit legal entities[1] may also declare as personnel costs **additional remuneration** for personnel assigned to the action (including payments on the basis of supplementary contracts regardless of their nature), if:

(a) it is part of the beneficiary's usual remuneration practices and is paid in a consistent manner whenever the same kind of work or expertise is required;

(b) the criteria used to calculate the supplementary payments are objective and generally applied by the beneficiary, regardless of the source of funding used.

'Additional remuneration' means any part of the remuneration which exceeds what the person would be paid for time worked in projects funded by national schemes.

Additional remuneration for personnel assigned to the action is eligible up to the following amount:

(a) if the person works full time and exclusively on the action during the full year: up to EUR 8 000;

(b) if the person works exclusively on the action but not full-time or not for the full year: up to the corresponding pro-rata amount of EUR 8 000, or

(c) if the person does not work exclusively on the action: up to a pro-rata amount calculated as follows:

{{EUR 8 000

divided by

the number of annual productive hours (see below)},

multiplied by

the number of hours that the person has worked on the action during the year}.

A.2 The **costs for natural persons working under a direct contract** with the beneficiary other than an employment contract are eligible personnel costs, if:

(a) the person works under conditions similar to those of an employee (in particular regarding the way the work is organised, the tasks that are performed and the premises where they are performed);

(b) the result of the work carried out belongs to the beneficiary (unless exceptionally agreed otherwise), and

[1] For the definition, see Article 2.1(14) of the Rules for Participation Regulation No 1290/2013: '**non-profit legal entity**' means a legal entity which by its legal form is non-profit-making or which has a legal or statutory obligation not to distribute profits to its shareholders or individual members.

(c) the costs are not significantly different from those for personnel performing similar tasks under an employment contract with the beneficiary.

A.3 The **costs of personnel seconded by a third party against payment** are eligible personnel costs, if the conditions in Article 11.1 are met.

A.4 **Costs of owners** of beneficiaries that are small and medium-sized enterprises ('**SME owners**') who are working on the action and who do not receive a salary are eligible personnel costs, if they correspond to the amount per unit set out in Annex 2a multiplied by the number of actual hours worked on the action.

A.5 **Costs of 'beneficiaries that are natural persons'** not receiving a salary are eligible personnel costs, if they correspond to the amount per unit set out in Annex 2a multiplied by the number of actual hours worked on the action.

Calculation

Personnel costs must be calculated by the beneficiaries as follows:

{{hourly rate

multiplied by

the number of actual hours worked on the action},

plus

for non-profit legal entities: additional remuneration to personnel assigned to the action under the conditions set out above (Point A.1)}.

The number of actual hours declared for a person must be identifiable and verifiable (see Article 18).

The total number of hours declared in EU or Euratom grants, for a person for a year, cannot be higher than the annual productive hours used for the calculations of the hourly rate. Therefore, the maximum number of hours that can be declared for the grant are:

{number of annual productive hours for the year (see below)

minus

total number of hours declared by the beneficiary, for that person in that year, for other EU or Euratom grants}.

The '**hourly rate**' is one of the following:

(a) for personnel costs declared as **actual costs** (i.e. budget categories A.1, A.2, A.3): the hourly rate is calculated *per full financial year*, as follows:

{actual annual personnel costs (excluding additional remuneration) for the person

divided by

number of annual productive hours}.

using the personnel costs and the number of productive hours for each full financial year covered by the reporting period concerned. If a financial year is not closed at the end of the

reporting period, the beneficiaries must use the hourly rate of the last closed financial year available.

For the 'number of annual productive hours', the beneficiaries may choose one of the following:

(i) 'fixed number of hours': 1 720 hours for persons working full time (or corresponding pro-rata for persons not working full time);

(ii) 'individual annual productive hours': the total number of hours worked by the person in the year for the beneficiary, calculated as follows:

{annual workable hours of the person (according to the employment contract, applicable collective labour agreement or national law)

plus

overtime worked

minus

absences (such as sick leave and special leave)}.

'Annual workable hours' means the period during which the personnel must be working, at the employer's disposal and carrying out his/her activity or duties under the employment contract, applicable collective labour agreement or national working time legislation.

If the contract (or applicable collective labour agreement or national working time legislation) does not allow to determine the annual workable hours, this option cannot be used;

(iii) 'standard annual productive hours': the 'standard number of annual hours' generally applied by the beneficiary for its personnel in accordance with its usual cost accounting practices. This number must be at least 90% of the 'standard annual workable hours'.

If there is no applicable reference for the standard annual workable hours, this option cannot be used.

For all options, the actual time spent on **parental leave** by a person assigned to the action may be deducted from the number of annual productive hours.

As an alternative, beneficiaries may calculate the hourly rate *per month*, as follows:

{actual monthly personnel cost (excluding additional remuneration) for the person

divided by

{number of annual productive hours / 12}}

using the personnel costs for each month and (one twelfth of) the annual productive hours calculated according to either option (i) or (iii) above, i.e.:

- fixed number of hours or
- standard annual productive hours.

Time spent on **parental leave** may not be deducted when calculating the hourly rate per month. However, beneficiaries may declare personnel costs incurred in periods of parental leave in proportion to the time the person worked on the action in that financial year.

If parts of a basic remuneration are generated over a period longer than a month, the beneficiaries may include only the share which is generated in the month (irrespective of the amount actually paid for that month).

Each beneficiary must use only one option (per full financial year or per month) for each full financial year;

(b) for personnel costs declared on the basis of **unit costs** (i.e. budget categories A.1, A.2, A.4, A.5): the hourly rate is one of the following:

(i) for SME owners or beneficiaries that are natural persons: the hourly rate set out in Annex 2a (see Points A.4 and A.5 above), or

(ii) for personnel costs declared on the basis of the beneficiary's usual cost accounting practices: the hourly rate calculated by the beneficiary in accordance with its usual cost accounting practices, if:

- the cost accounting practices used are applied in a consistent manner, based on objective criteria, regardless of the source of funding;

- the hourly rate is calculated using the actual personnel costs recorded in the beneficiary's accounts, excluding any ineligible cost or costs included in other budget categories.

  The actual personnel costs may be adjusted by the beneficiary on the basis of budgeted or estimated elements. Those elements must be relevant for calculating the personnel costs, reasonable and correspond to objective and verifiable information;

and

- the hourly rate is calculated using the number of annual productive hours (see above).

B. Direct costs of subcontracting (including related duties, taxes and charges such as non-deductible value added tax (VAT) paid by the beneficiary) are eligible if the conditions in Article 13.1.1 are met.

C. Direct costs of providing financial support to third parties

Not applicable

D. Other direct costs

D.1 **Travel costs and related subsistence allowances** (including related duties, taxes and charges such as non-deductible value added tax (VAT) paid by the beneficiary) are eligible if they are in line with the beneficiary's usual practices on travel.

D.2 The **depreciation costs of equipment, infrastructure or other assets** (new or second-hand) as recorded in the beneficiary's accounts are eligible, if they were purchased in accordance with

Article 10.1.1 and written off in accordance with international accounting standards and the beneficiary's usual accounting practices.

The **costs of renting or leasing** equipment, infrastructure or other assets (including related duties, taxes and charges such as non-deductible value added tax (VAT) paid by the beneficiary) are also eligible, if they do not exceed the depreciation costs of similar equipment, infrastructure or assets and do not include any financing fees.

The costs of equipment, infrastructure or other assets **contributed in-kind against payment** are eligible, if they do not exceed the depreciation costs of similar equipment, infrastructure or assets, do not include any financing fees and if the conditions in Article 11.1 are met.

The only portion of the costs that will be taken into account is that which corresponds to the duration of the action and rate of actual use for the purposes of the action.

D.3 **Costs of other goods and services** (including related duties, taxes and charges such as non-deductible value added tax (VAT) paid by the beneficiary) are eligible, if they are:

(a) purchased specifically for the action and in accordance with Article 10.1.1 or

(b) contributed in kind against payment and in accordance with Article 11.1.

Such goods and services include, for instance, consumables and supplies, dissemination (including open access), protection of results, certificates on the financial statements (if they are required by the Agreement), certificates on the methodology, translations and publications.

D.4 **Capitalised and operating costs of 'large research infrastructure'**[2] directly used for the action are eligible, if:

(a) the value of the large research infrastructure represents at least 75% of the total fixed assets (at historical value in its last closed balance sheet before the date of the signature of the Agreement or as determined on the basis of the rental and leasing costs of the research infrastructure[3]);

(b) the beneficiary's methodology for declaring the costs for large research infrastructure has been positively assessed by the Commission ('**ex-ante assessment**');

(c) the beneficiary declares as direct eligible costs only the portion which corresponds to the duration of the action and the rate of actual use for the purposes of the action, and

(d) they comply with the conditions as further detailed in the annotations to the H2020 grant agreements.

[2] '**Large research infrastructure**' means research infrastructure of a total value of at least EUR 20 million, for a beneficiary, calculated as the sum of historical asset values of each individual research infrastructure of that beneficiary, as they appear in its last closed balance sheet before the date of the signature of the Agreement or as determined on the basis of the rental and leasing costs of the research infrastructure.

[3] For the definition, see Article 2(6) of the H2020 Framework Programme Regulation No 1291/2013: '**Research infrastructure**' are facilities, resources and services that are used by the research communities to conduct research and foster innovation in their fields. Where relevant, they may be used beyond research, e.g. for education or public services. They include: major scientific equipment (or sets of instruments); knowledge-based resources such as collections, archives or scientific data; e-infrastructures such as data and computing systems and communication networks; and any other infrastructure of a unique nature essential to achieve excellence in research and innovation. Such infrastructures may be 'single-sited', 'virtual' or 'distributed'.

D.5 **Costs of internally invoiced goods and services** directly used for the action are eligible, if:

(a) they are declared on the basis of a unit cost calculated in accordance with the beneficiary's usual cost accounting practices;

(b) the cost accounting practices used are applied in a consistent manner, based on objective criteria, regardless of the source of funding;

(c) the unit cost is calculated using the actual costs for the good or service recorded in the beneficiary's accounts, excluding any ineligible cost or costs included in other budget categories.

The actual costs may be adjusted by the beneficiary on the basis of budgeted or estimated elements. Those elements must be relevant for calculating the costs, reasonable and correspond to objective and verifiable information;

(d) the unit cost excludes any costs of items which are not directly linked to the production of the invoiced goods or service.

'Internally invoiced goods and services' means goods or services which are provided by the beneficiary directly for the action and which the beneficiary values on the basis of its usual cost accounting practices.

E. Indirect costs

Indirect costs are eligible if they are declared on the basis of the flat-rate of 25% of the eligible direct costs (see Article 5.2 and Points A to D above), from which are excluded:

(a) costs of subcontracting and

(b) costs of in-kind contributions provided by third parties which are not used on the beneficiary's premises;

(c) not applicable;

(d) not applicable.

Beneficiaries receiving an operating grant[4] financed by the EU or Euratom budget cannot declare indirect costs for the period covered by the operating grant, unless they can demonstrate that the operating grant does not cover any costs of the action.

F. Specific cost category(ies)

Not applicable

6.3 Conditions for costs of linked third parties to be eligible

[4] For the definition, see Article 121(1)(b) of Regulation (EU, Euratom) No 966/2012 of the European Parliament and of the Council of 25 October 2012 on the financial rules applicable to the general budget of the Union and repealing Council Regulation (EC, Euratom) No 1605/2002 ('**Financial Regulation No 966/2012**')(OJ L 218, 26.10.2012, p.1): '**operating grant**' means direct financial contribution, by way of donation, from the budget in order to finance the functioning of a body which pursues an aim of general EU interest or has an objective forming part of and supporting an EU policy.

Not applicable

6.4 Conditions for in-kind contributions provided by third parties free of charge to be eligible

In-kind contributions provided free of charge are eligible direct costs (for the beneficiary), if the costs incurred by the third party fulfil — *mutatis mutandis* — the general and specific conditions for eligibility set out in this Article (Article 6.1 and 6.2) and Article 12.1.

6.5 Ineligible costs

'**Ineligible costs**' are:

(a) costs that do not comply with the conditions set out above (Article 6.1 to 6.4), in particular:

(i) costs related to return on capital;

(ii) debt and debt service charges;

(iii) provisions for future losses or debts;

(iv) interest owed;

(v) doubtful debts;

(vi) currency exchange losses;

(vii) bank costs charged by the beneficiary's bank for transfers from the Agency;

(viii) excessive or reckless expenditure;

(ix) deductible VAT;

(x) costs incurred during suspension of the implementation of the action (see Article 49);

(b) costs declared under another EU or Euratom grant (including grants awarded by a Member State and financed by the EU or Euratom budget and grants awarded by bodies other than the Agency for the purpose of implementing the EU or Euratom budget); in particular, indirect costs if the beneficiary is already receiving an operating grant financed by the EU or Euratom budget in the same period, unless it can demonstrate that the operating grant does not cover any costs of the action.

6.6 Consequences of declaration of ineligible costs

Declared costs that are ineligible will be rejected (see Article 42).

This may also lead to any of the other measures described in Chapter 6.

CHAPTER 4 RIGHTS AND OBLIGATIONS OF THE PARTIES

SECTION 1 RIGHTS AND OBLIGATIONS RELATED TO IMPLEMENTING THE ACTION

ARTICLE 7 — GENERAL OBLIGATION TO PROPERLY IMPLEMENT THE ACTION

7.1 General obligation to properly implement the action

The beneficiaries must implement the action as described in Annex 1 and in compliance with the provisions of the Agreement and all legal obligations under applicable EU, international and national law.

7.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 8 — RESOURCES TO IMPLEMENT THE ACTION — THIRD PARTIES INVOLVED IN THE ACTION

The beneficiaries must have the appropriate resources to implement the action.

If it is necessary to implement the action, the beneficiaries may:

- purchase goods, works and services (see Article 10);
- use in-kind contributions provided by third parties against payment (see Article 11);
- use in-kind contributions provided by third parties free of charge (see Article 12);
- call upon subcontractors to implement action tasks described in Annex 1 (see Article 13);
- call upon linked third parties to implement action tasks described in Annex 1 (see Article 14);
- call upon international partners to implement action tasks described in Annex 1 (see Article 14a).

In these cases, the beneficiaries retain sole responsibility towards the Agency and the other beneficiaries for implementing the action.

ARTICLE 9 — IMPLEMENTATION OF ACTION TASKS BY BENEFICIARIES NOT RECEIVING EU FUNDING

Not applicable

ARTICLE 10 — PURCHASE OF GOODS, WORKS OR SERVICES

10.1 Rules for purchasing goods, works or services

10.1.1 If necessary to implement the action, the beneficiaries may purchase goods, works or services.

The beneficiaries must make such purchases ensuring the best value for money or, if appropriate, the lowest price. In doing so, they must avoid any conflict of interests (see Article 35).

The beneficiaries must ensure that the Agency, the Commission, the European Court of Auditors (ECA) and the European Anti-Fraud Office (OLAF) can exercise their rights under Articles 22 and 23 also towards their contractors.

10.1.2 Beneficiaries that are 'contracting authorities' within the meaning of Directive 2004/18/EC[5] (or 2014/24/EU[6]) or 'contracting entities' within the meaning of Directive 2004/17/EC[7] (or 2014/25/EU[8]) must comply with the applicable national law on public procurement.

10.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under Article 10.1.1, the costs related to the contract concerned will be ineligible (see Article 6) and will be rejected (see Article 42).

If a beneficiary breaches any of its obligations under Article 10.1.2, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 11 — USE OF IN-KIND CONTRIBUTIONS PROVIDED BY THIRD PARTIES AGAINST PAYMENT

11.1 Rules for the use of in-kind contributions against payment

If necessary to implement the action, the beneficiaries may use in-kind contributions provided by third parties against payment.

The beneficiaries may declare costs related to the payment of in-kind contributions as eligible (see Article 6.1 and 6.2), up to the third parties' costs for the seconded persons, contributed equipment, infrastructure or other assets or other contributed goods and services.

The third parties and their contributions must be set out in Annex 1. The Agency may however approve in-kind contributions not set out in Annex 1 without amendment (see Article 55), if:

- they are specifically justified in the periodic technical report and
- their use does not entail changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

The beneficiaries must ensure that the Agency, the Commission, the European Court of Auditors

[5] Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004 on the coordination of procedures for the award of public work contracts, public supply contracts and public service contracts (OJ L 134, 30.04.2004, p. 114).

[6] Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC. (OJ L 94, 28.03.2014, p. 65).

[7] Directive 2004/17/EC of the European Parliament and of the Council of 31 March 2004 coordinating the procurement procedures of entities operating in the water, energy, transport and postal services sectors (OJ L 134, 30.04.2004, p. 1)

[8] Directive 2014/25/EU of the European Parliament and of the Council of 26 February 2014 on procurement by entities operating in the water, energy, transport and postal services sectors and repealing Directive 2004/17/EC (OJ L 94, 28.03.2014, p. 243).

(ECA) and the European Anti-Fraud Office (OLAF) can exercise their rights under Articles 22 and 23 also towards the third parties.

11.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the costs related to the payment of the in-kind contribution will be ineligible (see Article 6) and will be rejected (see Article 42).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 12 — USE OF IN-KIND CONTRIBUTIONS PROVIDED BY THIRD PARTIES FREE OF CHARGE

12.1 Rules for the use of in-kind contributions free of charge

If necessary to implement the action, the beneficiaries may use in-kind contributions provided by third parties free of charge.

The beneficiaries may declare costs incurred by the third parties for the seconded persons, contributed equipment, infrastructure or other assets or other contributed goods and services as eligible in accordance with Article 6.4.

The third parties and their contributions must be set out in Annex 1. The Agency may however approve in-kind contributions not set out in Annex 1 without amendment (see Article 55), if:

- they are specifically justified in the periodic technical report and
- their use does not entail changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

The beneficiaries must ensure that the Agency, the Commission, the European Court of Auditors (ECA) and the European Anti-Fraud Office (OLAF) can exercise their rights under Articles 22 and 23 also towards the third parties.

12.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the costs incurred by the third parties related to the in-kind contribution will be ineligible (see Article 6) and will be rejected (see Article 42).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 13 — IMPLEMENTATION OF ACTION TASKS BY SUBCONTRACTORS

13.1 Rules for subcontracting action tasks

13.1.1 If necessary to implement the action, the beneficiaries may award subcontracts covering the implementation of certain action tasks described in Annex 1.

Subcontracting may cover only a limited part of the action.

The beneficiaries must award the subcontracts ensuring the best value for money or, if appropriate, the lowest price. In doing so, they must avoid any conflict of interests (see Article 35).

The tasks to be implemented and the estimated cost for each subcontract must be set out in Annex 1 and the total estimated costs of subcontracting per beneficiary must be set out in Annex 2. The Agency may however approve subcontracts not set out in Annex 1 and 2 without amendment (see Article 55), if:

- they are specifically justified in the periodic technical report and
- they do not entail changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

The beneficiaries must ensure that the Agency, the Commission, the European Court of Auditors (ECA) and the European Anti-Fraud Office (OLAF) can exercise their rights under Articles 22 and 23 also towards their subcontractors.

13.1.2 The beneficiaries must ensure that their obligations under Articles 35, 36, 38 and 46 also apply to the subcontractors.

Beneficiaries that are 'contracting authorities' within the meaning of Directive 2004/18/EC (or 2014/24/EU) or 'contracting entities' within the meaning of Directive 2004/17/EC (or 2014/25/EU) must comply with the applicable national law on public procurement.

13.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under Article 13.1.1, the costs related to the subcontract concerned will be ineligible (see Article 6) and will be rejected (see Article 42).

If a beneficiary breaches any of its obligations under Article 13.1.2, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 14 — IMPLEMENTATION OF ACTION TASKS BY LINKED THIRD PARTIES

Not applicable

ARTICLE 14a — IMPLEMENTATION OF ACTION TASKS BY INTERNATIONAL PARTNERS

Not applicable

ARTICLE 15 — FINANCIAL SUPPORT TO THIRD PARTIES

15.1 Rules for providing financial support to third parties

Not applicable

15.2 Financial support in the form of prizes

Not applicable

15.3 Consequences of non-compliance

Not applicable

ARTICLE 16 — PROVISION OF TRANS-NATIONAL OR VIRTUAL ACCESS TO RESEARCH INFRASTRUCTURE

16.1 Rules for providing trans-national access to research infrastructure

Not applicable

16.2 Rules for providing virtual access to research infrastructure

Not applicable

16.3 Consequences of non-compliance

Not applicable

SECTION 2 RIGHTS AND OBLIGATIONS RELATED TO THE GRANT ADMINISTRATION

ARTICLE 17 — GENERAL OBLIGATION TO INFORM

17.1 General obligation to provide information upon request

The beneficiaries must provide — during implementation of the action or afterwards and in accordance with Article 41.2 — any information requested in order to verify eligibility of the costs, proper implementation of the action and compliance with any other obligation under the Agreement.

17.2 Obligation to keep information up to date and to inform about events and circumstances likely to affect the Agreement

Each beneficiary must keep information stored in the Participant Portal Beneficiary Register (via the electronic exchange system; see Article 52) up to date, in particular, its name, address, legal representatives, legal form and organisation type.

Each beneficiary must immediately inform the coordinator — which must immediately inform the Agency and the other beneficiaries — of any of the following:

(a) **events** which are likely to affect significantly or delay the implementation of the action or the EU's financial interests, in particular:

  (i) changes in its legal, financial, technical, organisational or ownership situation

(b) **circumstances** affecting:

  (i) the decision to award the grant or

  (ii) compliance with requirements under the Agreement.

17.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 18 — KEEPING RECORDS — SUPPORTING DOCUMENTATION

18.1 Obligation to keep records and other supporting documentation

The beneficiaries must — for a period of five years after the payment of the balance — keep records and other supporting documentation in order to prove the proper implementation of the action and the costs they declare as eligible.

They must make them available upon request (see Article 17) or in the context of checks, reviews, audits or investigations (see Article 22).

If there are on-going checks, reviews, audits, investigations, litigation or other pursuits of claims under the Agreement (including the extension of findings; see Article 22), the beneficiaries must keep the records and other supporting documentation until the end of these procedures.

The beneficiaries must keep the original documents. Digital and digitalised documents are considered originals if they are authorised by the applicable national law. The Agency may accept non-original documents if it considers that they offer a comparable level of assurance.

18.1.1 Records and other supporting documentation on the scientific and technical implementation

The beneficiaries must keep records and other supporting documentation on scientific and technical implementation of the action in line with the accepted standards in the respective field.

18.1.2 Records and other documentation to support the costs declared

The beneficiaries must keep the records and documentation supporting the costs declared, in particular the following:

(a) for **actual costs**: adequate records and other supporting documentation to prove the costs declared, such as contracts, subcontracts, invoices and accounting records. In addition, the beneficiaries' usual cost accounting practices and internal control procedures must enable direct reconciliation between the amounts declared, the amounts recorded in their accounts and the amounts stated in the supporting documentation;

(b) for **unit costs**: adequate records and other supporting documentation to prove the number of units declared. Beneficiaries do not need to identify the actual eligible costs covered or to keep or provide supporting documentation (such as accounting statements) to prove the amount per unit.

In addition, **for unit costs calculated in accordance with the beneficiary's usual cost accounting practices**, the beneficiaries must keep adequate records and documentation to prove that the cost accounting practices used comply with the conditions set out in Article 6.2.

The beneficiaries may submit to the Commission, for approval, a certificate (drawn up in accordance with Annex 6) stating that their usual cost accounting practices comply with these

conditions ('**certificate on the methodology**'). If the certificate is approved, costs declared in line with this methodology will not be challenged subsequently, unless the beneficiaries have concealed information for the purpose of the approval.

(c) for **flat-rate costs**: adequate records and other supporting documentation to prove the eligibility of the costs to which the flat-rate is applied. The beneficiaries do not need to identify the costs covered or provide supporting documentation (such as accounting statements) to prove the amount declared at a flat-rate.

In addition, for **personnel costs** (declared as actual costs or on the basis of unit costs), the beneficiaries must keep **time records** for the number of hours declared. The time records must be in writing and approved by the persons working on the action and their supervisors, at least monthly. In the absence of reliable time records of the hours worked on the action, the Agency may accept alternative evidence supporting the number of hours declared, if it considers that it offers an adequate level of assurance.

As an exception, for **persons working exclusively on the action**, there is no need to keep time records, if the beneficiary signs a **declaration** confirming that the persons concerned have worked exclusively on the action.

18.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, costs insufficiently substantiated will be ineligible (see Article 6) and will be rejected (see Article 42), and the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 19 — SUBMISSION OF DELIVERABLES

19.1 Obligation to submit deliverables

The coordinator must submit the '**deliverables**' identified in Annex 1, in accordance with the timing and conditions set out in it.

19.2 Consequences of non-compliance

If the coordinator breaches any of its obligations under this Article, the Agency may apply any of the measures described in Chapter 6.

ARTICLE 20 — REPORTING — PAYMENT REQUESTS

20.1 Obligation to submit reports

The coordinator must submit to the Agency (see Article 52) the technical and financial reports set out in this Article. These reports include requests for payment and must be drawn up using the forms and templates provided in the electronic exchange system (see Article 52).

20.2 Reporting periods

The action is divided into the following '**reporting periods**':

- RP1: from month 1 to month 18
- RP2: from month 19 to month 36
- RP3: from month 37 to month 48

20.3 Periodic reports — Requests for interim payments

The coordinator must submit a periodic report within 60 days following the end of each reporting period.

The **periodic report** must include the following:

(a) a '**periodic technical report**' containing:

(i) an **explanation of the work carried out** by the beneficiaries;

(ii) an **overview of the progress** towards the objectives of the action, including milestones and deliverables identified in Annex 1.

This report must include explanations justifying the differences between work expected to be carried out in accordance with Annex 1 and that actually carried out.

The report must detail the exploitation and dissemination of the results and — if required in Annex 1 — an updated '**plan for the exploitation and dissemination of the results**'.

The report must indicate the communication activities;

(iii) a **summary** for publication by the Agency;

(iv) the answers to the '**questionnaire**', covering issues related to the action implementation and the economic and societal impact, notably in the context of the Horizon 2020 key performance indicators and the Horizon 2020 monitoring requirements;

(b) a '**periodic financial report**' containing:

(i) an '**individual financial statement**' (see Annex 4) from each beneficiary, for the reporting period concerned.

The individual financial statement must detail the eligible costs (actual costs, unit costs and flat-rate costs; see Article 6) for each budget category (see Annex 2).

The beneficiaries must declare all eligible costs, even if — for actual costs, unit costs and flat-rate costs — they exceed the amounts indicated in the estimated budget (see Annex 2). Amounts which are not declared in the individual financial statement will not be taken into account by the Agency.

If an individual financial statement is not submitted for a reporting period, it may be included in the periodic financial report for the next reporting period.

The individual financial statements of the last reporting period must also detail the **receipts of the action** (see Article 5.3.3).

Each beneficiary must **certify** that:

- the information provided is full, reliable and true;
- the costs declared are eligible (see Article 6);
- the costs can be substantiated by adequate records and supporting documentation (see Article 18) that will be produced upon request (see Article 17) or in the context of checks, reviews, audits and investigations (see Article 22), and
- for the last reporting period: that all the receipts have been declared (see Article 5.3.3);

(ii) an **explanation of the use of resources** and the information on subcontracting (see Article 13) and in-kind contributions provided by third parties (see Articles 11 and 12) from each beneficiary, for the reporting period concerned;

(iii) not applicable;

(iv) a '**periodic summary financial statement**', created automatically by the electronic exchange system, consolidating the individual financial statements for the reporting period concerned and including — except for the last reporting period — the **request for interim payment**.

20.4 Final report — Request for payment of the balance

In addition to the periodic report for the last reporting period, the coordinator must submit the final report within 60 days following the end of the last reporting period.

The **final report** must include the following:

(a) a '**final technical report**' with a **summary** for publication containing:

(i) an overview of the results and their exploitation and dissemination;

(ii) the conclusions on the action, and

(iii) the socio-economic impact of the action;

(b) a '**final financial report**' containing:

(i) a '**final summary financial statement**', created automatically by the electronic exchange system, consolidating the individual financial statements for all reporting periods and including the **request for payment of the balance** and

(ii) a '**certificate on the financial statements**' (drawn up in accordance with Annex 5) for each beneficiary, if it requests a total contribution of EUR 325 000 or more, as reimbursement of actual costs and unit costs calculated on the basis of its usual cost accounting practices (see Article 5.2 and Article 6.2).

20.5 Information on cumulative expenditure incurred

Not applicable

20.6 Currency for financial statements and conversion into euro

Financial statements must be drafted in euro.

Beneficiaries with accounting established in a currency other than the euro must convert the costs recorded in their accounts into euro, at the average of the daily exchange rates published in the C series of the *Official Journal of the European Union*, calculated over the corresponding reporting period.

If no daily euro exchange rate is published in the *Official Journal of the European Union* for the currency in question, they must be converted at the average of the monthly accounting rates published on the Commission's website, calculated over the corresponding reporting period.

Beneficiaries with accounting established in euro must convert costs incurred in another currency into euro according to their usual accounting practices.

20.7 Language of reports

All reports (technical and financial reports, including financial statements) must be submitted in the language of the Agreement.

20.8 Consequences of non-compliance

If the reports submitted do not comply with this Article, the Agency may suspend the payment deadline (see Article 47) and apply any of the other measures described in Chapter 6.

If the coordinator breaches its obligation to submit the reports and if it fails to comply with this obligation within 30 days following a written reminder, the Agency may terminate the Agreement (see Article 50) or apply any of the other measures described in Chapter 6.

ARTICLE 21 — PAYMENTS AND PAYMENT ARRANGEMENTS

21.1 Payments to be made

The following payments will be made to the coordinator:

- one **pre-financing payment**;
- one or more **interim payments**, on the basis of the request(s) for interim payment (see Article 20), and
- one **payment of the balance**, on the basis of the request for payment of the balance (see Article 20).

21.2 Pre-financing payment — Amount — Amount retained for the Guarantee Fund

The aim of the pre-financing is to provide the beneficiaries with a float.

It remains the property of the EU until the payment of the balance.

The amount of the pre-financing payment will be EUR **2 554 952.67** (two million five hundred and fifty four thousand nine hundred and fifty two EURO and sixty seven eurocents).

The Agency will — except if Article 48 applies — make the pre-financing payment to the coordinator within 30 days, either from the entry into force of the Agreement (see Article 58) or from 10 days before the starting date of the action (see Article 3), whichever is the latest.

An amount of EUR **239 526.81** (two hundred and thirty nine thousand five hundred and twenty six EURO and eighty one eurocents), corresponding to 5% of the maximum grant amount (see Article 5.1), is retained by the Agency from the pre-financing payment and transferred into the '**Guarantee Fund**'.

21.3 Interim payments — Amount — Calculation

Interim payments reimburse the eligible costs incurred for the implementation of the action during the corresponding reporting periods.

The Agency will pay to the coordinator the amount due as interim payment within 90 days from receiving the periodic report (see Article 20.3), except if Articles 47 or 48 apply.

Payment is subject to the approval of the periodic report. Its approval does not imply recognition of the compliance, authenticity, completeness or correctness of its content.

The **amount due as interim payment** is calculated by the Agency in the following steps:

Step 1 — Application of the reimbursement rates

Step 2 — Limit to 90% of the maximum grant amount

21.3.1 Step 1 — Application of the reimbursement rates

The reimbursement rate(s) (see Article 5.2) are applied to the eligible costs (actual costs, unit costs and flat-rate costs; see Article 6) declared by the beneficiaries (see Article 20) and approved by the Agency (see above) for the concerned reporting period.

21.3.2 Step 2 — Limit to 90% of the maximum grant amount

The total amount of pre-financing and interim payments must not exceed 90% of the maximum grant amount set out in Article 5.1. The maximum amount for the interim payment will be calculated as follows:

{90% of the maximum grant amount (see Article 5.1)

minus

{pre-financing and previous interim payments}}.

21.4 Payment of the balance — Amount — Calculation — Release of the amount retained for the Guarantee Fund

The payment of the balance reimburses the remaining part of the eligible costs incurred by the beneficiaries for the implementation of the action.

If the total amount of earlier payments is greater than the final grant amount (see Article 5.3), the payment of the balance takes the form of a recovery (see Article 44).

If the total amount of earlier payments is lower than the final grant amount, the Agency will pay the balance within 90 days from receiving the final report (see Article 20.4), except if Articles 47 or 48 apply.

Payment is subject to the approval of the final report. Its approval does not imply recognition of the compliance, authenticity, completeness or correctness of its content.

The **amount due as the balance** is calculated by the Agency by deducting the total amount of pre-financing and interim payments (if any) already made, from the final grant amount determined in accordance with Article 5.3:

{final grant amount (see Article 5.3)

minus

{pre-financing and interim payments (if any) made}}.

At the payment of the balance, the amount retained for the Guarantee Fund (see above) will be released and:

- if the balance is positive: the amount released will be paid in full to the coordinator together with the amount due as the balance;
- if the balance is negative (payment of the balance taking the form of recovery): it will be deducted from the amount released (see Article 44.1.2). If the resulting amount:
    - is positive, it will be paid to the coordinator
    - is negative, it will be recovered.

The amount to be paid may however be offset — without the beneficiaries' consent — against any other amount owed by a beneficiary to the Agency, the Commission or another executive agency (under the EU or Euratom budget), up to the maximum EU contribution indicated, for that beneficiary, in the estimated budget (see Annex 2).

21.5 Notification of amounts due

When making payments, the Agency will formally notify to the coordinator the amount due, specifying whether it concerns an interim payment or the payment of the balance.

For the payment of the balance, the notification will also specify the final grant amount.

In the case of reduction of the grant or recovery of undue amounts, the notification will be preceded by the contradictory procedure set out in Articles 43 and 44.

21.6 Currency for payments

The Agency will make all payments in euro.

21.7 Payments to the coordinator — Distribution to the beneficiaries

Payments will be made to the coordinator.

Payments to the coordinator will discharge the Agency from its payment obligation.

The coordinator must distribute the payments between the beneficiaries without unjustified delay.

Pre-financing may however be distributed only:

(a) if the minimum number of beneficiaries set out in the call for proposals has acceded to the Agreement (see Article 56) and

(b) to beneficiaries that have acceded to the Agreement (see Article 56).

21.8 Bank account for payments

All payments will be made to the following bank account:

Name of bank: NATIONAL BANK OF GREECE S.A.
Full name of the account holder: NATIONAL TECHNICAL UNIVERSITY OF ATHENS
IBAN code: GR6901100800000008030007960

21.9 Costs of payment transfers

The cost of the payment transfers is borne as follows:

- the Agency bears the cost of transfers charged by its bank;
- the beneficiary bears the cost of transfers charged by its bank;
- the party causing a repetition of a transfer bears all costs of the repeated transfer.

21.10 Date of payment

Payments by the Agency are considered to have been carried out on the date when they are debited to its account.

21.11 Consequences of non-compliance

21.11.1 If the Agency does not pay within the payment deadlines (see above), the beneficiaries are entitled to **late-payment interest** at the rate applied by the European Central Bank (ECB) for its main refinancing operations in euros (‘reference rate’), plus three and a half points. The reference rate is the rate in force on the first day of the month in which the payment deadline expires, as published in the C series of the *Official Journal of the European Union*.

If the late-payment interest is lower than or equal to EUR 200, it will be paid to the coordinator only upon request submitted within two months of receiving the late payment.

Late-payment interest is not due if all beneficiaries are EU Member States (including regional and local government authorities or other public bodies acting on behalf of a Member State for the purpose of this Agreement).

Suspension of the payment deadline or payments (see Articles 47 and 48) will not be considered as late payment.

Late-payment interest covers the period running from the day following the due date for payment (see above), up to and including the date of payment.

Late-payment interest is not considered for the purposes of calculating the final grant amount.

21.11.2 If the coordinator breaches any of its obligations under this Article, the grant may be reduced (see Article 43) and the Agreement or the participation of the coordinator may be terminated (see Article 50).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 22 — CHECKS, REVIEWS, AUDITS AND INVESTIGATIONS — EXTENSION OF FINDINGS

22.1 Checks, reviews and audits by the Agency and the Commission

22.1.1 Right to carry out checks

The Agency or the Commission will — during the implementation of the action or afterwards — check the proper implementation of the action and compliance with the obligations under the Agreement, including assessing deliverables and reports.

For this purpose the Agency or the Commission may be assisted by external persons or bodies.

The Agency or the Commission may also request additional information in accordance with Article 17. The Agency or the Commission may request beneficiaries to provide such information to it directly.

Information provided must be accurate, precise and complete and in the format requested, including electronic format.

22.1.2 Right to carry out reviews

The Agency or the Commission may — during the implementation of the action or afterwards — carry out reviews on the proper implementation of the action (including assessment of deliverables and reports), compliance with the obligations under the Agreement and continued scientific or technological relevance of the action.

Reviews may be started up to two years after the payment of the balance. They will be formally notified to the coordinator or beneficiary concerned and will be considered to have started on the date of the formal notification.

If the review is carried out on a third party (see Articles 10 to 16), the beneficiary concerned must inform the third party.

The Agency or the Commission may carry out reviews directly (using its own staff) or indirectly (using external persons or bodies appointed to do so). It will inform the coordinator or beneficiary concerned of the identity of the external persons or bodies. They have the right to object to the appointment on grounds of commercial confidentiality.

The coordinator or beneficiary concerned must provide — within the deadline requested — any information and data in addition to deliverables and reports already submitted (including information

on the use of resources). The Agency or the Commission may request beneficiaries to provide such information to it directly.

The coordinator or beneficiary concerned may be requested to participate in meetings, including with external experts.

For **on-the-spot** reviews, the beneficiaries must allow access to their sites and premises, including to external persons or bodies, and must ensure that information requested is readily available.

Information provided must be accurate, precise and complete and in the format requested, including electronic format.

On the basis of the review findings, a '**review report**' will be drawn up.

The Agency or the Commission will formally notify the review report to the coordinator or beneficiary concerned, which has 30 days to formally notify observations ('**contradictory review procedure**').

Reviews (including review reports) are in the language of the Agreement.

22.1.3 Right to carry out audits

The Agency or the Commission may — during the implementation of the action or afterwards — carry out audits on the proper implementation of the action and compliance with the obligations under the Agreement.

Audits may be started up to two years after the payment of the balance. They will be formally notified to the coordinator or beneficiary concerned and will be considered to have started on the date of the formal notification.

If the audit is carried out on a third party (see Articles 10 to 16), the beneficiary concerned must inform the third party.

The Agency or the Commission may carry out audits directly (using its own staff) or indirectly (using external persons or bodies appointed to do so). It will inform the coordinator or beneficiary concerned of the identity of the external persons or bodies. They have the right to object to the appointment on grounds of commercial confidentiality.

The coordinator or beneficiary concerned must provide — within the deadline requested — any information (including complete accounts, individual salary statements or other personal data) to verify compliance with the Agreement. The Agency or the Commission may request beneficiaries to provide such information to it directly.

For **on-the-spot** audits, the beneficiaries must allow access to their sites and premises, including to external persons or bodies, and must ensure that information requested is readily available.

Information provided must be accurate, precise and complete and in the format requested, including electronic format.

On the basis of the audit findings, a '**draft audit report**' will be drawn up.

The Agency or the Commission will formally notify the draft audit report to the coordinator or beneficiary concerned, which has 30 days to formally notify observations ('**contradictory audit procedure**'). This period may be extended by the Agency or the Commission in justified cases.

The '**final audit report**' will take into account observations by the coordinator or beneficiary concerned. The report will be formally notified to it.

Audits (including audit reports) are in the language of the Agreement.

The Agency or the Commission may also access the beneficiaries' statutory records for the periodical assessment of unit costs or flat-rate amounts.

22.2 Investigations by the European Anti-Fraud Office (OLAF)

Under Regulations No 883/2013[16] and No 2185/96[17] (and in accordance with their provisions and procedures), the European Anti-Fraud Office (OLAF) may — at any moment during implementation of the action or afterwards — carry out investigations, including on-the-spot checks and inspections, to establish whether there has been fraud, corruption or any other illegal activity affecting the financial interests of the EU.

22.3 Checks and audits by the European Court of Auditors (ECA)

Under Article 287 of the Treaty on the Functioning of the European Union (TFEU) and Article 161 of the Financial Regulation No 966/2012[18], the European Court of Auditors (ECA) may — at any moment during implementation of the action or afterwards — carry out audits.

The ECA has the right of access for the purpose of checks and audits.

22.4 Checks, reviews, audits and investigations for international organisations

Not applicable

22.5 Consequences of findings in checks, reviews, audits and investigations — Extension of findings

22.5.1 Findings in this grant

Findings in checks, reviews, audits or investigations carried out in the context of this grant may lead to the rejection of ineligible costs (see Article 42), reduction of the grant (see Article 43), recovery of undue amounts (see Article 44) or to any of the other measures described in Chapter 6.

Rejection of costs or reduction of the grant after the payment of the balance will lead to a revised final grant amount (see Article 5.4).

Findings in checks, reviews, audits or investigations may lead to a request for amendment for the modification of Annex 1 (see Article 55).

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[16] Regulation (EU, Euratom) No 883/2013 of the European Parliament and of the Council of 11 September 2013 concerning investigations conducted by the European Anti-Fraud Office (OLAF) and repealing Regulation (EC) No 1073/1999 of the European Parliament and of the Council and Council Regulation (Euratom) No 1074/1999 (OJ L 248, 18.09.2013, p. 1).

[17] Council Regulation (Euratom, EC) No 2185/1996 of 11 November 1996 concerning on-the-spot checks and inspections carried out by the Commission in order to protect the European Communities' financial interests against fraud and other irregularities (OJ L 292, 15.11.1996, p. 2).

[18] Regulation (EU, Euratom) No 966/2012 of the European Parliament and of the Council of 25 October 2012 on the financial rules applicable to the general budget of the Union and repealing Council Regulation (EC, Euratom) No 1605/2002 (OJ L 298, 26.10.2012, p. 1).

Checks, reviews, audits or investigations that find systemic or recurrent errors, irregularities, fraud or breach of obligations may also lead to consequences in other EU or Euratom grants awarded under similar conditions ('**extension of findings from this grant to other grants**').

Moreover, findings arising from an OLAF investigation may lead to criminal prosecution under national law.

22.5.2 Findings in other grants

The Agency or the Commission may extend findings from other grants to this grant ('**extension of findings from other grants to this grant**'), if:

(a) the beneficiary concerned is found, in other EU or Euratom grants awarded under similar conditions, to have committed systemic or recurrent errors, irregularities, fraud or breach of obligations that have a material impact on this grant and

(b) those findings are formally notified to the beneficiary concerned — together with the list of grants affected by the findings — no later than two years after the payment of the balance of this grant.

The extension of findings may lead to the rejection of costs (see Article 42), reduction of the grant (see Article 43), recovery of undue amounts (see Article 44), suspension of payments (see Article 48), suspension of the action implementation (see Article 49) or termination (see Article 50).

22.5.3 Procedure

The Agency or the Commission will formally notify the beneficiary concerned the systemic or recurrent errors and its intention to extend these audit findings, together with the list of grants affected.

22.5.3.1 If the findings concern **eligibility of costs**: the formal notification will include:

(a) an invitation to submit observations on the list of grants affected by the findings;

(b) the request to submit **revised financial statements** for all grants affected;

(c) the **correction rate for extrapolation** established by the Agency or the Commission on the basis of the systemic or recurrent errors, to calculate the amounts to be rejected if the beneficiary concerned:

(i) considers that the submission of revised financial statements is not possible or practicable or

(ii) does not submit revised financial statements.

The beneficiary concerned has 90 days from receiving notification to submit observations, revised financial statements or to propose a duly substantiated **alternative correction method**. This period may be extended by the Agency or the Commission in justified cases.

The Agency or the Commission may then start a rejection procedure in accordance with Article 42, on the basis of:

- the revised financial statements, if approved;

- the proposed alternative correction method, if accepted

or

- the initially notified correction rate for extrapolation, if it does not receive any observations or revised financial statements, does not accept the observations or the proposed alternative correction method or does not approve the revised financial statements.

22.5.3.2 If the findings concern **substantial errors**, **irregularities or fraud** or **serious breach of obligations**: the formal notification will include:

(a) an invitation to submit observations on the list of grants affected by the findings and

(b) the flat-rate the Agency or the Commission intends to apply according to the principle of proportionality.

The beneficiary concerned has 90 days from receiving notification to submit observations or to propose a duly substantiated alternative flat-rate.

The Agency or the Commission may then start a reduction procedure in accordance with Article 43, on the basis of:

- the proposed alternative flat-rate, if accepted

or

- the initially notified flat-rate, if it does not receive any observations or does not accept the observations or the proposed alternative flat-rate.

22.6 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, any insufficiently substantiated costs will be ineligible (see Article 6) and will be rejected (see Article 42).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 23 — EVALUATION OF THE IMPACT OF THE ACTION

23.1 Right to evaluate the impact of the action

The Agency or the Commission may carry out interim and final evaluations of the impact of the action measured against the objective of the EU programme.

Evaluations may be started during implementation of the action and up to five years after the payment of the balance. The evaluation is considered to start on the date of the formal notification to the coordinator or beneficiaries.

The Agency or the Commission may make these evaluations directly (using its own staff) or indirectly (using external bodies or persons it has authorised to do so).

The coordinator or beneficiaries must provide any information relevant to evaluate the impact of the action, including information in electronic format.

23.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the Agency may apply the measures described in Chapter 6.

SECTION 3 RIGHTS AND OBLIGATIONS RELATED TO BACKGROUND AND RESULTS

SUBSECTION 1 GENERAL

ARTICLE 23a — MANAGEMENT OF INTELLECTUAL PROPERTY

23a.1 Obligation to take measures to implement the Commission Recommendation on the management of intellectual property in knowledge transfer activities

Beneficiaries that are universities or other public research organisations must take measures to implement the principles set out in Points 1 and 2 of the Code of Practice annexed to the Commission Recommendation on the management of intellectual property in knowledge transfer activities[19].

This does not change the obligations set out in Subsections 2 and 3 of this Section.

The beneficiaries must ensure that researchers and third parties involved in the action are aware of them.

23a.2 Consequences of non-compliance

If a beneficiary breaches its obligations under this Article, the Agency may apply any of the measures described in Chapter 6.

SUBSECTION 2 RIGHTS AND OBLIGATIONS RELATED TO BACKGROUND

ARTICLE 24 — AGREEMENT ON BACKGROUND

24.1 Agreement on background

The beneficiaries must identify and agree (in writing) on the background for the action ('**agreement on background**').

'**Background**' means any data, know-how or information — whatever its form or nature (tangible or intangible), including any rights such as intellectual property rights — that:

(a) is held by the beneficiaries before they acceded to the Agreement, and

(b) is needed to implement the action or exploit the results.

24.2 Consequences of non-compliance

[19] Commission Recommendation C(2008) 1329 of 10.4.2008 on the management of intellectual property in knowledge transfer activities and the Code of Practice for universities and other public research institutions attached to this recommendation.

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 25 — ACCESS RIGHTS TO BACKGROUND

25.1 Exercise of access rights — Waiving of access rights — No sub-licensing

To exercise access rights, this must first be requested in writing ('**request for access**').

'**Access rights**' means rights to use results or background under the terms and conditions laid down in this Agreement.

Waivers of access rights are not valid unless in writing.

Unless agreed otherwise, access rights do not include the right to sub-license.

25.2 Access rights for other beneficiaries, for implementing their own tasks under the action

The beneficiaries must give each other access — on a royalty-free basis — to background needed to implement their own tasks under the action, unless the beneficiary that holds the background has — before acceding to the Agreement —:

(a) informed the other beneficiaries that access to its background is subject to legal restrictions or limits, including those imposed by the rights of third parties (including personnel), or

(b) agreed with the other beneficiaries that access would not be on a royalty-free basis.

25.3 Access rights for other beneficiaries, for exploiting their own results

The beneficiaries must give each other access — under fair and reasonable conditions — to background needed for exploiting their own results, unless the beneficiary that holds the background has — before acceding to the Agreement — informed the other beneficiaries that access to its background is subject to legal restrictions or limits, including those imposed by the rights of third parties (including personnel).

'**Fair and reasonable conditions**' means appropriate conditions, including possible financial terms or royalty-free conditions, taking into account the specific circumstances of the request for access, for example the actual or potential value of the results or background to which access is requested and/or the scope, duration or other characteristics of the exploitation envisaged.

Requests for access may be made — unless agreed otherwise — up to one year after the period set out in Article 3.

25.4 Access rights for affiliated entities

Unless otherwise agreed in the consortium agreement, access to background must also be given — under fair and reasonable conditions (see above; Article 25.3) and unless it is subject to legal restrictions or limits, including those imposed by the rights of third parties (including personnel) —

to affiliated entities[20] established in an EU Member State or '**associated country**'[21], if this is needed to exploit the results generated by the beneficiaries to which they are affiliated.

Unless agreed otherwise (see above; Article 25.1), the affiliated entity concerned must make the request directly to the beneficiary that holds the background.

Requests for access may be made — unless agreed otherwise — up to one year after the period set out in Article 3.

25.5 Access rights for third parties

Not applicable

25.6 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

SUBSECTION 3 RIGHTS AND OBLIGATIONS RELATED TO RESULTS

ARTICLE 26 — OWNERSHIP OF RESULTS

26.1 Ownership by the beneficiary that generates the results

Results are owned by the beneficiary that generates them.

'**Results**' means any (tangible or intangible) output of the action such as data, knowledge or information — whatever its form or nature, whether it can be protected or not — that is generated in the action, as well as any rights attached to it, including intellectual property rights.

26.2 Joint ownership by several beneficiaries

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[20] For the definition see Article 2.1(2) Rules for Participation Regulation No 1290/2013: '**affiliated entity**' means any legal entity that is:
- under the direct or indirect control of a participant, or
- under the same direct or indirect control as the participant, or
- directly or indirectly controlling a participant.

'Control' may take any of the following forms:
(a) the direct or indirect holding of more than 50% of the nominal value of the issued share capital in the legal entity concerned, or of a majority of the voting rights of the shareholders or associates of that entity;
(b) the direct or indirect holding, in fact or in law, of decision-making powers in the legal entity concerned.

However the following relationships between legal entities shall not in themselves be deemed to constitute controlling relationships:
(a) the same public investment corporation, institutional investor or venture-capital company has a direct or indirect holding of more than 50% of the nominal value of the issued share capital or a majority of voting rights of the shareholders or associates;
(b) the legal entities concerned are owned or supervised by the same public body.

[21] For the definition, see Article 2.1(3) of the Rules for Participation Regulation No 1290/2013: '**associated country**' means a third country which is party to an international agreement with the Union, as identified in Article 7 of Horizon 2020 Framework Programme Regulation No 1291/2013. Article 7 sets out the conditions for association of non-EU countries to Horizon 2020.

Two or more beneficiaries own results jointly if:

(a) they have jointly generated them and

(b) it is not possible to:

(i) establish the respective contribution of each beneficiary, or

(ii) separate them for the purpose of applying for, obtaining or maintaining their protection (see Article 27).

The joint owners must agree (in writing) on the allocation and terms of exercise of their joint ownership ('**joint ownership agreement**'), to ensure compliance with their obligations under this Agreement.

Unless otherwise agreed in the joint ownership agreement, each joint owner may grant non-exclusive licences to third parties to exploit jointly-owned results (without any right to sub-license), if the other joint owners are given:

(a) at least 45 days advance notice and

(b) fair and reasonable compensation.

Once the results have been generated, joint owners may agree (in writing) to apply another regime than joint ownership (such as, for instance, transfer to a single owner (see Article 30) with access rights for the others).

26.3 Rights of third parties (including personnel)

If third parties (including personnel) may claim rights to the results, the beneficiary concerned must ensure that it complies with its obligations under the Agreement.

If a third party generates results, the beneficiary concerned must obtain all necessary rights (transfer, licences or other) from the third party, in order to be able to respect its obligations as if those results were generated by the beneficiary itself.

If obtaining the rights is impossible, the beneficiary must refrain from using the third party to generate the results.

26.4 Agency ownership, to protect results

26.4.1 The Agency may — with the consent of the beneficiary concerned — assume ownership of results to protect them, if a beneficiary intends — up to four years after the period set out in Article 3 — to disseminate its results without protecting them, except in any of the following cases:

(a) the lack of protection is because protecting the results is not possible, reasonable or justified (given the circumstances);

(b) the lack of protection is because there is a lack of potential for commercial or industrial exploitation, or

(c) the beneficiary intends to transfer the results to another beneficiary or third party established in an EU Member State or associated country, which will protect them.

Before the results are disseminated and unless any of the cases above under Points (a), (b) or (c) applies, the beneficiary must formally notify the Agency and at the same time inform it of any reasons for refusing consent. The beneficiary may refuse consent only if it can show that its legitimate interests would suffer significant harm.

If the Agency decides to assume ownership, it will formally notify the beneficiary concerned within 45 days of receiving notification.

No dissemination relating to these results may take place before the end of this period or, if the Agency takes a positive decision, until it has taken the necessary steps to protect the results.

26.4.2 The Agency may — with the consent of the beneficiary concerned — assume ownership of results to protect them, if a beneficiary intends — up to four years after the period set out in Article 3 — to stop protecting them or not to seek an extension of protection, except in any of the following cases:

(a) the protection is stopped because of a lack of potential for commercial or industrial exploitation;

(b) an extension would not be justified given the circumstances.

A beneficiary that intends to stop protecting results or not seek an extension must — unless any of the cases above under Points (a) or (b) applies — formally notify the Agency at least 60 days before the protection lapses or its extension is no longer possible and at the same time inform it of any reasons for refusing consent. The beneficiary may refuse consent only if it can show that its legitimate interests would suffer significant harm.

If the Agency decides to assume ownership, it will formally notify the beneficiary concerned within 45 days of receiving notification.

26.5 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to the any of the other measures described in Chapter 6.

ARTICLE 27 — PROTECTION OF RESULTS — VISIBILITY OF EU FUNDING

27.1 Obligation to protect the results

Each beneficiary must examine the possibility of protecting its results and must adequately protect them — for an appropriate period and with appropriate territorial coverage — if:

(a) the results can reasonably be expected to be commercially or industrially exploited and

(b) protecting them is possible, reasonable and justified (given the circumstances).

When deciding on protection, the beneficiary must consider its own legitimate interests and the legitimate interests (especially commercial) of the other beneficiaries.

27.2 Agency ownership, to protect the results

If a beneficiary intends not to protect its results, to stop protecting them or not seek an extension of

protection, the Agency may — under certain conditions (see Article 26.4) — assume ownership to ensure their (continued) protection.

27.3 Information on EU funding

Applications for protection of results (including patent applications) filed by or on behalf of a beneficiary must — unless the Agency requests or agrees otherwise or unless it is impossible — include the following:

> "The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814945".

27.4 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such a breach may also lead to any of the other measures described in Chapter 6.

ARTICLE 28 — EXPLOITATION OF RESULTS

28.1 Obligation to exploit the results

Each beneficiary must — up to four years after the period set out in Article 3 — take measures aiming to ensure '**exploitation**' of its results (either directly or indirectly, in particular through transfer or licensing; see Article 30) by:

(a) using them in further research activities (outside the action);

(b) developing, creating or marketing a product or process;

(c) creating and providing a service, or

(d) using them in standardisation activities.

This does not change the security obligations in Article 37, which still apply.

28.2 Results that could contribute to European or international standards — Information on EU funding

If results are incorporated in a standard, the beneficiary concerned must — unless the Agency requests or agrees otherwise or unless it is impossible — ask the standardisation body to include the following statement in (information related to) the standard:

> "Results incorporated in this standard received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814945".

28.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced in accordance with Article 43.

Such a breach may also lead to any of the other measures described in Chapter 6.

ARTICLE 29 — DISSEMINATION OF RESULTS — OPEN ACCESS — VISIBILITY OF EU FUNDING

29.1 Obligation to disseminate results

Unless it goes against their legitimate interests, each beneficiary must — as soon as possible — '**disseminate**' its results by disclosing them to the public by appropriate means (other than those resulting from protecting or exploiting the results), including in scientific publications (in any medium).

This does not change the obligation to protect results in Article 27, the confidentiality obligations in Article 36, the security obligations in Article 37 or the obligations to protect personal data in Article 39, all of which still apply.

A beneficiary that intends to disseminate its results must give advance notice to the other beneficiaries of — unless agreed otherwise — at least 45 days, together with sufficient information on the results it will disseminate.

Any other beneficiary may object within — unless agreed otherwise — 30 days of receiving notification, if it can show that its legitimate interests in relation to the results or background would be significantly harmed. In such cases, the dissemination may not take place unless appropriate steps are taken to safeguard these legitimate interests.

If a beneficiary intends not to protect its results, it may — under certain conditions (see Article 26.4.1) — need to formally notify the Agency before dissemination takes place.

29.2 Open access to scientific publications

Each beneficiary must ensure open access (free of charge online access for any user) to all peer-reviewed scientific publications relating to its results.

In particular, it must:

(a) as soon as possible and at the latest on publication, deposit a machine-readable electronic copy of the published version or final peer-reviewed manuscript accepted for publication in a repository for scientific publications;

Moreover, the beneficiary must aim to deposit at the same time the research data needed to validate the results presented in the deposited scientific publications.

(b) ensure open access to the deposited publication — via the repository — at the latest:

(i) on publication, if an electronic version is available for free via the publisher, or

(ii) within six months of publication (twelve months for publications in the social sciences and humanities) in any other case.

(c) ensure open access — via the repository — to the bibliographic metadata that identify the deposited publication.

The bibliographic metadata must be in a standard format and must include all of the following:

- the terms “European Union (EU)” and “Horizon 2020”;
- the name of the action, acronym and grant number;
- the publication date, and length of embargo period if applicable, and
- a persistent identifier.

29.3 Open access to research data

Regarding the digital research data generated in the action (‘**data**’), the beneficiaries must:

(a) deposit in a research data repository and take measures to make it possible for third parties to access, mine, exploit, reproduce and disseminate — free of charge for any user — the following:

(i) the data, including associated metadata, needed to validate the results presented in scientific publications, as soon as possible;

(ii) not applicable;

(iii) other data, including associated metadata, as specified and within the deadlines laid down in the ‘data management plan’ (see Annex 1);

(b) provide information — via the repository — about tools and instruments at the disposal of the beneficiaries and necessary for validating the results (and — where possible — provide the tools and instruments themselves).

This does not change the obligation to protect results in Article 27, the confidentiality obligations in Article 36, the security obligations in Article 37 or the obligations to protect personal data in Article 39, all of which still apply.

As an exception, the beneficiaries do not have to ensure open access to specific parts of their research data under Point (a)(i) and (iii), if the achievement of the action's main objective (as described in Annex 1) would be jeopardised by making those specific parts of the research data openly accessible. In this case, the data management plan must contain the reasons for not giving access.

29.4 Information on EU funding — Obligation and right to use the EU emblem

Unless the Agency requests or agrees otherwise or unless it is impossible, any dissemination of results (in any form, including electronic) must:

(a) display the EU emblem and

(b) include the following text:

> “This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 814945”.

When displayed together with another logo, the EU emblem must have appropriate prominence.

For the purposes of their obligations under this Article, the beneficiaries may use the EU emblem without first obtaining approval from the Agency.

This does not however give them the right to exclusive use.

Moreover, they may not appropriate the EU emblem or any similar trademark or logo, either by registration or by any other means.

29.5 Disclaimer excluding Agency responsibility

Any dissemination of results must indicate that it reflects only the author's view and that the Agency is not responsible for any use that may be made of the information it contains.

29.6 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such a breach may also lead to any of the other measures described in Chapter 6.

ARTICLE 30 — TRANSFER AND LICENSING OF RESULTS

30.1 Transfer of ownership

Each beneficiary may transfer ownership of its results.

It must however ensure that its obligations under Articles 26.2, 26.4, 27, 28, 29, 30 and 31 also apply to the new owner and that this owner has the obligation to pass them on in any subsequent transfer.

This does not change the security obligations in Article 37, which still apply.

Unless agreed otherwise (in writing) for specifically-identified third parties or unless impossible under applicable EU and national laws on mergers and acquisitions, a beneficiary that intends to transfer ownership of results must give at least 45 days advance notice (or less if agreed in writing) to the other beneficiaries that still have (or still may request) access rights to the results. This notification must include sufficient information on the new owner to enable any beneficiary concerned to assess the effects on its access rights.

Unless agreed otherwise (in writing) for specifically-identified third parties, any other beneficiary may object within 30 days of receiving notification (or less if agreed in writing), if it can show that the transfer would adversely affect its access rights. In this case, the transfer may not take place until agreement has been reached between the beneficiaries concerned.

30.2 Granting licenses

Each beneficiary may grant licences to its results (or otherwise give the right to exploit them), if:

(a) this does not impede the access rights under Article 31 and

(b) not applicable.

In addition to Points (a) and (b), exclusive licences for results may be granted only if all the other beneficiaries concerned have waived their access rights (see Article 31.1).

This does not change the dissemination obligations in Article 29 or security obligations in Article 37, which still apply.

30.3 Agency right to object to transfers or licensing

Not applicable

30.4 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such a breach may also lead to any of the other measures described in Chapter 6.

ARTICLE 31 — ACCESS RIGHTS TO RESULTS

31.1 Exercise of access rights — Waiving of access rights — No sub-licensing

The conditions set out in Article 25.1 apply.

The obligations set out in this Article do not change the security obligations in Article 37, which still apply.

31.2 Access rights for other beneficiaries, for implementing their own tasks under the action

The beneficiaries must give each other access — on a royalty-free basis — to results needed for implementing their own tasks under the action.

31.3 Access rights for other beneficiaries, for exploiting their own results

The beneficiaries must give each other — under fair and reasonable conditions (see Article 25.3) — access to results needed for exploiting their own results.

Requests for access may be made — unless agreed otherwise — up to one year after the period set out in Article 3.

31.4 Access rights of affiliated entities

Unless agreed otherwise in the consortium agreement, access to results must also be given — under fair and reasonable conditions (Article 25.3) — to affiliated entities established in an EU Member State or associated country, if this is needed for those entities to exploit the results generated by the beneficiaries to which they are affiliated.

Unless agreed otherwise (see above; Article 31.1), the affiliated entity concerned must make any such request directly to the beneficiary that owns the results.

Requests for access may be made — unless agreed otherwise — up to one year after the period set out in Article 3.

31.5 Access rights for the EU institutions, bodies, offices or agencies and EU Member States

The beneficiaries must give access to their results — on a royalty-free basis — to EU institutions, bodies, offices or agencies, for developing, implementing or monitoring EU policies or programmes.

Such access rights are limited to non-commercial and non-competitive use.

This does not change the right to use any material, document or information received from the beneficiaries for communication and publicising activities (see Article 38.2).

31.6 Access rights for third parties

Not applicable

31.7 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

SECTION 4 OTHER RIGHTS AND OBLIGATIONS

ARTICLE 32 — RECRUITMENT AND WORKING CONDITIONS FOR RESEARCHERS

32.1 Obligation to take measures to implement the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers

The beneficiaries must take all measures to implement the principles set out in the Commission Recommendation on the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers[23], in particular regarding:

- working conditions;
- transparent recruitment processes based on merit, and
- career development.

The beneficiaries must ensure that researchers and third parties involved in the action are aware of them.

32.2 Consequences of non-compliance

If a beneficiary breaches its obligations under this Article, the Agency may apply any of the measures described in Chapter 6.

ARTICLE 33 — GENDER EQUALITY

33.1 Obligation to aim for gender equality

[23] Commission Recommendation 2005/251/EC of 11 March 2005 on the European Charter for Researchers and on a Code of Conduct for the Recruitment of Researchers (OJ L 75, 22.3.2005, p. 67).

The beneficiaries must take all measures to promote equal opportunities between men and women in the implementation of the action. They must aim, to the extent possible, for a gender balance at all levels of personnel assigned to the action, including at supervisory and managerial level.

33.2 Consequences of non-compliance

If a beneficiary breaches its obligations under this Article, the Agency may apply any of the measures described in Chapter 6.

ARTICLE 34 — ETHICS AND RESEARCH INTEGRITY

34.1 Obligation to comply with ethical and research integrity principles

The beneficiaries must carry out the action in compliance with:

(a) ethical principles (including the highest standards of research integrity)

and

(b) applicable international, EU and national law.

Funding will not be granted for activities carried out outside the EU if they are prohibited in all Member States or for activities which destroy human embryos (for example, for obtaining stem cells).

The beneficiaries must ensure that the activities under the action have an exclusive focus on civil applications.

The beneficiaries must ensure that the activities under the action do not:

(a) aim at human cloning for reproductive purposes;

(b) intend to modify the genetic heritage of human beings which could make such changes heritable (with the exception of research relating to cancer treatment of the gonads, which may be financed), or

(c) intend to create human embryos solely for the purpose of research or for the purpose of stem cell procurement, including by means of somatic cell nuclear transfer.

In addition, the beneficiaries must respect the fundamental principle of research integrity — as set out, for instance, in the European Code of Conduct for Research Integrity[24].

This implies compliance with the following fundamental principles:

- **reliability** in ensuring the quality of research reflected in the design, the methodology, the analysis and the use of resources;

- **honesty** in developing, undertaking, reviewing, reporting and communicating research in a transparent, fair and unbiased way;

[24] European Code of Conduct for Research Integrity of ALLEA (All European Academies) http://ec.europa.eu/research/participants/data/ref/h2020/other/hi/h2020-ethics_code-of-conduct_en.pdf

- **respect** for colleagues, research participants, society, ecosystems, cultural heritage and the environment;

- **accountability** for the research from idea to publication, for its management and organisation, for training, supervision and mentoring, and for its wider impacts

and means that beneficiaries must ensure that persons carrying out research tasks follow the good research practices and refrain from the research integrity violations described in this Code.

This does not change the other obligations under this Agreement or obligations under applicable international, EU or national law, all of which still apply.

34.2 Activities raising ethical issues

Activities raising ethical issues must comply with the '**ethics requirements**' set out as deliverables in Annex 1.

Before the beginning of an activity raising an ethical issue, each beneficiary must have obtained:

(a) any ethics committee opinion required under national law and

(b) any notification or authorisation for activities raising ethical issues required under national and/or European law

needed for implementing the action tasks in question.

The documents must be kept on file and be submitted upon request by the coordinator to the Agency (see Article 52). If they are not in English, they must be submitted together with an English summary, which shows that the action tasks in question are covered and includes the conclusions of the committee or authority concerned (if available).

34.3 Activities involving human embryos or human embryonic stem cells

Activities involving research on human embryos or human embryonic stem cells may be carried out, in addition to Article 34.1, only if:

- they are set out in Annex 1 or

- the coordinator has obtained explicit approval (in writing) from the Agency (see Article 52).

34.4 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43) and the Agreement or participation of the beneficiary may be terminated (see Article 50).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 35 — CONFLICT OF INTERESTS

35.1 Obligation to avoid a conflict of interests

The beneficiaries must take all measures to prevent any situation where the impartial and objective

implementation of the action is compromised for reasons involving economic interest, political or national affinity, family or emotional ties or any other shared interest ('**conflict of interests**').

They must formally notify to the Agency without delay any situation constituting or likely to lead to a conflict of interests and immediately take all the necessary steps to rectify this situation.

The Agency may verify that the measures taken are appropriate and may require additional measures to be taken by a specified deadline.

35.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43) and the Agreement or participation of the beneficiary may be terminated (see Article 50).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 36 — CONFIDENTIALITY

36.1 General obligation to maintain confidentiality

During implementation of the action and for four years after the period set out in Article 3, the parties must keep confidential any data, documents or other material (in any form) that is identified as confidential at the time it is disclosed ('**confidential information**').

If a beneficiary requests, the Agency may agree to keep such information confidential for an additional period beyond the initial four years.

If information has been identified as confidential only orally, it will be considered to be confidential only if this is confirmed in writing within 15 days of the oral disclosure.

Unless otherwise agreed between the parties, they may use confidential information only to implement the Agreement.

The beneficiaries may disclose confidential information to their personnel or third parties involved in the action only if they:

(a) need to know to implement the Agreement and

(b) are bound by an obligation of confidentiality.

This does not change the security obligations in Article 37, which still apply.

The Agency may disclose confidential information to its staff, other EU institutions and bodies. It may disclose confidential information to third parties, if:

(a) this is necessary to implement the Agreement or safeguard the EU's financial interests and

(b) the recipients of the information are bound by an obligation of confidentiality.

Under the conditions set out in Article 4 of the Rules for Participation Regulation No 1290/2013[25],

[25] Regulation (EU) No 1290/2013 of the European Parliament and of the Council of 11 December 2013 laying down the

the Commission must moreover make available information on the results to other EU institutions, bodies, offices or agencies as well as Member States or associated countries.

The confidentiality obligations no longer apply if:

(a) the disclosing party agrees to release the other party;

(b) the information was already known by the recipient or is given to him without obligation of confidentiality by a third party that was not bound by any obligation of confidentiality;

(c) the recipient proves that the information was developed without the use of confidential information;

(d) the information becomes generally and publicly available, without breaching any confidentiality obligation, or

(e) the disclosure of the information is required by EU or national law.

36.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 37 — SECURITY-RELATED OBLIGATIONS

37.1 Results with a security recommendation

Not applicable

37.2 Classified information

Not applicable

37.3 Activities involving dual-use goods or dangerous materials and substances

Not applicable

37.4 Consequences of non-compliance

Not applicable

ARTICLE 38 — PROMOTING THE ACTION — VISIBILITY OF EU FUNDING

38.1 Communication activities by beneficiaries

38.1.1 Obligation to promote the action and its results

rules for participation and dissemination in "Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020)" (OJ L 347, 20.12.2013 p.81).

The beneficiaries must promote the action and its results, by providing targeted information to multiple audiences (including the media and the public) in a strategic and effective manner.

This does not change the dissemination obligations in Article 29, the confidentiality obligations in Article 36 or the security obligations in Article 37, all of which still apply.

Before engaging in a communication activity expected to have a major media impact, the beneficiaries must inform the Agency (see Article 52).

38.1.2 Information on EU funding — Obligation and right to use the EU emblem

Unless the Agency requests or agrees otherwise or unless it is impossible, any communication activity related to the action (including in electronic form, via social media, etc.) and any infrastructure, equipment and major results funded by the grant must:

(a) display the EU emblem and

(b) include the following text:

For communication activities:

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814945".

For infrastructure, equipment and major results:

"This *[infrastructure][equipment][insert type of result]* is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814945".

When displayed together with another logo, the EU emblem must have appropriate prominence.

For the purposes of their obligations under this Article, the beneficiaries may use the EU emblem without first obtaining approval from the Agency.

This does not, however, give them the right to exclusive use.

Moreover, they may not appropriate the EU emblem or any similar trademark or logo, either by registration or by any other means.

38.1.3 Disclaimer excluding Agency and Commission responsibility

Any communication activity related to the action must indicate that it reflects only the author's view and that the Agency and the Commission are not responsible for any use that may be made of the information it contains.

38.2 Communication activities by the Agency and the Commission

38.2.1 Right to use beneficiaries' materials, documents or information

The Agency and the Commission may use, for its communication and publicising activities, information relating to the action, documents notably summaries for publication and public deliverables as well as any other material, such as pictures or audio-visual material received from any beneficiary (including in electronic form).

This does not change the confidentiality obligations in Article 36 and the security obligations in Article 37, all of which still apply.

If the Agency's or the Commission's use of these materials, documents or information would risk compromising legitimate interests, the beneficiary concerned may request the Agency or the Commission not to use it (see Article 52).

The right to use a beneficiary's materials, documents and information includes:

(a) **use for its own purposes** (in particular, making them available to persons working for the Agency, the Commission or any other EU institution, body, office or agency or body or institutions in EU Member States; and copying or reproducing them in whole or in part, in unlimited numbers);

(b) **distribution to the public** (in particular, publication as hard copies and in electronic or digital format, publication on the internet, as a downloadable or non-downloadable file, broadcasting by any channel, public display or presentation, communicating through press information services, or inclusion in widely accessible databases or indexes);

(c) **editing or redrafting** for communication and publicising activities (including shortening, summarising, inserting other elements (such as meta-data, legends, other graphic, visual, audio or text elements), extracting parts (e.g. audio or video files), dividing into parts, use in a compilation);

(d) translation;

(e) giving **access in response to individual requests** under Regulation No 1049/2001[27], without the right to reproduce or exploit;

(f) **storage** in paper, electronic or other form;

(g) **archiving**, in line with applicable document-management rules, and

(h) the right to authorise **third parties** to act on its behalf or sub-license the modes of use set out in Points (b), (c), (d) and (f) to third parties if needed for the communication and publicising activities of the Agency or the Commission.

If the right of use is subject to rights of a third party (including personnel of the beneficiary), the beneficiary must ensure that it complies with its obligations under this Agreement (in particular, by obtaining the necessary approval from the third parties concerned).

Where applicable (and if provided by the beneficiaries), the Agency or the Commission will insert the following information:

> "© – [year] – [name of the copyright owner]. All rights reserved. Licensed to the Innovation and Networks Executive Agency (INEA) and the European Union (EU) under conditions."

38.3 Consequences of non-compliance

[27] Regulation (EC) No 1049/2001 of the European Parliament and of the Council of 30 May 2001 regarding public access to European Parliament, Council and Commission documents, OJ L 145, 31.5.2001, p. 43.

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 39 — PROCESSING OF PERSONAL DATA

39.1 Processing of personal data by the Agency and the Commission

Any personal data under the Agreement will be processed by the Agency or the Commission under Regulation No 45/2001[28] and according to the 'notifications of the processing operations' to the Data Protection Officer (DPO) of the Agency or the Commission (publicly accessible in the DPO register).

Such data will be processed by the '**data controller**' of the Agency or the Commission for the purposes of implementing, managing and monitoring the Agreement or protecting the financial interests of the EU or Euratom (including checks, reviews, audits and investigations; see Article 22).

The persons whose personal data are processed have the right to access and correct their own personal data. For this purpose, they must send any queries about the processing of their personal data to the data controller, via the contact point indicated in the privacy statement(s) that are published on the Agency and the Commission websites.

They also have the right to have recourse at any time to the European Data Protection Supervisor (EDPS).

39.2 Processing of personal data by the beneficiaries

The beneficiaries must process personal data under the Agreement in compliance with applicable EU and national law on data protection (including authorisations or notification requirements).

The beneficiaries may grant their personnel access only to data that is strictly necessary for implementing, managing and monitoring the Agreement.

The beneficiaries must inform the personnel whose personal data are collected and processed by the Agency or the Commission. For this purpose, they must provide them with the privacy statement(s) (see above), before transmitting their data to the Agency or the Commission.

39.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under Article 39.2, the Agency may apply any of the measures described in Chapter 6.

ARTICLE 40 — ASSIGNMENTS OF CLAIMS FOR PAYMENT AGAINST THE AGENCY

The beneficiaries may not assign any of their claims for payment against the Agency to any third party, except if approved by the Agency on the basis of a reasoned, written request by the coordinator (on behalf of the beneficiary concerned).

[28] Regulation (EC) No 45/2001 of the European Parliament and of the Council of 18 December 2000 on the protection of individuals with regard to the processing of personal data by the Community institutions and bodies and on the free movement of such data (OJ L 8, 12.01.2001, p. 1).

If the Agency has not accepted the assignment or the terms of it are not observed, the assignment will have no effect on it.

In no circumstances will an assignment release the beneficiaries from their obligations towards the Agency.

CHAPTER 5 DIVISION OF BENEFICIARIES' ROLES AND RESPONSIBILITIES — RELATIONSHIP WITH COMPLEMENTARY BENEFICIARIES — RELATIONSHIP WITH PARTNERS OF A JOINT ACTION

ARTICLE 41 — DIVISION OF BENEFICIARIES' ROLES AND RESPONSIBILITIES — RELATIONSHIP WITH COMPLEMENTARY BENEFICIARIES — RELATIONSHIP WITH PARTNERS OF A JOINT ACTION

41.1 Roles and responsibility towards the Agency

The beneficiaries have full responsibility for implementing the action and complying with the Agreement.

The beneficiaries are jointly and severally liable for the **technical implementation** of the action as described in Annex 1. If a beneficiary fails to implement its part of the action, the other beneficiaries become responsible for implementing this part (without being entitled to any additional EU funding for doing so), unless the Agency expressly relieves them of this obligation.

The **financial responsibility** of each beneficiary is governed by Article 44.

41.2 Internal division of roles and responsibilities

The internal roles and responsibilities of the beneficiaries are divided as follows:

(a) Each **beneficiary** must:

(i) keep information stored in the Participant Portal Beneficiary Register (via the electronic exchange system) up to date (see Article 17);

(ii) inform the coordinator immediately of any events or circumstances likely to affect significantly or delay the implementation of the action (see Article 17);

(iii) submit to the coordinator in good time:

- individual financial statements for itself and, if required, certificates on the financial statements (see Article 20);
- the data needed to draw up the technical reports (see Article 20);
- ethics committee opinions and notifications or authorisations for activities raising ethical issues (see Article 34);
- any other documents or information required by the Agency or the Commission under the Agreement, unless the Agreement requires the beneficiary to submit this information directly to the Agency or the Commission.

(b) The **coordinator** must:

(i) monitor that the action is implemented properly (see Article 7);

(ii) act as the intermediary for all communications between the beneficiaries and the Agency (in particular, providing the Agency with the information described in Article 17), unless the Agreement specifies otherwise;

(iii) request and review any documents or information required by the Agency and verify their completeness and correctness before passing them on to the Agency;

(iv) submit the deliverables and reports to the Agency (see Articles 19 and 20);

(v) ensure that all payments are made to the other beneficiaries without unjustified delay (see Article 21);

(vi) inform the Agency of the amounts paid to each beneficiary, when required under the Agreement (see Articles 44 and 50) or requested by the Agency.

The coordinator may not delegate or subcontract the above-mentioned tasks to any other beneficiary or third party (including linked third parties).

41.3 Internal arrangements between beneficiaries — Consortium agreement

The beneficiaries must have internal arrangements regarding their operation and co-ordination to ensure that the action is implemented properly. These internal arrangements must be set out in a written '**consortium agreement**' between the beneficiaries, which may cover:

- internal organisation of the consortium;
- management of access to the electronic exchange system;
- distribution of EU funding;
- additional rules on rights and obligations related to background and results (including whether access rights remain or not, if a beneficiary is in breach of its obligations) (see Section 3 of Chapter 4);
- settlement of internal disputes;
- liability, indemnification and confidentiality arrangements between the beneficiaries.

The consortium agreement must not contain any provision contrary to the Agreement.

41.4 Relationship with complementary beneficiaries — Collaboration agreement

Not applicable

41.5 Relationship with partners of a joint action — Coordination agreement

Not applicable

CHAPTER 6 REJECTION OF COSTS — REDUCTION OF THE GRANT — RECOVERY — SANCTIONS — DAMAGES — SUSPENSION — TERMINATION — FORCE MAJEURE

SECTION 1 REJECTION OF COSTS — REDUCTION OF THE GRANT — RECOVERY — SANCTIONS

ARTICLE 42 — REJECTION OF INELIGIBLE COSTS

42.1 Conditions

The Agency will — after **termination of the participation of a beneficiary**, at the time of an **interim payment**, **at the payment of the balance** or **afterwards** — reject any costs which are ineligible (see Article 6), in particular following checks, reviews, audits or investigations (see Article 22).

The rejection may also be based on the **extension of findings from other grants to this grant** (see Article 22.5.2).

42.2 Ineligible costs to be rejected — Calculation — Procedure

Ineligible costs will be rejected in full.

If the rejection of costs does not lead to a recovery (see Article 44), the Agency will formally notify the coordinator or beneficiary concerned of the rejection of costs, the amounts and the reasons why (if applicable, together with the notification of amounts due; see Article 21.5). The coordinator or beneficiary concerned may — within 30 days of receiving notification — formally notify the Agency of its disagreement and the reasons why.

If the rejection of costs leads to a recovery, the Agency will follow the contradictory procedure with pre-information letter set out in Article 44.

42.3 Effects

If the Agency rejects costs at the time of an **interim payment** or **the payment of the balance**, it will deduct them from the total eligible costs declared, for the action, in the periodic or final summary financial statement (see Articles 20.3 and 20.4). It will then calculate the interim payment or payment of the balance as set out in Articles 21.3 or 21.4.

If the Agency rejects costs **after termination of the participation of a beneficiary**, it will deduct them from the costs declared by the beneficiary in the termination report and include the rejection in the calculation after termination (see Article 50.2 and 50.3).

If the Agency — **after an interim payment but before the payment of the balance** — rejects costs declared in a periodic summary financial statement, it will deduct them from the total eligible costs declared, for the action, in the next periodic summary financial statement or in the final summary financial statement. It will then calculate the interim payment or payment of the balance as set out in Articles 21.3 or 21.4.

If the Agency rejects costs **after the payment of the balance**, it will deduct the amount rejected from

the total eligible costs declared, by the beneficiary, in the final summary financial statement. It will then calculate the revised final grant amount as set out in Article 5.4.

ARTICLE 43 — REDUCTION OF THE GRANT

43.1 Conditions

The Agency may — **after termination of the participation of a beneficiary**, **at the payment of the balance** or **afterwards** — reduce the grant amount (see Article 5.1), if :

(a) a beneficiary (or a natural person who has the power to represent or take decisions on its behalf) has committed:

(i) substantial errors, irregularities or fraud or

(ii) serious breach of obligations under the Agreement or during the award procedure (including improper implementation of the action, submission of false information, failure to provide required information, breach of ethical principles) or

(b) a beneficiary (or a natural person who has the power to represent or take decision on its behalf) has committed — in other EU or Euratom grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant (**extension of findings from other grants to this grant**; see Article 22.5.2).

43.2 Amount to be reduced — Calculation — Procedure

The amount of the reduction will be proportionate to the seriousness of the errors, irregularities or fraud or breach of obligations.

Before reduction of the grant, the Agency will formally notify a '**pre-information letter**' to the coordinator or beneficiary concerned:

- informing it of its intention to reduce the grant, the amount it intends to reduce and the reasons why and

- inviting it to submit observations within 30 days of receiving notification.

If the Agency does not receive any observations or decides to pursue reduction despite the observations it has received, it will formally notify **confirmation** of the reduction (if applicable, together with the notification of amounts due; see Article 21).

43.3 Effects

If the Agency reduces the grant **after termination of the participation of a beneficiary**, it will calculate the reduced grant amount for that beneficiary and then determine the amount due to that beneficiary (see Article 50.2 and 50.3).

If the Agency reduces the grant **at the payment of the balance**, it will calculate the reduced grant amount for the action and then determine the amount due as payment of the balance (see Articles 5.3.4 and 21.4).

If the Agency reduces the grant **after the payment of the balance**, it will calculate the revised final grant amount for the beneficiary concerned (see Article 5.4). If the revised final grant amount for the beneficiary concerned is lower than its share of the final grant amount, the Agency will recover the difference (see Article 44).

ARTICLE 44 — RECOVERY OF UNDUE AMOUNTS

44.1 Amount to be recovered — Calculation — Procedure

The Agency will — after **termination of the participation of a beneficiary, at the payment of the balance** or **afterwards** — claim back any amount that was paid, but is not due under the Agreement.

Each beneficiary's financial responsibility in case of recovery is limited to its own debt, except for the amount retained for the Guarantee Fund (see Article 21.4).

44.1.1 Recovery after termination of a beneficiary's participation

If recovery takes place after termination of a beneficiary's participation (including the coordinator), the Agency will claim back the undue amount from the beneficiary concerned, by formally notifying it a debit note (see Article 50.2 and 50.3). This note will specify the amount to be recovered, the terms and the date for payment.

If payment is not made by the date specified in the debit note, the Agency or the Commission will **recover** the amount:

(a) by '**offsetting**' it — without the beneficiary's consent — against any amounts owed to the beneficiary concerned by the Agency, the Commission or another executive agency (from the EU or Euratom budget).

In exceptional circumstances, to safeguard the EU's financial interests, the Agency or the Commission may offset before the payment date specified in the debit note;

(b) not applicable;

(c) by **taking legal action** (see Article 57) or by **adopting an enforceable decision** under Article 299 of the Treaty on the Functioning of the EU (TFEU) and Article 79(2) of the Financial regulation No 966/2012.

If payment is not made by the date specified in the debit note, the amount to be recovered (see above) will be increased by **late-payment interest** at the rate set out in Article 21.11, from the day following the payment date in the debit note, up to and including the date the Agency or the Commission receives full payment of the amount.

Partial payments will be first credited against expenses, charges and late-payment interest and then against the principal.

Bank charges incurred in the recovery process will be borne by the beneficiary, unless Directive 2007/64/EC[29] applies.

[29] Directive 2007/64/EC of the European Parliament and of the Council of 13 November 2007 on payment services in the internal market amending Directives 97/7/EC, 2002/65/EC, 2005/60/EC and 2006/48/EC and repealing Directive 97/5/EC (OJ L 319, 05.12.2007, p. 1).

44.1.2 Recovery at payment of the balance

If the payment of the balance takes the form of a recovery (see Article 21.4), the Agency will formally notify a '**pre-information letter**' to the coordinator:

- informing it of its intention to recover, the amount due as the balance and the reasons why;
- specifying that it intends to deduct the amount to be recovered from the amount retained for the Guarantee Fund;
- requesting the coordinator to submit a report on the distribution of payments to the beneficiaries within 30 days of receiving notification, and
- inviting the coordinator to submit observations within 30 days of receiving notification.

If no observations are submitted or the Agency decides to pursue recovery despite the observations it has received, it will **confirm recovery** (together with the notification of amounts due; see Article 21.5) and:

- pay the difference between the amount to be recovered and the amount retained for the Guarantee Fund, **if the difference is positive** or
- formally notify to the coordinator a **debit note** for the difference between the amount to be recovered and the amount retained for the Guarantee Fund, **if the difference is negative**. This note will also specify the terms and the date for payment.

If the coordinator does not repay the Agency by the date in the debit note and has not submitted the report on the distribution of payments: the Agency or the Commission will **recover** the amount set out in the debit note from the coordinator (see below).

If the coordinator does not repay the Agency by the date in the debit note, but has submitted the report on the distribution of payments: the Agency will:

(a) identify the beneficiaries for which the amount calculated as follows is negative:

{{{{beneficiary's costs declared in the final summary financial statement and approved by the Agency multiplied by the reimbursement rate set out in Article 5.2 for the beneficiary concerned}

divided by

the EU contribution for the action calculated according to Article 5.3.1}

multiplied by

the final grant amount (see Article 5.3)},

minus

{pre-financing and interim payments received by the beneficiary}.

(b) formally notify to each beneficiary identified according to point (a) a **debit note** specifying the terms and date for payment. The amount of the debit note is calculated as follows:

{{amount calculated according to point (a) for the beneficiary concerned

divided by

the sum of the amounts calculated according to point (a) for all the beneficiaries identified according to point (a)}

multiplied by

the amount set out in the debit note formally notified to the coordinator}.

If payment is not made by the date specified in the debit note, the Agency or the Commission will **recover** the amount:

(a) by **offsetting** it — without the beneficiary's consent — against any amounts owed to the beneficiary concerned by the Agency, the Commission or another executive agency (from the EU or Euratom budget).

In exceptional circumstances, to safeguard the EU's financial interests, the Agency or the Commission may offset before the payment date specified in the debit note;

(b) by **drawing on the Guarantee Fund**. The Agency or the Commission will formally notify the beneficiary concerned the debit note on behalf of the Guarantee Fund and recover the amount:

(i) not applicable;

(ii) by **taking legal action** (see Article 57) or by **adopting an enforceable decision** under Article 299 of the Treaty on the Functioning of the EU (TFEU) and Article 79(2) of the Financial Regulation No 966/2012.

If payment is not made by the date in the debit note, the amount to be recovered (see above) will be increased by **late-payment interest** at the rate set out in Article 21.11, from the day following the payment date in the debit note, up to and including the date the Agency or the Commission receives full payment of the amount.

Partial payments will be first credited against expenses, charges and late-payment interest and then against the principal.

Bank charges incurred in the recovery process will be borne by the beneficiary, unless Directive 2007/64/EC applies.

44.1.3 Recovery of amounts after payment of the balance

If, for a beneficiary, the revised final grant amount (see Article 5.4) is lower than its share of the final grant amount, it must repay the difference to the Agency.

The beneficiary's share of the final grant amount is calculated as follows:

{{{beneficiary's costs declared in the final summary financial statement and approved by the Agency multiplied by the reimbursement rate set out in Article 5.2 for the beneficiary concerned}

divided by

the EU contribution for the action calculated according to Article 5.3.1}

multiplied by

the final grant amount (see Article 5.3)}.

If the coordinator has not distributed amounts received (see Article 21.7), the Agency will also recover these amounts.

The Agency will formally notify a **pre-information letter** to the beneficiary concerned:

- informing it of its intention to recover, the due amount and the reasons why and
- inviting it to submit observations within 30 days of receiving notification.

If no observations are submitted or the Agency decides to pursue recovery despite the observations it has received, it will **confirm** the amount to be recovered and formally notify to the beneficiary concerned a **debit note**. This note will also specify the terms and the date for payment.

If payment is not made by the date specified in the debit note, the Agency or the Commission will **recover** the amount:

(a) by **offsetting** it — without the beneficiary's consent — against any amounts owed to the beneficiary concerned by the Agency, the Commission or another executive agency (from the EU or Euratom budget).

In exceptional circumstances, to safeguard the EU's financial interests, the Agency or the Commission may offset before the payment date specified in the debit note;

(b) by **drawing on the Guarantee Fund**. The Agency or the Commission will formally notify the beneficiary concerned the debit note on behalf of the Guarantee Fund and recover the amount:

(i) not applicable;

(ii) by **taking legal action** (see Article 57) or by **adopting an enforceable decision** under Article 299 of the Treaty on the Functioning of the EU (TFEU) and Article 79(2) of the Financial Regulation No 966/2012.

If payment is not made by the date in the debit note, the amount to be recovered (see above) will be increased by **late-payment interest** at the rate set out in Article 21.11, from the day following the date for payment in the debit note, up to and including the date the Agency or the Commission receives full payment of the amount.

Partial payments will be first credited against expenses, charges and late-payment interest and then against the principal.

Bank charges incurred in the recovery process will be borne by the beneficiary, unless Directive 2007/64/EC applies.

ARTICLE 45 — ADMINISTRATIVE SANCTIONS

In addition to contractual measures, the Agency or the Commission may also adopt administrative sanctions under Articles 106 and 131(4) of the Financial Regulation No 966/2012 (i.e. exclusion from future procurement contracts, grants, prizes and expert contracts and/or financial penalties).

SECTION 2 LIABILITY FOR DAMAGES

ARTICLE 46 — LIABILITY FOR DAMAGES

46.1 Liability of the Agency

The Agency cannot be held liable for any damage caused to the beneficiaries or to third parties as a consequence of implementing the Agreement, including for gross negligence.

The Agency cannot be held liable for any damage caused by any of the beneficiaries or third parties involved in the action, as a consequence of implementing the Agreement.

46.2 Liability of the beneficiaries

Except in case of force majeure (see Article 51), the beneficiaries must compensate the Agency for any damage it sustains as a result of the implementation of the action or because the action was not implemented in full compliance with the Agreement.

SECTION 3 SUSPENSION AND TERMINATION

ARTICLE 47 — SUSPENSION OF PAYMENT DEADLINE

47.1 Conditions

The Agency may — at any moment — suspend the payment deadline (see Article 21.2 to 21.4) if a request for payment (see Article 20) cannot be approved because:

(a) it does not comply with the provisions of the Agreement (see Article 20);

(b) the technical or financial reports have not been submitted or are not complete or additional information is needed, or

(c) there is doubt about the eligibility of the costs declared in the financial statements and additional checks, reviews, audits or investigations are necessary.

47.2 Procedure

The Agency will formally notify the coordinator of the suspension and the reasons why.

The suspension will **take effect** the day notification is sent by the Agency (see Article 52).

If the conditions for suspending the payment deadline are no longer met, the suspension will be **lifted** — and the remaining period will resume.

If the suspension exceeds two months, the coordinator may request the Agency if the suspension will continue.

If the payment deadline has been suspended due to the non-compliance of the technical or financial reports (see Article 20) and the revised report or statement is not submitted or was submitted but is also rejected, the Agency may also terminate the Agreement or the participation of the beneficiary (see Article 50.3.1(l)).

ARTICLE 48 — SUSPENSION OF PAYMENTS

48.1 Conditions

The Agency may — at any moment — suspend payments, in whole or in part and interim payments or the payment of the balance for one or more beneficiaries, if:

(a) a beneficiary (or a natural person who has the power to represent or take decision on its behalf) has committed or is suspected of having committed:

(i) substantial errors, irregularities or fraud or

(ii) serious breach of obligations under the Agreement or during the award procedure (including improper implementation of the action, submission of false information, failure to provide required information, breach of ethical principles) or

(b) a beneficiary (or a natural person who has the power to represent or take decision on its behalf) has committed — in other EU or Euratom grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant (**extension of findings from other grants to this grant**; see Article 22.5.2).

If payments are suspended for one or more beneficiaries, the Agency will make partial payment(s) for the part(s) not suspended. If suspension concerns the payment of the balance, — once suspension is lifted — the payment or the recovery of the amount(s) concerned will be considered the payment of the balance that closes the action.

48.2 Procedure

Before suspending payments, the Agency will formally notify the coordinator or beneficiary concerned:

- informing it of its intention to suspend payments and the reasons why and
- inviting it to submit observations within 30 days of receiving notification.

If the Agency does not receive observations or decides to pursue the procedure despite the observations it has received, it will formally notify **confirmation** of the suspension. Otherwise, it will formally notify that the suspension procedure is not continued.

The suspension will **take effect** the day the confirmation notification is sent by the Agency.

If the conditions for resuming payments are met, the suspension will be **lifted**. The Agency will formally notify the coordinator or beneficiary concerned.

During the suspension, the periodic report(s) for all reporting periods except the last one (see Article 20.3), must not contain any individual financial statements from the beneficiary concerned. The coordinator must include them in the next periodic report after the suspension is lifted or — if suspension is not lifted before the end of the action — in the last periodic report.

The beneficiaries may suspend implementation of the action (see Article 49.1) or terminate the Agreement or the participation of the beneficiary concerned (see Article 50.1 and 50.2).

ARTICLE 49 — SUSPENSION OF THE ACTION IMPLEMENTATION

49.1 Suspension of the action implementation, by the beneficiaries

49.1.1 Conditions

The beneficiaries may suspend implementation of the action or any part of it, if exceptional circumstances — in particular *force majeure* (see Article 51) — make implementation impossible or excessively difficult.

49.1.2 Procedure

The coordinator must immediately formally notify to the Agency the suspension (see Article 52), stating:

- the reasons why and
- the expected date of resumption.

The suspension will **take effect** the day this notification is received by the Agency.

Once circumstances allow for implementation to resume, the coordinator must immediately formally notify the Agency and request an **amendment** of the Agreement to set the date on which the action will be resumed, extend the duration of the action and make other changes necessary to adapt the action to the new situation (see Article 55) — unless the Agreement or the participation of a beneficiary has been terminated (see Article 50).

The suspension will be **lifted** with effect from the resumption date set out in the amendment. This date may be before the date on which the amendment enters into force.

Costs incurred during suspension of the action implementation are not eligible (see Article 6).

49.2 Suspension of the action implementation, by the Agency

49.2.1 Conditions

The Agency may suspend implementation of the action or any part of it, if:

(a) a beneficiary (or a natural person who has the power to represent or take decisions on its behalf) has committed or is suspected of having committed:

  (i) substantial errors, irregularities or fraud or

  (ii) serious breach of obligations under the Agreement or during the award procedure (including improper implementation of the action, submission of false information, failure to provide required information, breach of ethical principles);

(b) a beneficiary (or a natural person who has the power to represent or take decisions on its behalf) has committed — in other EU or Euratom grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant (**extension of findings from other grants to this grant**; see Article 22.5.2), or

(c) the action is suspected of having lost its scientific or technological relevance.

49.2.2 Procedure

Before suspending implementation of the action, the Agency will formally notify the coordinator or beneficiary concerned:

- informing it of its intention to suspend the implementation and the reasons why and
- inviting it to submit observations within 30 days of receiving notification.

If the Agency does not receive observations or decides to pursue the procedure despite the observations it has received, it will formally notify **confirmation** of the suspension. Otherwise, it will formally notify that the procedure is not continued.

The suspension will **take effect** five days after confirmation notification is received (or on a later date specified in the notification).

It will be **lifted** if the conditions for resuming implementation of the action are met.

The coordinator or beneficiary concerned will be formally notified of the lifting and the Agreement will be **amended** to set the date on which the action will be resumed, extend the duration of the action and make other changes necessary to adapt the action to the new situation (see Article 55) — unless the Agreement has already been terminated (see Article 50).

The suspension will be lifted with effect from the resumption date set out in the amendment. This date may be before the date on which the amendment enters into force.

Costs incurred during suspension are not eligible (see Article 6).

The beneficiaries may not claim damages due to suspension by the Agency (see Article 46).

Suspension of the action implementation does not affect the Agency's right to terminate the Agreement or participation of a beneficiary (see Article 50), reduce the grant or recover amounts unduly paid (see Articles 43 and 44).

ARTICLE 50 — TERMINATION OF THE AGREEMENT OR OF THE PARTICIPATION OF ONE OR MORE BENEFICIARIES

50.1 Termination of the Agreement, by the beneficiaries

50.1.1 Conditions and procedure

The beneficiaries may terminate the Agreement.

The coordinator must formally notify termination to the Agency (see Article 52), stating:

- the reasons why and
- the date the termination will take effect. This date must be after the notification.

If no reasons are given or if the Agency considers the reasons do not justify termination, the Agreement will be considered to have been '**terminated improperly**'.

The termination will **take effect** on the day specified in the notification.

50.1.2 Effects

The coordinator must — within 60 days from when termination takes effect — submit:

(i) a periodic report (for the open reporting period until termination; see Article 20.3) and

(ii) the final report (see Article 20.4).

If the Agency does not receive the reports within the deadline (see above), only costs which are included in an approved periodic report will be taken into account.

The Agency will **calculate** the final grant amount (see Article 5.3) and the balance (see Article 21.4) on the basis of the reports submitted. Only costs incurred until termination are eligible (see Article 6). Costs relating to contracts due for execution only after termination are not eligible.

Improper termination may lead to a reduction of the grant (see Article 43).

After termination, the beneficiaries' obligations (in particular Articles 20, 22, 23, Section 3 of Chapter 4, 36, 37, 38, 40, 42, 43 and 44) continue to apply.

50.2 Termination of the participation of one or more beneficiaries, by the beneficiaries

50.2.1 Conditions and procedure

The participation of one or more beneficiaries may be terminated by the coordinator, on request of the beneficiary concerned or on behalf of the other beneficiaries.

The coordinator must formally notify termination to the Agency (see Article 52) and inform the beneficiary concerned.

If the coordinator's participation is terminated without its agreement, the formal notification must be done by another beneficiary (acting on behalf of the other beneficiaries).

The notification must include:

- the reasons why;
- the opinion of the beneficiary concerned (or proof that this opinion has been requested in writing);
- the date the termination takes effect. This date must be after the notification, and
- a request for amendment (see Article 55), with a proposal for reallocation of the tasks and the estimated budget of the beneficiary concerned (see Annexes 1 and 2) and, if necessary, the addition of one or more new beneficiaries (see Article 56). If termination takes effect after the period set out in Article 3, no request for amendment must be included unless the beneficiary concerned is the coordinator. In this case, the request for amendment must propose a new coordinator.

If this information is not given or if the Agency considers that the reasons do not justify termination, the participation will be considered to have been **terminated improperly**.

The termination will **take effect** on the day specified in the notification.

50.2.2 Effects

The coordinator must — within 30 days from when termination takes effect — submit:

(i) a report on the distribution of payments to the beneficiary concerned and

(ii) if termination takes effect during the period set out in Article 3, a '**termination report**' from the beneficiary concerned, for the open reporting period until termination, containing an overview of the progress of the work, an overview of the use of resources, the individual financial statement and, if applicable, the certificate on the financial statement (see Articles 20.3 and 20.4).

The information in the termination report must also be included in the periodic report for the next reporting period (see Article 20.3).

If the request for amendment is rejected by the Agency (because it calls into question the decision awarding the grant or breaches the principle of equal treatment of applicants), the Agreement may be terminated according to Article 50.3.1(c).

If the request for amendment is accepted by the Agency, the Agreement is **amended** to introduce the necessary changes (see Article 55).

The Agency will — on the basis of the periodic reports, the termination report and the report on the distribution of payments — **calculate** the amount which is due to the beneficiary and if the (pre-financing and interim) payments received by the beneficiary exceed this amount.

The **amount which is due** is calculated in the following steps:

Step 1 — Application of the reimbursement rate to the eligible costs

The grant amount for the beneficiary is calculated by applying the reimbursement rate(s) to the total eligible costs declared by the beneficiary in the termination report and approved by the Agency.

Only costs incurred by the beneficiary concerned until termination takes effect are eligible (see Article 6). Costs relating to contracts due for execution only after termination are not eligible.

Step 2 — Reduction due to substantial errors, irregularities or fraud or serious breach of obligations

In case of a reduction (see Article 43), the Agency will calculate the reduced grant amount for the beneficiary by deducting the amount of the reduction (calculated in proportion to the seriousness of the errors, irregularities or fraud or breach of obligations, in accordance with Article 43.2) from the grant amount for the beneficiary.

If the payments received **exceed the amounts due**:

- if termination takes effect during the period set out in Article 3 and the request for amendment is accepted, the beneficiary concerned must repay to the coordinator the amount

unduly received. The Agency will formally notify the amount unduly received and request the beneficiary concerned to repay it to the coordinator within 30 days of receiving notification. If it does not repay the coordinator, the Agency will draw upon the Guarantee Fund to pay the coordinator and then notify a **debit note** on behalf of the Guarantee Fund to the beneficiary concerned (see Article 44);

- in all other cases, in particular if termination takes effect after the period set out in Article 3, the Agency will formally notify a **debit note** to the beneficiary concerned. If payment is not made by the date in the debit note, the Guarantee Fund will pay to the Agency the amount due and the Agency will notify a debit note on behalf of the Guarantee Fund to the beneficiary concerned (see Article 44);

- if the beneficiary concerned is the former coordinator, it must repay the new coordinator according to the procedure above, unless:

    - termination takes effect after an interim payment and

    - the former coordinator has not distributed amounts received as pre-financing or interim payments (see Article 21.7).

    In this case, the Agency will formally notify a **debit note** to the former coordinator. If payment is not made by the date in the debit note, the Guarantee Fund will pay to the Agency the amount due. The Agency will then pay the new coordinator and notify a debit note on behalf of the Guarantee Fund to the former coordinator (see Article 44).

If the payments received **do not exceed the amounts due**: amounts owed to the beneficiary concerned will be included in the next interim or final payment.

If the Agency does not receive the termination report within the deadline (see above), only costs included in an approved periodic report will be taken into account.

If the Agency does not receive the report on the distribution of payments within the deadline (see above), it will consider that:

- the coordinator did not distribute any payment to the beneficiary concerned and that

- the beneficiary concerned must not repay any amount to the coordinator.

Improper termination may lead to a reduction of the grant (see Article 43) or termination of the Agreement (see Article 50).

After termination, the concerned beneficiary's obligations (in particular Articles 20, 22, 23, Section 3 of Chapter 4, 36, 37, 38, 40, 42, 43 and 44) continue to apply.

50.3 Termination of the Agreement or the participation of one or more beneficiaries, by the Agency

50.3.1 Conditions

The Agency may terminate the Agreement or the participation of one or more beneficiaries, if:

(a) one or more beneficiaries do not accede to the Agreement (see Article 56);

(b) a change to their legal, financial, technical, organisational or ownership situation is likely to substantially affect or delay the implementation of the action or calls into question the decision to award the grant;

(c) following termination of participation for one or more beneficiaries (see above), the necessary changes to the Agreement would call into question the decision awarding the grant or breach the principle of equal treatment of applicants (see Article 55);

(d) implementation of the action is prevented by force majeure (see Article 51) or suspended by the coordinator (see Article 49.1) and either:

(i) resumption is impossible, or

(ii) the necessary changes to the Agreement would call into question the decision awarding the grant or breach the principle of equal treatment of applicants;

(e) a beneficiary is declared bankrupt, being wound up, having its affairs administered by the courts, has entered into an arrangement with creditors, has suspended business activities, or is subject to any other similar proceedings or procedures under national law;

(f) a beneficiary (or a natural person who has the power to represent or take decisions on its behalf) has been found guilty of professional misconduct, proven by any means;

(g) a beneficiary does not comply with the applicable national law on taxes and social security;

(h) the action has lost scientific or technological relevance;

(i) not applicable;

(j) not applicable;

(k) a beneficiary (or a natural person who has the power to represent or take decisions on its behalf) has committed fraud, corruption, or is involved in a criminal organisation, money laundering or any other illegal activity;

(l) a beneficiary (or a natural person who has the power to represent or take decisions on its behalf) has committed:

(i) substantial errors, irregularities or fraud or

(ii) serious breach of obligations under the Agreement or during the award procedure (including improper implementation of the action, submission of false information, failure to provide required information, breach of ethical principles);

(m) a beneficiary (or a natural person who has the power to represent or take decisions on its behalf) has committed — in other EU or Euratom grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant (**extension of findings from other grants to this grant**; see Article 22.5.2);

(n) not applicable.

50.3.2 Procedure

Before terminating the Agreement or participation of one or more beneficiaries, the Agency will formally notify the coordinator or beneficiary concerned:

- informing it of its intention to terminate and the reasons why and

- inviting it, within 30 days of receiving notification, to submit observations and — in case of Point (l.ii) above — to inform the Agency of the measures to ensure compliance with the obligations under the Agreement.

If the Agency does not receive observations or decides to pursue the procedure despite the observations it has received, it will formally notify to the coordinator or beneficiary concerned **confirmation** of the termination and the date it will take effect. Otherwise, it will formally notify that the procedure is not continued.

The termination will **take effect**:

- for terminations under Points (b), (c), (e), (g), (h), (j), (l.ii) and (n) above: on the day specified in the notification of the confirmation (see above);

- for terminations under Points (a), (d), (f), (i), (k), (l.i) and (m) above: on the day after the notification of the confirmation is received.

50.3.3 Effects

(a) for **termination of the Agreement**:

The coordinator must — within 60 days from when termination takes effect — submit:

(i) a periodic report (for the last open reporting period until termination; see Article 20.3) and

(ii) a final report (see Article 20.4).

If the Agreement is terminated for breach of the obligation to submit reports (see Articles 20.8 and 50.3.1(l)), the coordinator may not submit any reports after termination.

If the Agency does not receive the reports within the deadline (see above), only costs which are included in an approved periodic report will be taken into account.

The Agency will **calculate** the final grant amount (see Article 5.3) and the balance (see Article 21.4) on the basis of the reports submitted. Only costs incurred until termination takes effect are eligible (see Article 6). Costs relating to contracts due for execution only after termination are not eligible.

This does not affect the Agency's right to reduce the grant (see Article 43) or to impose administrative sanctions (Article 45).

The beneficiaries may not claim damages due to termination by the Agency (see Article 46).

After termination, the beneficiaries' obligations (in particular Articles 20, 22, 23, Section 3 of Chapter 4, 36, 37, 38, 40, 42, 43 and 44) continue to apply.

(b) for **termination of the participation of one or more beneficiaries**:

The coordinator must — within 60 days from when termination takes effect — submit:

(i) a report on the distribution of payments to the beneficiary concerned;

(ii) a request for amendment (see Article 55), with a proposal for reallocation of the tasks and estimated budget of the beneficiary concerned (see Annexes 1 and 2) and, if necessary, the addition of one or more new beneficiaries (see Article 56). If termination is notified after the period set out in Article 3, no request for amendment must be submitted unless the beneficiary concerned is the coordinator. In this case the request for amendment must propose a new coordinator, and

(iii) if termination takes effect during the period set out in Article 3, a **termination report** from the beneficiary concerned, for the open reporting period until termination, containing an overview of the progress of the work, an overview of the use of resources, the individual financial statement and, if applicable, the certificate on the financial statement (see Article 20).

The information in the termination report must also be included in the periodic report for the next reporting period (see Article 20.3).

If the request for amendment is rejected by the Agency (because it calls into question the decision awarding the grant or breaches the principle of equal treatment of applicants), the Agreement may be terminated according to Article 50.3.1(c).

If the request for amendment is accepted by the Agency, the Agreement is **amended** to introduce the necessary changes (see Article 55).

The Agency will — on the basis of the periodic reports, the termination report and the report on the distribution of payments — **calculate** the amount which is due to the beneficiary and if the (pre-financing and interim) payments received by the beneficiary exceed this amount.

The **amount which is due** is calculated in the following steps:

Step 1 — Application of the reimbursement rate to the eligible costs

The grant amount for the beneficiary is calculated by applying the reimbursement rate(s) to the total eligible costs declared by the beneficiary in the termination report and approved by the Agency.

Only costs incurred by the beneficiary concerned until termination takes effect are eligible (see Article 6). Costs relating to contracts due for execution only after termination are not eligible.

Step 2 — Reduction due to substantial errors, irregularities or fraud or serious breach of obligations

In case of a reduction (see Article 43), the Agency will calculate the reduced grant amount for the beneficiary by deducting the amount of the reduction (calculated in proportion to the seriousness of the errors, irregularities or fraud or breach of obligations, in accordance with Article 43.2) from the grant amount for the beneficiary.

If the payments received **exceed the amounts due**:

- if termination takes effect during the period set out in Article 3 and the request for amendment is accepted, the beneficiary concerned must repay to the coordinator the amount unduly received. The Agency will formally notify the amount unduly received and request the beneficiary concerned to repay it to the coordinator within 30 days of receiving notification. If it does not repay the coordinator, the Agency will draw upon the Guarantee Fund to pay the coordinator and then notify a **debit note** on behalf of the Guarantee Fund to the beneficiary concerned (see Article 44);

- in all other cases, in particular if termination takes effect after the period set out in Article 3, the Agency will formally notify a **debit note** to the beneficiary concerned. If payment is not made by the date in the debit note, the Guarantee Fund will pay to the Agency the amount due and the Agency will notify a debit note on behalf of the Guarantee Fund to the beneficiary concerned (see Article 44);

- if the beneficiary concerned is the former coordinator, it must repay the new coordinator according to the procedure above, unless:

  - termination takes effect after an interim payment and

  - the former coordinator has not distributed amounts received as pre-financing or interim payments (see Article 21.7).

  In this case, the Agency will formally notify a **debit note** to the former coordinator. If payment is not made by the date in the debit note, the Guarantee Fund will pay to the Agency the amount due. The Agency will then pay the new coordinator and notify a debit note on behalf of the Guarantee Fund to the former coordinator (see Article 44).

If the payments received **do not exceed the amounts due**: amounts owed to the beneficiary concerned will be included in the next interim or final payment.

If the Agency does not receive the termination report within the deadline (see above), only costs included in an approved periodic report will be taken into account.

If the Agency does not receive the report on the distribution of payments within the deadline (see above), it will consider that:

- the coordinator did not distribute any payment to the beneficiary concerned and that

- the beneficiary concerned must not repay any amount to the coordinator.

After termination, the concerned beneficiary's obligations (in particular Articles 20, 22, 23, Section 3 of Chapter 4, 36, 37, 38, 40, 42, 43 and 44) continue to apply.

SECTION 4 FORCE MAJEURE

ARTICLE 51 — FORCE MAJEURE

'Force majeure' means any situation or event that:

- prevents either party from fulfilling their obligations under the Agreement,
- was unforeseeable, exceptional situation and beyond the parties' control,
- was not due to error or negligence on their part (or on the part of third parties involved in the action), and
- proves to be inevitable in spite of exercising all due diligence.

The following cannot be invoked as force majeure:

- any default of a service, defect in equipment or material or delays in making them available, unless they stem directly from a relevant case of force majeure,
- labour disputes or strikes, or
- financial difficulties.

Any situation constituting force majeure must be formally notified to the other party without delay, stating the nature, likely duration and foreseeable effects.

The parties must immediately take all the necessary steps to limit any damage due to force majeure and do their best to resume implementation of the action as soon as possible.

The party prevented by force majeure from fulfilling its obligations under the Agreement cannot be considered in breach of them.

CHAPTER 7 FINAL PROVISIONS

ARTICLE 52 — COMMUNICATION BETWEEN THE PARTIES

52.1 Form and means of communication

Communication under the Agreement (information, requests, submissions, 'formal notifications', etc.) must:

- be made in writing and
- bear the number of the Agreement.

All communication must be made through the Participant Portal **electronic** exchange system and using the forms and templates provided there.

If — after the payment of the balance — the Agency finds that a formal notification was not accessed, a second formal notification will be made by registered post with proof of delivery ('formal notification on **paper**'). Deadlines will be calculated from the moment of the second notification.

Communications in the electronic exchange system must be made by persons authorised according to the Participant Portal Terms & Conditions. For naming the authorised persons, each beneficiary must have designated — before the signature of this Agreement — a 'legal entity appointed representative

(LEAR)'. The role and tasks of the LEAR are stipulated in his/her appointment letter (see Participant Portal Terms & Conditions).

If the electronic exchange system is temporarily unavailable, instructions will be given on the Agency and Commission websites.

52.2 Date of communication

Communications are considered to have been made when they are sent by the sending party (i.e. on the date and time they are sent through the electronic exchange system).

Formal notifications through the **electronic** exchange system are considered to have been made when they are received by the receiving party (i.e. on the date and time of acceptance by the receiving party, as indicated by the time stamp). A formal notification that has not been accepted within 10 days after sending is considered to have been accepted.

Formal notifications **on paper** sent by **registered post** with proof of delivery (only after the payment of the balance) are considered to have been made on either:

- the delivery date registered by the postal service or
- the deadline for collection at the post office.

If the electronic exchange system is temporarily unavailable, the sending party cannot be considered in breach of its obligation to send a communication within a specified deadline.

52.3 Addresses for communication

The **electronic** exchange system must be accessed via the following URL:

https://ec.europa.eu/research/participants/portal/desktop/en/projects/

The Agency will formally notify the coordinator and beneficiaries in advance any changes to this URL.

Formal notifications on paper (only after the payment of the balance) addressed **to the Agency** must be sent to the official mailing address indicated on the Agency's website.

Formal notifications on paper (only after the payment of the balance) addressed **to the beneficiaries** must be sent to their legal address as specified in the Participant Portal Beneficiary Register.

ARTICLE 53 — INTERPRETATION OF THE AGREEMENT

53.1 Precedence of the Terms and Conditions over the Annexes

The provisions in the Terms and Conditions of the Agreement take precedence over its Annexes.

Annex 2 takes precedence over Annex 1.

53.2 Privileges and immunities

Not applicable

ARTICLE 54 — CALCULATION OF PERIODS, DATES AND DEADLINES

In accordance with Regulation No 1182/71[30], periods expressed in days, months or years are calculated from the moment the triggering event occurs.

The day during which that event occurs is not considered as falling within the period.

ARTICLE 55 — AMENDMENTS TO THE AGREEMENT

55.1 Conditions

The Agreement may be amended, unless the amendment entails changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

Amendments may be requested by any of the parties.

55.2 Procedure

The party requesting an amendment must submit a request for amendment signed in the electronic exchange system (see Article 52).

The coordinator submits and receives requests for amendment on behalf of the beneficiaries (see Annex 3).

If a change of coordinator is requested without its agreement, the submission must be done by another beneficiary (acting on behalf of the other beneficiaries).

The request for amendment must include:

- the reasons why;
- the appropriate supporting documents, and
- for a change of coordinator without its agreement: the opinion of the coordinator (or proof that this opinion has been requested in writing).

The Agency may request additional information.

If the party receiving the request agrees, it must sign the amendment in the electronic exchange system within 45 days of receiving notification (or any additional information the Agency has requested). If it does not agree, it must formally notify its disagreement within the same deadline. The deadline may be extended, if necessary for the assessment of the request. If no notification is received within the deadline, the request is considered to have been rejected

An amendment **enters into force** on the day of the signature of the receiving party.

An amendment **takes effect** on the date agreed by the parties or, in the absence of such an agreement, on the date on which the amendment enters into force.

[30] Regulation (EEC, Euratom) No 1182/71 of the Council of 3 June 1971 determining the rules applicable to periods, dates and time-limits (OJ L 124, 8.6.1971, p. 1).

ARTICLE 56 — ACCESSION TO THE AGREEMENT

56.1 Accession of the beneficiaries mentioned in the Preamble

The other beneficiaries must accede to the Agreement by signing the Accession Form (see Annex 3) in the electronic exchange system (see Article 52) within 30 days after its entry into force (see Article 58).

They will assume the rights and obligations under the Agreement with effect from the date of its entry into force (see Article 58).

If a beneficiary does not accede to the Agreement within the above deadline, the coordinator must — within 30 days — request an amendment to make any changes necessary to ensure proper implementation of the action. This does not affect the Agency's right to terminate the Agreement (see Article 50).

56.2 Addition of new beneficiaries

In justified cases, the beneficiaries may request the addition of a new beneficiary.

For this purpose, the coordinator must submit a request for amendment in accordance with Article 55. It must include an Accession Form (see Annex 3) signed by the new beneficiary in the electronic exchange system (see Article 52).

New beneficiaries must assume the rights and obligations under the Agreement with effect from the date of their accession specified in the Accession Form (see Annex 3).

ARTICLE 57 — APPLICABLE LAW AND SETTLEMENT OF DISPUTES

57.1 Applicable law

The Agreement is governed by the applicable EU law, supplemented if necessary by the law of Belgium.

57.2 Dispute settlement

If a dispute concerning the interpretation, application or validity of the Agreement cannot be settled amicably, the General Court — or, on appeal, the Court of Justice of the European Union — has sole jurisdiction. Such actions must be brought under Article 272 of the Treaty on the Functioning of the EU (TFEU).

If a dispute concerns administrative sanctions, offsetting or an enforceable decision under Article 299 TFEU (see Articles 44, 45 and 46), the beneficiaries must bring action before the General Court — or, on appeal, the Court of Justice of the European Union — under Article 263 TFEU. Actions against offsetting and enforceable decisions must be brought against the Commission (not against the Agency).

ARTICLE 58 — ENTRY INTO FORCE OF THE AGREEMENT

The Agreement will enter into force on the day of signature by the Agency or the coordinator, depending on which is later.

SIGNATURES

For the coordinator

For the Agency

EUROPEAN COMMISSION
Innovation and Networks Executive Agency
ENERGY RESEARCH

ANNEX 1 (part A)

Research and Innovation action

NUMBER — 814945 — SolBio-Rev

Table of Contents

1.1. The project summary

Project Number [1]	814945	Project Acronym [2]	SolBio-Rev

One form per project

General information	
Project title [3]	Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings
Starting date [4]	01/05/2019
Duration in months [5]	48
Call (part) identifier [6]	H2020-LC-SC3-2018-RES-TwoStages
Topic	LC-SC3-RES-4-2018 Renewable energy system integrated at the building scale
Fixed EC Keywords	RES integration in buildings
Free keywords	heat pump, solar thermal, adsorption chiller, cascade, reversible, biomass, combined heat and power, solar thermoelectric, flexible operation, buildings

Abstract [7]

The SolBio-Rev project will develop a flexible energy system suitable for building integration based on renewables for covering a large share of energy demand (heating/cooling/electricity). Its flexibility is derived from the long-term collaboration of key industrial partners with research organisations, having in mind the large variety of EU buildings, especially non-residential (types, uses and sizes).
The overall objective is to develop a configuration based on renewables that allows covering all heating and cooling demand and a variable electricity demand (from zero up to even 100%) in a cost-effective manner. This configuration is based on solar, ambient and bioenergy, while it is suitable to be installed in various buildings types and sizes without any geographical restriction. The main technologies included have already proven their performance and they are combined with the aim to exploit all possible energy flows/sources, ensuring their cost-effectiveness compared to standard solutions.
The SolBio-Rev concept is based on solar thermal collectors with vacuum tubes combined with thermoelectrics, a cascade thermal chiller with electrical-driven heat pump for very high performance under cooling operation even at extreme hot conditions, a reversible heat pump/ORC for enhancing flexibility and switching operating modes between summer and winter, exploiting all available solar heat, and an advanced biomass boiler coupled with the above ORC for CHP operation. A smart control is also envisaged to manage and optimise the system operation with user-friendly features. The project also includes dissemination and communication activities to ensure outreach of its results, as well as an active participation of end-users and installers in the technology development. Moreover, exploitation activities include long-term deployment path development through a technology roadmap.

1.2. List of Beneficiaries

Project Number [1]	814945	Project Acronym [2]	SolBio-Rev

List of Beneficiaries

No	Name	Short name	Country	Project entry month[8]	Project exit month
1	NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA	NTUA	Greece	1	48
2	FRIEDRICH-ALEXANDER-UNIVERSITAET ERLANGEN NUERNBERG	FAU	Germany	1	48
3	FAHRENHEIT GMBH	FAHREN	Germany	1	48
4	CONSIGLIO NAZIONALE DELLE RICERCHE	ITAE	Italy	1	48
5	T.E.A.V.E LTD	TEAVE	Greece	1	48
6	AKOTEC PRODUKTIONSGESELLSCHAFT MBH	AKOTEC	Germany	1	48
7	UNIVERSIDAD DE LLEIDA	UDL	Spain	1	48
8	DAIKIN AIRCONDITIONING HELLAS SA	Daikin	Greece	1	48
9	THE UNIVERSITY OF SUSSEX	UOS	United Kingdom	1	48
10	DBC EUROPE	DBC	Belgium	1	48
11	TECHLINK ASBL	TECH	Belgium	1	48
12	KARLSRUHER INSTITUT FUER TECHNOLOGIE	KIT	Germany	1	48
13	OKOFEN FORSCHUNGS-UND ENTWICKLUNGSG	OKOFEN	Austria	1	48
14	STRABAG BELGIUM	STRABAG	Belgium	1	48
15	UNIVERSITA DEGLI STUDI DI MESSINA	UNIME	Italy	1	48

1.3. Workplan Tables - Detailed implementation

1.3.1. WT1 List of work packages

WP Number[9]	WP Title	Lead beneficiary[10]	Person-months[11]	Start month[12]	End month[13]
WP1	Project coordination and management	1 - NTUA	40.00	1	48
WP2	Innovative SolBio-Rev components and configuration	4 - ITAE	129.50	1	27
WP3	Simulation and smart control	1 - NTUA	75.00	4	30
WP4	Prototypes design, production and commissioning	8 - Daikin	73.50	25	36
WP5	System testing and technology validation	2 - FAU	78.50	37	48
WP6	Social acceptance, potential for uptake and engagement	9 - UOS	40.00	13	48
WP7	LCA, economic analysis and building integration	7 - UDL	45.00	19	45
WP8	Dissemination and exploitation of results	10 - DBC	36.00	1	48
WP9	Communication activities	10 - DBC	25.00	1	48
		Total	542.50		

1.3.2. WT2 list of deliverables

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D1.1	Stakeholder advisory board composition and functions	WP1	7 - UDL	Websites, patents filling, etc.	Public	12
D1.2	Knowledge Management and IP strategy	WP1	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	6
D1.3	Data Management Plan (DMP)	WP1	1 - NTUA	ORDP: Open Research Data Pilot	Public	3
D1.4	Accomplished tasks of SHAB and its meetings minutes	WP1	7 - UDL	Report	Confidential, only for members of the consortium (including the Commission Services)	48
D1.5	Compilation of minutes from the project meetings	WP1	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	48
D1.6	Project Management Plan	WP1	1 - NTUA	Websites, patents filling, etc.	Confidential, only for members of the consortium (including the Commission Services)	2
D2.1	Definition of climate and building typologies	WP2	7 - UDL	Websites, patents filling, etc.	Public	3
D2.2	Key design and sizing features of the generic energy system	WP2	4 - ITAE	Report	Confidential, only for members of the consortium (including the Commission Services)	6
D2.3	Cascade chiller with heat pump	WP2	4 - ITAE	Report	Confidential, only for members of the consortium (including the Commission Services)	21

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D2.4	Reversible heat pump/ ORC	WP2	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	21
D2.5	Solar thermal collector with TEGs	WP2	12 - KIT	Report	Confidential, only for members of the consortium (including the Commission Services)	24
D2.6	Biomass boiler for CHP operation	WP2	2 - FAU	Report	Confidential, only for members of the consortium (including the Commission Services)	21
D2.7	Test results of the heat pump-based configuration	WP2	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	27
D3.1	User behavioural model including user-building interaction	WP3	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	12
D3.2	Optimised system control and strategies	WP3	7 - UDL	Report	Confidential, only for members of the consortium (including the Commission Services)	24
D3.3	Prototype smart control environment	WP3	5 - TEAVE	Websites, patents filling, etc.	Confidential, only for members of the consortium (including the Commission Services)	27
D3.4	System performance for different climates and buildings	WP3	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	27

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D3.5	European map of SolBio-Rev system sizing at each geographical location	WP3	1 - NTUA	Websites, patents filling, etc.	Public	30
D4.1	Design of the two prototype systems	WP4	8 - Daikin	Report	Confidential, only for members of the consortium (including the Commission Services)	30
D4.2	Produced building prototype at FAU	WP4	2 - FAU	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	30
D4.3	SolBio-Rev prototype systems produced and installed	WP4	2 - FAU	Report	Confidential, only for members of the consortium (including the Commission Services)	33
D4.4	Monitoring protocol and evaluation	WP4	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	33
D4.5	Extended commissioning test results	WP4	2 - FAU	Report	Confidential, only for members of the consortium (including the Commission Services)	36
D5.1	First test results of the two prototype SolBio-Rev systems	WP5	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	42
D5.2	Energy performance of SolBio-Rev system in Greece	WP5	1 - NTUA	Report	Public	48
D5.3	Energy performance of SolBio-Rev system in Germany	WP5	2 - FAU	Report	Public	48
D5.4	Validated simulation platform	WP5	1 - NTUA	Report	Confidential, only for members of the consortium	48

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
					(including the Commission Services)	
D5.5	Technology validation in different climatic zones	WP5	2 - FAU	Report	Confidential, only for members of the consortium (including the Commission Services)	48
D6.1	Surveys outcome report	WP6	9 - UOS	Report	Public	27
D6.2	Definition of user and installer needs and their introduction in the design process	WP6	9 - UOS	Report	Public	30
D6.3	User acceptance and policy strategies	WP6	9 - UOS	Report	Public	48
D7.1	Life Cycle Assessment (LCA) report	WP7	7 - UDL	Report	Confidential, only for members of the consortium (including the Commission Services)	30
D7.2	Life Cycle Costing (LCC) analysis report	WP7	7 - UDL	Report	Confidential, only for members of the consortium (including the Commission Services)	45
D7.3	System integration procedures and case-studies in new and existing buildings	WP7	11 - TECH	Report	Public	36
D8.1	Dissemination and exploitation plans	WP8	10 - DBC	Websites, patents filling, etc.	Confidential, only for members of the consortium (including the Commission Services)	6
D8.2	Compilation of all dissemination activities carried out during the project	WP8	10 - DBC	Report	Public	48
D8.3	Exploitable results table	WP8	10 - DBC	Websites, patents filling, etc.	Confidential, only for members of the consortium (including the Commission Services)	12

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D8.4	Local and EU key technical & market codes and framework conditions relevant to the SolBio-Rev system	WP8	10 - DBC	Report	Public	30
D8.5	Market analysis and business models	WP8	10 - DBC	Report	Confidential, only for members of the consortium (including the Commission Services)	42
D8.6	Synergies between SolBio-Rev and other initiatives	WP8	7 - UDL	Report	Public	48
D8.7	Technology roadmap and alternative applications	WP8	1 - NTUA	Websites, patents filling, etc.	Public	48
D8.8	Partner exploitation agreement	WP8	10 - DBC	Other	Confidential, only for members of the consortium (including the Commission Services)	48
D8.9	Standardisation activities for future EU wide exploitation	WP8	8 - Daikin	Report	Confidential, only for members of the consortium (including the Commission Services)	48
D9.1	Communication strategy and plan	WP9	10 - DBC	Report	Public	6
D9.2	Project website and logo	WP9	1 - NTUA	Websites, patents filling, etc.	Public	2
D9.3	Project videos (2) promoting the activities to various stakeholders and the public	WP9	1 - NTUA	Websites, patents filling, etc.	Public	42
D9.4	Compilation of all communication activities carried out during the project	WP9	10 - DBC	Report	Public	48

1.3.3. WT3 Work package descriptions

Work package number [9]	WP1	**Lead beneficiary** [10]	1 - NTUA
Work package title	Project coordination and management		
Start month	1	**End month**	48

Objectives

• Efficient day-to-day project management and coordination ensuring progress in line with the budget and the schedule of milestones and deliverables, including on-time delivery of scientific and financial reports.
• Ensuring proper implementation of Work Plan and achievement of project objectives.
• Risk and innovation management and overall strategic project guidance.
• Effective communication within the consortium, with the Project Officer, and the external Advisory Board.

Description of work and role of partners

WP1 - Project coordination and management [Months: 1-48]
NTUA, FAU, FAHREN, ITAE, TEAVE, AKOTEC, UDL, Daikin, UOS, DBC, TECH, KIT, OKOFEN, STRABAG, UNIME
Task 1.1: Project coordination and management (M1 to M48)
Task leader: NTUA; Contributing partners: ALL
NTUA will implement the day-to-day coordination of the project as well as the communication between the consortium and the EU Project Officer. The coordinator will ensure a quick information flow between the participants and provide that deliverables are completed on time with respect to the project planning as defined in this proposal. NTUA will also ensure that the partners are aware of their responsibilities and reporting duties and will be in regular contact with them to ensure the timely completion of their tasks and to provide support, where necessary.
The management structure is presented with detail in § 3.2, including various committees and boards.

Task 1.2: Setting up a Stakeholder Advisory Board – SHAB (M10 to M48)
Task leader: UDL; Contributing partners: ALL
An advisory board will be set-up composed of external experts from both industry and research organisations, with its members finalised during the first year of the project. The SHAB members will ensure the innovative character of the project and strengthen its impacts. The members will be invited under terms of confidentiality and will usually meet every 12 months in parallel with the General Assembly. The chairwoman of SHAB is Prof. L.F. Cabeza (UDL). Further details are provided in § 3.2.

Task 1.3: Managing contractual and administrative issues (M1 to M48)
Task leader: NTUA; Contributing partners: ALL
The coordinator will be in close cooperation with all project partners and with the EC Project Officer to ensure the smooth fulfilment of contractual obligations. The required documentation and information will be collected for the development of the contract and the periodic and final reports, as well as all financial reports. Additionally, continuous communication will be held with the Project Officer to adapt the deliverables and events when needed, while keeping them in line with the contract obligations and the project objectives.
The consortium will elaborate a Consortium Agreement, in order to specify the roles and responsibilities of each partner and to clarify their legal matters and IP. NTUA will elaborate a first draft and coordinate the agreement.

Task 1.4: Risks mitigation and innovation management (M1 to M48)
Task leader: ITAE; Contributing partners: ALL
Risk mitigation starts with monitoring, communicating and evaluating the research progress within the clearly specified objectives and deliverables. The procedures and tools outlined in § 3.2 ensure that the coordinator and the WP leaders will have an overview of the status of the results, while the project progress will be evaluated every three months (e.g. when a milestone is achieved, reports delivered).
If necessary, the Coordinator and the Management Board will propose mitigation actions according to the feedback from the risks manager, when deliverables of critical tasks are expected to be delayed or when there is an important and unexpected deviation from the estimated results, proposing, if needed, well-considered resource reallocation.
Regarding the innovation management, valuable input will be provided by the SHAB for the partners to evaluate the level of innovation in the relevant fields and how this develops as the project progresses compared to the state of the art. Innovative ideas & concepts are the result of this process, feeding the technology roadmap (Task 8.6).

Task 1.5: Knowledge management and IP protection (M1 to M48)
Task leader: NTUA; Contributing partners: ALL
An IP manager from NTUA is included in the management structure, who provides advices on the management of knowledge, IP and other innovation-related activities arising in the project. This manager will also monitor the implementation of the principles governing IPR, which will partially be covered by the international dispositions. Further details for the tasks of this manager are given in § 3.2.

Task 1.6: Data management & GDPR compliant data sharing (M1 to M48)
Task leader: NTUA; Contributing partners: ALL
A Data Management Plan (DMP) will be developed, outlining how research data will be collected, processed or generated within the project, and how this data will be curated and preserved during and after the project. The DMP aims to ensure that the project's activities are compliant with the H2020 Open Access policy.
All partners individually as well as the project consortium as a whole are taking all measures to be fully compliant with the European and national General Data Protection Regulation (GDPR) guidelines for the protection of personal data. Data management will enable data handling and processing, according to prevailing methodologies & standards, supporting only GDPR compliant data sharing within the SolBio-Rev stakeholder community.

Task 1.7: Project management meetings (M1 to M48)
Task leader: NTUA; Contributing partners: ALL
A kick-off meeting in M1 will be organised at NTUA with representatives of all partners, in order to define in detail the expected work of each partner and the actual roles and links between partners and WPs. All WP leaders in close collaboration with their task leaders will have realistic protocols (and/or action plans) and updated time schedules, which will be thoroughly discussed, finalised and accepted by the partners during the kick-off meeting. Possible adjustment to the predicted time schedule may be required, depending on the approved project starting date. This issue will also be addressed and finalised in the kick-off meeting.
Eight more progress meetings (M7, M13, M19, M25, M31, M37, M43, and M48) on a bi-annual basis will be organised, reporting and analysing the progress and fine-tuning the upcoming work. The place and time will be defined at the previous meeting. Effort will be put to organise these meetings in parallel to events, in order to create synergies and reduce travel costs. Technical meetings may also be organised with a limited number of partners, when crucial technical issues arise. NTUA will be chairing all meetings (except from the SHAB meetings) and will be keeping their minutes, assisted by the hosting partner.

Task 1.8: Consortium communication and monitoring (M1 to M48)
Task leader: NTUA; Contributing partners: ALL
The work quality will be ensured through regular and systematic monitoring processes, organised by NTUA with the support of each WP leader (e.g. tele-conferences) will help to monitor progress and resolve any issue. Milestones and deliverables will be the primary basis for progress monitoring. The WP Leaders are responsible for the detailed coordination, planning, monitoring and reporting of the tasks in their WPs.
NTUA will be in close contact with the EC representatives (e.g. Project and Financial Officers) and will inform them about the project progress and any unexpected challenges and changes. NTUA will assume responsibility to complete and timely report to the EC, and will be the link for all financial matters between EC and the consortium.

Participation per Partner

Partner number and short name	WP1 effort
1 - NTUA	24.00
2 - FAU	1.00
3 - FAHREN	1.00
4 - ITAE	2.00
5 - TEAVE	1.00
6 - AKOTEC	1.00
7 - UDL	3.00
8 - Daikin	1.00

Partner number and short name	WP1 effort
9 - UOS	1.50
10 - DBC	1.00
11 - TECH	0.50
12 - KIT	1.00
13 - OKOFEN	1.00
14 - STRABAG	0.50
15 - UNIME	0.50
Total	40.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D1.1	Stakeholder advisory board composition and functions	7 - UDL	Websites, patents filling, etc.	Public	12
D1.2	Knowledge Management and IP strategy	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	6
D1.3	Data Management Plan (DMP)	1 - NTUA	ORDP: Open Research Data Pilot	Public	3
D1.4	Accomplished tasks of SHAB and its meetings minutes	7 - UDL	Report	Confidential, only for members of the consortium (including the Commission Services)	48
D1.5	Compilation of minutes from the project meetings	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	48
D1.6	Project Management Plan	1 - NTUA	Websites, patents filling, etc.	Confidential, only for members of the consortium (including the Commission Services)	2

Description of deliverables

D1.1 Stakeholder advisory board composition and functions M12
D1.2 Knowledge Management and IP strategy M06
D1.3 Data Management Plan (DMP) M03
D1.4 Accomplished tasks of SHAB and its meetings minutes M48
D1.5 Compilation of minutes from the project meetings M48

D1.6 Project Management Plan M02

D1.1 : Stakeholder advisory board composition and functions [12]

SHAB composition (with proof of acceptance by its members) and description of its functions

D1.2 : Knowledge Management and IP strategy [6]

Defined IP management and strategy between all partners

D1.3 : Data Management Plan (DMP) [3]

Plan for managing all data produced during the project with all pertinent regulations of data management, access, preservation, etc., and fully aligned to the "Open Research Data Pilot". The plan will be updated in each reporting period

D1.4 : Accomplished tasks of SHAB and its meetings minutes [48]

Description of the accomplished tasks of SHAB and a summary of their meetings minutes

D1.5 : Compilation of minutes from the project meetings [48]

Compilation of the minutes from all meetings during the project

D1.6 : Project Management Plan [2]

A detailed Project Management Plan with a Gantt chart and a Work Breakdown Structure (WBS) that includes a schedule per task, responsible partner related subtasks, related deliverables, and dependencies on other tasks. This plan will be revised just before the end of each reporting period

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification

Work package number [9]	WP2	Lead beneficiary [10]	4 - ITAE
Work package title	Innovative SolBio-Rev components and configuration		
Start month	1	End month	27

Objectives

• Description of the application contexts and the definition of the generic energy system, according to climates, buildings and user behaviour.
• Development and testing of the innovative system components: (1) cascade chiller/heat pump, (2) the reversible HP/ORC, (3) solar collector with TEGs, and (4) biomass-fired boiler.
• Lab testing of the heat pump-based configuration, ensuring an efficient operation at both modes.

Description of work and role of partners

WP2 - Innovative SolBio-Rev components and configuration [Months: 1-27]
ITAE, NTUA, FAU, FAHREN, TEAVE, AKOTEC, UDL, Daikin, KIT, OKOFEN, STRABAG, UNIME
Task 2.1: Specific climate considerations and building typological classification (M1 to M3)
Task leader: UDL; Contributing partners: NTUA, ITAE, DAIKIN, STRABAG
The initial aim is to characterise the concerned climatic zones that correspond to south/central/north Europe, and correlate them with the different uses and constraints of energy consumption, introducing energy performance standards. All available data will be used for this purpose, such as other EU projects (see § 1.3.6), current EU standards, databases (e.g. EU Buildings database), policy papers and EC Communications and Recommendations.
The final aim is to propose tools to characterise and classify the typologies of different building types (residential, commercial, public, etc.), in order to identify potential adopters of the developed system. The classification will be carried out in terms of construction age, renovation categories, specific energy consumption, architectural configuration, building size and key geometry indicators, and type of management system (private/public owned).

Task 2.2: Generic energy system development (M1 to M6)
Task leader: ITAE; Contributing partners: NTUA, AKOTEC, FAU, DAIKIN, OKOFEN, KIT, STRABAG
Parallel to and based on the results of Task 2.1, a generic energy system will be developed for integrating the SolBio-Rev system in different EU climatic zones. The key design/sizing and operational specifications to be met by each component (e.g. capacity, monthly yield), as well as sets of components (e.g. the heat pump-based configuration) will be defined. The output of this task will refine the starting point of the component development in Tasks 2.3-2.6 and of the simulation and control development activities in WP3. Furthermore, based on the generic energy system, the initial system specifications will be defined for the two pilot systems in WP5.

Task 2.3: Development and lab testing of the cascade chiller with heat pump (M1 to M21)
Task leader: ITAE; Contributing partners: UNIME, FAHREN, NTUA, DAIKIN
The two key components of the cascade chiller will be developed: the adsorber and the integrated evaporator/ condenser. The adsorber will be based on the integration between a high efficiency HEX and a direct-synthesis coating technology, using as starting point the FAHREN patented solution, improved by a high-efficiency post-synthesis process by UNIME. A thermo-fluid dynamic model in COMSOL Multiphysics will be developed by ITAE to simulate the HEX coupled to the adsorbent coating. At least two promising HEX technologies (e.g. finned flat tubes, micro-channel HEX) will be simulated to optimise the adsorber, in terms of HEX design and adsorbent coating thickness. This process will be performed by finding the best compromise between specific cooling power, reduction of production costs/time, and thermal COP. In parallel to the modelling activity, the coating process of FAHREN will be optimised by UNIME, by an innovative post-synthesis process, based on a multi-stage pre-washing and calcination of the adsorber, for reducing the residual chemicals contaminating the SAPO-34 coating after the synthesis phase (e.g. phosphorous acid, ammonium phosphate, silicate) increasing its purity and porosity.
Initially, UNIME will realise the pre-washing system, based on a multi-stage approach. Different water flow rates and possible additives will be investigated on small-scale samples synthesised in the UNIME lab. In parallel, UNIME will study different calcination procedures in a dedicated furnace, by varying heating ramps and protective gas fluxes. Once the overall setup for the post-synthesis process is realised and verified, FAHREN will produce few small-scale coated HEXs (e.g. cooling power of 250 W) with different process parameters, which will be pre-washed and calcinated by UNIME. They will be then tested in a dedicated test-rig at the ITAE lab, to validate the numerical model and identify the most effective one that will be used for the final full-scale adsorber (i.e. cooling power of 4-5 kW). This will be produced by FAHREN, according to the optimised process.

The integrated evaporator/condenser will be developed by means of an experimental approach. A screening procedure has showed that at least four different HEX technologies (e.g. finned flat tube, axisymmetric plate) and integration inside the vacuum chamber (i.e. orientation, number of HEXs) are highly promising, which will be tested in a dedicated test-rig at the ITAE lab, able to evaluate achievable performance in terms of evaporation/ condensation power density at sub-atmospheric water vapour pressure conditions. The experimental data will be then used to validate semi-empirical correlations that will be used for the final design of the full-scale component.
Finally, the realised adsorbers and evaporator/condenser, will be integrated in the prototype adsorption chiller, produced by FAHREN and coupled with a vapour compression heat pump provided by DAIKIN, integrating sensors and controls. This component will be then tested at the ITAE lab in a dedicated experimental setup. The tests will be performed by varying the driving temperature, simulating sunny and partly cloudy days (at 90 and 70 °C respectively). Furthermore, different heat rejection temperatures (i.e. ambient temperature) will be considered, to conclude to a full performance map, in terms of electric COP and rated cooling power. This activity will also conclude and verify different control logics with the use of dedicated hardware (e.g. National Instrument c-Rio, Siemens Simatic). The outcomes of these tests will also identify the most effective control strategy, providing input to Task 3.2. Finally, the numerical sub-model will be validated with the test results, and will feed Task 2.7, to produce the complete sub-model of the heat pump-based configuration.

Task 2.4: Development and lab testing of the reversible heat pump/ORC (M1 to M21)
Task leader: NTUA; Contributing partners: FAU, ITAE, DAIKIN
A numerical model of the reversible HP/ORC module will be developed in Matlab software for detailed thermodynamic simulation, according to the anticipated boundary conditions (e.g. temperatures and heat flows in the HEXs). This will allow to calculate the component performance and technical specifications and proceed to an initial sizing of its parts (e.g. evaporator, condenser, ORC pump, reversible compressor/expander), by taking into account both operating modes, focusing at the same time on a suitable refrigerant with the support of DAIKIN. A close interaction is envisaged with ITAE relevant to the common HEX (evaporator/condenser) developed in Task 2.3. The component capacity will be defined according to the heating/cooling needs of the pilot prototype system (up to 4-5 kW cooling capacity). These specifications will be then matched to a DAIKIN heat pump, which will be then installed in the NTUA lab and modified to operate in reverse. An ORC pump along its by-pass circuit will be added. The compressor and its necessary lubrication will be modified to enable its operation in reverse as an expander, replacing some of its parts (e.g. sealings, valves) to allow a trouble-free operation at higher temperature than usual. Additional sensors and electronic/control equipment and software (LabView) will be procured and the experimental test rig will be assembled and connected to a hot water/ thermal oil (up to 120 °C) boiler (at ORC mode) or chilled/hot water to simulate the heating and cooling loads (at heat pump mode).
The performance of the system in terms of heating/cooling capacities, COP, as well as thermal efficiency will be measured and evaluated under different pressures, temperatures and flow rates corresponding to nominal and part load conditions. The maximum temperature of the component will be defined (corresponding to the heat supplied by the biomass boiler), by considering the durability of its main parts and the optimal performance at both modes, according to the total annual operating hours. The experimental results will be also used for the validation of the numerical model, the characterisation of the reversible compressor/expander and for making an operating map of the component to be used in conjunction with the other sub-systems, feeding both Task 2.7 (for heat pump-based configuration) and Task 3.4 (system simulation, in case no cascade chiller is included in central/north Europe).

Task 2.5: Development and testing of the solar thermal collectors with TEG (M1 to M24)
Task leader: KIT; Contributing partners: AKOTEC, NTUA
A hybrid numerical model (thermal and electrical) in Modelica/OpenModelica software will be developed to simulate the TEG system including the heat exchanger and determine the key/optimal system parameters, such as TEG thickness, TEG materials, size of heat sink/source, and flow rates. Parallel to this, a lab-scale TEG prototype (capacity of 20 W electric, corresponding to the maximum capacity per collector) will be set up at KIT, and will be operated under realistic conditions provided by AKOTEC (hot water temperatures and flow rates), with the test results focusing on electricity production. The TEG capacity will be refined according to the system simulation in WP3, considering cost effects as well. The lab prototype will be used to validate the simulation tool and estimate the thermal and electrical performance of the final TEG system. This includes the development of the power electronics for optimum load matching of the TEG-system and the connection with the building's electric network over a broad range of operational temperatures. The operating conditions (e.g. annual operating hours and temperature differences) of the TEG system are then determined by combining the validated TEG simulation model with the data from AKOTEC and the other subsystems of the SolBio-Rev system with feedback from Tasks 3.2-3.4. The knowledge gained will then be used to select the best TEG technology in terms of efficiency, costs, durability and environmental impact. Based on these results, the potential of the printed TEGs will be determined for the SolBio-Rev system.

In the meantime, AKOTEC will be exploring appropriate methods on integrating the TEG modules in the manifold of the collector, by modifying its design also taking in consideration the unique shape flexibility of the printed TEGs. This requires to re-arrange its housed parts (e.g. tube fastening, insulation), in order not to enlarge the manifold, and make sure that: (1) it is accessible for maintenance work, and (2) there is adequate heat transfer to the housing cover and then to the outer fins for rejecting heat to the ambient.
One solar collector-TEG prototype will be jointly produced by AKOTEC and KIT, which will be initially tested indoors and then outdoors by AKOTEC, focusing on efficient thermal integration and adequate heat sink. The test results will be processed and any improvement in the design will be evaluated, along with the validation of the numerical sub-model to feed WP3. Finally, a design of a centrally-mounted TEG module will be also realised (one module receiving heat from all collectors), which can be used in case of renovations.

Task 2.6: Development and lab testing of the biomass boiler for cogeneration (M1 to M21)
Task leader: FAU; Contributing partners: OKOFEN, NTUA
OKOFEN, FAU and NTUA will evaluate different internal HEX designs for the integration in domestic pellets boilers based on tube bundles. This initially includes thermal calculations, the selection of appropriate fluids and safety assessments. The fluid-depending maximum temperature level for the supply to the ORC will be initially examined with the support of NTUA, in order to deliver data for the simulation and testing within Task 2.4. The results will drive the development of a prototype boiler based on the current pellets boiler design of OKOFEN. This prototype will include the most promising HEX designs, and a fully controllable EGR circuit with the use of a valve. It will be then tested in the lab by OKOFEN and FAU. Tests will be conducted with/without EGR and the internal HEX, in order to examine the effect of each one to the boiler efficiency. Moreover, NOx emissions characteristics of different pellets from wood and mixtures with herbaceous biomass having typically higher nitrogen contents will be examined, as well as boiler efficiencies. The tests with different fuels will also assist the understanding of emissions production mechanisms of CO and especially PMs, in order to optimise the EGR flow rate and identify any control features. The boiler operation will be characterised with short-term part-load tests and its ash-related fouling behaviour in 72-h long-term tests.
The overall result is to reach an optimised cost-effective HEX design and load-depending EGR rate strategies for maximising the efficiency by even over 94% and at the same time reduce the NOx emissions by 20%, with the potential for a minor decrease of other air pollutants as well. Finally, a numerical sub-model will be produced, feeding Task 3.4 and included in the complete system simulation.

Task 2.7: Testing of the integrated heat pump-based configuration (M19 to M27)
Task leader: NTUA; Contributing partners: ITAE, FAHREN, DAIKIN, TEAVE, UDL
As soon as the development of the cascade chiller and the reversible HP/ORC is finalised, the developed adsorption chiller with the new HEXs of Task 2.3 will be shipped to NTUA. It will be then connected to the reversible unit at NTUA to form the heat pump-based configuration and tested at the lab under all possible operating conditions and modes (winter/summer mode, solar-assisted mode, and HP or ORC mode), fine-tuning the control strategy, and providing input to Task 3.2. A key outcome is a detailed performance map and numerical sub-models (based on the models developed in Tasks 2.3 and 2.4) to feed the simulation platform in WP3. This configuration will be then included in the NTUA pilot building in WP4 and tested in WP5.

Participation per Partner

Partner number and short name	WP2 effort
1 - NTUA	19.00
2 - FAU	18.00
3 - FAHREN	8.00
4 - ITAE	24.00
5 - TEAVE	2.00
6 - AKOTEC	12.00
7 - UDL	4.00
8 - Daikin	14.00
12 - KIT	14.00

Partner number and short name	WP2 effort
13 - OKOFEN	4.00
14 - STRABAG	0.50
15 - UNIME	10.00
Total	129.50

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D2.1	Definition of climate and building typologies	7 - UDL	Websites, patents filling, etc.	Public	3
D2.2	Key design and sizing features of the generic energy system	4 - ITAE	Report	Confidential, only for members of the consortium (including the Commission Services)	6
D2.3	Cascade chiller with heat pump	4 - ITAE	Report	Confidential, only for members of the consortium (including the Commission Services)	21
D2.4	Reversible heat pump/ ORC	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	21
D2.5	Solar thermal collector with TEGs	12 - KIT	Report	Confidential, only for members of the consortium (including the Commission Services)	24
D2.6	Biomass boiler for CHP operation	2 - FAU	Report	Confidential, only for members of the consortium (including the Commission Services)	21
D2.7	Test results of the heat pump-based configuration	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	27

Description of deliverables

D2.1 Definition of climate and building typologies M03
D2.2 Key design and sizing features of the generic energy system M06
D2.3 Cascade chiller with heat pump M21

D2.4 Reversible heat pump/ORC M21
D2.5 Solar thermal collector with TEGs M24
D2.6 Biomass boiler for CHP operation M21
D2.7 Test results of the heat pump-based configuration M27

D2.1 : Definition of climate and building typologies [3]

Report presenting the climatological constraints affecting system efficiency indicators and building typologies for further dynamic simulation of a variety at real-world conditions

D2.2 : Key design and sizing features of the generic energy system [6]

Report on the key design and sizing features of the generic heating system for integrating the solar seasonal adsorption storage in different climatic zones in Europe

D2.3 : Cascade chiller with heat pump [21]

Development and lab testing of the cascade chiller with heat pump involving the two key components: the adsorber and the integrated evaporator/ condenser

D2.4 : Reversible heat pump/ORC [21]

Simulation of the operation, development and experimental testing of the reversible heat pump/ORC.

D2.5 : Solar thermal collector with TEGs [24]

Simulation of the operation, development and experimental testing of the solar thermal collectors with TEG

D2.6 : Biomass boiler for CHP operation [21]

Development and experimental testing of biomass CHP boiler featuring cost-effective HEX design and EGR.

D2.7 : Test results of the heat pump-based configuration [27]

Development and experimental testing of integrated heat pump-based configuration under different operating scenarios for fine tuning the control strategy. Generation of detailed performance map and numerical sub-models. Heat pump-based configuration installation in NTUA pilot building.

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	Cascade chiller/heat pump shows high performance and compactness	4 - ITAE	21	Prototype unit manufactured and installed. Performance tests under typical operating conditions performed at ITAE lab / D2.3 delivered
MS2	Reversible heat pump/ORC shows high performance under both modes	1 - NTUA	21	Prototype unit manufactured and installed. Performance tests under typical operating conditions performed at NTUA lab / D2.4 delivered
MS3	Biomass-fired boiler reaches cogeneration efficiency of over 94%	2 - FAU	21	Boiler tested under controlled lab conditions at OKOFEN and FAU / D2.6 delivered
MS4	Solar-TEGs developed with high thermal matching and adequate heat sink	6 - AKOTEC	24	Solar collector-TEG integrated solution tested by AKOTEC both indoors and outdoors / D2.5 delivered
MS5	Heat pump-based configuration has high performance at all modes	1 - NTUA	27	Integrated heat pump-based configuration installed and

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
				tested at NTUA lab / D2.7 delivered

Work package number [9]	WP3	Lead beneficiary [10]	1 - NTUA
Work package title	Simulation and smart control		
Start month	4	End month	30

Objectives

- Assessment of specific user-building interaction models.
- Development of a control strategy based on users' profile & weather forecast.
- Design and testing of a smart control environment, with user-friendly operational and maintenance features.
- Development of a numerical platform with optimisation capabilities.
- Simulation of system performance for different buildings, and climatic and user conditions.

Description of work and role of partners

WP3 - Simulation and smart control [Months: 4-30]
NTUA, FAU, FAHREN, ITAE, TEAVE, AKOTEC, UDL, Daikin, KIT, OKOFEN
Task 3.1: Assessment of user behavioural models (M4 to M12)
Task leader: NTUA; Contributing partners: UDL, TEAVE
In parallel and after Task 2.1, the building dynamics will be also defined in terms of different (new and consolidated) user behavioural models. User profiles and their control and management access will be identified through dynamic simulation models, investigating energy attitudes of different groups and buildings (e.g. residential, commercial), while interacting with their HVAC and electricity system. The aim is to better identify the role of user variability and use conditions in affecting the performance of the SolBio-Rev system, in terms of heating, cooling and electricity demand and their profile. These models will be defined as key indoor variable represented by users in various buildings.
The performance of the behavioural models will be dynamically investigated with varying user profiles within EnergyPlus, Transient System Simulation (TRNSYS) software, and stochastic tools in several EU climatic zones building types, also including potential synergy effects with heating/cooling and electricity networks.

Task 3.2: Development of a control strategy based on users' profile & weather forecast (M7 to M24)
Task leader: UDL; Contributing partners: TEAVE, DAIKIN, AKOTEC, FAHREN, KIT, OKOFEN, NTUA
Basic control strategies will be examined numerically to fully understand the integration of the sub-systems (cascade chiller, reversible ORC/heat pump, and biomass boiler with ORC) and the effect of the main parameters as a function of weather conditions (e.g. pumps operation, solar field control, hot water tank charging). Focus is given on both performance values (e.g. energy share covered by renewables), as well as component sizing (e.g. collectors' surface, heat pump and boiler capacity) under different weather conditions and heating/cooling demand profiles from Task 3.1. The numerical results with the use of different strategies will be processed and the best-performing strategy will be finalised (e.g. the one that maximises the energy share for a given sizing). Optimisation will be performed by maximising/ minimising proper objective functions formulated in terms of the performance indicators, using the input of WP2 on the different system components.
The outcome is a control strategy based on users' profile & weather forecast, adapted with Model Predictive Control (MPC), as described in Task 3.3.

Task 3.3: Development and testing of a smart control environment (M16 to M27)
Task leader: TEAVE; Contributing partners: UDL, NTUA, AKOTEC, FAHREN, DAIKIN, FAU, KIT
The goal of this Task is to develop control algorithms using a hardware real-time complex model. Objective functions at different level will be defined for the above identified control strategy (Task 3.2) and translated into algorithms. Subsequently, sets of optimisation actions will be developed, which will be converted in commands by the controller (e.g. actuation of valves and of the solar field, setting of pumps frequency, on/off operation of TEGs, start-up of the biomass boiler). The control algorithm will be broken into logic components/blocks (e.g. solar circuit, cascade chiller, biomass boiler) and optimise control scheme per subsystem and then incorporate data exchange flow between sub-systems and realise stability of the control loops, both on component level and system-wise.
Before porting the controllers to the real environment, the underlying algorithms will be tested in a real, but simplified environment for fine-tuning. Lab tests will simulate different environments and system demand that will be carried out with the provision of simulated values to the controller's input and evaluating its output, thus providing evidence of control stability. The tests will prove the capability of the control system to effectively adjust its operation according

to weather forecasts, using deep learning techniques, which is a key feature of the proposed smart control system, with the final aim to optimise the control and operation of the system components at any operating mode.
Operation and maintenance aspects of the SolBio-Rev system will be considered in the controller including various features, such as real-time monitoring, preventive maintenance, and remote operation through web services, with the aim to minimise the implications for the end-users and reduce the annual energy costs, which are both important identified needs. Any other user need that will be identified in WP6 will be explicitly included in the controller.
Finally, an open interface of the controller will be developed for coupling with any building energy management system (BEMS), if there is any available, with the aim to be readily available for installation in any type of building using the existing infrastructure and without replacing any equipment. It will evaluate requirements arising from the BEMS installation to decide critical points of integration and data exchange between the developed controller and the upper level BEMS. In addition, the control software development/adaptation and maintenance will be finalised, according to the different protocols and interfaces, e.g. for monitoring heating/cooling requests from the BEMS. The different communication/control interfaces, and the algorithms computational needs will be specified, in order to develop and set the final system control.

Task 3.4: System simulation for different buildings, climatic and user conditions (M4 to M30)
Task leader: NTUA; Contributing partners: UDL, AKOTEC, FAU, TEAVE, ITAE, KIT
A numerical platform will be developed based on Engineering Equation Software (EES) software, which has built-in multi-parametric optimisation capabilities and can easily include subroutines for the different components, weather conditions and control. This platform will be of open-architecture to allow the introduction of sub-models from WP2 and Tasks 3.1 and 3.2 relevant to components, configuration and control. Weather conditions, solar irradiation level and solar heat potential at various locations will be provided by a sub-model developed in TRNSYS software (with TMY2 data). These data will be processed and added in EES as lookup tables.
An important sub-model is the user behaviour (Task 3.1), which includes the impact of the users' behaviour on energy consumption and comfort. This aspect is essential for improving the consistency and reliability of the simulations, since in most cases numerical models fail to accurately predict the energy behaviour of the building.
Dynamic simulations will be conducted for various climatic zones, including annual local weather data and typical heating/cooling/electricity demand profiles (data from Task 2.1), as well as demand produced from behavioural models (from Task 3.1). The system simulation will be conducted for various building types (e.g. multi-family residential, commercial) of different energy class and use (main residence, industrial, public, etc.). The building energy performance for reaching NZEB or ZEB standards for both new and renovated buildings in the three main climatic zones, according to the future standards will be applied.
A similar procedure will be followed for the simulation of the two pilot buildings at NTUA and FAU. Their specifications will be used as input to the simulation tool, and an optimisation study will then follow. This procedure will provide feedback to the development process of the system components (Tasks 2.3-2.6) and most importantly to the pilot system design in Task 4.1, about the optimised operation and sizing of all parts.
Finally, all simulation results and sizing activities will be processed, in order to produce a European map showing the main system sizing (e.g. collectors' surface and heat pump sizing) to achieve a certain energy share coverage by renewables at each geographical location, which will be used for exploitation purposes in WP8.

Participation per Partner

Partner number and short name	WP3 effort
1 - NTUA	24.00
2 - FAU	3.00
3 - FAHREN	1.00
4 - ITAE	5.00
5 - TEAVE	18.00
6 - AKOTEC	2.00
7 - UDL	14.00
8 - Daikin	2.00
12 - KIT	5.00

Partner number and short name	WP3 effort
13 - OKOFEN	1.00
Total	75.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D3.1	User behavioural model including user-building interaction	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	12
D3.2	Optimised system control and strategies	7 - UDL	Report	Confidential, only for members of the consortium (including the Commission Services)	24
D3.3	Prototype smart control environment	5 - TEAVE	Websites, patents filling, etc.	Confidential, only for members of the consortium (including the Commission Services)	27
D3.4	System performance for different climates and buildings	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	27
D3.5	European map of SolBio-Rev system sizing at each geographical location	1 - NTUA	Websites, patents filling, etc.	Public	30

Description of deliverables

D3.1 User behavioural model including user-building interaction M12
D3.2 Optimised system control and strategies M24
D3.3 Prototype smart control environment M27
D3.4 System performance for different climates and buildings M27
D3.5 European map of SolBio-Rev system sizing at each geographical location M30

D3.1 : User behavioural model including user-building interaction [12]

Investigation of the performance of behavioral models considering different user profiles and potential synergy effects with heating/cooling/electricity networks.

D3.2 : Optimised system control and strategies [24]

Report describing the algorithms developed, mathematical representation of the system, definition of inputs, outputs, optimisation objectives, algorithms for predictive control, and finalised control strategies

D3.3 : Prototype smart control environment [27]

Prototype controller (including interface) development and its tests for proper functionality.

D3.4 : System performance for different climates and buildings [27]

Development of numerical platform to simulate different building types under various climatic conditions and user behavior profiles.

D3.5 : European map of SolBio-Rev system sizing at each geographical location [30]

Generation of a European map showing the main system sizing (e.g. collectors' surface and heat pump sizing) to achieve a certain energy share coverage by renewables at each geographical location

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS6	Simulation and smart control developed	1 - NTUA	27	The numerical tools have been finalized and the smart control developed / D3.3 and D3.4 delivered

Work package number [9]	WP4	Lead beneficiary [10]	8 - Daikin
Work package title	Prototypes design, production and commissioning		
Start month	25	End month	36

Objectives

• Design of the two prototype systems for the two sites.
• Production of the prototype components to be included in the two pilot building prototypes.
• Preparation of the pilot buildings.
• Commissioning of the SolBio-Rev systems within the building prototypes.

Description of work and role of partners

WP4 - Prototypes design, production and commissioning [Months: 25-36]
Daikin, NTUA, FAU, FAHREN, ITAE, TEAVE, AKOTEC, UDL, TECH, KIT, OKOFEN, STRABAG
Task 4.1: Prototype systems design (M25 to M30)
Task leader: DAIKIN; Contributing partners: AKOTEC, KIT, ITAE, FAHREN, FAU, OKOFEN, NTUA, UDL, TECH, STRABAG
The design of each prototype system will be accomplished, according to the outcomes of WPs 2 and 3. This design process will also consider the specifications of each pilot building (e.g. building size, energy class), and local weather conditions in Greece (at NTUA) and Germany (at FAU).
To cover the high cooling needs with the most efficient way, a cascade chiller is necessary in Greece. On the other hand, the prototype system in Germany will include only the heat pump for cooling (without the chiller). The design procedure will include the sizing of each main component of WP2, and any other, such as the short-term storage tanks (handled by UDL) that are necessary for storing hot or chilled water. The result is a detailed design for producing the system components in Task 4.2.

Task 4.2: Production of the prototype main components of the SolBio-Rev systems (M28 to M33)
Task leader: DAIKIN; Contributing partners: AKOTEC, KIT, OKOFEN, ITAE, TEAVE, FAU, NTUA, UDL
The main objective is the manufacturing of all the components, configuration, and parts for the two prototype systems, according to the designs of Task 4.1. The prototype components will be equipped with the appropriate sensors for performance monitoring and control (defined in WP3) according to the development phase of each one (from WP2) and of their integrated operation (defined by the control and simulation activities in WP3). The main components are the following:
Heat pump-based configuration: It houses the cascade chiller and the reversible heat pump/ORC. The developed configuration in WP2 (produced by FAHREN and DAIKIN) will be included in the pilot system at NTUA with some possible modifications, according to the test results at ITAE and NTUA in WP2. The prototype system in Germany will not include a chiller, due to the low cooling needs, requiring only a reversible HP/ORC. This will be produced by DAIKIN and NTUA, based on the outcomes of Task 2.4.
Solar thermal collectors with TEGs: Prototype solar thermal collectors including the developed TEGs will be produced by AKOTEC and KIT. The gross surface of the solar field will be up to 6-8 m2 for each system, according to the dedicated system design of Task 4.1.
Biomass boilers: Two fully equipped biomass boilers will be produced by OKOFEN with the support of FAU, to be included in the two pilot systems. The heating capacity of each boiler will be defined in Task 4.1.
How water storage tanks: One short-term thermal energy storage tank and one buffer tank is required for each pilot system. These tanks will be provided by AKOTEC with the support of UDL for their sizing and specifications, according to the outcomes of Task 4.1.
Controllers: The stand-alone controller developed and tested in WP3 will be used in the pilot system at NTUA. Another one will be produced by TEAVE for the pilot system at FAU, according to its design, considering all system parameters, system/building sizing, and local weather conditions. Both controllers will be remotely re-programmed by TEAVE.
All other standard parts (e.g. valves, pumps, electric panels) will be purchased according to their specifications and the feedback of the industrial partners, to ensure the components' compatibility, system reliability and cost.

Task 4.3: Site preparation and commissioning of the prototype systems (M25 to M36)
Task leader: FAU; Contributing partners: NTUA, UDL, DAIKIN, TEAVE, AKOTEC, KIT, OKOFEN, ITAE

A containerised (well-insulated) building prototype with a surface of 30-40 m2 will be designed, manufactured and installed at an appropriate location at FAU premises with no shading and good orientation, serving as the pilot building for the project purposes. The two sites at FAU and NTUA will be then prepared to host the prototype system. Minor modifications to the pilot buildings will be implemented, such as the adjustment of the interior space, addition of heating/cooling appliances (e.g. fan coils), and installation of heating/electricity loads to simulate realistic energy uses. Electrical and hydraulic connections will be installed, as well as the communication and internet connections established.
The next step is to assemble, install and commission the two prototype systems in NTUA and FAU, as soon as all the components are produced in Task 4.2 and delivered. One part of the building simulates the building energy demand with the installation of heating/cooling loads and appliances, and the other part incorporates the SolBio-Rev system to be tested. A monitoring protocol and an evaluation plan will be defined, which will include the description of the monitoring system to be established.
Extended commissioning tests in three successive steps will ensure the proper functionality of all electrical connections, computers, data loggers, valves, switches, and the SolBio-Rev system itself. These commissioning tests are described next:
Manual sub-system testing: A series of tests will be defined to analyse the performance of specific components under manual mode. The aim is to evaluate the performance of each one under different operating conditions, and to ensure their proper functioning.
Semi-automatic sub-system testing: The automatic mode functioning is limited to just one main component (e.g. boiler, solar-TEG). These tests are used to check robustness of control routines for each one. Any adjustment in the controller software will be conducted at this stage remotely by TEAVE.
Fully-automatic testing: The final step of the commissioning tests concerns the fully automatic operation of the system, when heating or cooling set points will be determined, as well as specific schedules such as DHW discharge or presence of internal gains.
All measured data of the above testing phases will be used for the simulation tool validation in Task 5.3.

Participation per Partner

Partner number and short name	WP4 effort
1 - NTUA	8.00
2 - FAU	15.00
3 - FAHREN	4.00
4 - ITAE	6.00
5 - TEAVE	9.00
6 - AKOTEC	4.00
7 - UDL	2.00
8 - Daikin	9.00
11 - TECH	1.00
12 - KIT	9.00
13 - OKOFEN	6.00
14 - STRABAG	0.50
Total	73.50

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D4.1	Design of the two prototype systems	8 - Daikin	Report	Confidential, only for members of the consortium (including the Commission Services)	30
D4.2	Produced building prototype at FAU	2 - FAU	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	30
D4.3	SolBio-Rev prototype systems produced and installed	2 - FAU	Report	Confidential, only for members of the consortium (including the Commission Services)	33
D4.4	Monitoring protocol and evaluation	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	33
D4.5	Extended commissioning test results	2 - FAU	Report	Confidential, only for members of the consortium (including the Commission Services)	36

Description of deliverables

D4.1 Design of the two prototype systems M30
D4.2 Produced building prototype at FAU M30
D4.3 SolBio-Rev prototype systems produced and installed M33
D4.4 Monitoring protocol and evaluation M33
D4.5 Extended commissioning test results M36

D4.1 : Design of the two prototype systems [30]

Design of the prototype systems to be tested in Greece and Germany taking into account the specifications of the pilot buildings and local weather conditions in the two countries.

D4.2 : Produced building prototype at FAU [30]

Design, manufacturing and installation of a containerised (well-insulated) building prototype at an appropriate location at FAU premises.

D4.3 : SolBio-Rev prototype systems produced and installed [33]

Development and commissioning of the SolBio-Rev prototypes in the test-sites.

D4.4 : Monitoring protocol and evaluation [33]

Protocol for monitoring hardware and software description and evaluation plan for the test campaign

D4.5 : Extended commissioning test results [36]

Definition and execution of the extended commissioning tests of the SolBio-Rev prototypes

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS8	Prototype components of the two pilot systems produced and installed	8 - Daikin	33	All main prototype components produced according to the design / D4.3 delivered
MS9	Prototype systems successfully commissioned	8 - Daikin	36	The prototype systems have been installed and all commissioning tests are successful / D4.5 delivered

Work package number [9]	WP5	Lead beneficiary [10]	2 - FAU
Work package title	System testing and technology validation		
Start month	37	End month	48

Objectives

• Testing of the prototype systems for one year in Greece and Germany.
• Technology validation in diverse European climatic zones with different energy needs.
• Validation of simulation platform using test data from the prototype systems.

Description of work and role of partners

WP5 - System testing and technology validation [Months: 37-48]
FAU, NTUA, FAHREN, ITAE, TEAVE, AKOTEC, UDL, Daikin, KIT, OKOFEN, STRABAG, UNIME
Task 5.1: Testing of the prototype system in Greece (M37 to M48)
Task leader: NTUA; Contributing partners: FAU, ITAE, UNIME, FAHREN, TEAVE, AKOTEC, DAIKIN, KIT, OKOFEN, UDL, STRABAG
The tests of the prototype/pilot system in Greece (at NTUA) will be conducted for a whole year to account for different seasonal climate conditions and operation at both heating (winter) and cooling (summer) modes. NTUA will be organising and leading these tests, with the active participation of other partners, each focussing on its specific field: ITAE, UNIME and FAHREN on the chiller, AKOTEC on the collectors, DAIKIN on the heat pump, OKOFEN on the biomass boiler, UDL on the storage tanks and control strategies, TEAVE on the controller, KIT on the TEGs.
Tests will be conducted at fully-automatic mode, re-programming the controller if necessary, to account for the different user behaviour and building (e.g. residential, commercial). The interpretation of the data will lead to a detailed verification of the effectiveness of the technology in realistic climatic and user-driven conditions. Energy results will be processed and analysed in connection to all registered experiences and system adjustments. The performance results with respect to energy, environmental impacts and energy costs for heating, cooling and electricity will be analysed, and compared with mainstream alternatives. The results of the data analysis will be transferred to WP6 for societal engagement and to WP7 for the Life Cycle Cost analysis.

Task 5.2: Testing of the prototype system in Germany (M37 to M48)
Task leader: FAU; Contributing partners: NTUA, TEAVE, AKOTEC, DAIKIN, KIT, OKOFEN, UDL, STRABAG
The same procedure as in Task 5.1 will be conducted for the prototype system tested in Germany at FAU premises. ITAE and FAHREN will not participate on these tests, since no chiller is included in this prototype.
Finally, there will be continuous exchange of everyday experience and data between the research teams of NTUA and FAU, including short-term visits of their personnel for synergistic work, aiming to further fine-tune some system parts, and conclude to the technology validation in Task 5.4.

Task 5.3: Validation of the simulation tools (M43 to M48)
Task leader: NTUA; Contributing partners: UDL, TEAVE, KIT, FAU, ITAE
The test data of the two prototype systems from both the commissioning and actual testing phases (Tasks 4.3 and 5.1, 5.2) will be used to validate all simulation tools and sub-models developed in WPs 2 and 3, in terms of performance, control and dynamic behaviour of each component and the total energy system. Results will be also used for fine-tuning any calibration parameter. The overall outcome is a validated simulation platform to be used for the further investigation of the SolBio-Rev system, and analysing different sizing and configurations in various buildings, aiding in the exploitation activities in WP8.

Task 5.4: Technology validation (M45 to M48)
Task leader: FAU; Contributing partners: NTUA, ITAE, TEAVE, AKOTEC, DAIKIN, KIT, OKOFEN, STRABAG
The processed results of Tasks 5.1 and 5.2 will define the anticipated benefits of the SolBio-Rev system in terms of the energy share covered, with the aim to reach at least 70% in both locations. This energy will be divided into heating, cooling and electricity, in order to have a better view of the share of each energy type and the possibilities of this promising technology. The overall outcome is the technology validation at two diverse climatic zones in relevant environment, reaching TRL5, and providing concrete evidence of the performance potential of the new energy system for buildings.
Finally, the test results and conditions will be transferred to actual sized buildings, in order to identify with detail the benefits of this technology. This will be supported with the validated simulation platform of Task 5.3, in order to analyse

the SolBio-Rev potential in typical buildings in different climatic zones in the EU, providing cases to showcase in the dissemination and communication activities of WPs 8 and 9.

Participation per Partner

Partner number and short name	WP5 effort
1 - NTUA	23.00
2 - FAU	22.00
3 - FAHREN	2.00
4 - ITAE	5.00
5 - TEAVE	4.00
6 - AKOTEC	4.00
7 - UDL	3.00
8 - Daikin	5.00
12 - KIT	4.00
13 - OKOFEN	3.00
14 - STRABAG	0.50
15 - UNIME	3.00
Total	78.50

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D5.1	First test results of the two prototype SolBio-Rev systems	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	42
D5.2	Energy performance of SolBio-Rev system in Greece	1 - NTUA	Report	Public	48
D5.3	Energy performance of SolBio-Rev system in Germany	2 - FAU	Report	Public	48
D5.4	Validated simulation platform	1 - NTUA	Report	Confidential, only for members of the consortium (including the Commission Services)	48
D5.5	Technology validation in different climatic zones	2 - FAU	Report	Confidential, only for members of the consortium (including	48

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
				the Commission Services)	

Description of deliverables

D5.1 First test results of the two prototype SolBio-Rev systems M42
D5.2 Energy performance of SolBio-Rev system in Greece M48
D5.3 Energy performance of SolBio-Rev system in Germany M48
D5.4 Validated simulation platform M48
D5.5 Technology validation in different climatic zones M48

D5.1 : First test results of the two prototype SolBio-Rev systems [42]

Acquisition and preliminary assessment of experimental data during the testing of the prototype in Greece and Germany.

D5.2 : Energy performance of SolBio-Rev system in Greece [48]

Processing/utilization and analysis of experimental results of the prototype system in Greece for evaluating its performance and comparing the system with mainstream alternatives and providing the data to WP6 (societal engagement) and WP7 (LCC analysis)

D5.3 : Energy performance of SolBio-Rev system in Germany [48]

Processing/utilization and analysis of experimental results of the prototype system in Germany for evaluating its performance and comparing the system with mainstream alternatives and providing the data to WP6 (societal engagement) and WP7 (LCC analysis)

D5.4 : Validated simulation platform [48]

The simulation platform using the available test data from the commissioning and the two sites is validated

D5.5 : Technology validation in different climatic zones [48]

The application of the developed systems under different climate conditions and heating/cooling loads will be validated.

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS11	SolBio-Rev achieves high energy share in Greece	1 - NTUA	48	The processed test results in Greece show that an energy share of > 70% is reached / D5.2 delivered
MS12	SolBio-Rev achieves high energy share in Germany	2 - FAU	48	The processed test results in Germany show that an energy share of > 70% is reached / D5.3 delivered

Work package number [9]	WP6	Lead beneficiary [10]	9 - UOS
Work package title	Social acceptance, potential for uptake and engagement		
Start month	13	End month	48

Objectives

• Conduct social science research through interaction with various stakeholder groups
• Carry out in-depth interviews and web-based surveys among key stakeholders
• Create an analytical model of coupling social acceptance of new technology with sustainable energy transitions

Description of work and role of partners

WP6 - Social acceptance, potential for uptake and engagement [Months: 13-48]
UOS, NTUA, FAU, AKOTEC, UDL, DBC, TECH, KIT, STRABAG
Task 6.1: Social acceptance of SolBio-Rev (M13 to M27)
Task leader: UOS; Contributing partners: NTUA, DBC, UDL, TECH
The aim is to examine the views of (1) existing users and installers of other renewable energy technologies that form part of the Sol-Bio-Rev concept (e.g. heat pumps, solar thermal, and biomass), (2) the developers of the SolBio-Rev concept, and (3) its prospective users and installers. UOS will interview various groups (e.g. users and installers, and concept developers) to analyse the extent to which the SolBio-Rev concept is different from current renewable energy systems regarding user and installer experience (e.g. features, limitations, delivered energy services). Interview findings will provide input into Task 6.2 for the integration of users and installers' views at the design stage. The interview data will also inform WP8 in relation to different business models.
Following the interviews, UOS will conduct an online survey examining further perceptions of SolBio-Rev. The survey will be conducted amongst a mix of stakeholders (e.g. users and installers, policy makers) in a mix of countries from south/central/north Europe, using a randomised sample. Questions will focus on aspects such as user expectations and practices of SolBio-Rev, heat/cold/electricity as an energy service, business models (providing input to Task 8.4) and policy implications and needs (input to Task 6.3).
Social aspects of SolBio-Rev and its potential positive and negative impacts will be analysed using the interview and survey data. These will focus on: user interface, delivered energy services, business models, estimated energy efficiency/ cost savings, indoor climate comfort, environmental impact, policy implications. The final outcome will be a report examining all social aspects of SolBio-Rev, including interview and survey results assessment.

Task 6.2: Introduction of user and installer needs to the design process (M22 to M30)
Task leader: UOS; Contributing partners: NTUA, AKOTEC, DBC, TECH, FAU, KIT, STRABAG
The results of the interviews and surveys (Task 6.1) will be processed and provide valuable input to the SolBio-Rev control of Task 3.3 and system design of Task 4.1. This input has versatile approaches, dealing with indoor comfort, system friendliness and ease-of-use, chosen business model (hardware based, or service based) and finally its cost. This is expected to enhance the user acceptance, since considering and meeting potential user needs is a vital part of the design process of the SolBio-Rev system.

Task 6.3: Interaction with policy makers (M31 to M48)
Task leader: UOS; Contributing partners: DBC, NTUA
User acceptance of SolBio-Rev will be enhanced through dedicated analysis that connects insights about users' views, technology complexity, real and perceived costs, and feasibility issues with potential business models (input from Task 8.4) and policy mechanisms to promote open innovation. UOS will investigate potential policy implications of SolBio-Rev in various countries. This includes in-depth interviews with policy makers related to energy and buildings. Results from interviews are expected to identify potential regulatory and planning issues, barriers to development, and potential benefits of SolBio-Rev to other policy areas. Examining policy implications will be a key component in analysing the potential for the wider uptake of SolBio-Rev.

Participation per Partner

Partner number and short name	WP6 effort
1 - NTUA	2.00
2 - FAU	2.00
6 - AKOTEC	1.00
7 - UDL	2.00
9 - UOS	26.00
10 - DBC	3.00
11 - TECH	3.00
12 - KIT	0.50
14 - STRABAG	0.50
Total	40.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D6.1	Surveys outcome report	9 - UOS	Report	Public	27
D6.2	Definition of user and installer needs and their introduction in the design process	9 - UOS	Report	Public	30
D6.3	User acceptance and policy strategies	9 - UOS	Report	Public	48

Description of deliverables

D6.1 Surveys outcome report M27
D6.2 Definition of user and installer needs and their introduction in the design process M30
D6.3 User acceptance and policy strategies M48

D6.1 : Surveys outcome report [27]

Report including the processed results and main outcomes of the surveys

D6.2 : Definition of user and installer needs and their introduction in the design process [30]

Identification of needs and constraints of end-users and equipment installers for their integration in the design process of the SolBio-Rev system

D6.3 : User acceptance and policy strategies [48]

User acceptance progress during the project and policy strategies

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS7	Social surveys campaign designed and implemented	9 - UOS	27	The key outcomes of the social science research

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
				through surveys are available / D6.1 delivered

Work package number [9]	WP7	Lead beneficiary [10]	7 - UDL
Work package title	LCA, economic analysis and building integration		
Start month	19	End month	45

Objectives

• Investigation of environmental impact through LCA analysis.
• Economic evaluation of SolBio-Rev system (LCC and CBA).
• Investigation of system integration aspects in buildings.

Description of work and role of partners

WP7 - LCA, economic analysis and building integration [Months: 19-45]
UDL, NTUA, FAHREN, ITAE, TEAVE, AKOTEC, Daikin, DBC, TECH, KIT, OKOFEN, STRABAG
Task 7.1: Life Cycle Assessment (LCA) (M19 to M30)
Task leader: UDL; Contributing partners: NTUA, ITAE, AKOTEC, FAHREN, TEAVE, KIT, OKOFEN
This Task concerns the development of LCA models for investigating the environmental impact of the proposed solution at building scale, focussing on various building types in several countries, using the simulated results of WP3.
Internationally acknowledged procedures will be implemented, involving the SimaPro calculation tool and the Ecoinvent database and other environmental assessment protocols (e.g. LEED), in order to estimate the environmental benefits of SolBio-Rev.
After a detailed analysis of the raw materials and the industrialisation processes' disaggregation, a detailed protocol-questionnaire will be framed, in order to collect real data from production companies (including the industrial partners) about the proposed system and about its competitors, in order to assess the whole LCA of the SolBio-Rev system.
The LCA analysis will be integrated with the LCC procedures in Task 7.2, in order to perform consistent assumptions and parallel verifications. The environmental impact and the reduction of air pollutants and CO2 emissions will be identified during the life cycle.

Task 7.2: Life Cycle Costing (LCC) (M28 to M45)
Task leader: UDL; Contributing partners: NTUA, DBC, FAHREN, AKOTEC, DAIKIN, TEAVE, OKOFEN, STRABAG, KIT
The LCC methodology will be primarily based on reference standards (e.g. ISO 15686-5; EN 15643- 4; prEN 16627). This analysis will be done, in order to control energy savings, annual costs and GHG emissions reduction during all stages to further the economic viability of the innovative system.
A Cost Benefit Analysis (CBA) will be conducted to compare the costs of the main competing solutions, providing feedback to the business models in WP8. A sensitivity analysis will then follow to identify the effect of key cost and performance parameters on end-user price, introducing uncertainty factors, due to the low TRL. A techno-economic analysis with main parameters the system sizing, the building's energy performance and energy share will be conducted based on the simulation results of WP3, providing feedback to the design process of Task 4.1.
The core process of the LCC is summed up as follows: (1) Defining the objective of the proposed LCC analysis, (2) Preliminary identification of parameters and analysis requirements, (3) Confirmation of project and facility requirements, (4) Assemble of cost and performance data, (5) Projection of costs once this technology reaches commercial level, (6) Carry out analysis, iterating as required, (7) Sensitivity analysis of the key parameters, and (8) Interpreting and reporting results.
The overall outcome is a detailed evaluation of the cost potential of this technology, as well as of its main parts/components, in order to evaluate its possible competitiveness in a future scenario.

Task 7.3: Integration of SolBio-Rev system in buildings (M25 to M36)
Task leader: TECH; Contributing partners: NTUA, ITAE, DAIKIN, AKOTEC, STRABAG, TEAVE
The SolBio-Rev system integration will be examined in both new and existing buildings of various types (e.g. multi-family residential, commercial, public) and connections to the heating/cooling appliances (e.g. low-temperature radiators, under-floor heating network, DHW piping, fan coils), documenting all necessary steps and the whole procedure, with direct input from Task 4.1. The main parameters considered are: (1) space requirements within the building for installing the SolBio-Rev system with the low-volume storage tanks, (2) rooftop surface availability for installing the collectors (e.g. orientation, roof inclination), and (3) connections to the heating/cooling network. Synergies with existing infrastructure (e.g. oil/gas boilers, connection to district heating, other renewables, such as PVs or solar

thermal collectors) will be explored, in order to minimise interventions. Typical case studies will be examined in selected EU countries in different climatic zones, followed by cost-benefit analysis.
All the above aspects and parameters will be examined, providing feedback to the design process in Task 4.1 and the social campaigns of Tasks 6.1, 6.2, and making adjustments, where necessary.

Participation per Partner

Partner number and short name	WP7 effort
1 - NTUA	3.00
3 - FAHREN	1.00
4 - ITAE	4.00
5 - TEAVE	2.00
6 - AKOTEC	4.00
7 - UDL	10.00
8 - Daikin	3.00
10 - DBC	4.00
11 - TECH	7.00
12 - KIT	2.00
13 - OKOFEN	1.00
14 - STRABAG	4.00
Total	45.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D7.1	Life Cycle Assessment (LCA) report	7 - UDL	Report	Confidential, only for members of the consortium (including the Commission Services)	30
D7.2	Life Cycle Costing (LCC) analysis report	7 - UDL	Report	Confidential, only for members of the consortium (including the Commission Services)	45
D7.3	System integration procedures and case-studies in new and existing buildings	11 - TECH	Report	Public	36

Description of deliverables

D7.1 Life Cycle Assessment (LCA) report M30
D7.2 Life Cycle Costing (LCC) analysis report M45

D7.3 System integration procedures and case-studies in new and existing buildings M36

D7.1 : Life Cycle Assessment (LCA) report [30]

Results of the LCA of the SolBio-Rev system and comparative analyses with competing solutions

D7.2 : Life Cycle Costing (LCC) analysis report [45]

Results of LCC analysis SolBio-Rev at various locations and conditions. Techno-economic studies for system sizing at the main climatic zones

D7.3 : System integration procedures and case-studies in new and existing buildings [36]

Integration procedures and design parameters in new and existing residential buildings

Schedule of relevant Milestones

Milestone number[18]	**Milestone title**	**Lead beneficiary**	**Due Date (in months)**	**Means of verification**
MS10	SolBio-Rev cost according to estimations	7 - UDL	45	System cost has the potential to become competitive once it reaches commercial level / D7.2 delivered

Work package number [9]	WP8	Lead beneficiary [10]	10 - DBC
Work package title	Dissemination and exploitation of results		
Start month	1	End month	48

Objectives

• Design and carry out the dissemination activities of the project.
• Shape and posture the project foreground for sustainable long-term impact in a structured and systematic way.
• Foster a culture entrepreneurial spirit and business mind-set into the project.

Description of work and role of partners

WP8 - Dissemination and exploitation of results [Months: 1-48]
DBC, NTUA, FAU, FAHREN, ITAE, TEAVE, AKOTEC, UDL, Daikin, UOS, TECH, KIT, OKOFEN, STRABAG, UNIME
Task 8.1: Finalising the dissemination and exploitation plans (M1 to M6)
Task leader: DBC; Contributing partners: ALL
A SolBio-Rev Project Dissemination and Exploitation team (PDE-team) will be assembled with repre-sentatives from all partners to ensure maximum visibility and impact of the project outcomes to achieve the maximum level of adoption of the new technology and minimisation of the uncertainty. The draft dissemination and exploitation plans, elaborated prior to the submission of the proposal (see §2.2.1), will be consolidated at the beginning of the project (month 6) and will be updated (if needed) every 12 months. The final plan will comprise innovation work for further developing the technology, with input from the technology roadmap of Task 8.6. This will ensure continued dissemination and exploitation with maximised impact.
At the end of the project, the final report will include the final version of the dissemination plan and the dissemination results achieved.

Task 8.2: Roll-out of the dissemination activities (M7 to M48)
Task leader: DBC; Contributing partners: ALL
Once the dissemination and exploitation plan (Task 8.1) is finalised, it will be implemented during the full project duration and beyond. The consortium will ensure that all relevant information is disseminated during and after the project. Dissemination activities include presentation of results in scientific conferences, publication of joint scientific papers, participation in workshops and organisation of workshops to incentivise stakeholders in accounting for future applications of the SolBio-Rev concept (see § 2.2.1). Articles in scientific journals and media work will be conducted, in order to reach a wide audience and inform them about the potential of the SolBio-Rev system, using the European map with the system sizing per geographical location (Task 3.4), and the potential in typical buildings (Task 5.4). The partners will participate in exhibitions, promoting the project concept. Project activities and results will be presented and disseminated in relevant national/international events (e.g. conferences, workshops), with the industrial partners participating in B2B meetings with key stakeholders.
Dissemination also comprises organising dedicated workshops with selected stakeholders especially from the construction building industry and the energy sector. To maximise future uptake of the SolBio-Rev concept, DBC, STRABAG, DAIKIN and TECH will be in charge to define the workshop contents and inspiring their peers and members to exchange ideas, to pinpoint potential risks, to assess the benefits and the ways to exploit at maximum the potential the SolBio-Rev concept. Inviting representatives of companies in charge of management and maintenance of buildings (e.g. SWECO and Rentokil) will ensure future maintenance of the buildings, which is an important aspect often underestimated, when developing a new concept. The SolBio-Rev team is aware of this pitfall and in every way will strive to act differently, pro-actively, involving as many as possible relevant stakeholders in the workshops. Information will be also shared liaising with the broad energy in the building community and platforms (e.g. BPIE, BUILD-UP).
Last but not least, the two prototype systems at NTUA and FAU will attract visibility, which will be the centrepiece of the dissemination work during and after the project, serving as reference installations for reaching various stakeholders. Their hosting partners will organise open-info days demonstrating their operation, while the three workshops scheduled (at FAU, NTUA and in Brussels) will make sure that they will be adequately promoted to a large audience.

Task 8.3: Creating synergies between SolBio-Rev and other initiatives (M1 to M48)
Task leader: UDL; Contributing partners: ALL

This Task will explore synergies between its work and international organisations, global policy makers and funders, other EU funded projects belonging to either the same call of H2020-RES-4 or others relevant to energy solutions in buildings, innovation platforms (e.g. Renewable Heating and Cooling – RHC), and on-going global initiatives in this field. The consortium partners will contribute, upon invitation by the INEA, to common information and dissemination activities to increase the visibility and synergies between H2020 supported actions.
A report outlining the options on the possible synergies between the SolBio-Rev and other initiatives (national/European/global) will be delivered to the Management Board. The Task will provide options to the Management Board for collaboration and knowledge sharing, with the aim to accelerate the system development and approach even more stakeholders.

Task 8.4: Market analysis and business model generation (M25 to M42)
Task leader: DBC; Contributing partners: DAIKIN, STRABAG, UOS, AKOTEC, TEAVE, KIT, OKOFEN
The technical and market codes relevant to residential, commercial, industrial and other buildings, either new and renovated/existing buildings on various markets will be reviewed to guide the business development and the definition of realistic market applications. Specifications will be set to meet basic requirements in compliance with regulations affecting all components and the system as a whole, with feedback to the development and design processes (WPs 2-4).
A summary of existing national/local regulatory framework conditions will be developed and insights on possible future directions will be gained.
The next step is a market analysis assessing the market potential and impact of project results tailored first to partner exploitation channels and then generalised for broader contexts (scaling to EU level). Receiving feedback from the survey results of Task 7.1, value chains will be identified in the context of strategic innovation (e.g. how can project results contribute to partner innovation potential and capacity, and be carried forward post project). In parallel business model shaping will be conducted, using the business model canvas as a guideline.
The development of value chains and a business model will feed into and facilitate the development of partner individual and joint replication planning activities for post-project exploitation, involving other key organisations (e.g. at both local and European level), such as technology providers and installers (and their associations) that can promote the new solution to their customers/end-users.
The work will identify potential new market barriers and assess those already identified (see § 2.1.3). Solutions will be proposed to overcome these barriers.
Along with the business plans, a plan for "Use and Exploitation of Foreground" will be developed and updated as the project progresses. Each partner is responsible for the exploitation of its own foreground, and may decide how to use and disseminate these results as long as it does not affect the interests of other partners. The use of foreground realised during the project and expected after the project end will be reported to the EC in the final Report on IPR and exploitable results generated in the project, with sufficient details to enable the EC to track the actions reported. This report will form an integral part of the business plans.

Task 8.5: Roll-out of the exploitation activities (M1 to M48)
Task leader: DBC; Contributing partners: ALL
This Task will establish and maintain an exploitation culture throughout the project. Key elements include:
Management of Exploitable results – a project exploitable results table will be created to identify, synchronise, and conduct an efficient management of the project foreground. Actions will be identified to execute exploitation activities associated with each result, and management of the collective project foreground will be a part of periodic reporting and project meetings. Risk management, IP protection, market analysis and business model generation are part of exploitable result management.
Replication Planning – development and documentation of the strategy to realise the potential identified in the market analysis. Partner level business modelling and potential future own resources associated with the further development and scaling-up are a part of this planning.
Partner Agreements – partners will receive assistance in the negotiation and drafting of the bi-lateral or multi-lateral agreements necessary to exploit project results. This will include strategies on third party licensing, first rights of refusal, minimum production quotas, IP protection, the ability to serve or expand to new markets, royalty rates, the adjustment of terms and conditions over time and legal dispute considerations.
The final result is the necessary background and documentation for a 3-5 year exploitation of the project foreground (after the project end), while all necessary development stages are examined in Task 8.6.

Task 8.6: Technology roadmap and alternative applications (M43 to M48)
Task leader: NTUA; Contributing partners: ALL
A technology roadmap will be developed and uploaded in the project website, which includes a timeline and projected activities of the consortium after the project end, including some identified major tasks that require further research (e.g. synergistic operation with other components such as PVs or geothermal energy, according to each building energy

needs, and district networks). The roadmap will also deal with the optimised design of the SolBio-Rev system for real-scale buildings and the design modifications to address an even wider addressable market, especially for renovations, with the active involvement of the industrial partners.
Young researchers will be engaged and a community of researchers will be established that could become the main base to handle the future development of this technology. Moreover, alternative applications of each technological field will be identified, in which the project results can be applied after further research. These applications will be also included in this roadmap, further enhancing the project impact.

Task 8.7: Standardisation activities (M43 to M48)
Task leader: DAIKIN; Contributing partners: AKOTEC, TEAVE, NTUA, FAHREN, TECH, KIT, OKOFEN
Standardisation activities will be a key for the future exploitation purposes of the developed technologies. The main objective of this Task is to facilitate the acceptance and utilisation by the market of the developed solution. Other objectives are to provide starting information for other WPs, ensuring compatibility and interoperability with market available systems through standards and regulations, as well as to use the current standardisation system as a tool for dissemination of the project results and interaction with the market stakeholders. The key national and international certification standards and protocols will be reviewed, in order to cross potential market and policy driven barriers, towards the future commercialisation in Europe. Operative analysis will be performed, for following these standards during the design process and receiving the CE mark through the reference directive.
The activities planned to reach the above objectives are grouped under three specific subtasks, which are mutually linked, and are the following:
The identification and analysis of related existing standards.
The collaboration with the relevant standardisation Technical Committees.
The contribution to the on-going and future standardisation developments from the project results.
Especially the latter can become a market barrier, since there is a lack of a certification for multi-energy systems for buildings. There is on-going work in this area, but more is needed to establish an international standard. SolBio-Rev will therefore provide concrete proposals to be considered by standardisation bodies.

Participation per Partner

Partner number and short name	WP8 effort
1 - NTUA	5.00
2 - FAU	2.00
3 - FAHREN	2.00
4 - ITAE	1.00
5 - TEAVE	1.00
6 - AKOTEC	2.00
7 - UDL	1.00
8 - Daikin	3.00
9 - UOS	1.00
10 - DBC	12.00
11 - TECH	1.00
12 - KIT	2.00
13 - OKOFEN	1.00
14 - STRABAG	1.00
15 - UNIME	1.00
Total	36.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D8.1	Dissemination and exploitation plans	10 - DBC	Websites, patents filling, etc.	Confidential, only for members of the consortium (including the Commission Services)	6
D8.2	Compilation of all dissemination activities carried out during the project	10 - DBC	Report	Public	48
D8.3	Exploitable results table	10 - DBC	Websites, patents filling, etc.	Confidential, only for members of the consortium (including the Commission Services)	12
D8.4	Local and EU key technical & market codes and framework conditions relevant to the SolBio-Rev system	10 - DBC	Report	Public	30
D8.5	Market analysis and business models	10 - DBC	Report	Confidential, only for members of the consortium (including the Commission Services)	42
D8.6	Synergies between SolBio-Rev and other initiatives	7 - UDL	Report	Public	48
D8.7	Technology roadmap and alternative applications	1 - NTUA	Websites, patents filling, etc.	Public	48
D8.8	Partner exploitation agreement	10 - DBC	Other	Confidential, only for members of the consortium (including the Commission Services)	48
D8.9	Standardisation activities for future EU wide exploitation	8 - Daikin	Report	Confidential, only for members of the consortium (including the Commission Services)	48

Description of deliverables

D8.1 Dissemination and exploitation plans M06
D8.2 Compilation of all dissemination activities carried out during the project M48
D8.3 Exploitable results table M12
D8.4 Local and EU key technical & market codes and framework conditions relevant to the SolBio-Rev system M30
D8.5 Market analysis and business models M42

D8.6 Synergies between SolBio-Rev and other initiatives M48
D8.7 Technology roadmap and alternative applications M48
D8.8 Partner exploitation agreement M48
D8.9 Standardisation activities for future EU wide exploitation M48

D8.1 : Dissemination and exploitation plans [6]

Dissemination and exploitation plan to ensure maximum and visibility and impact of the project outcomes

D8.2 : Compilation of all dissemination activities carried out during the project [48]

Compilation of all communication activities during the project

D8.3 : Exploitable results table [12]

Table that documents and roadmaps treatment of the foreground. The table will be updated in each periodic report

D8.4 : Local and EU key technical & market codes and framework conditions relevant to the SolBio-Rev system [30]

Report summarizing the current local and European key technical and market codes and framework conditions relevant to the SWS-heating system in a variety of buildings types and sizes

D8.5 : Market analysis and business models [42]

Market analysis description and business models generation

D8.6 : Synergies between SolBio-Rev and other initiatives [48]

Report on potential synergies between this project and international organisations, global policy makers and funders, and on-going global initiatives in this field

D8.7 : Technology roadmap and alternative applications [48]

Technology roadmap and alternative applications, including the projected activities of the consortium after the project end

D8.8 : Partner exploitation agreement [48]

Agreement between partners for exploitation activities

D8.9 : Standardisation activities for future EU wide exploitation [48]

Report presenting the existing standards relevant to SWS-heating system and interaction with standardisation bodies towards the set-up of a standard for seasonal storage units

Schedule of relevant Milestones

Milestone number[18]	**Milestone title**	**Lead beneficiary**	**Due Date (in months)**	**Means of verification**

Work package number [9]	WP9	Lead beneficiary [10]	10 - DBC
Work package title	Communication activities		
Start month	1	End month	48

Objectives

• Create project awareness to appropriate user communities and stakeholders across Europe and beyond.
• Preparation of suitable information materials for each targeted group.
• Ensure European-wide and international stakeholder and industry engagement with SolBio-Rev.

Description of work and role of partners

WP9 - Communication activities [Months: 1-48]
DBC, NTUA, FAU, FAHREN, ITAE, TEAVE, AKOTEC, UDL, Daikin, UOS, TECH, KIT, OKOFEN, STRABAG, UNIME
Task 9.1: Finalising the communication strategy and plan (M1 to M6)
Task leader: DBC; Contributing partners: ALL
Targeted combinations of the objectives, target audience, message, communication activities and tools for each scope of the project communication will be established. The draft communication plan (see § 2.2.4) will be adapted to the dynamic time defined in the project timeline. Dedicated communication strategies and tools will be used depending on the phase of the adoption process and the adaptor type, to ensure that the messages are understood and are adapted to each specific audience/stakeholder group with measurable objectives and results. Key performance indicators (KPIs) will be defined for the communication activities and followed during the project (e.g. website visits, number of participants in the workshops and in the open-info days).
Adequate communication channels for the dissemination and exploitation of the project results will be identified and tools to measure the success of communication activities will be rolled-out with input from the KPIs.

Task 9.2: Project website, logo and videos development (M1 to M48)
Task leader: NTUA; Contributing partners: ALL
The project website with the logo will be developed by Month 2 and will be regularly updated, informing the visitors on the project activities, consortium, news and results. The logo – easily recognisable and representing the project theme – will be included in all internal and external communications. Two videos will be produced (M6, 42), showing the project activities and results, and uploaded in various web-media (e.g. project website, Twitter, LinkedIn).

Task 9.3: Communication activities and events (M1 to M48)
Task leader: DBC; Contributing partners: ALL
The communication activities will be implemented during the whole project duration and beyond. The partners will participate in exhibitions and B2B meetings with key stakeholders, promoting the project concept. The communication activities will follow those described in the draft communication plan (details given in § 2.2.4), such as leaflets, workshops, events, publications, and social media: LinkedIn, Twitter, through the necessary communication tools. All activities will be evaluated against contribution to the expected impacts and KPIs, as described in Task 9.1.

Participation per Partner

Partner number and short name	WP9 effort
1 - NTUA	4.00
2 - FAU	1.00
3 - FAHREN	1.00
4 - ITAE	1.00
5 - TEAVE	1.00
6 - AKOTEC	1.00

Partner number and short name	WP9 effort
7 - UDL	1.00
8 - Daikin	1.00
9 - UOS	0.50
10 - DBC	10.00
11 - TECH	0.50
12 - KIT	1.00
13 - OKOFEN	1.00
14 - STRABAG	0.50
15 - UNIME	0.50
Total	25.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D9.1	Communication strategy and plan	10 - DBC	Report	Public	6
D9.2	Project website and logo	1 - NTUA	Websites, patents filling, etc.	Public	2
D9.3	Project videos (2) promoting the activities to various stakeholders and the public	1 - NTUA	Websites, patents filling, etc.	Public	42
D9.4	Compilation of all communication activities carried out during the project	10 - DBC	Report	Public	48

Description of deliverables

D9.1 Communication strategy and plan M06
D9.2 Project website and logo M02
D9.3 Project videos (2) promoting the activities to various stakeholders and the public M42
D9.4 Compilation of all communication activities carried out during the project M48

D9.1 : Communication strategy and plan [6]

Dissemination and exploitation plan to ensure maximum and visibility and impact of the project outcomes

D9.2 : Project website and logo [2]

A website will be created to present the overview of the project and its progress.

D9.3 : Project videos (2) promoting the activities to various stakeholders and the public [42]

Production of two project videos, showing the project activities and communicated to various stakeholders

D9.4 : Compilation of all communication activities carried out during the project [48]

Compilation of all dissemination activities carried out during the project

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification

1.3.4. WT4 List of milestones

Milestone number[18]	Milestone title	WP number[9]	Lead beneficiary	Due Date (in months)[17]	Means of verification
MS1	Cascade chiller/heat pump shows high performance and compactness	WP2	4 - ITAE	21	Prototype unit manufactured and installed. Performance tests under typical operating conditions performed at ITAE lab / D2.3 delivered
MS2	Reversible heat pump/ ORC shows high performance under both modes	WP2	1 - NTUA	21	Prototype unit manufactured and installed. Performance tests under typical operating conditions performed at NTUA lab / D2.4 delivered
MS3	Biomass-fired boiler reaches cogeneration efficiency of over 94%	WP2	2 - FAU	21	Boiler tested under controlled lab conditions at OKOFEN and FAU / D2.6 delivered
MS4	Solar-TEGs developed with high thermal matching and adequate heat sink	WP2	6 - AKOTEC	24	Solar collector-TEG integrated solution tested by AKOTEC both indoors and outdoors / D2.5 delivered
MS5	Heat pump-based configuration has high performance at all modes	WP2	1 - NTUA	27	Integrated heat pump-based configuration installed and tested at NTUA lab / D2.7 delivered
MS6	Simulation and smart control developed	WP3	1 - NTUA	27	The numerical tools have been finalized and the smart control developed / D3.3 and D3.4 delivered
MS7	Social surveys campaign designed and implemented	WP6	9 - UOS	27	The key outcomes of the social science research through surveys are available / D6.1 delivered
MS8	Prototype components of the two pilot systems produced and installed	WP4	8 - Daikin	33	All main prototype components produced according to the design / D4.3 delivered
MS9	Prototype systems successfully commissioned	WP4	8 - Daikin	36	The prototype systems have been installed and all commissioning tests are successful / D4.5 delivered
MS10	SolBio-Rev cost according to estimations	WP7	7 - UDL	45	System cost has the potential to become competitive once it reaches commercial level / D7.2 delivered
MS11	SolBio-Rev achieves high energy share in Greece	WP5	1 - NTUA	48	The processed test results in Greece show that an energy share of > 70% is reached / D5.2 delivered

Milestone number[18]	Milestone title	WP number[9]	Lead beneficiary	Due Date (in months)[17]	Means of verification
MS12	SolBio-Rev achieves high energy share in Germany	WP5	2 - FAU	48	The processed test results in Germany show that an energy share of > 70% is reached / D5.3 delivered

1.3.5. WT5 Critical Implementation risks and mitigation actions

Risk number	Description of risk	WP Number	Proposed risk-mitigation measures
1	Pilot building at NTUA not available for testing in the 4th year of the project. Risk level: Low Risk impact: Not applicable	WP1	NTUA has checked the availability of the testing building, and has reserved it. In case any issue arises, NTUA will either follow the FAU approach and develop a containerised building prototype, or install the prototype SolBio-Rev system at the NTUA lab rooftop, covering the energy needs of 3 office rooms (~ 30 m2 in total).
2	Low heat and/or mass transfer effectiveness of adsorber HEX. Risk level: Medium Risk impact: Low	WP2	(1) The adsorber HEXs will be carefully re-designed by means of numerical and experimental methods to limit possible inefficiency. (2) Adjust the post-synthesis process after tested in the lab and re-iterate for optimising the effectiveness through an experimental approach. (3) Integrate porous structures (e.g. metallic foams, fibers) inside the heat exchanger for enhancing the heat/mass transfer. (4) Use a HEX with a larger surface, in order to match the needed cooling capacity, slightly penalising the compactness of the system, but holding the same high performance.
3	Post-synthesis process inside the PST process of FAHREN brings minor improvements. Risk level: Low Risk impact: Low	WP2	(1) A standard post-synthesis process has been already tested and validated by FAHREN. Further innovative development at lab-scale will be carried out to improve the technology. (2) FAHREN and UNIME will identify the most effective solution to integrate the innovative post-synthesis technology in the PST process. (3) Use the current PST process of FAHREN to coat the full-scale adsorber.
4	Evaporator and condenser HEX coupling the chiller with the heat pump shows low heat transfer rates. Risk level: Low Risk impact: Low	WP2	(1) Numerical semi-empirical model will be used to optimise the final HEX configuration. (2) The main HEX parameters can be optimised experimentally to minimise this risk. (3) Consider falling film helical tube evaporator/condenser made of Ni-Cu or stainless steel for high corrosion resistance.
5	Reversible heat pump/ORC shows low efficiency at either heat pump and/or ORC mode. Risk level: Medium Risk impact: Medium	WP2	(1) Examine alternative design of the compressor/ expander that shows a higher performance at both modes. (2) Adjust the system design (e.g. cascade chiller), bringing a negligible effect in case the heat pump mode underperforms. (3) Adjust the temperature of the biomass boiler supplying with heat the ORC in case the ORC mode underperforms.
6	The heat pump-based configuration shows higher cost than expected. Risk level: Medium Risk impact: Low	WP2	(1) Adjust the capacity of the adsorption chiller to reduce the cost, or eliminate this component for locations with moderate/low cooling needs. (2) Revise the production sequences and delivery chains to reduce production time and cost. (3)

Risk number	Description of risk	WP Number	Proposed risk-mitigation measures
			Reduce the heat pump capacity in favour of the biomass boiler.
7	Solar-TEGs show reduced annual electric yield. Risk level: Medium Risk impact: Low/Medium	WP2	(1) Increase the annual running hours by further examining the control and system optimisation measures, for working in-parallel with other components mainly in summer (e.g. chiller). (2) Increase the TEG capacity per collector. (3) Exploit the rejected heat for preheating the tap water for DHW.
8	Solar-TEGs show reduced heat rejection and/or electric efficiency at ΔT~60 K. Risk level: Low Risk impact: Low	WP2	(1) Increase the heat sink size (e.g. larger fins) on the manifold. (2) Adjust the design of the manifold and/or placement of the by-pass pipe with the attached TEGs. (3) Use other TEG material with higher thermal conductivity. (4) Increase their on/off events for cooling down in-between.
9	The biomass boiler shows lower CHP efficiency than expected. Risk level: Medium Risk impact: Medium	WP2	(1) Modify the internal HEX for increasing its effectiveness and the boiler efficiency. (2) Use of an external HEX for heat recovery from the flue gases, however with marginal efficiency increase. (3) Adjust the temperature of heat supply to the ORC.
10	EGR strategy of the biomass boiler leads to minor emissions reduction. Risk level: Medium Risk impact: Low	WP2	(1) Optimise the trade-off of efficiency vs. emissions with further testing.
11	Controller complicated with high cost. Risk level: Medium Risk impact: Low	WP3	Some commercial hardware parts will be used in the controller, which could lead to high cost. However, new dedicated hardware parts of low cost can be produced in case of commercialisation.
12	Achieving low energy share even with a large sizing in real buildings. Risk level: High Risk impact: High	WP3	(1) Modification of the final design is possible, with the aim to adjust the system to perfectly fit to as many buildings as possible. (2) Focus on multi-family residential houses with higher potential, due to the reduced electricity needs compared to commercial ones.
13	Delayed commissioning of the prototype systems, due to more effort required in WPs 2-4. Risk level: Low Risk impact: Low	WP4	(1) There is adequate time frame for system testing in WP5. Even if there is a delay, many test results will be still available for technology validation. (2) Test sets of components independently within the two prototype systems (e.g. solar-TEGs with the biomass boiler).
14	Test data from the prototype systems show that the 70% energy share is not reached. Risk level: High Risk impact: High	WP5	(1) Examine numerically a larger solar surface or components sizing for increasing the energy share and identify sizing differences. (2) Adjust & fine-tune the controller, for increasing the energy share. (3) Up-scale the results to a real building, with the risk that its energy demand behaviour is not 100% scalable.

Risk number	Description of risk	WP Number	Proposed risk-mitigation measures
15	Low interest from stakeholders and end-users for participating in the surveys. Risk level: Low Risk impact: High	WP6	(1) In case of too few participants in the surveys, these will be repeated and the key barriers will be identified, in order to propose more effective and appealing ways to reach the various stakeholders. (2) TECH has access to more than 3,000 installers in Belgium, having a large pool for this stakeholder type.
16	Technology not understood and accepted by the society. Risk level: Medium Risk impact: Low	WP6	The dedicated awareness and social impact enhancement campaigns will highlight from the very first stage of the project the societal impact of the SolBio-Rev system. Their outcomes will be used to re-tune such consequent campaigns well before the project end.
17	Market/stakeholders/end-users not yet interested in the proposed technologies. Risk level: Medium Risk impact: Low	WP6, WP8	(1) Involvement of stakeholders at an early stage is planned to stimulate their interest, and take into account their needs. The consortium will focus on increasing society awareness by setting up a huge campaign of disseminating project results. (2) The SolBio-Rev system is based on existing renewable energy systems that stakeholders are well aware of (solar collectors, heat pumps, biomass boiler), minimising the effect of this risk.

1.3.6. WT6 Summary of project effort in person-months

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	Total Person/Months per Participant
1 - NTUA	24	19	24	8	23	2	3	5	4	112
2 - FAU	1	18	3	15	22	2	0	2	1	64
3 - FAHREN	1	8	1	4	2	0	1	2	1	20
4 - ITAE	2	24	5	6	5	0	4	1	1	48
5 - TEAVE	1	2	18	9	4	0	2	1	1	38
6 - AKOTEC	1	12	2	4	4	1	4	2	1	31
7 - UDL	3	4	14	2	3	2	10	1	1	40
8 - Daikin	1	14	2	9	5	0	3	3	1	38
9 - UOS	1.50	0	0	0	0	26	0	1	0.50	29
10 - DBC	1	0	0	0	0	3	4	12	10	30
11 - TECH	0.50	0	0	1	0	3	7	1	0.50	13
12 - KIT	1	14	5	9	4	0.50	2	2	1	38.50
13 - OKOFEN	1	4	1	6	3	0	1	1	1	18
14 - STRABAG	0.50	0.50	0	0.50	0.50	0.50	4	1	0.50	8
15 - UNIME	0.50	10	0	0	3	0	0	1	0.50	15
Total Person/Months	40	129.50	75	73.50	78.50	40	45	36	25	542.50

1.3.7. WT7 Tentative schedule of project reviews

Review number [19]	Tentative timing	Planned venue of review	Comments, if any
RV1	21		
RV2	33		
RV3	48		

1. Project number

The project number has been assigned by the Commission as the unique identifier for your project. It cannot be changed. The project number **should appear on each page of the grant agreement preparation documents (part A and part B)** to prevent errors during its handling.

2. Project acronym

Use the project acronym as given in the submitted proposal. It can generally not be changed. The same acronym **should appear on each page of the grant agreement preparation documents (part A and part B)** to prevent errors during its handling.

3. Project title

Use the title (preferably no longer than 200 characters) as indicated in the submitted proposal. Minor corrections are possible if agreed during the preparation of the grant agreement.

4. Starting date

Unless a specific (fixed) starting date is duly justified and agreed upon during the preparation of the Grant Agreement, the project will start on the first day of the month following the entry into force of the Grant Agreement (NB : entry into force = signature by the Commission). Please note that if a fixed starting date is used, you will be required to provide a written justification.

5. Duration

Insert the duration of the project in full months.

6. Call (part) identifier

The Call (part) identifier is the reference number given in the call or part of the call you were addressing, as indicated in the publication of the call in the Official Journal of the European Union. You have to use the identifier given by the Commission in the letter inviting to prepare the grant agreement.

7. Abstract

8. Project Entry Month

The month at which the participant joined the consortium, month 1 marking the start date of the project, and all other start dates being relative to this start date.

9. Work Package number

Work package number: WP1, WP2, WP3, ..., WPn

10. Lead beneficiary

This must be one of the beneficiaries in the grant (not a third party) - Number of the beneficiary leading the work in this work package

11. Person-months per work package

The total number of person-months allocated to each work package.

12. Start month

Relative start date for the work in the specific work packages, month 1 marking the start date of the project, and all other start dates being relative to this start date.

13. End month

Relative end date, month 1 marking the start date of the project, and all end dates being relative to this start date.

14. Deliverable number

Deliverable numbers: D1 - Dn

15. Type

Please indicate the type of the deliverable using one of the following codes:

R	Document, report
DEM	Demonstrator, pilot, prototype
DEC	Websites, patent fillings, videos, etc.
OTHER	
ETHICS	Ethics requirement
ORDP	Open Research Data Pilot

16. Dissemination level

Please indicate the dissemination level using one of the following codes:

PU	Public
CO	Confidential, only for members of the consortium (including the Commission Services)
EU-RES	Classified Information: RESTREINT UE (Commission Decision 2005/444/EC)
EU-CON	Classified Information: CONFIDENTIEL UE (Commission Decision 2005/444/EC)
EU-SEC	Classified Information: SECRET UE (Commission Decision 2005/444/EC)

17. Delivery date for Deliverable

Month in which the deliverables will be available, month 1 marking the start date of the project, and all delivery dates being relative to this start date.

18. Milestone number

Milestone number:MS1, MS2, ..., MSn

19. Review number

Review number: RV1, RV2, ..., RVn

20. Installation Number

Number progressively the installations of a same infrastructure. An installation is a part of an infrastructure that could be used independently from the rest.

21. Installation country

Code of the country where the installation is located or IO if the access provider (the beneficiary or linked third party) is an international organization, an ERIC or a similar legal entity.

22. Type of access

VA	if virtual access,
TA-uc	if trans-national access with access costs declared on the basis of unit cost,
TA-ac	if trans-national access with access costs declared as actual costs, and
TA-cb	if trans-national access with access costs declared as a combination of actual costs and costs on the basis of unit cost.

23. Access costs

Cost of the access provided under the project. For virtual access fill only the second column. For trans-national access fill one of the two columns or both according to the way access costs are declared. Trans-national access costs on the basis of unit cost will result from the unit cost by the quantity of access to be provided.

History of changes

Nr.	Date	Changes
1	23/11/2018	Timetable, Fig. 32, adjusted for the three reporting periods (1-18 / 19-30 / 31-48), the additional milestone of WP3, and the additional deliverable "*Project Management Plan*" of WP1.
2	23/11/2018	Table of risks. (1) Risk level of the low CHP efficiency of the biomass boiler has been increased from low to medium. (2) Mitigation measures of the 2nd risk (low heat/mass transfer of HEX) have been enriched to be more convincing.
3	23/11/2018	The roles of the innovation manager have been extended in Section 3.2.
4	23/11/2018	The description of Task 8.3 has been extended by adding the sentence "*The consortium partners will contribute, upon invitation by the INEA, to common information and dissemination activities to increase the visibility and synergies between H2020 supported actions*".
5	25/11/2018	Confirmation that no dual-use items will be used has been added in Section 5.2.
6	25/11/2018	Additional information on feedback loops and interconnection of WPs and Tasks has been added in the WP description.
7	27/11/2018	Risk impacts have been added in the risks table of Part A.
8	08/12/2018	The type of D1.6: Data management plan has been changed from DEC to ORDP.
9	09/12/2018	Three additional team members have been added to the NTUA team (section 4.1).
10	17/12/2018	OTEGO partner has been completely removed from the text. KIT handled all its tasks.

Table of Contents

List of main abbreviations

A/C	Air-Conditioning
BEMS	Building Energy Management System
CBA	Cost Benefit Analysis
CHP	Combined Heat and Power
COP	Coefficient of Performance
DHW	Domestic Hot Water
EGR	Exhaust Gas Recirculation
GWP	Global Warming Potential
HEX	Heat EXchanger
HP	Heat Pump
HVAC	Heating, Ventilation, and Air-Conditioning
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
MFB	Multi-Family residential Building
(N)ZEB	(Nearly) Zero Energy Building
ODP	Ozone Depletion Potential
ORC	Organic Rankine Cycle
PBP	Payback Period
PV	Photovoltaic
SoA	State of the Art
TEG	Thermoelectric Generator

1. Excellence

The SolBio-Rev project will develop an innovative renewable energy system based on a novel and creative heat pump-based configuration, for the production of heating (space heating and domestic hot water – DHW), space cooling and electricity according to the daily and seasonal energy demand of buildings. This configuration hosts a **reversible heat pump/organic Rankine cycle (ORC)** coupled with a **cascade chiller with a heat pump**, as shown in Fig. 1. These two components share the same heat pump, in order to attain enhanced flexibility and compactness. Heat is supplied to this configuration primarily by vacuum tube solar thermal collectors equipped with thermoelectric generators (TEGs) for additional electricity production by maximising the utilisation of excess, otherwise wasted, solar heat and avoiding overheating. The heat utilised by TEGs does not have any impact on the operation of the other components (e.g. ORC, chiller), operating in a supplemental fashion. The heating needs not covered by solar thermal energy or the heat pump during winter are provided by the backup heater: a biomass boiler operating at combined heat and power (CHP) mode with low air pollutants, supplying high-temperature heat to the same ORC, and using the ORC rejected heat for space heating, reaching a high cogeneration efficiency.

The **targeted benefit of the SolBio-Rev that combines different renewable energy systems is to reach an energy share of up to 100%** in a variety of EU buildings, with a modular, flexible and compact energy system. However, this **share is decreased to a maximum 85%**, if the rooftop surface availability and the system cost-effectiveness are taken into account, covering in that cases 100% of heating and cooling needs and a fraction of electricity. The overall aim is to **validate this new technology** in an intended environment (TRL5) and to prove all challenging objectives.

The **key advantages of the SolBio-Rev** system are: **(1)** high flexibility for producing heating, cooling and electricity according to the energy needs and operating modes (summer ↔ winter mode), **(2)** reduction of equipment due to synergistic operation of the heat pump-based configuration, reaching highly compact solutions, **(3)** applicability in a variety of buildings (e.g. multi-family residential, commercial) all over Europe, and **(4)** low cost due to its innovative features, high compactness, and advanced integration aspects.

The research work aims at the development and integration of the system components and configuration along with the smart system control, allowing the realisation of the complete SolBio-Rev system, with the specific aim to greatly increase its achievable energy share well beyond the state of the art and at the same time reduce: (1) the dependence on fossil fuels, and (2) air pollutant emissions. For that purpose, two prototype/pilot systems will be developed and **tested for one year in Greece and in Germany**, for reaching an energy share of over 70% and thus validate this technology. These tests will be conducted in small-scale pilot buildings in two universities that are used for testing energy systems (relevant environment). The work plan also comprises extensive social engagement activities by interacting with users and installers and considering their needs and requirements in the development process.

The combination and effective integration of renewable energy systems (based on solar, ambient and bioenergy) is at the core of the SolBio-Rev concept (see Fig. 1), which is perfectly suited for either new or renovated buildings (for a detailed description of the SolBio-Rev system, its core components and main operating modes see § 1.3).

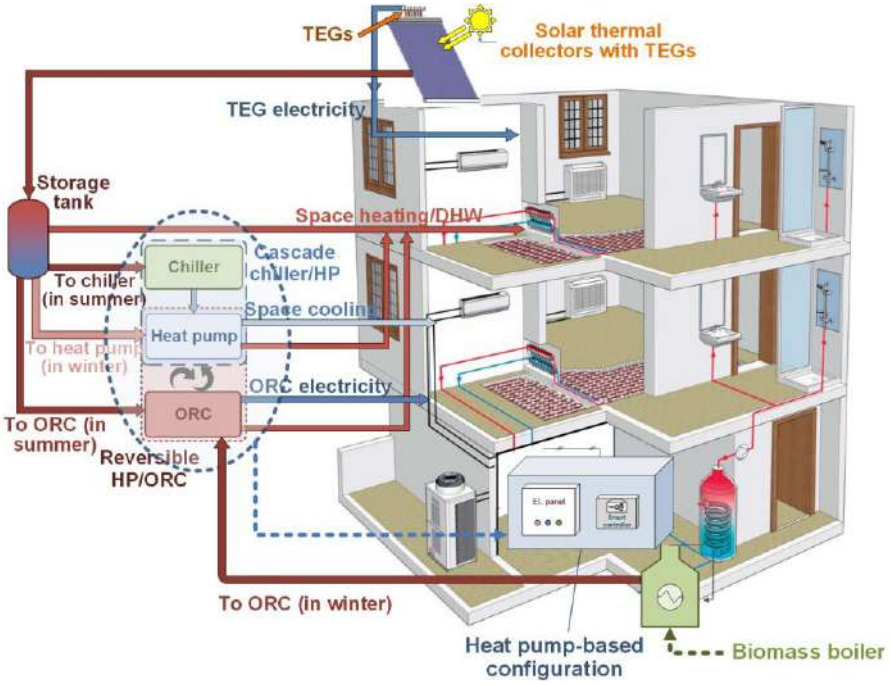


Fig. 1. *Heat pump-based configuration with a biomass-CHP boiler and two storage tanks (all in the boiler room) and solar-TEGs (on the rooftop), resulting to the SolBio-Rev system for very high energy shares in buildings*

1.1 Objectives

The core objective of the SolBio-Rev project is to combine promising renewable energy technologies based on solar, ambient and bioenergy, having at the core an innovative heat pump-based configuration and to allow the efficient application of this solution, without any geographical restriction at least in the EU.

The overall objective of the proposed SolBio-Rev system is to **cover a very high energy share** in a variety of buildings in a **cost-effective manner**, and at the same time secure the **needs of the users**.

To develop the innovative SolBio-Rev system, ***the specific objectives are the following***:

- Develop a cascade adsorption chiller coupled with a vapour compression heat pump, with advanced heat exchangers (HEXs): (1) a dedicated HEX for efficient coupling the chiller with the heat pump, and (2) an adsorber HEX with an improved production technique for increasing heat transfer efficiency and reducing production cost. The aim is to reach an electric Coefficient of Performance (COP) of > 6 for space cooling production in south Europe.
- Develop a reversible heat pump/ORC, focusing on the compressor/expander technology, and the use of an environmentally-friendly refrigerant. The aim is to perform equally well at all modes with a COP > 4.5 for heating in north Europe (> 5 in south Europe), once assisted by very low-temperature solar heat (< 30 °C), and an ORC efficiency of up to 8%.
- Effectively combine the cascade chiller with the reversible unit into a highly-compact novel heat pump-based configuration for heating, cooling, and electricity production, with lower cost by 20-30%, compared to separately having the same components.
- Develop an innovative solar thermal collector with TEGs to exploit all wasted heat with a temperature different (ΔT) of ~60 K, holding the high efficiency of the AKOTEC vacuum tube collector, and without any performance degradation on other components.
- Develop a biomass boiler for CHP with an optimised internal HEX for high-temperature heat supply to the ORC (up to 120 °C) and Exhaust Gas Recirculation (EGR) for reducing air pollutants by over 20% (mostly NOx emissions), compared to standard biomass boilers. The aim is to reach a CHP efficiency of over 94%, which is 5-10% higher than commercial or state of the art CHP units, and a similar cost.
- Develop a predictive and smart control with advanced features and interoperability among components, contributing to the large energy share. The aim is to optimise energy management according to real-time and forecasted needs, based on various parameters (e.g. minimum energy costs or primary energy demand).
- Interact with end-users, installers and other stakeholders (e.g. building owners) for considering their needs and including their requirements in the design process towards the next development stages of the SolBio-Rev concept, and analyse the opportunities and challenges for uptake in different EU countries.
- Realise & test two SolBio-Rev prototype systems in small-scale pilot buildings of 30-40 m^2 at two diverse climatic zones (Greece/Germany) for one year, covering the (simulated) energy needs of various buildings types.
- Validate the SolBio-Rev concept at intended environment (TRL5) based on the test results of the two pilot systems, for reaching an energy share of over 70% (100% of heating/cooling needs and a fraction of electricity needs), and demonstrate its cost-effectiveness, achieving a payback period of even 4 years in residential buildings.
- Define a technology roadmap, with suitable business models to address different buildings and users. This roadmap will also define the next steps of innovation actions and the path to commercialisation in 2025.
- Roll-out a comprehensive communication, dissemination and exploitation plan, sharing the project insights and results with various stakeholders through different methods. The overall aim is to tailor strategies for **societal awareness and engagement** for a variety of groups.

Terminology

- **Adsorption (thermal) chiller**: a component based on the adsorption process that produces cooling, when supplied with heat.
- **Cascade chiller/HP**: the above chiller in a cascade configuration with an electrical heat pump for cooling production with very high performance, even at hot ambient conditions.
- **ORC**: a component that produces electricity, when supplied with heat (heat-to-power).
- **Reversible HP/ORC**: a component that operates at either heat pump mode for producing heating and cooling, or in reverse as an ORC, with a minor equipment addition.
- **Heat pump-based configuration**: the full layout of the reversible HP/ORC and cascade chiller, sharing the same heat pump.
- **Thermoelectric generator (TEG)**: a component that converts heat to electricity without any moving parts.
- **Solar-TEGs**: solar thermal collectors with TEGs for producing both heat and electricity.
- **Biomass boiler for CHP**: a biomass boiler with EGR for reduced air pollutants and with an internal HEX for high-temperature heat supply to the ORC.

The ambitious objectives will be realised by working on each main component separately and then combining them to form the highly-flexible SolBio-Rev system. This will allow the building sector to rely on a new configuration based on renewables with a large potential for many building installations.

1.2 Relation to the work programme

The project relates to the call H2020-LC-SC3-RES-4-2018, topic "*Renewable energy system integrated at the building scale*", addressing all specific challenges and scopes, as presented next.

Specific challenge-1: ... integrate several technologies based on one or more renewable energy sources (and their combination with energy storage systems …) … highest possible share of renewable energy …

The SolBio-Rev concept **effectively integrates innovative technologies (e.g. reversible HP/ORC, solar-TEGs) based on three renewable energy sources**: solar, ambient and bioenergy, into a highly compact system without imposing space issues in buildings. A **short-term thermal energy storage tank** is included to smooth the intermittency of solar energy with a small volume, easily integrated in buildings (footprint < 3 m^2). Space restrictions in buildings and on rooftops are included in the work plan (building integration activities).

The flexible operation of SolBio-Rev covers **100% of heating/cooling** needs in various EU buildings with no geographical limitation. Respecting the rooftop availability, it **also covers a fraction of electricity needs** (except for system operation) in a cost-effective manner, reaching **up to 85% of total energy needs**, as presented in § 1.3.4.

Specific challenge-2: This integration requires innovative approaches, due consideration of the implications for the user and a proper assessment of the cost-effectiveness.

An innovative approach of combining a **novel heat pump-based technology**, with a **biomass boiler** and **solar collectors with TEGs**, is developed, eliminating the effect of solar intermittency. The **smart control** fully handles the SolBio-Rev operation, ensuring minimum implication for the users.

Calculations of the payback period (PBP) are presented in § 1.4.2, revealing the cost-effectiveness of SolBio-Rev. A cost-benefit analysis is included in the work plan, supported with user-specific business models. The aim is to make SolBio-Rev **a commercial solution in 2025 with a short PBP** for different buildings types and EU wide locations.

Specific challenge-3: … in line with the objectives of the SET-Plan, of Innovation Challenge n. 7 ("…") of Mission Innovation and the roadmap of the Energy-efficient Buildings (EeB) cPPP.

The defined objectives of SET-Plan, Mission Innovation (*challenge nr. 7*) and the roadmap of EeB focus on energy efficiency in buildings with the use of local renewables (e.g. solar) and the effective integration of heat pumps supplied by various sources. The suggested CHP component of *Mission Innovation* is also considered in the SolBio-Rev concept. The objective of *EeB* regarding the increase of competitiveness of the EU building industry is fully ensured, due to the active participation of key construction companies in the project.

Scope-1: …combination of different renewable energy technologies to cover the highest possible share of electricity, heating and cooling needs of a multi-family residential or commercial or public or industrial ….

The SolBio-Rev solution can cover **up to 100% of energy needs** by combining three renewable energy technologies. By considering rooftop surface limitations and cost-effectiveness, the aim is to cover **an energy share of up to 85% across Europe**, in either new or renovated buildings, with the priority to cover all heating/cooling needs.

The solution is applicable in **any building type**, including both non-residential (e.g. commercial, public, industrial) and multi-family buildings (MFBs). Its high modularity allows the system to be applied in all building sizes and even combined with existing/standard components, especially in renovations (e.g. PVs, existing boilers).

Scope-2: …operated by users and installed by installers, their needs and requirements (…) shall be taken into account and the relevant expertise in terms of social sciences and humanities has to be included...

Interaction with stakeholders (e.g. users, building owners) and installers is included in the work plan to accelerate the acceptance of SolBio-Rev and its future commercialisation. These aspects are highlighted next:

- ✓ **Social engagement** introduces the stakeholders' needs in the design process, with some critical ones already addressed: (1) reasonable cost, (2) user-friendly control, (3) low space needed in the building and on rooftops, (4) use of standard heating/cooling appliances, and (5) designed for long lifetime (> 20 years).
- ✓ **Installation and maintenance procedures** are similar to heat pumps, solar collectors and boilers, without requiring additional effort or specialised personnel. However, their integration increases the complexity and these procedures will be carefully examined for ease of use.

Scope-3: …reducing emissions of air pollutants.

The SolBio-Rev solution eliminates the need for heating appliances (e.g. gas boiler) and electrical and cooling appliances powered by electricity, eliminating their emissions. The pollutants from biomass will be minimised due to its high combustion efficiency and EGR strategy. In a 1,000 m^2 new MFB in Athens **the total avoided air pollutants are 43 kg/year** (50% reduction) with a reduction of up to 33% in other locations (details in § 2.1.2). A Life Cycle Assessment (LCA) is included in the work plan to quantify the environmental properties.

1.3 Concept and methodology

1.3.1 Overall concept

The system concept relies on integrating a **creative heat pump-based configuration** with innovative components and an advanced system control that, combined, allow the maximised use of renewable energy in buildings at any moment of the year in all EU climatic zones[1]. This flexible configuration is illustrated in Fig. 2, and except from utilising ambient energy, is supplied by solar and bioenergy: **(1) solar thermal collectors equipped with TEGs** for producing heat and electricity, adjusting the on/off operation of TEGs according to the operating mode, and **(2) a biomass boiler** with low air pollutants operating as backup heater in winter at CHP mode.

Including also a short-term heat storage for daily use, properly managing the solar heat and making use of even the lowest grade solar heat amount (within 5 – 30 °C) to supply the heat pump in winter for increasing its COP (solar-assisted mode), the system will reach very high energy shares. These are currently not achieved at a reasonable installation cost and within low space requirements for fitting in the buildings and on rooftops.

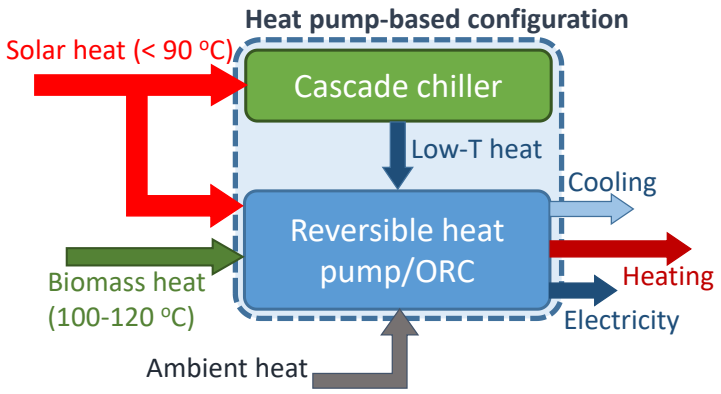


Fig. 2. *SolBio-Rev concept for trigeneration*

In order to better understand the SolBio-Rev concept, each of its individual key components is presented in § 1.3.2. A detailed system description based on its main operating modes (e.g. summer/winter) is then provided in § 1.3.3. Last but not least, the energy/sizing results for three representative EU cities/regions (Athens, Berlin and Stockholm) are presented in § 1.3.4, providing evidence for the potential of the SolBio-Rev system to achieve maximum renewable energy share in diverse EU climates.

1.3.2 The core technologies of the SolBio-Rev system

The concept of the innovative components and control is presented next, supplemented with the social engagement concept, mainly addressing users and installers.

Cascade adsorption chiller/heat pump (HP)

A cascade adsorption/compression component consists of an adsorption chiller, whose cold output is used by the vapour compression HP for rejecting heat at its condenser (see Fig. 2). ITAE has already developed and tested this concept, showing that a high electric COP > 6 of the HP is reached (~50% higher than a HP) thanks to its reduced temperature lift (~ 20 K), securing at the same time a thermal COP of 0.6. The cascade chiller/HP performance will be greatly enhanced, leading to a cost reduction, by developing the following key HEXs:

- ✓ **A coated adsorber HEX** will be developed with an improved production method by UNIME, based on the patented "*Partial Support Transformation (PST)*" technique by FAHREN[2,3], consisting in growing the SAPO-34 adsorbent material directly onto the surface of the aluminium HEX. After the SAPO-34 *direct synthesis* process, a *post-synthesis* treatment is needed to eliminate the organic template inside the adsorbent material, thus leaving the needed porosity for the water vapour adsorption. This post synthesis process will implement a pre-washing phase and an optimised calcination process, with the aim to reduce the energy and water consumption, as well as the necessary production time, while increasing the SAPO-34 purity and available porosity, for increasing performance. This coating procedure minimises the heat transfer resistance between the adsorbent material and the HEX surface, thus reaching high specific cooling power (> 90 kW/m^3 of adsorbent material) and COP, and at the same time reduces the production cost by 10% compared to the advanced technique applied by FAHREN.

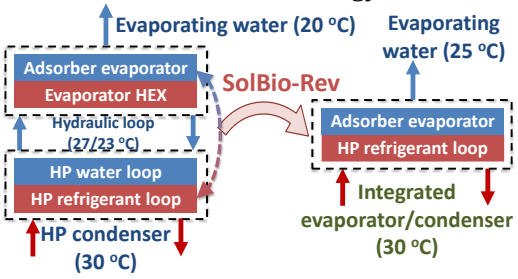


Fig. 3. *Left: hydraulic integration with 2 HEXs. Right: direct integration with one HEX*

- ✓ **A fully integrated evaporator/condenser HEX** (see Fig. 3) will be developed to directly connect the bottom vapour compression

[1] Main EU zones: South Europe (Mediterranean zone, e.g. Greece, Italy, Spain, Portugal). Central Europe (Oceanic and Continental zones, e.g. Germany, Austria, UK, Belgium, France, the Netherlands). North Europe (Nordic zone, e.g. Sweden, Finland, Denmark).

[2] Patent N. US20090090491A1. Method for production of a substrate coated with a zeolite layer. W. Schiwieger, R. Hermann, S. Thangaraj, M. Reddy, F. Scheffler, F. Schmidt, W. Mittelbach, H.M. Henning, J. Bauer. 29/10/2004.

[3] J. Bauer, et al. Zeolite/aluminium adsorbents for application in adsorption refrigeration. Int J Energy Research 2009;33:1233-1249.

HP to the top adsorption chiller, with possible HEX types of micro-channels finned tube and axisymmetric plate. This overcomes the current bottleneck of coupling these two cycles with an additional hydraulic loop, reducing the number of HEXs and cost. The outcome is an enhanced thermal matching (lower temperature differences) and higher efficiency.

Reversible heat pump/ORC

A reversible heat pump/ORC is based on a vapour compression heat pump (the same heat pump of the cascade chiller) that its operation is reversed, leading to a heat-to-power unit → ORC. Accordingly, this component produces either heating and cooling (*heat pump mode*) or electricity (*ORC mode*), using the same equipment[4] (e.g. HEXs, reversible compressor/expander), requiring only an additional pump and a by-pass circuit to enable the ORC mode. This leads to a minor cost increase by up to 10% compared to a heat pump-only solution.

NTUA has already developed and tested in the lab a small-scale heat pump/ORC system[5] for trigeneration, shown in Fig. 4, and identified the **reversible compressor/expander as the key part**. A scroll-type compressor will be reversed, starting from the DAIKIN compressor technology. This development stage will ensure that an ORC efficiency up to 8% is reached. The ORC maximum temperature (in the range of 100-120 °C) when supplied with biomass heat will be defined during the initial testing campaign, with the aim to optimise the operation of both modes.

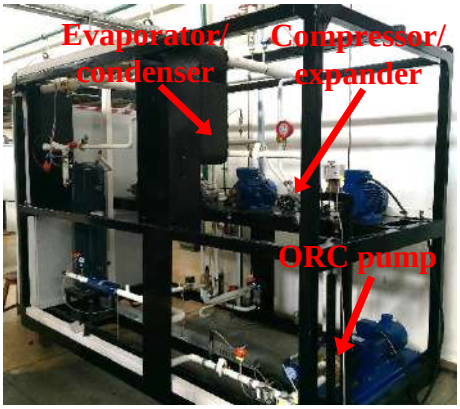


Fig. 4. *Heat pump/ORC at NTUA lab*

The **refrigerant** of the heat pump will be a hydrofluoroolefin (HFO) with **perfect environmental properties**: zero Ozone Depletion Potential (ODP), ultra-low Global Warming Potential (GWP) of < 10, respecting the F-gas Regulation, and non-toxic and non-flammable.

Creative heat pump-based configuration

The two previous components are coupled and integrated into the heat pump-based configuration, shown in Fig. 5. The chiller operates only when cooling is required and shares the new dedicated HEX with the heat pump, while the space cooling is supplied by the HP evaporator. An additional condenser is included that provides heating during winter, when solar heat of very low temperature (< 30 °C) is supplied to the HP evaporator, for reaching a high COP of over 4.5 in central/north Europe and even over 5 in south Europe.

At ORC mode (red coloured circuit in Fig. 5), the chiller does not operate and the HP cycle is reversed. Solar or biomass heat supplies the evaporator for power production by the expander. Heat rejected at the condenser is used for space heating when needed, otherwise rejected to the ambient.

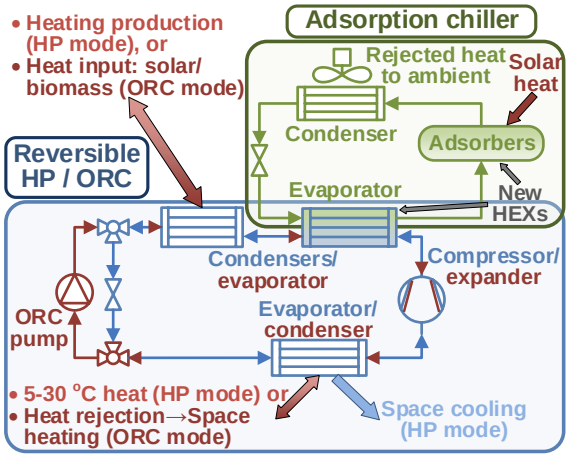


Fig. 5. *Heat pump-based configuration*

Innovative integration of TEGs in solar thermal collectors

The TEGs are mounted within the collector manifold, shown in Fig. 6, where there is adequate space for installation. They are optionally operated (on/off) according to the availability of surplus solar heat with the use of by-pass piping, actuated with a valve. This approach offers high flexibility by exploiting all solar heat that would be otherwise wasted. The TEGs are spatially separated from the heat flow (by-passed), when either the ORC or chiller operate, without affecting their performance. Their main operating modes are presented next that will be included in the smart system control:

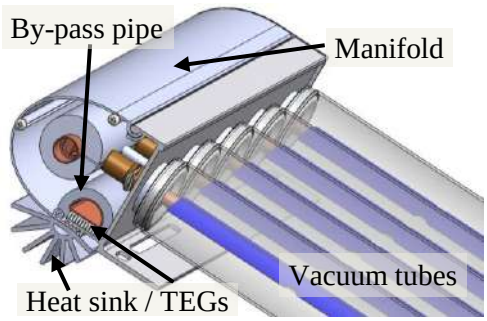


Fig. 6. *Solar-TEG concept*

✓ During periods of high solar irradiation, top Fig. 7, with solar heat overproduction and the storage tank fully charged, the TEG module exploits the otherwise wasted overload, with an efficiency of up to 3% for ΔT ~ 60 K, while also preventing the stagnation or overheating of the collector. This leads to **system security and higher collector lifetime**.

[4] Schimpf S, Span R. Simulation of a solar assisted combined heat pump – ORC system. Energy Convers Manage 2015;102:151-60.
[5] Karellas S, Braimakis K. Energy–exergy analysis and economic investigation of a cogeneration and trigeneration ORC–VCC hybrid system utilizing biomass fuel and solar power. Energy Convers Manage 2016;107:103-13.

- ✓ During the night (partial) heat discharge, bottom Fig. 7, the TEGs generate electricity even at low temperature differences, working in a temperature range (< 75 °C) in which the ORC operation becomes inefficient. Contrary to an ORC, TEGs have no moving parts, ensuring a silent operation.
- ✓ During intermediate seasons (mode with highest production potential) when no cooling is required and heating needs are low or even zero, large amounts of solar heat are available at a temperature of up to 65-75 ºC. This are utilised by the TEGs with a similar temperature difference of ~ 60 K, due to the low ambient temperature.

The current cost of a commercial TEG module lies between 20-50 €/We (for ΔT ~ 60 K), with a declining trend, with the potential to use printed TEGs to reach even 1-2 €/We by 2025.

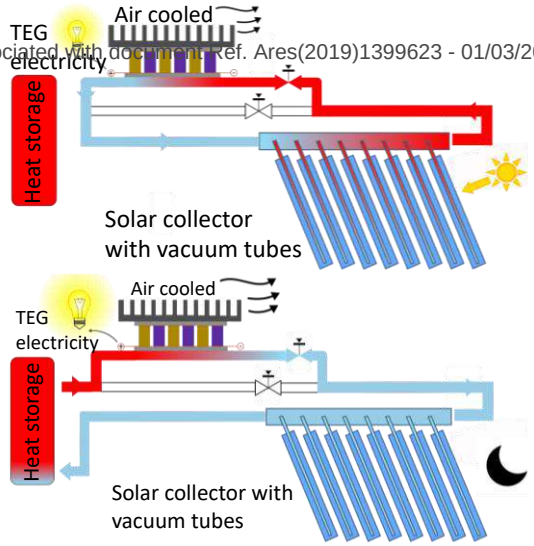


Fig. 7. *Top: protection from collector overheating. Bottom: night time discharging*

Biomass boiler for cogeneration

The key challenges of any boiler for CHP[6] are: **(1)** reach a high cogeneration efficiency, **(2)** increase the electrical output by supplying high temperature heat[7] (> 100 °C) to the ORC, and **(3)** decrease the air pollutants. In order to achieve these, the following development tasks are foreseen within SolBio-Rev, using as a starting point the OKOFEN prototype pellet boilers that have been already tested in the lab:

- ✓ **Integration of an internal HEX**: A HEX based on tube bundles will be added within the hot area of the combustion chamber (see Fig. 8), transferring heat at a temperature of up to 120 °C to the ORC with a small pressurised fluid cycle (respecting the regulation of steam boilers: Directive 2014/68/EU). OKOFEN has tested this concept in its lab and reached a heat supply temperature of 130 °C with a CHP efficiency of 90%. The aim is to improve the thermal matching of this heat transfer cycle to the ORC using an optimised HEX layout.
- ✓ **EGR in domestic boilers**: OKOFEN has developed a prototype pellet boiler with EGR for domestic use. The first lab tests in a non-optimised configuration showed a NOx emissions reduction of 10% with plenty of room for further improvement, and with a potential for reducing other emissions as well (e.g. CO and PM). The air-to-fuel ratio (λ) can then approach stoichiometric conditions and keep the same flue gas temperature, avoiding the hot spots and ash-melting temperatures, with the aim to reach a higher combustion efficiency by more than 5%. The EGR rate will be adjusted, achieving an optimised trade-off between high efficiency and low air pollutants.

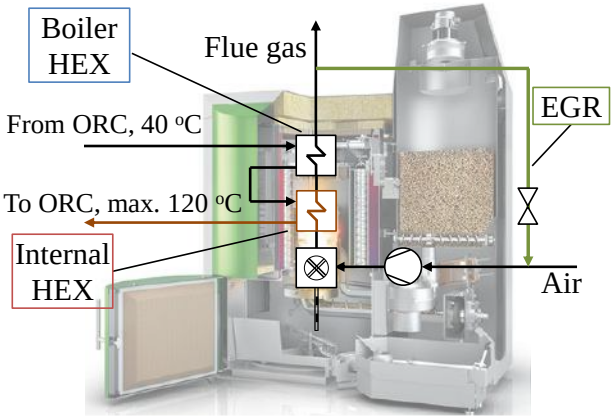


Fig. 8. *Biomass boiler with internal HEX & EGR*

The overall result is a CHP efficiency of at least 94%, which is 5-10% higher than commercial/state of the art pellets boilers for CHP[8], while reducing air pollutants by over 20%. This high efficiency is ensured even at part load, due to the optimised heat transfer to the ORC, and the low flue gas temperature. The boiler cost will remain practically the same (in €/kW of heat), as a combined result of: (1) higher boiler cost due to the additional HEX and EGR, but (2) higher heating capacity due to the increased efficiency. It should be highlighted that the pellet fuel is available even in urban areas with a standard fuel quality, leading to the same boiler efficiency around EU with minimum emissions.

Advanced system control

A smart and predictive system and self-learning control with extended features is foreseen to provide efficient operation and monitoring of all components. According to real-time and forecasted energy needs and solar availability, this controller will manage: (1) the solar heat temperature and the operation of the TEGs, (2) the heat pump-based configuration for covering the daily heating/cooling demand, by storing hot/chilled water for later use, (3) the operation of either the HP or the biomass boiler for heating in winter. The developed operational strategy of the SolBio-Rev system will be hosted in this controller by contributing to the maximisation of renewable energy share, while self-consuming all electricity generation, and ensuring thermal comfort of the users/occupants. It will

[6] Staub S, Bauer J, Müller D, Franke J, Karl J. CO2-Neutral Generation of Heat and Power in Smart Homes by Organic Rankine Cycle Powered Combined Heat and Power Micro Plants. AEF 2016;19:10–19.
[7] Zhou N, Wang X, Chen Z, Wang Z. Experimental study on Organic Rankine Cycle for waste heat recovery from low-temperature flue gas. Energy2013;55:216–25.
[8] Rezaie B, Rosen MA. District heating and cooling. Review of technology and potential enhancements. Appl Energy 2012;93:2–10.

include various optimisation objectives, such as minimisation of energy costs, maximisation of self-consumption of electricity, or minimisation of primary energy demand. This controller will include an intuitive Human-Machine-Interface (HMI) for its users controlling and monitoring their system. It will also support communication and interoperability (Machine-to-Machine-Interface), in order to become part of a standard Building Energy Management System (BEMS) (if available) with bidirectional communication using standard protocols, such as Bacnet/IP or Modbus TCP/IP, once properly optimised and calibrated, facilitating the application of the SolBio-Rev system in either new or existing buildings without replacing or modifying any existing equipment. Moreover, it will have a user-friendly web interface providing to the building energy manager complete control of the system. Other advanced features are: (1) communication with local weather station to adjust operation when needed, and (2) deep learning techniques to predict the building's heating/cooling demand based on the forecasted weather conditions.

The controller operation is highly coupled with two water storage tanks that: (1) contribute to the efficient management of the solar heat according to the real-time energy needs, (2) enhance the controller stability, and (3) offer high flexibility by decoupling the heating/cooling supply and demand, for reducing the consumption of grid electricity at peak hours or at moments with high energy prices. These tanks are:

- ✓ A short-term heat storage tank sized for a daily storage capacity, resulting to a low volume of 3-6 m^3 in typical MFBs (< 0.3 m^3/dwelling) and non-residential ones, easily fitted in buildings (footprint < 3 m^2).
- ✓ A thermal buffer tank with volume about one third of the previous tank. This buffer tank stores the produced hot (at 45 °C) or chilled water (at 7-12 °C), according to the season.

Societal engagement and business models

An effective user uptake is essential to realise the benefits of SolBio-Rev. This work will analyse opportunities and barriers for social acceptance and the potential for the uptake of SolBio-Rev, engaging with a range of relevant stakeholders. Specific questions that this research aims to answer are: (1) what are the technological perceptions of end-users and installers, (2) how is the expected energy share and user interface of the SolBio-Rev system likely to affect uptake, and (3) how will the chosen business models affect acceptance/uptake from both end-users and installers. In addition, the work aims to create broader connections between the case of SolBio-Rev and wider aspects of accelerating sustainable energy transition. Emerging 'service based' business models that provide useful energy services (i.e. internal temperature guarantees, hot water volume, ongoing maintenance) may make the technical solution more appealing, than the traditional technology installation and 'energy throughput' business model (i.e. heating system and units of heating fuel)[9]. Thus, the aim is to tailor the interrelated ways, in which the business models affect the perceptions of users, the practices of installers, and the interest of energy service companies.

In analysing the social acceptance and uptake potential for SolBio-Rev, attention will be given on the following aspects: (1) creating an analytical model of connecting social acceptance of new technology with sustainability transition schemes and policies, (2) interacting with end-users, installers and policymakers to examine their viewpoints on SolBio-Rev in terms of acceptability, benefits and barriers, and (3) analysing the opportunities and challenges for uptake in various EU countries through a survey among key stakeholder groups.

1.3.3 Operating modes

The main operating modes (summer and winter) are illustrated in Fig. 9. These two modes are described next, as well as the ones during the intermediate seasons.

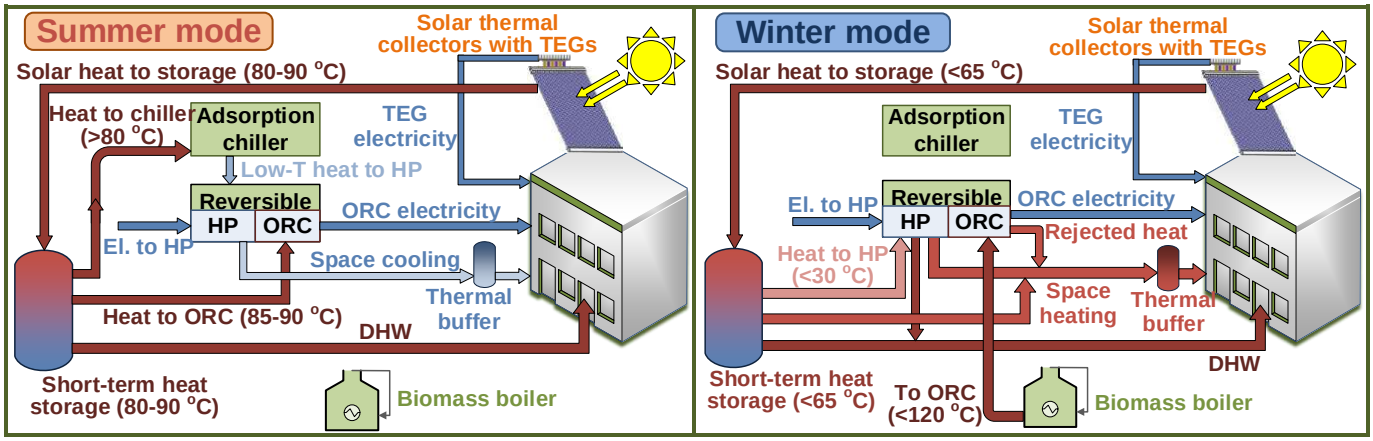


Fig. 9. *SolBio-Rev concept with main operating modes (summer and winter) and energy flows*

[9] Steinberger JK, van Niel J, Bourg D. Profiting from negawatts: Reducing absolute consumption and emissions through a performance-based energy economy. Energy Policy 2009;37:361–70.

Summer: Using solar heat for either cooling or electricity production

At moments with solar energy availability, solar heat at 90 ºC is stored in the short-term heat storage tank for supplying the DHW demand at 60 ºC (if required) and for either cooling or electricity production as follows:

- ✓ Cooling production: The stored heat supplies *in priority* the cascade chiller for space cooling, which requires heat at over 80 ºC to reach a high thermal COP.
- ✓ Electricity production: When cooling is not required or the forecasted daily cooling needs are covered by charging the thermal buffer tank, the stored heat supplies the ORC for electricity production. Its operation is preferred over TEGs, having 30% higher efficiency for the same heat input temperature. At all moments, the TEGs operate to dissipate the excess solar heat in case of collector overheating, extending their lifetime.

At moments with no solar energy availability:

- ✓ The remaining stored heat is primarily used for DHW and then for cooling production, if required.
- ✓ At night time and if all daily or forecasted heating/cooling needs are covered (or buffer tank charged), a fraction of the stored heat at temperature < 75-80 ºC supplies the TEGs for electricity production.

Winter: Using either the heat pump for heating at solar-assisted mode or the biomass boiler for CHP

At moments with solar energy availability, the pump of the solar field is controlled to reduce the temperature of the solar heat at up to 65 ºC, and thus increase the collector efficiency at cold conditions. This heat is stored and is used as follows, according to its temperature:

- ✓ Heat at 65 ºC is used for (1) DHW, and (2) space heating at up to 45 ºC. In buildings with no DHW needs, the solar heat temperature is reduced to 50 ºC for space heating only, further enhancing the collector efficiency.
- ✓ Heat at very low temperature (5 < T < 30 ºC) supplies the evaporator of the electric HP for assisting the heating production and increasing its COP to over 4.5, reaching 5 in south Europe.

At moments with no solar energy availability or higher heating needs than the heat pump production, the biomass boiler operates to cover the excess of heating demand, by operating at CHP mode.

***Intermediate seasons*.** System operation according to the solar energy availability and heating/cooling needs.

Spring: The moderate solar heat production covers all the heat demand (if any). No cooling is required, allowing the operation of either the TEGs or the ORC, according to the solar heat temperature (ORC for T > 80 ºC).

Autumn: In case that it is not possible to fully cover the heating demand by the direct solar heat gain, the heat pump operates at solar-assisted mode, leaving as the last resort the biomass boiler.

The optimum decision and exact operating mode during each season (e.g. TEGs vs. ORC, heat pump vs. biomass boiler) depend mostly on the available solar irradiation, and energy needs and prices (e.g. gas, electricity or district heating). Therefore, the SolBio-Rev system relies on an **advanced control strategy**, with several optimisation parameters for maximising the renewable energy share and/or minimising energy costs. Finally, at all moments and seasons, **TEGs offer the option to exploit all heat that is not utilised or otherwise wasted**, not competing with the ORC, and especially in intermediate seasons, when their production potential is the highest.

1.3.4 The innovative SolBio-Rev system potential to achieve high energy shares throughout the EU

To show the potential and compactness of the SolBio-Rev system, the necessary solar collector surface and components sizing have been calculated to achieve a certain energy share in two reference buildings: a MFB and a commercial one (e.g. offices). Table 1 gives their specifications, based on a BPIE report, with the specific primary energy demand according to the EU Recommendation 2016/1318.

Table 1. Specifications of the two reference buildings

Specifications	MFB	Commercial
Storeys	~ 4 (EU average)	
Dwellings	10 (of 100 m^2 each)	None
Total surface area	1,000 m^2 (rooftop: 250 m^2)	
Solar collectors fitted	up to 125 m^2	
Space heating system	Low temp. distribution up to 45 ºC (with gas)	
DHW	Up to 60 ºC	None
Cooling system	Split A/C (3/dwelling)	Central A/C
Specific primary energy demand	New: NZEB standard [10]	
	Existing: two times higher than NZEB standard	

Annual calculations have been conducted by NTUA for three different EU climates: for the south (Athens), the centre (Berlin) and the

[10] Specific primary energy demand of NZEB standards, according to EU Recommendation. For new MFBs: 55, 65, and 75 kWh/m^2/year in Greece, Germany, and Sweden respectively. For new offices: 85, 90, and 95 kWh/m^2/year in Greece, Germany, and Sweden respectively.

north (Stockholm) of Europe, in order to demonstrate the concept and the energy share of SolBio-Rev in the two typical buildings of Table 1. The DHW demand is constant in each month and zone for the residential building (no DHW needs in the commercial one), given as a function of only the number of occupants[11] (137.5 kWh/month for three occupants). Space heating and cooling demand is extrapolated according to the mean ambient temperature and heating/cooling days from EC-JRC PVGIS tool, based on the average day of each month and location. Electricity demand is kept constant during each day of the year (the same for all locations) and is calculated based on the specific electricity demand of typical EU residential and commercial buildings (about two times higher for the commercial one). A primary energy factor (PEF) of 2 is used for electricity (EU average for post-2020 period), for converting primary energy to final electricity demand. The result of this analysis is the *monthly final energy demand* of the two new reference buildings in Athens, Berlin and Stockholm, not yet implementing the SolBio-Rev system, divided into space cooling, heating (space heating and DHW provided by a gas boiler), and electricity demand (not including the electricity to power the air-conditioning, A/C, systems).

To prove the **potential of the SolBio-Rev concept**, calculations have been made to estimate the energy share based on the above energy demand in the two reference buildings of Table 1, as a function of the solar collectors surface in the three typical climatic zones (Athens/Berlin/Stockholm). The solar heat is calculated with the AKOTEC vacuum collector certification data (Solar Keymark), with local weather data processed in TRNSYS software with an hourly time-step. Figure 10 shows the necessary solar surface of the SolBio-Rev solution (non-optimal sizing) for covering 100% of heating and cooling needs and a fraction of electricity ranging from 0 up to 100% in these two buildings, while considering no rooftop surface limitation. However for clarity, the rooftop availability is also indicated in this figure ("*Max. rooftop*").

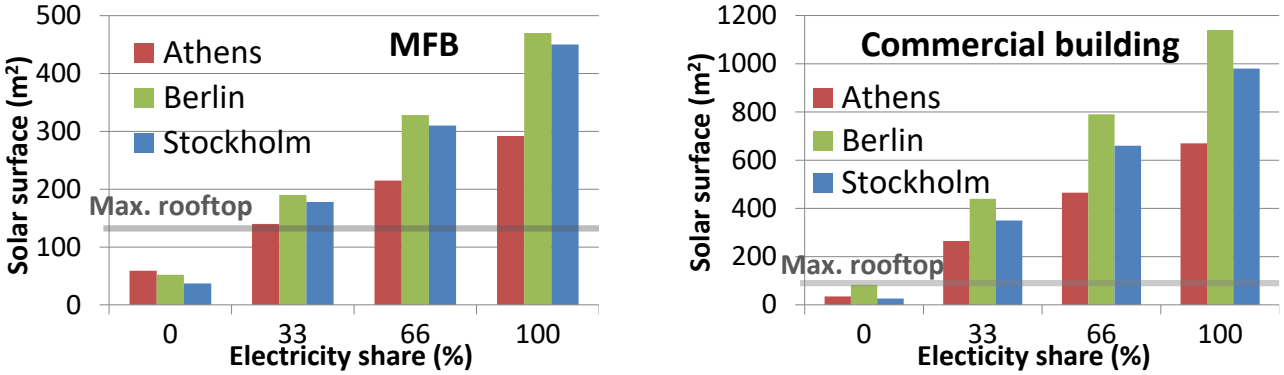
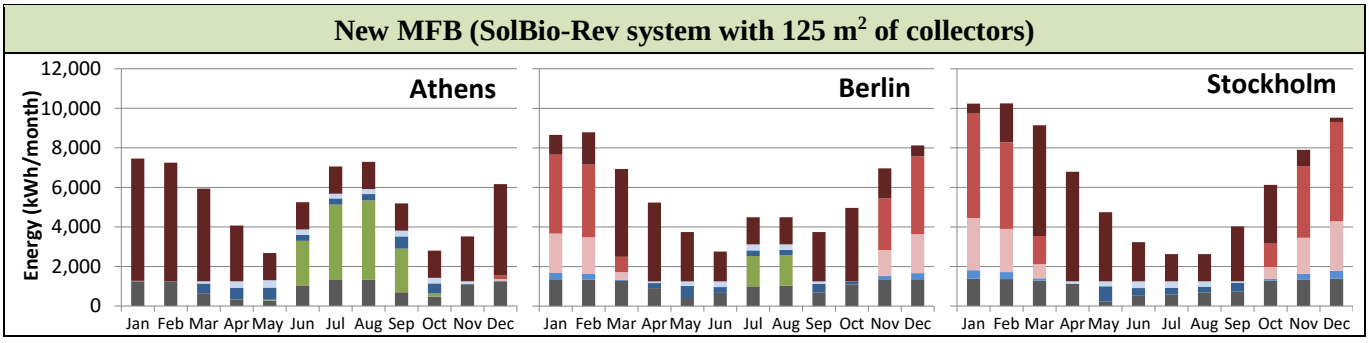


Fig. 10. *Solar surface as a function of electricity covered in a new MFB (left) and a commercial building (right) in Athens, Berlin and Stockholm*

The necessary solar surface is similar in Berlin and Stockholm for covering the same amount of electricity (slightly lower in Stockholm due to no cooling needs), and much lower in Athens, due to its high solar availability. This surface greatly increases for an electricity share > 33%, introducing space limitations on rooftops, especially in offices, and resulting to long PBP (see § 1.4.2).

By introducing the rooftop limitation, the maximum solar collector surface is fixed to 125 m² in both building types. The calculations have been repeated for this sizing, in order to examine how the monthly final energy demand of the two reference buildings in the three locations is covered in a realistic scenario. The results of this analysis are shown in Fig. 11, by presenting the contribution of the SolBio-Rev components for 100% of heating (no gas boiler or other conventional heating appliance exists), and cooling (by the cascade chiller/HP in Athens and the heat pump only in Berlin), and a fraction of electricity by the TEGs and the ORC. All electricity required to run the system is produced by its components. The electricity needs not covered by the system are referred to as "*grid electricity*".



[11] R Dott, et al. Models of Sub-Components and Validation for the IEA SHC Task 44 / HPP Annex 38 Part C: Heat Pump Models, A technical report of subtask C Deliverable C2.1 Part C. International Energy Agency, 2012.

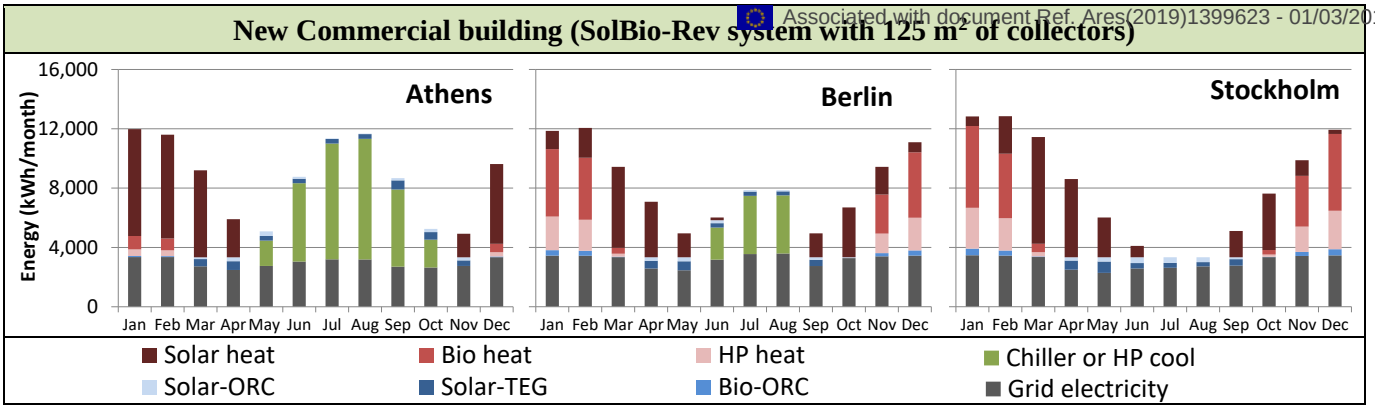


Fig. 11. *Monthly energy demand in Athens, Berlin and Stockholm in a new MFB and a commercial one and the contribution of the SolBio-Rev components for covering all heating/cooling and an electricity fraction*

There is an important variation of the energy demand between summer and winter in central and north Europe in both building types, while in south Europe these peaks are closer, due to the cooling needs. This is effectively handled by the SolBio-Rev system, due to the heating production by three different components (solar collectors, heat pump, biomass boiler), with a similar approach for electricity (solar-TEG, and ORC by solar or biomass heat), **bringing forward the critical benefits of combining different renewable energy systems**.

According to these results, the energy share over a year (split into heating, cooling and electricity) covered by each system component is shown in Fig. 12.

In Athens, most of the heating demand in winter is directly covered by solar heat, whereas in Berlin and Stockholm it is provided by the heat pump and the biomass boiler. Cooling demand (where required) is covered by the cascade chiller, except in the MFB in Berlin that uses the heat pump for that purpose, due to the low cooling needs. Finally, the solar-TEGs produce large amounts of electricity, 3-5% in MFBs and ~3% in the commercial building, mostly during the intermediate seasons, with a slightly lower share by the ORC (~ 2-3%).

The highlights of these results in terms of energy and electricity share are shown in Table 2, considering the previous 125-m^2 system version (referred to as *2nd version*), indicating the achieved final specific energy demand. Additionally, a version for covering all heating and cooling only (no electricity) is examined as well (referred to as *1st version*).

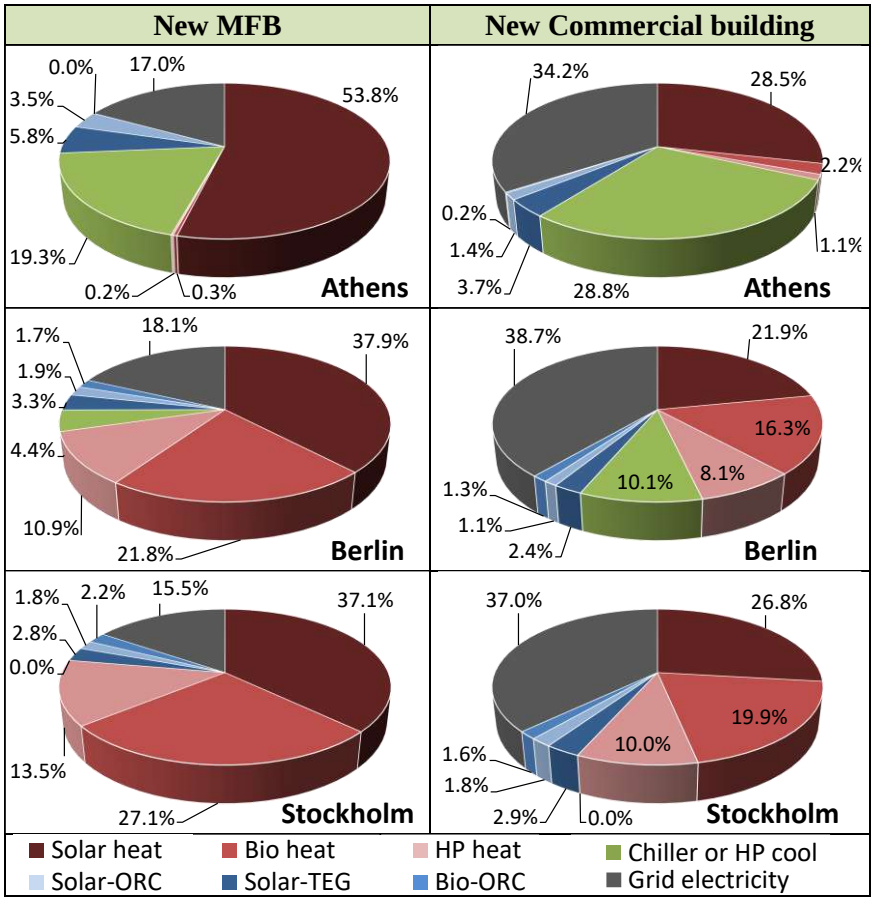


Fig. 12. *Components' annual energy share in a new MFB and a commercial one in three cities (SolBio-Rev with 125 m^2 of collectors)*

Table 2. Energy indicators for the two reference buildings of 1,000 m^2

Energy indicators of the two SolBio-Rev system versions	New multi-family residential			New commercial building		
	Athens	Berlin	Stockholm	Athens	Berlin	Stockholm
SolBio-Rev for 100% of heating/cooling, zero electricity (*1st system version*)						
Energy share / collectors required	73% / 59 m^2	77% / 52 m^2	80% / 37 m^2	53% / 35 m^2	56% / 83 m^2	58% / 26 m^2
SolBio-Rev for 100% of heating/cooling, plus electricity (*2nd system version*)						
Energy share / electricity share	81% / 27%	81% / 17%	85% / 20%	58% / 11%	58% / 4%	62% / 10%
Final sp. energy demand (kWh/m^2/year)	10	12	12	36	38	29

The SolBio-Rev system covers a very large energy share (100% of heating/cooling) in a **new MFB** all over Europe (energy share > 75%) with a solar surface of 59 m^2 in south Europe reducing to 37 m^2 in north Europe. By respecting the rooftop availability, it is possible to additionally cover up to 27% of electricity in south Europe, decreasing to ~20% in central/north Europe, while reaching very low specific final energy demand of 10-12 kWh/m^2/year. However, an important advantage of the *1st system version* is its straightforward implementation in MFBs, avoiding any complex method of sharing the generated electricity among the different dwelling owners/users. In any case, this aspect will be examined in the business model generation, included in the work plan.

In a **new commercial building**, the energy share is reduced to about 55% for covering all heating and cooling (*1st system version*). This share is lower than in MFBs, due to a higher specific electricity demand, while it is covered with a similar solar surface. A lower electricity share can be achieved in case the whole rooftop is covered with collectors, up to 11% in south Europe and less in other regions. The higher energy share is observed in Stockholm, due to the higher heating needs.

In terms of total energy share, the SolBio-Rev system can achieve **up to 85% energy share in new MFBs and up to 62% in new commercial buildings**. This share is very high and already considers all space limitations within the buildings. It can be further increased, in case additional collectors are installed on the façade, or combined mainly with electricity generation equipment (e.g. PVs) especially in renovations.

For renovations with higher specific energy demand (from 110 in Greece up to 150 kWh/m^2/year in Sweden) mostly for heating and cooling, a larger solar surface is necessary: 60-110 m^2 to cover all heating and cooling needs (0% of electricity) in a 1,000 m^2 renovated MFB, having an **energy share of about 87%**, while in a renovated commercial building the solar surface increases up to 130 m^2 (reaching the rooftop surface limitation) with an **energy share of about 75%**. However, the cost-effectiveness of the SolBio-Rev is reduced in these cases, due to the large number of collectors and component capacity, making it critical to initially install passive components for increasing the building's energy efficiency (e.g. envelope insulation, double-glazing, ventilation with heat recovery), before installing the SolBio-Rev system, in order to maximise its benefits with a reasonable solar surface and reach a very short PBP.

Finally, the **flexibility of the SolBio-Rev concept** ensures a smooth integration with the existing infrastructures, including the use of storage tanks, without the need for major interventions. The most common cases are the following:

- ✓ Existing connection to district heating and/or oil/gas-fired boiler: In those cases, the biomass-CHP boiler of the SolBio-Rev solution can be omitted, relying as backup heater on the district heating or the standard boiler. The energy share of SolBio-Rev decreases, covering a fraction of heating, and producing less electricity in winter. This energy share penalty is negligible in south Europe, according to Fig. 12, while it reaches about 20% in the other two regions. In any case, this penalty is minimised by increasing the loading of the heat pump-based configuration, by operating more hours exploiting ambient heat with reduced COP though.
- ✓ Existing solar thermal collectors: In case they are adequate to supply solar heat to the system, a larger TEGs module can be mounted at the central inlet/outlet piping of the solar field. For low collector surface, additional solar collectors with TEGs are necessary, for increasing the energy share.
- ✓ Existing PVs: Solar-TEGs are installed according to the rooftop availability. The controller will require additional settings to optimise the self-consumption of the PV electricity or even to convert it to heating/cooling and store it for later use, according to the energy needs and prices.

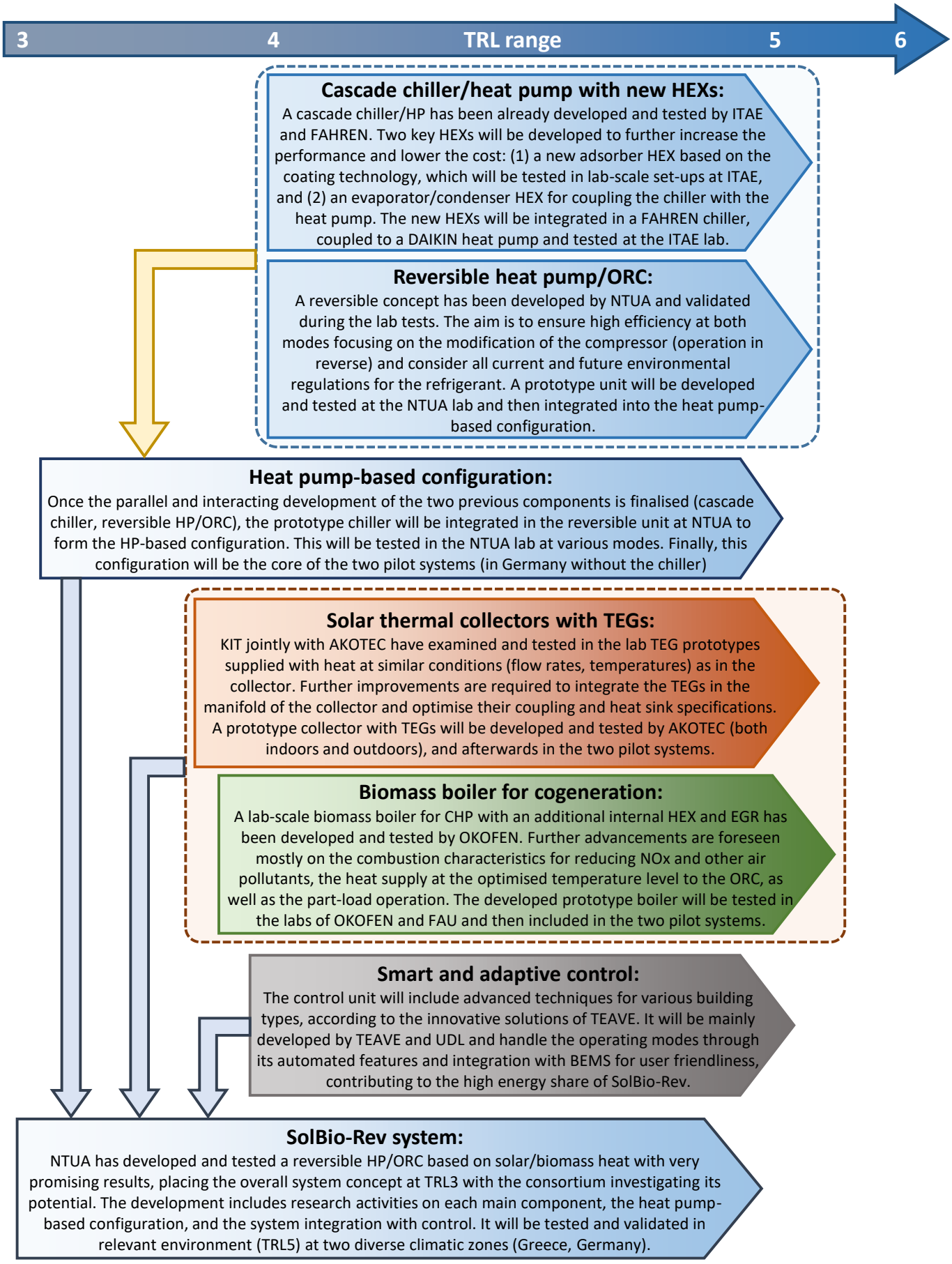
Combinations of the above might apply as well, making it necessary to conduct building-specific studies to conclude to the optimised solution. Some typical cases are included in the work plan (in WP7) to examine building integration aspects. In any case, the core of the SolBio-Rev system, the heat pump-based configuration, is included in the final solution, while the communication features of the controller based on common protocols ensure a smooth interoperability with the existing components.

In conclusion, SolBio-Rev is intended to **cover all heating and cooling needs in various buildings (new or renovated) and additionally a fraction of electricity**, **with a collector surface that fits on rooftops**, overcoming the passive-house standards and approaching the ZEB standards, especially in MFBs. This is extremely important, as it anticipates any future energy performance standard that will replace the NZEB standard after 2030. On top of that, cost-effective solutions are reached for a similar range of energy shares, as presented in detail in § 1.4.2.

1.3.5 Positioning of the technology

All key technologies are at TRL3-4, as described in Table 3. The aim is to integrate them and bring the overall SolBio-Rev solution to TRL5 (validated in relevant environment) at the project end, but with sufficient evidence and industrial contribution to ensure easy transition to higher TRL and commercialisation in the few subsequent years.

Table 3. TRL of the main parts of the technology



1.3.6 National and international research and innovation activities linked with the project

The project will build up and link with national and international research relevant to renewable energy systems in buildings. Consortium partners participate in many relevant projects bringing-in their background knowledge. The main identified activities to be linked with SolBio-Rev are given in Table 4.

Table 4. Projects and initiatives linked with SolBio-Rev (consortium partners mentioned in parenthesis)

Acronym	Brief description	Links with SolBio-Rev
HEAT4COOL, H2020-EEB, 2016-20 (FAHREN partner)	Advanced energy solutions based on renewables for building renovations	Background knowledge & data exchange: PV with heat pumps, predictive control, system testing, and system integration in renovations.
ZEOSOL, H2020-FTI, 2017-20 (NTUA coordinator, FAHREN, ITAE, AKOTEC partners)	New zeolite adsorption chiller, supplied with solar energy for heating/cooling.	Background knowledge & data exchange: Solar field supplying a chiller, business models for advanced cooling systems.
SWS-HEATING, H2020-LCE, 2018-22 (NTUA coordinator, ITAE, TEAVE, FAHREN, UDL, AKOTEC, UOS partners)	Innovative sorption material for seasonal storage of heating in single-family houses.	Background knowledge & data exchange: Solar field control, business models for advanced heating systems, building prototype and testing protocol.
HYCOOL, H2020-LCE, 2018-21 (ITAE, FAHREN partners)	Innovative solution for solar thermal energy integration in industries, for heating/cooling.	Background knowledge & data exchange: Solar system design, sorption cooling technology integration.
BioTric, National-funded, 2014-15 (NTUA coordinator)	Development of a hybrid solar-biomass trigeneration system using a supercritical ORC	Background knowledge: Reversible configuration of a HP and ORC for trigeneration energy production.
HomeORC, National-funded, 2015-18 (FAU coordinator)	Implementation of an ORC based micro-CHP solution for single and multi-family houses.	Background knowledge: Coupling of a commercial pellets firing boiler with a 1 kWe ORC unit for CHP mode.
BioWasteStirling, National-funded, 2017-20 (FAU coordinator)	Development of a highly efficient and fuel-flexible micro CHP system.	Background knowledge & data exchange: Impacts of different biomass fuels on boiler combustors. High-T boiler operation.
Single HPA unit, Eurostars, 2015-17	Solar/geothermal reversible HP/ORC for heating, cooling, and electricity in buildings	Background knowledge: Reference system for comparison, sizing recommendations of the reversible HP/ORC unit.
MERITS, FP7-Energy, 2013-16 (UDL partner)	Thermal energy storage units for seasonal heating and cooling in buildings.	Background knowledge: Design of containerised building prototype for pilot tests. Storage tanks and their sizing, system control.
HYBUILD, H2020-EEB, 2017-21 (UDL, FAHREN, ITAE, NTUA, DAIKIN partners)	Hybrid electrical and thermal energy storage in buildings.	Background knowledge & data exchange: Thermal storage configuration, control, flexible heat pump units.
EXP-HEAT, FP7-SME, 2014-17 (NTUA coordinator)	Energy recovery in electrically-driven heat pumps using a dedicated expander.	Background knowledge: Expander design, heat pump evaporator/condenser design, control of heating/cooling systems in buildings.
PRINTTEG, KIT, 2011-14	Roll-to-Roll printing of organic thermoelectric generators	Background knowledge: Scalable/automatable production processes for organic TEGs.
LEHII/CIED. UK initiative, 2015-2018 (UOS directing)	Low Energy Housing Innovations and the role of Intermediaries	Background knowledge: Intermediation in the development of both new and retrofitted low-energy housing innovation.
CIED. UK initiative (UOS directing)	Potential for technology and innovation to enhance the decarbonisation of buildings.	Background knowledge & data exchange: Business models and social acceptance of new and innovative energy technologies.
TABULA, IEE, 2009-12	Residential EU building stock	Background knowledge: Building typologies and energy demand for heating, cooling, and electricity. Policy, governance and regulations.
EPISCOPE, IEE, 2013-16	Buildings' energy demand.	
ZEBRA2020, IEE, 2014-16	Database of EU nZEBs, policies.	

1.3.7 Methodology

The SolBio-Rev project has a duration of **48 months** and includes **9 WPs** to integrate the diverse sectors, skills, and capabilities of the consortium, and develop the involved technologies for achieving the project objectives. The different levels of the core drivers of SolBio-Rev system are shown in Fig. 13, providing an overview of the various tasks and partners involved. The methodology includes three interacting phases, as presented next.

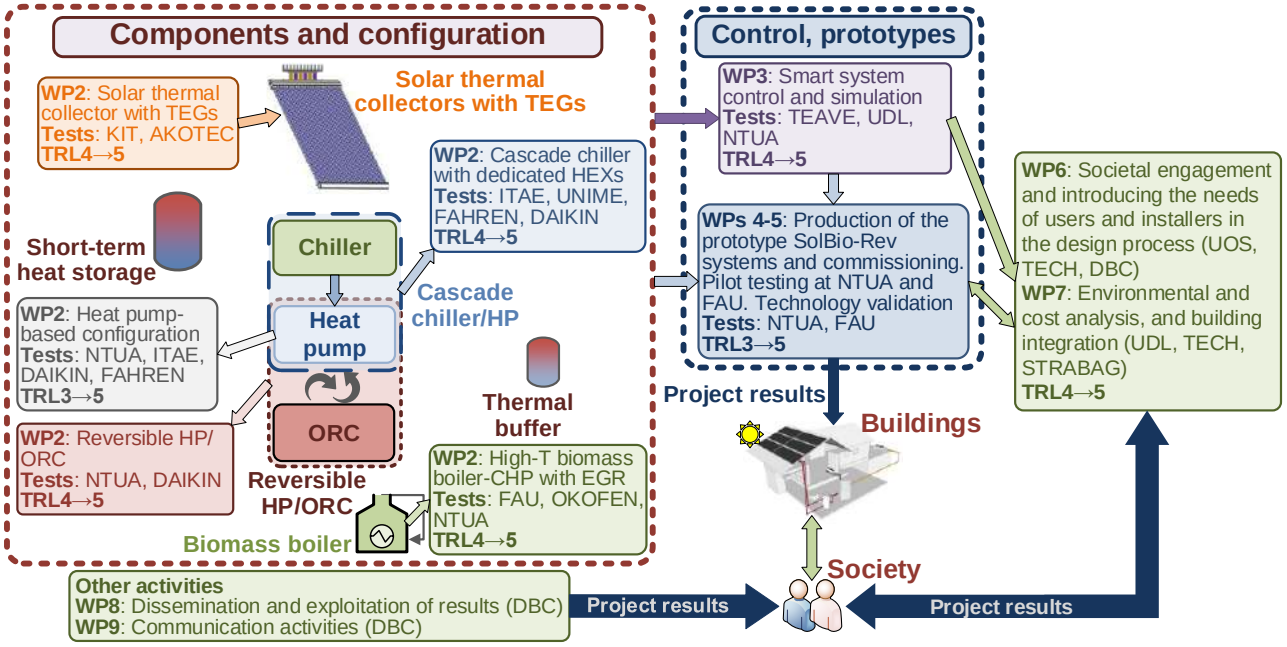


Fig. 13. *SolBio-Rev methodology and overview of activities*

Phase 1: Innovative components, configuration and control development (M1-30). This phase is the core of the project and concerns research and development activities relevant to the main components and configuration, corresponding to WPs 2-3, and covering the first 2.5 years of the project. During this phase, the appropriate building typologies for applying the SolBio-Rev system will be initially identified in WP2 along with the specifications of the generic energy system (e.g. heat pump capacity per m^2 of living surface) based on existing EU standards considering relevant climatic zones, building types/sizes, and energy performance classifications. Energy demand in future buildings will be also projected according to user behaviour and other key boundary conditions.

According to these defined specifications of the generic energy system, the component development will start in WP2. ITAE and UNIME will work together with FAHREN and DAIKIN for developing the cascade chiller with heat pump component. The *adsorber HEX* will include the coating technique patented by FAHREN, further optimised by UNIME, focusing on compactness, high heat transfer efficiency and improved post-synthesis treatment. The adsorber developed by FAHREN and UNIME will be based on the direct crystallisation of the adsorbent material onto the HEX surface and tested at the ITAE lab, for analysing the heat and mass transfer phenomena during the sorption/desorption phases, thus optimising its specific cooling power. Indeed, the post synthesis washing process is an important step to get a good calcination quality. This process will be optimised by temperature, time and flushing water amount. The cascading steps for a multi HEX treatment have the potential to reuse water in a counterflow concept and reduce the operating costs together with improved zeolite quality. The test parameters for both the washing and the thermal calcination will be energy consumption and process time. The final design of this HEX will comprise both the identification of high-efficiency HEXs through a dedicated thermo-fluid dynamic analysis, as well as the optimisation of the post-synthesis coating procedure in terms of energy efficiency and cost. For the *evaporator/condenser* that couples the chiller with the heat pump, the starting point is the HEX technology of the DAIKIN heat pump, evaluating any other alternative solution. Small-scale tests will be conducted in a dedicated test rig at ITAE under real operating conditions (i.e. low water vapour pressure) to analyse the heat transfer capacities under different operating modes and evaluate all solutions. This research work will conclude to the development of a complete prototype cascade chiller with dedicated HEXs, based on the heat pump design of DAIKIN and the chiller design of FAHREN (cooling capacity of the chiller to match the needs of the pilot system at NTUA). It will be then produced by FAHREN and tested at ITAE for full characterisation, and adjusting the control of both parts.

The reversible heat pump/ORC will be developed by NTUA, using as a starting point a commercial heat pump of DAIKIN of suitable capacity, to match the energy needs of the two pilot buildings. Focus will be given on the compressor/expander technology and the HEX sizing, in order to reach a compact unit with maximised performance under both modes. The reverse operation mandates a similar pressure/volume ratio in both compression and expansion, introducing significant constraints and requiring a careful optimisation study. This aspect will be at the

core of the simulation process of this component and included in the simulation platform of the entire system. The results of this analysis will conclude to a definition of the operating temperature and pressure ranges, and technical specifications of the compressor/expander. A commercial DAIKIN scroll-type volumetric machine will be used, after being properly modified and replacing some of its parts for allowing high temperature operation and compatibility, when using a HFO refrigerant (e.g. compressor sealing, lubrication). A prototype unit will be developed and tested at the NTUA lab with the support of DAIKIN, under the two main modes, supplied by either a high-temperature gas-fired boiler (simulating the solar/biomass heat at ORC mode), or low-temperature heat and rejecting heat to chilled water (simulating the heating/cooling at heat pump mode). The exact temperature of the boiler heat supply (in the range of 100-120 ^{o}C) will be determined after the first simulation and testing activities in close collaboration with FAU, in order to maximise the performance of both modes, respecting the pressure/volume ratios of the compressor.

Intensive data exchange and close collaboration is envisaged between ITAE, NTUA, DAIKIN and FAHREN, in order to fine-tune the overall heat pump-based configuration. The developed chiller tested at ITAE will be decoupled from the heat pump and shipped to Greece, to be integrated with the existing reversible unit at NTUA, forming the complete heat pump-based configuration, conducting any final modification. This configuration will be tested at the NTUA lab for complete characterisation under heating (space heating and DHW), space cooling (operating the cascade chiller/HP part), and power (including CHP) production modes under different heat supply/rejection temperatures, identifying the key control parameters, and evaluating its dynamic and off-design operation as well.

At the same time, AKOTEC will work with KIT for the development of the vacuum tube solar collector with TEGs, focusing on the optimal integration and operation of the TEGs in the SolBio-Rev system. This requires an ideal thermal and electrical management of TEGs with a maximisation of their operating hours, while avoiding any negative impact on the performance of other components. Small-scale prototype modules of few Watts, will be developed by KIT with the printed TEGs and tested at the KIT lab under realistic operating conditions, in order to identify the electricity production capacity, the heat sink characteristics with the support of NTUA, and finally evaluate the cost of these modules. The results will drive the development of the up-scaled solar-TEG integration, concerning a collector with re-designed manifold including the by-pass pipe on which the TEGs are mounted with capacity of 20 W electric. This will be tested both indoors and outdoors by AKOTEC. This development stage will also conclude to a design of a central-mounted TEG module on the main pipes of the whole solar field, which is suitable for renovations with existing solar thermal collectors. Once all performance issues are resolved and the solar-TEG concept is validated, it will be used in the pilot systems in Germany and Greece.

In the meantime, OKOFEN and FAU will develop the advanced pellet boiler technology, focusing on: (1) its high temperature operation for efficient coupling with the ORC, and (2) the use of EGR for reducing the air pollutants and reaching high combustion efficiencies. Initially, numerical simulations will be conducted by FAU, leading to a set of internal HEX geometries/designs and EGR rates. The results will be evaluated based on the existing test results of OKOFEN from its prototypes, and then used to develop a flexible prototype boiler produced by OKOFEN (capacity up to 5 kW), integrating both technical approaches. This flexibility concerns the adjustment of EGR rates and the modification of the internal HEX configuration (e.g. capacity/sizing, location, materials), as well as testing each mechanism separately (e.g. with/without EGR). OKOFEN with FAU will test this prototype in the lab under relevant conditions (heat capacity, air/EGR flow rates, and biomass supply) at both full and part load. The test results will be used for evaluating the effect of the two technical approaches on flue gas emissions reduction (NOx, CO, and PMs) and increase of combustion efficiency, properly adjusting the boiler design, if needed. The heat supply temperature to the ORC will be jointly examined with NTUA, as explained previously. Finally, OKOFEN will provide two fully equipped and optimised prototype boilers for the prototype SolBio-Rev systems.

The research up to this point will produce complete sub-models for each component and the heat pump-based configuration to be used for the integrated system simulation by NTUA in WP3. A numerical platform will be thus developed for multi-parametric system optimisation, supported by careful user behavioural models aimed at identifying and minimising the uncertainties of building dynamic calculations, which are frequently responsible for massive deviations between predicted and in-situ measured energy performance[12]. The simulations will be conducted for typical residential and non-residential buildings of various sizes/types covering the main EU climatic zones using local weather data and energy demand profiles (from WP2), and for different user profiles. The same procedure will be also conducted for the two pilot buildings, providing input to the design process in WP4.

All previous numerical and test results will be processed, in order to finalise the control strategy in WP3. Possible non-linear building models and operational constraints will drive the appropriate tailored control algorithms. Model Predictive Control (MPC) techniques will be implemented for real-time control, deriving to an optimal predictive window, according to the computing capabilities of the control unit. The optimised controller with its advanced features and user-friendly environment will be mainly handled by TEAVE and UDL, setting all operational

[12] R Gupta, M Gregg. Do deep low carbon domestic retrofits actually work? Energy and Buildings 2016;129:330-43.

parameters of the system components, and operating modes. The controller will be tested in the lab by TEAVE in WP3 to verify its functionality, before mounted in the pilot systems in WP5.

Phase 2: Prototype systems design, production, and commissioning (M25-36). All previous results are feeding *Phase 2*, covering the third year of the project, and corresponding to WP4. The design of each of the two prototype systems based on the outcomes of WPs 2-3 will be realised, according to the pilot building specifications, energy needs, and local weather data. Valuable feedback from users and installers (from WP6) will be considered in this design process, in order to include their needs and requirements, and exploit all stakeholder knowledge. At the same time, the containerised prototype building at FAU will be designed and produced. The main components of the prototype systems will be manufactured by the industrial partners, supplemented with the storage tanks provided by AKOTEC with the design support by UDL. These will be then shipped to NTUA and FAU and assembled/installed on-site, after properly prepared the pilot buildings. Extended commissioning tests at various modes will be conducted by the hosting partners with the active participation of personnel from other partners (e.g. FAHREN, DAIKIN, TEAVE, ITAE, UDL, AKOTEC, KIT) to enhance synergies and ensure proper operation of all components.

Phase 3: Prototype systems testing and technology validation (M37-48). *Phase 3* corresponds to WP5 and covers the last year of the project. Extended tests will be conducted for one year at FAU and NTUA, measuring and processing all system properties and energy flows. Each partner will be focussing on test data relevant to its field, making it necessary for partners with different skills to effectively work together towards the **validation of this innovative technology in two diverse climatic zones for covering an energy share of > 70%, and reaching TRL5**. The test results will be also used to validate the simulation platform of WP3, in order to implement reliable cost analysis in WP7 and examine the potential impact in typical buildings.

Other on-going key activities (M1-48). Environmental aspects (LCA), costs (LCC), and cost-benefit analysis (CBA) will be examined in WP7. The system integration and installation aspects in buildings will be investigated by TECH assessing space restrictions and design adjustments, providing feedback to the design process in WP4, as well as system variations suitable for renovations.

Large focus is given on **social aspects** through various activities in WP6, to increase the social acceptance, and awareness of the proposed technology and its user-friendliness level through dedicated social and user-driven barrier identification, and design of dedicated crosscutting strategies. The first activity is to identify the key stakeholder categories (including end-users and installers). Insights into potential policy barriers and opportunities for SolBio-Rev will also be defined. Data will be collected in two phases. Based on the analytical model created on connecting social acceptance of new technology with sustainability transitions, semi-structured interviews within key stakeholder groups (e.g. end-users, installers and policy makers) will be firstly carried out, in order to identify relevant challenges and opportunities for uptake. The interviews will be complemented by an online survey that will examine whether initial findings from interviews hold true more widely and identify further challenges and opportunities for SolBio-Rev. The interview and survey data collection will be conducted according to the UOS Research Ethics Committee approval and guidelines. All data will be **anonymised** and data collection and management will adhere to the latest General Data Protection Regulation (GDPR, Regulation (EU) 2016/679). The interview and survey results will provide data suitable for a comparative analysis between different stakeholder groups and across different EU countries in various climatic zones (e.g. Finland, Germany, Greece, and UK). The results will aid in improving and accelerating the uptake of the technology, by identifying the needs and requirements of these groups and introduce their needs in the design process, as well as define recommendations for policy. These campaigns will be repeated with varying environmental, social and climate boundaries as independent variables, in order to identify recursive behaviour and trigger SolBio-Rev exploitation actions within the society and into the market.

Dissemination and exploitation activities are included in WP8, setting-up appropriate networks for the further development stages of SolBio-Rev and reach even higher TRL. Communication activities in WP9 include, among others, a technology roadmap communicated to various target groups, dedicated workshops, the project website and two videos targeting various stakeholders.

1.3.8 Pilot systems in Greece and in Germany

The description of the two pilot systems in Greece and in Germany is presented next.

Pilot system in Greece: The small-scale pilot building in Athens is shown in Fig. 14. It is a two-storey mockup located in the NTUA campus with a **surface area of 30 m²** (dimensions: 3.65 × 3.65 × 7.53 m) for testing insulation materials and energy demand profiles compared to reference buildings. It is well-insulated (heat transfer coefficient of 0.5 W/m²K for the envelope, 1 W/m²K for the roof), corresponding to an "A" energy class, based on national technical codes. In total 49 sensors are installed at key locations (at wall surfaces and internal ambient spaces) at the ground level and the upper floor (39 temperature sensors, 8 humidity sensors, 6 heat flux sensors). A data acquisition system is available that (remotely) monitors and records the sensors readings and local weather data.

One part of the building is used to simulate the energy demand for heating, cooling and electricity, equipped with fully-programmable heating and electricity loads, according to the user needs and behavioural profiles. This allows to test the system performance in different building types (residential, commercial) by appropriately adjusting the energy demand. The other part hosts the new system to be tested. The roof of the pilot building has an excellent north-south orientation with no shading, making it possible to install an adequate number of collectors (up to 5-8 m^2 needed).

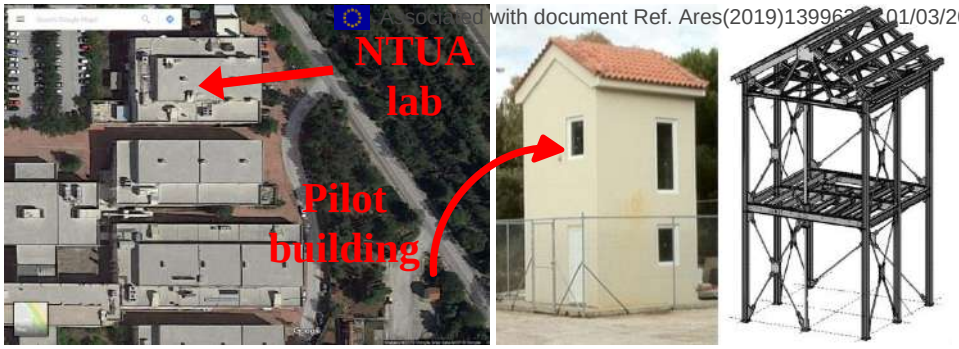


Fig. 14. *Left: Satellite view of the building and the NTUA lab. Right: Southwest view of the building and its steel frame*

Pilot system in Germany: A containerised, well-insulated, building prototype for hosting the SolBio-Rev system will be developed by FAU at their premises with a **surface of 30-40 m^2**, according to the final prototype system design. The relevant expertise of some consortium partners (e.g. UDL, NTUA, and ITAE) gained in EC-funded projects[13] will be exploited for that purpose. Figure 15 shows a sketch of the envisaged pilot building with the prototype SolBio-Rev system.

Sensors will be installed, as well as heating/electric loads to simulate the energy needs of different buildings, as in the NTUA building. The solar collectors are installed on the rooftop (with surface 6-10 m^2), supplying the short-term heat storage tank, and then the system components.

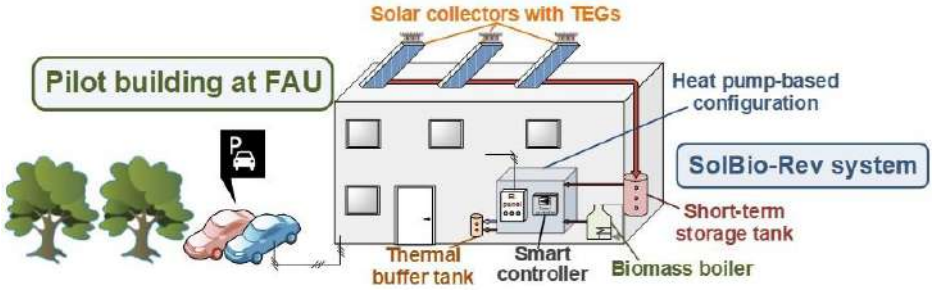


Fig. 15. *Envisaged pilot building at FAU with the prototype SolBio-Rev system*

General specifications of the pilot systems: The pilot SolBio-Rev system will be a downscaled version of the real full-scale system, considering the ratio of the pilot building size (about 30 m^2) and the size of the reference building (1,000 m^2). Moreover, the similar surface of the two pilot systems allows to conduct direct comparisons. The down-sized heat pump-based configuration (heating capacity up to 4-5 kW) with the other components, auxiliaries, and measurement instruments are installed in one part of the pilot building resembling the boiler room of buildings.

The purpose of having two separate pilot systems is to have adequate time for testing in-parallel (one year) and reach solid conclusions about the system performance. Also, the two systems will operate under different climatic conditions and energy needs (see § 1.3.4). The site-specific testing will thus aid in an extensive and robust technology validation. Finally, the two prototype systems will continue to operate and conduct further tests after the project end, in order to validate the technology at a wider range of building types, user behaviour, and for a larger duration.

1.3.9 Gender considerations

The project will include a gender mainstreaming approach in the operation frameworks, taking into consideration the user-acceptance of the technologies (gender needs, behaviour and assumptions) implemented during the project, and building the capacity of female researchers to work in the energy and building sectors – and everyone to engage with gender in the field. This action will be done following the RRI approach and under the umbrella of the GREiA group RRI plan at UDL. Operationalising gender approaches can improve performance and increase benefits for everyone. Therefore, there is a need to quantify how all genders interact with the proposed technologies, and identify any variation in the energy share covered by the system, and if so what changes need to be made to eliminate these variations. This issue will be handled during the surveys and provide feedback to the design process and the control.

Finally, the activities of the project are compliant with Council Resolution 1999/C 201/01 of women and science, with a strong determination to give the same opportunities to everyone. Within the partners, women have responsibilities, leading WP6 (UOS: Dr. Mari Martiskainen) and WP7 (UDL: Prof. Dr. Luisa F. Cabeza). Moreover, Prof. L.F. Cabeza is chairing the external stakeholder advisory board. Currently, around 23% of the key personnel are women (similar to the gender balance of the energy sector, according to EIGE), and by further recruitment the female participation will increase, approaching a gender balance across the project.

[13] MERITS (FP7-Energy): www.merits.eu; SWS-HEATING (H2020-LCE): https://cordis.europa.eu/project/rcn/214060_en.html.

1.4 Ambition

1.4.1 Advances that SolBio-Rev will provide beyond the state-of-the-art

The overall SolBio-Rev ambition is depicted in Fig. 16 with current and envisaged development steps. The technology roadmap (developed in WP8) will define the further activities for the post-project period, in order for this next generation technology to reach the market in 2025, and directly compete with existing solutions.

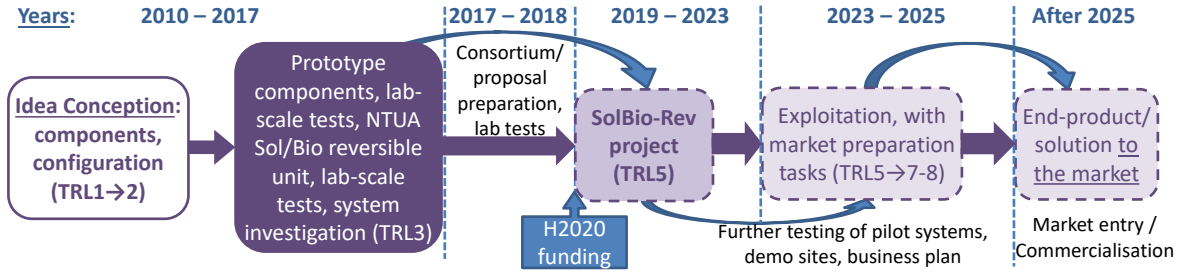


Fig. 16. *SolBio-Rev: From idea conception to commercialisation*

Within the SolBio-Rev project new technologies will be developed at three discrete levels: (1) Components, (2) Configuration, and (3) Control. They are combined to form the innovative renewable energy-based system. The ambition at each level, as well as for the overall system and for the societal engagement is presented next.

SolBio-Rev ambition at component level

The component development included in the work plan are described next.

Cascade adsorption chiller with heat pump: The cooling performance of both thermal chillers (based on either adsorption or absorption) and vapour compression heat pumps is greatly reduced by about 20% at hot ambient conditions (> 30-35 ºC), due to the increase of heat rejection temperature, especially when cooling is needed the most (e.g. at noon during summer in south Europe). The cascade chiller/HP concept overcomes this critical drawback, ensuring a high performance even in areas with high summer ambient temperatures. In areas with low cooling needs and moderate summer ambient temperatures (e.g. central Europe), a cost-benefit analysis will be carried out to decide on its addition, according to the added cost, cooling needs, and the expected COP increase. The performance of the chiller will be further enhanced by the development and improvement of the following two key HEXs, allowing to reach a thermal COP of 0.6 and an electric COP > 6 for cooling in south Europe, which is higher by 20% and 50% compared to state of the art chillers and heat pumps respectively.

Fig. 17. *Left: standard loose-grains adsorber. Right: envisaged coated adsorber HEX*

Adsorber HEX: The most common method to integrate an adsorbent material inside an adsorber HEX is based on loose adsorbent grains[14]. This approach relies only on point contact between the adsorbent material and the HEX surface, thus limiting the overall heat transfer efficiency and the achievable specific cooling power. A dedicated activity on **direct synthesis of SAPO-34 onto the HEX surface** will use as starting point a patent of FAHREN, for improving the post-synthesis process (see Fig. 17). This will reduce the necessary production time, water and production costs by 10%. Indeed, a pre-washing procedure will allow to reduce the quantity of residual chemicals on the synthesised SAPO-34, thus improving the effectiveness of the subsequent calcination process and the quality of the adsorber HEX, by reducing the possibility of coke formation, and increasing the SAPO-34 purity and available porosity. The developed prototype HEX will guarantee high heat transfer efficiency by up to 40% compared to state of the art[15], and high stability, proved by the high number of ad-/desorption cycles of the adsorbent material of up to 220,000 cycles. Experimental characterisation of the sorption kinetic on lab-scale coated adsorbers has been already performed[16], with the potential to enhance the specific cooling power by up to 40% compared to a typical loose adsorbent grains. The proposed solution is also characterised by high mechanical stability, thanks to the strong interaction between the SAPO-34 and the HEX surface, and high corrosion resistance, due to the protective SAPO-34 layer[17].

[14] Aristov YI, et al. Optimization of adsorption dynamics in adsorptive chillers: Loose grains configuration. Energy 2012;46:484-92.
[15] Wittstadt U, et al. A new adsorbent composite material based on metal fiber technology and its application in adsorption heat exchangers. Energies 2015:8:8431-46.
[16] Freni A, et al. SAPO-34 coated adsorbent heat exchanger for adsorption chillers. Appl Therm Engin 2015;82:1-7.
[17] Herrmann R, et al. Novel adsorption chiller and heat pump based on Partial-Support-Transformation. Sorption Friends Conference, 2015.

Evaporator/condenser: Existing cascade chiller/HP units are based on a hydraulic connection with an additional heat transfer circuit between the condenser of the heat pump and the evaporator of the chiller[18]. This coupling brings heat losses due to the temperature difference between the hot/cold fluids, and increases the manufacturing cost (2 HEXs needed). SolBio-Rev will overcome this drawback by developing an **integrated evaporator/condenser**, based on properly designed HEX (e.g. micro-channel finned HEX, axisymmetric plate HEX), as shown in Fig. 18, allowing for higher system efficiency. The core target is to maximise heat transfer characteristics, thus achieving a 30% increase of cooling power density and seasonal efficiency compared to the current state of the art[18], and reducing the cost and volume of the chiller (only one HEX is needed for this process).

Fig. 18. *Micro-channel finned HEX for the integrated evaporator/condenser*

Reversible heat pump/ORC: A reversible unit has been coupled with solar/geothermal energy[19] for nearly-zero energy buildings, with a COP of over 3 and a moderate ORC thermal efficiency of about 4%, due to poor expansion efficiency (up to 58%) mostly at part load. Similar findings have been reached with lower heat source temperature[20], with a maximum COP of 3.6. The use of ground heat exchangers is site-specific and introduces limitations especially in small or medium-sized buildings. NTUA has instead examined the use of solar/biomass energy for trigeneration, overcoming the site-specific limitations of geothermal energy, and validated in the lab a hybrid reversible system based on an ORC and a heat pump[21] with a separate expander and compressor. An advancement of this set-up concerns the use of a single compressor/expander to further reduce the complexity and equipment cost.

The expertise of NTUA in ORC and HP technologies will be exploited with the support of DAIKIN, in order to overcome the bottlenecks of a reversible HP/ORC unit and reach COP at heating mode over 4.5 at solar-assisted mode and thermal efficiency in the range of 4-8%, depending on the heat source: solar at 85-90 ºC or biomass at up to 120 ºC, which is similar to the state of the art ORC-only solutions[22]. The key is to reach **high performance for the scroll-type expander/compressor**[23] with isentropic efficiency of at least 65-70% at both modes, and an optimal control and sizing of HEXs as a result of steady state and dynamic and optimisation simulations. The pressure/volume ratios across the compressor greatly decide the operating constraints in reverse operation. These ratios mostly depend on the temperatures of heat supply and rejection and on the refrigerant's properties, introducing many optimisation parameters, which will be prioritised when analysing the performance of the reversible unit.

Moreover, SolBio-Rev will hold a **perfect environmental profile**, with the working fluid (refrigerant) having perfect environmental properties (zero ODP, ultra-low GWP), it will be non-toxic and non-flammable, as presented in § 1.3.2, respecting the F-gas Regulation. The newly developed hydrofluoroolefins (HFOs) are perfect choices to replace hydrofluorocarbons (HFCs) that are to be phased-out due to their high GWP, with similar cycle performance[24], ensuring the system sustainability.

Finally, the additional cost for reversing the heat pump is low, requiring only a feed pump and a by-pass circuit, with an estimated extra cost of about 30 €/kW of heating capacity[25]. This corresponds to less than 10% of the heat pump cost for the system scales considered in real-sized buildings.

Solar collector with TEGs: The state of the art solar energy technology for producing both heat and electricity is a **PV/Thermal** (PV/T) collector. This collector can only achieve high efficiencies at low temperatures (< 40-50 ºC) if solar heat cools the PV cells. For higher temperatures, its electric and thermal efficiency greatly decrease, making it not appropriate to operate over 60-70 ºC even during summer[26], and thus not capable of supplying the heat-activated components (ORC, adsorption chiller). Apart from that, its performance during winter is very low. An alternative technology is to use a **vacuum tube solar collector with TEGs**[27], with the latter being integrated directly into the heat pipes of the collector. This concept utilises all produced solar heat, but has major drawbacks: (1) TEGs bring an

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[19] Dumont O, Quoilin S, Lemort V. Experimental investigation of a reversible heat pump/organic Rankine cycle unit designed to be coupled with a passive house to get a Net Zero Energy Building. Int J Refrigeration 2015;54:190-203.
[20] He Z, Zhang Y, Wu Z, Ma H, Dong S. Experimental study on a bifunctional heat utilization system of heat pump and power generation using low-grade heat source. Appl Therm Engin 2017;124:71-82.
[21] Karellas S, Braimakis K. Energy–exergy analysis and economic investigation of a cogeneration and trigeneration ORC–VCC hybrid system utilizing biomass fuel and solar power. Energy Convers Manage 2016;107:103-13.
[22] Ntavou E, et al. Experimental testing of a small-scale two stage ORC engine operating at low temperature. Energy 2017;141:869-79.
[23] Staub S, et al. Reversible Heat Pump–ORC Systems for the Storage of Renewable Electricity. Energies 2018;11(6):1352.
[24] Li J, Liu Q, Ge Z, Duan Y, Yang Z. Thermodynamic Performance Analyses and Optimization of Subcritical and Transcritical Organic Rankine Cycles using R1234ze(E) for 100–200 C Heat Sources. Energy Convers Manage 2017;149:140–54.
[25] Schimpf S, Span R. Techno-economic evaluation of a solar assisted combined heat pump – Organic Rankine Cycle system. Energy Convers Manage 2015;94:430-7.
[26] Koronaki IP, Nitsas MT. Experimental and theoretical performance investigation of asymmetric photovoltaic/thermal hybrid solar collectors connected in series. Renew Energy 2018;118:654-72.
[27] He W, et al. A study on incorporation of thermoelectric modules with evacuated-tube HP solar collectors. Renew Energy 2012;37(1):142-9.

important thermal resistance between the condensing part of the heat pipe and the cold water flow, restricting the effective heat transfer (TEGs have low heat transfer coefficient) and without having the ability to de-couple them from the heat flow, (2) many additional parts are necessary, increasing the complexity and cost of this solution, and most importantly (3) the temperature differences are very low (~ 10-20 K) greatly reducing the TEG efficiency.

A core advantage of the proposed solar TEG system concerns the ability to fully control its operation (on/off operation), not affecting the solar heat production at moments when high-grade heat is supplied to the ORC or the chiller (both require heat above 80 °C for efficient operation). In addition, the collector's thermal efficiency is kept the same, without affecting the operation of the vacuum tubes. To achieve this, the additional annual electricity production is low compared to the thermal yield (up to 10%), with the TEG capacity selected as a fraction of collector heat capacity (this fraction will be the result of an optimisation study).

TEGs have no moving parts and thus are mostly used in conditions where reliability and low maintenance surpass the need for high efficiency. This makes them a suitable match for solar thermal collectors, which have high demands on reliability. For applications with temperature below 200 °C, commercial/standard TEGs are made of bismuth telluride (Bi_2Te_3), shown in Fig. 19, with a ZT value up to 1 (thermoelectric efficiency), making this material the benchmark in TEG technology. They show a thermal efficiency in the range of 2-5%, according to the temperature difference. The cost of these standard TEGs are currently in the range of 20-50 €/We (for ΔT ~ 60 K) with a slowly declining trend. However, they have significant environmental impact[28] (e.g. toxicity), and on top of that Tellurium is a rare-earth material with volatile resource price.

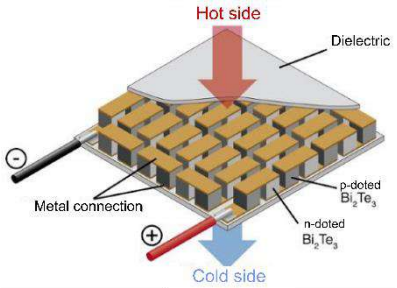

Fig. 19. *TEG made of Bi_2Te_3*

Fig. 20. *Printed and folded KIT TEG*

As an alternative TEG technology, the KIT has developed a new production method via roll-to-roll printing, with a great potential in terms of cost and performance. The core of this innovative method is the use of specially developed and liquid processable semiconductor materials, with perfect environmental properties (e.g. recyclable, non-toxic, safe, abundant materials). The combination of these low-cost materials with large industrial printing and patented folding processes allow the development of new generation of TEGs for heat conversion (see Fig. 20), with the production capacity easily up-scaled to produce large surface TEGs. Especially with regard to a possible commercialisation in 2025, the printed TEGs with a targeted value of 1-2 €/We (for ΔT ~ 60 K) show superior economic potential compared to conventional (high-quality) TEGs.

Biomass boiler for cogeneration: The use of biomass is locally independent (in contrast to geothermal energy) with the option to use sustainable biomass resources (e.g. pellets with similar quality all over Europe, and available even in urban areas) in cogeneration mode. CHP merges the commonly split generation of heat and electricity with higher overall efficiency[29], and approaching even 90%. A domestic biomass boiler will be thus developed based on the OKOFEN pellet boiler design, capable of supplying high amounts of heat to the ORC, with high efficiency and reduced air pollutants, while keeping its cost at the same level as that of the commercial OKOFEN boilers.

In principle, the boiler efficiency is improved by decreasing: **(1)** the *flue gas temperature* by integrating an external HEX for flue gas heat recovery, without being able to deliver high-T heat to the ORC and is not opted for SolBio-Rev, or **(2)** the *flue gas mass flow rate* by pushing the air-to-fuel ratio closer to stoichiometric conditions (λ→1, from λ=2), requiring to cool the combustion chamber for not exceeding the ash-melting temperature of biomass fuel[30]. The reduction of flue gas rates is done with the use of EGR, increasing the boiler efficiency by about 4%, as shown in Fig. 21, with the necessary cooling accomplished with an internal HEX placed near the grate for delivering high-T heat to the ORC. The use of a slightly pressurised cycle based on standard pipes allows to reduce the boiler cost and to use this technology for retrofitting existing boilers as well.

EGR except from leading to higher boiler efficiency with lower excess air of combustion, has a large effect on emissions reduction. EGR is a common technique in industrial boilers for reducing combustion temperatures and is combined with air staging to reduce NOx emissions by over 30% compared to standard boiler design[31]. However, EGR is not established in domestic boilers, mainly because there are no emission limits for NOx (only for CO and

[28] Champier D. Thermoelectric generators: A review of applications. Energy Convers Manage 2017;140:167-81.
[29] Mago PJ, Hueffed A, Chamra LM. Analysis and optimization of the use of CHP-ORC systems for small commercial buildings. Energy and Buildings 2010;42(9):1491–8.
[30] Karl J. Dezentrale Energiesysteme, vol. 3. Auflage, no. 1. München: Oldenburg Verlag, 2012.
[31] Houshfar E, Khalil RA, Løvås T, Skreiberg Ø. Enhanced NOx reduction by combined staged air and flue gas recirculation in biomass grate combustion. Energy and Fuels 2012;26(5):3003–11.

PM), which will probably change in the upcoming regulations.

On the other hand, domestic boilers typically operate with a staged combustion, limiting the NOx reduction potential with EGR up to 20-30%. The effect of EGR on other emissions (CO, PMs, and SOx) is minor, depending on the boiler type as well[32]. This makes it necessary to focus on the combined reduction of all emissions as a function of achievable efficiency. SOx is merely depending on the sulphur content of the fuel and is negligible for woody biomass. The aim of SolBio-Rev is to achieve a NOx reduction of over 20%, accompanied by a minor reduction of other air pollutant emissions, while at the same time ensure a cogeneration efficiency of at least 94%.

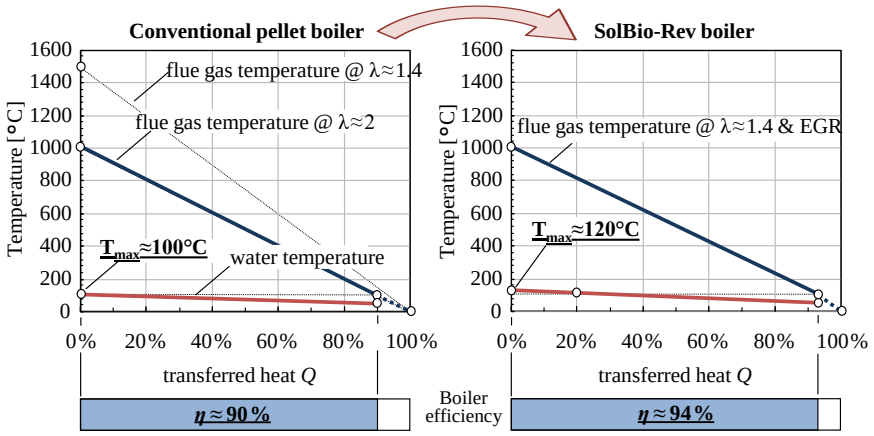

Fig. 21. *Thermodynamic advantages of EGR for high boiler efficiency*

At **components level,** the SolBio-Rev ambitions are summarised as follows:

- ✓ **Increase the heat transfer characteristics and compactness of the cascade chiller with heat pump**, by developing an advanced adsorber HEX based on a patented direct crystallisation coating technique, and an integrated evaporator/condenser, for superior coupling of the chiller with the HP.
- ✓ **Develop a reversible heat pump/ORC unit** that shows high performance under both modes, with limited cost increase and a minimum footprint, with its refrigerant having **perfect environmental properties**.
- ✓ **Develop a highly flexible solar thermal system by integrating a new generation of printed TEGs** with low environmental impact, for heat and electricity production, and exploit all (wasted) heat sources.
- ✓ **Develop the biomass boiler** for CHP operation by supplying high-T heat to the ORC with an optimised internal HEX, combined with EGR for increased efficiency and reduced emissions.

SolBio-Rev ambition at configuration level – the heat pump-based configuration

State of the art heat pumps for heating and cooling in buildings involve: (1) electrically-driven heat pumps featuring advanced cycle designs[33], multiple stages/compressors with heat recuperation, or ejectors, and (2) thermally-driven chillers based on adsorption technology, focusing on improved cycle designs[34], the use of highly-stable sorption materials, and the reduction of their costs[35]. In order to also produce electricity and increase the energy share, additional components are necessary, such as: (1) PVs, and (2) cogeneration units, supplied with heat from solar and/or biomass for increasing their capacity factor. This approach of using separate components for heating, cooling and electricity (see left Fig. 22) greatly increases the complexity and the final system cost. It is also subject to restrictions related to the buildings' available surface and the control environment, since their combined operation is not optimised.

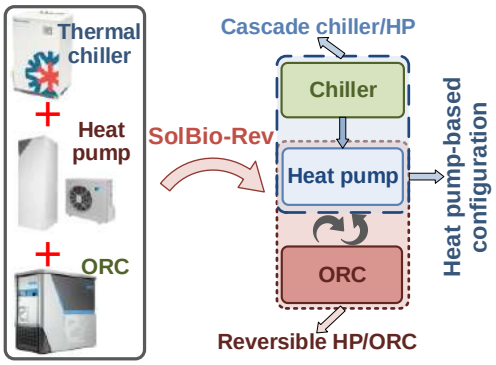

Fig. 22. *Left: Separate components for heating, cooling, electricity. Right: Novel heat pump-based configuration*

The proposed heat pump-based configuration hosts both a vapour compression heat pump and a thermally-driven chiller, effectively coupled with the dedicated HEX. At the same time, the heat pump reverses its operation for power production (ORC mode), **sharing many parts**, and enhancing their integration. Thus, all components are developed to work together with a single controller, eliminating any compatibility issues. This makes it possible to reach **high performance and compactness**, as shown in Fig. 22 (right). Further advantages are the high flexibility (operation according to the energy demand) and modularity with its size easily adapted to match the energy needs of various buildings. The overall outcome is the reduction of volume by 30% and cost by 20-30% (at commercial level) compared to a similar system with separate components.

[32] Hasler P, Nussbaumer T. Particle Size Distribution of the Fly Ash from Biomass Combustion. 10th European Conference and Technology Exhibition, 1998, pp. 8–11.
[33] Arpagaus C, Bless F, Schiffmann J, Bertsch SS. Multi-temperature heat pumps: A literature review. Int J Refrig 2016;69:437-65.
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[35] Ziegler F. Sorption heat pumping technologies: comparisons and challenges. Int J Refrig 2009;32(4):566-76.

At **configuration level,** the SolBio-Rev ambitions are summarised as follows:

- ✓ **Develop the heat pump-based configuration** that is at the core of the SolBio-Rev system with high flexibility for trigeneration production, and enhanced modularity and flexibility of operating mode.
- ✓ **Experimentally investigate and optimise** *the integration of the cascade chiller with the reversible heat pump/ORC unit for trigeneration.*
- ✓ **Demonstrate a high compactness (30% lower volume) and a cost reduction of about 20-30%**, compared to having separate components, while covering the same energy needs.

SolBio-Rev ambition at control level

The key challenge at control level is the optimisation of the control, operation and monitoring system to **automatically manage the different operating modes, depending on the real-time energy supply/demand balance**. An essential element of the control algorithms is self-learning to adapt to the characteristics of the building and load, the nature and variability to the heat source (solar, biomass) and to the behaviour patterns of the users. The controller will store user profiles to determine optimum operation and thus adopting system set-points, while it will record user behaviour to extend operation of the system, and minimise the energy use.

State of the art controllers use conventional algorithms and control hardware (distributed control, DSC) with scarce implementation of advanced smart control in the building sector. The SolBio-Rev control system will be based on Model Predictive Control (MPC)[36] and on building's Digital Data Control (DDC) with dedicated CPU with flash memory capable of storing control algorithms and trend-data, ensuring the optimisation of system operation[37]. The control system will also supervise the remote monitoring unit, preventing any major failures. Another integrated feature is a direct communication with local weather station, enabling it to adjust the heating/cooling supply and minimise the use of the biomass boiler and the loading of the short-term heat storage and the thermal buffer tanks in case adequate solar radiation is expected. Deep learning techniques will be used to estimate the heating/cooling demand[38] based on weather forecasts and the occupancy behaviour.

Finally, the controller will provide a web interface for user interaction through a standard web-browser (from a PC or a smart device: phone, tablet) and support its users and/or the building manager by e-mail alarming and reporting about the system's operation, while enabling remote access and/or configuration. Moreover, it will be equipped with an interface for coupling with any commercial BEMS, in case one exists, in order to effectively combine the SolBio-Rev system with new and/or existing appliances, and enhance interoperability.

At **control level,** SolBio-Rev ambitions are summarised as follows:

- ✓ **Development** of control unit to manage the system modes according to supply/demand balance.
- ✓ **Optimisation** of system operation by automatic switching of heat supply between the solar collectors, the heat pump and the biomass boiler.
- ✓ Option for **integration to BEMS** for overall facility management & energy demand optimisation.
- ✓ **Enable services** for: (1) preventive and restoring maintenance, (2) user-friendliness operation, (3) adjusting operation according to weather forecasts, and (4) remote operation and reporting.

SolBio-Rev ambition at social level

Social acceptance of any emerging technology is a prerequisite for its uptake and further diffusion. This is the case especially for energy technologies that address energy supply/demand in new ways, and implicate the users. Thus, recent conceptual work on social acceptance of new technologies[39] will be drawn. This will be combined with a sustainability transitions perspective that adopts a systemic perspective on energy system change, and sees users as an important actor in a broader network of actors in accelerating energy transitions[40]. Thus in addition to acceptance, challenges and opportunities for actual uptake will be examined.

The nature and quality of the energy services delivered to users, and the extent to which these are divergent from the

[36] Blevins T, Wojsznis W. Advances in model predictive control - Advances in processors and memory make it possible to embed MPC in the DCS, http://www.controlglobal.com, Jun 28, 2015.
[37] Stadler P, Girardin L, Ashouri A, Maréchal F. Contribution of model predictive control in the integration of renewable energy sources within the built environment. Frontiers in Energy Research 2018;6:22.
[38] Mocanu E, et al. Deep learning for estimating building energy consumption. Sustainable Energy, Grids and Networks 2016;6:91-9.
[39] Devine-Wright P, Batel S, Aas O, Sovacool BK, LaBelle MC, Ruud A. A conceptual framework for understanding the social acceptance of energy infrastructure: Insights from energy storage. Energy Policy 2017;107:27–31.
[40] Hyysalo S, et al. Energy Internet forums as acceleration phase transition intermediaries. Research Policy 2018;47:872–85.

characteristics of existing energy service provision, will be crucial for social acceptance and uptake. Equally, the technical characteristics of the SolBio-Rev concept and the current practices and knowledge of installers, will influence how they perceive the concept, and communicate its features to users/customers.

At **social level,** the SolBio-Rev ambitions are summarised as follows:

- ✓ Examine **social acceptance** of the SolBio-Rev concept amongst key stakeholder groups.
- ✓ Identify **opportunities and challenges** for the uptake of SolBio-Rev amongst installers, users, policy makers.
- ✓ Provide insights into how SolBio-Rev can **engage with end-user groups**.

SolBio-Rev ambition for the integrated renewable energy system

The most commercially diffused technologies of renewable energy utilisation in buildings include:

- ✓ Solar thermal collectors for DHW/space heating, with typical energy share of about 50% for DHW (5-10% of total share) and 25-40% for combi-systems in central/north Europe[41].
- ✓ PV panels for electricity production with energy share of up to 20% (large fraction of electricity needs only).
- ✓ Biomass-CHP units that face high investment costs[42] (> 5,000 €/kW_e), resulting to a limited market share[43]. Their typical energy share is up to 30-40%, but show low capacity factor (operation mostly in winter).
- ✓ Heat pumps for heating/cooling, associated with high capital costs but with good performance. They also require backup energy supply under very hot or cold ambient conditions.
- ✓ Heat pumps combined with geothermal energy (→ geothermal heat pump), or PVs (→ PV with heat pump), in order to reduce operating costs. Typical energy shares of these combinations are up to 40%.

Solar-based technologies are highly dependent on solar availability. Moreover, their intermittency (during seasons, days, hours) requires either the installation of backup, on-demand, equipment (e.g. gas boilers) or energy storage systems. The capacity of the latter should be high to offer seasonal storage features, introducing high costs, especially if advanced materials are used for storing thermal energy (e.g. phase-change materials), or electricity storage is used (e.g. Li-ion battery stacks). Furthermore, solar-based and biomass-CHP technologies are capable of producing heat and electricity. In order to also provide space cooling and increase the energy share to > 50%, additional equipment is necessary, such as a thermally driven (sorption) chiller with a cost of about 900-1,000 €/kW (SHC-IEA, Task 48).

Considering the above, in order to ensure a high energy share throughout the year in different climatic zones, the installation of highly adaptable and efficient, hybrid multi-generation renewable energy systems are necessary, as the above listed ones. The SolBio-Rev effectively integrates many of these concepts (except from PVs and geothermal energy), and invests on its components' synergistic operation, in order to reach highly compact solutions, and reduce the cost. Once this is combined with the dedicated advanced control, and the technology is validated in diverse climates, a very high energy share will be achieved, approaching 85% in new EU buildings.

The **overall ambitions** of the **SolBio-Rev system** are summarised as follows:

- ✓ Reach **compact solutions** that can be **integrated in new or existing buildings of different types**.
- ✓ **Potential to reach similar system cost** compared to other renewable energy systems in buildings, but with higher energy savings and a shorter PBP.
- ✓ Optimised system design and sizing for achieving **a very high energy share up to 85% all over Europe**.
- ✓ **Validation** of SolBio-Rev system (TRL5) at two different climatic conditions and **preparation of its further development stages**.

1.4.2 Cost-benefit ambition

A detailed cost-benefit analysis is presented between the main competing solutions with moderate/high energy share, supporting evidence for the market potential of SolBio-Rev in both new and renovated buildings. To fully account for the potential developments of alternative solutions, the cost-benefit analysis is performed not only looking at the current available technology, but also taking into account promising developments, i.e. PVs combined with heat

[41] Infante Ferreira C, Kim D-S. Techno-economic review of solar cooling technologies based on location-specific data. Int J Refrig 2014;39(Supplement C):23-37.
[42] Maraver D, Sin A, Royo J, Sebastián F. Assessment of CCHP systems based on biomass combustion for small-scale applications through a review of the technology and analysis of energy efficiency parameters. Appl Energy 2013;102:1303-13.
[43] European Technology Platform on Renewable Heating and Cooling. Strategic Research and Innovation Agenda for RHC, 2013.

pumps[44]. These competing solutions are presented in Table 5, with their advantages/disadvantages compared to the two SolBio-Rev system versions.

Table 5. Competing solutions with advantages/disadvantages compared to SolBio-Rev solution

Solutions	Advantages	Disadvantages
Solution 1: Solar thermal collectors with biomass-CHP for heating and electricity	Existing technology with few biomass-CHP manufacturers (TRL9). Exploitation of heat during all seasons. Standard installation and maintenance procedures.	Problematic operation of the power production equipment with solar heat. Suitable only in buildings with DHW demand, for utilising solar heat in summer. No cooling production. Very high cost due to biomass-CHP. Moderate energy share (< 50%).
Solution 2: Solar thermal collectors with thermal chiller for cooling and heating	Existing technology with few chiller manufacturers (TRL9). Exploitation of most of the heat during all seasons. Standard installation and maintenance.	High cost due to chiller and large solar surface. Suitable in areas with cooling needs. Inefficient operation at hot ambient conditions for cooling. No electricity production. Moderate energy share (< 40%)
Solution 3: Solar PV with heat pump	Technology demonstrated (TRL6-7). Conversion of PV electricity to heating-cooling according to the demand.	Advanced control needed. Conversion losses (except if DC operation). Backup heating solution required (e.g. gas boiler). Moderate energy share (< 30-40%).
Solution 4: Geothermal heat pump for heating/cooling	Existing technology with many manufacturers (TRL9). High COP for both heating and cooling (~4).	Site-specific. Very high costs for drilling → suitable for large buildings. No electricity production. Moderate energy share (< 20-35%).
Solution 5: SolBio-Rev system	1st version: Covering all heating and cooling. Energy share 53-80%. 2nd version: Covering additionally the maximum share of electricity. Energy share 58-85%.	

The cost-benefit analysis is provided in the next paragraphs, which quantifies a typical, non-optimised, sizing (e.g. solar surface) and cost estimates for equipment plus installation costs for the solutions of Table 5. The maintenance cost is considered to be the same for all solutions. According to this sizing, the energy needs, the energy share of each solution and annual energy costs are calculated for the two reference (new) buildings of Table 1 (with a 1,000 m^2 surface each). For that purpose, the most recent local energy prices are used for both household and non-household consumers for gas (for heating) and electricity (for cooling as well), according to Eurostat (2017 prices), and an average cost of dry biomass (wood pellets) in EU equal to 200 €/ton (IEA, 2017).

The main components of the above solutions for both buildings are: (1) Vacuum tube solar collectors by Kingspan (type HP400), with high efficiency, as the AKOTEC one, (2) thermal chiller product by FAHREN, (3) heat pump Altherma by DAIKIN, (4) PV panels by Panasonic (type N24047), and (5) biomass-CHP unit by OKOFEN with Stirling engine (type Pelematic e-max). Their costs are communicated by the industrial partners, supplemented by commercial prices. All the above solutions include a gas boiler, either as the main heat source or as backup with heat pumps. The **reference solution** includes a gas boiler for heating (cost/building: from 7,000 € in south Europe up to 10,000 € in north Europe), split air-conditioning for MFBs (cost/dwelling: 1,200 € in south Europe, 1,000 € in central Europe) and central chiller for offices (cost/building: 20,000 € in south Europe, 15,000 € in central Europe).

The analysis is based on the calculation of the payback period (PBP) compared to the reference solution for the three representative locations (Athens, Berlin and Stockholm) for both building types of the same size of 1,000 m^2. The building size has a minor effect on PBP for the scales considered, as will be presented later in § 2.1.1.

Cost benefit analysis for New multi-family residential building:

Two versions of the SolBio-Rev are examined, as shown in Table 5. The costs of the solutions in the MFB are projected to 2025, given in Fig. 23 for the three locations in south/central/north Europe, indicating their uncertainty (e.g. low/zero uncertainty for high-TRL solution). *Solution 2* (STC+chiller) is applied in north Europe without the chiller, ending up to solar collector-only solution with lower cost. The uncertainty factor for SolBio-Rev also considers the successful achievement of project objectives and is thus higher than the other solutions.

The 1st SolBio-Rev version for only heating/cooling has a similar cost as the other solutions, due to its high compactness and synergistic operation. This aspect **removes any market barrier related to the high initial cost**. The above are achieved, while covering a high energy share of about 75%.

The 2nd SolBio-Rev version that additionally covers the maximum share of electricity shows an increased cost due to the large number of collectors, covering a very high energy share of up to 85% in all three regions. The market barrier of the higher up-front cost by 50-60% compared to the other solutions will be examined in the project with

[44] Braimakis K, Thimo A, Karellas S. Technoeconomic analysis and comparison of a solar-based biomass ORC-VCC system and a PV heat pump for domestic trigeneration. J Energy Engin 2016;143(2):04016048.

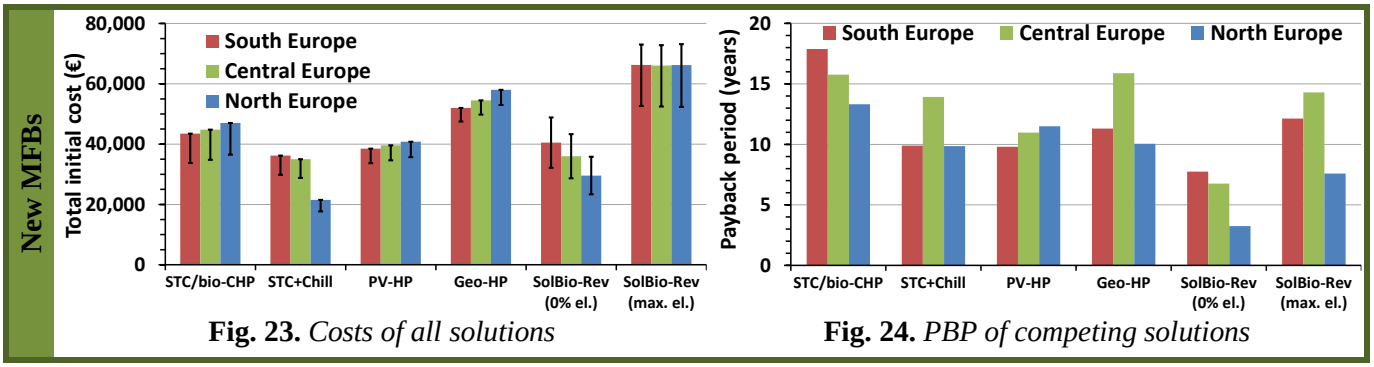


Fig. 23. *Costs of all solutions*

Fig. 24. *PBP of competing solutions*

Figure 24 shows the PBP results for the competing solutions in the new 1,000-m^2 MFB. *PBP is defined* as excess investment cost of each solution compared to the reference one, divided by annual energy savings. The SolBio-Rev is very cost-effective for covering only heating and cooling in all three regions, with a **very short PBP of < 7 years** (similar initial cost as the reference one, but with very high energy savings). The SolBio-Rev is less cost-effective, when more collectors are installed for reaching the maximum possible electricity production (2nd system version), with a **PBP of 12-14 years in south and central Europe, reducing to 8 years in north Europe**. The favourable PBP in Stockholm is due to the high gas price and no need for cooling, allowing to use all solar heat for electricity production during summer. In general, the higher PBP for this case compared to the 1st SolBio-Rev version is because the solar surface greatly increases, resulting to higher equipment cost, as shown in Fig. 23. The other (promising) competing solutions show a PBP of more than 10 years with moderate energy savings. The two versions of SolBio-Rev promise much higher savings with the 1st version being ideal **"value for money"** solution, and implemented in MFBs with less complexities relevant to the sharing of the generated electricity among the swellings owners/users.

In case the **energy prices** continue to increase (2017 prices considered), the benefits will be even higher. A simplified example concerns their annual increase of 1.5% for both electricity and gas. This results to PBP reduction by 18% in 2025, reducing the PBP to > 5 years for the 1st SolBio-Rev version, and to 6-10 years for the 2nd version.

Cost benefit analysis for New commercial building:

A similar analysis has been conducted for a new commercial building, considering the solutions of Table 5, except from *Solution 1* (solar with biomass-CHP), since it is not suitable for commercial buildings without DHW demand. Figure 25 shows their equipment cost, with their uncertainty for 2025. The same equipment is also considered here.

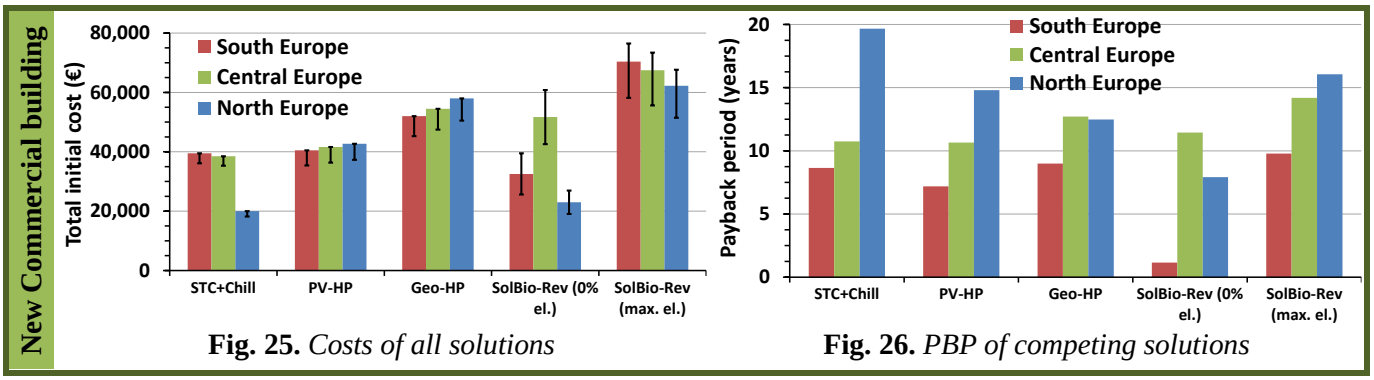


Fig. 25. *Costs of all solutions*

Fig. 26. *PBP of competing solutions*

The solution of collectors with the thermal chiller shows the lowest cost, but is associated with a low energy share, due to the low fraction of heating. On the other hand, the geothermal heat pump solution brings a high COP of 4 for both heating and cooling, but has very high initial cost. The cost of the 1st SolBio-Rev version is again similar as the reference one (in Germany its higher cost is due to the many collectors needed to cover the cooling needs in this type of buildings), with the 2nd system version having a higher cost by 60%, while covering a much higher energy share.

The cost-effectiveness of SolBio-Rev is shown by the PBP calculations, presented in Fig. 26 for the competing solutions in the new 1,000-m^2 commercial building. The SolBio-Rev is cost-effective for covering only heating and cooling (1st version), with a **PBP of 2 years in south Europe**, with high cooling needs. On the other hand, it shows a much longer PBP in Berlin, with high electricity price even for non-household consumers (0.15 €/kWh), due to the high cooling needs, requiring to increase the solar surface.

The 2nd SolBio-Rev version shows a long PBP of 10-16 years. This is mainly because of the high specific electric needs of this type of buildings. Therefore, the 1st SolBio-Rev version seems more attractive in this type of buildings to cover only all heating and cooling needs (including the electricity needed to run the system).

For renovations with high specific energy demand (see § 1.3.4), the energy savings are even higher for covering heating and cooling. *PBP is defined* as the SolBio-Rev investment cost divided by annual energy savings compared to the reference solution. The calculations show that the **PBP is 9-11 years in Athens and Berlin, reducing to just 4 years in Stockholm in MFBs**, due to the large amounts of gas required with high gas price in Sweden. In commercial buildings, a **PBP of about 15-18 years** is reached with the SolBio-Rev system for heating/cooling. This makes it necessary to work together with passive measures for increasing the building energy performance (e.g. wall insulation, double-glazing), before applying the SolBio-Rev solution.

In any case, the specific cost of SolBio-Rev per living area is 40-45 €/m^2 in MFBs and 70-80 €/m^2 in commercial ones, reaching a very low specific energy demand of 12 kWh/m^2/year in MFBs and 40 kWh/m^2/year in commercial ones. These are compared to the average deep renovation cost in EU[45], which is ~ 580 €/m^2 (> 8 times higher), reaching similar energy performance levels, and favouring the SolBio-Rev compared to the renovation level.

The SolBio-Rev system is suitable for installation in either new or refurbished buildings in the three main zones in EU, having **even similar cost to that of its competing solutions**, and demonstrating a short PBP. A detailed cost-benefit analysis will be conducted in WP7, considering a larger variety of buildings types/sizes/locations to support these findings, and become the base for further developing the technology.

1.4.3 Ambition for applying the SolBio-Rev solution in different building types

The SolBio-Rev system is mostly suitable in buildings with a high ratio of heating and cooling needs compared to electricity. Buildings perfectly matching these requirements are **MFBs** in all EU climatic zones, as well as **hotels and restaurants**, which show even higher heating and cooling demand than MFBs, and represent 12% of energy consumption of non-residential buildings (BPIE report). Other targeted building types are **commercial buildings** (both private and public owned, e.g. offices), for which an extensive analysis has been presented in the previous sections. Their energy consumption is similar to the **wholesale and retail trade buildings**, which usually have less storeys, resulting to an even higher rooftop surface than commercial ones for the same surface area. These two types represent about the half energy consumption of the non-residential buildings in EU (BPIE report). The energy needs of educational buildings (e.g. schools), healthcare (e.g. hospitals), sports (e.g. swimming pools), and industrial buildings (e.g. warehouses) also match to the SolBio-Rev features, with the ambition in those types provided next.

- ✓ **Educational buildings**. These buildings are not occupied for the whole year (e.g. not during summer holidays, weekends), making it necessary to apply the SolBio-Rev only for heating and cooling, otherwise large amounts of electricity will not be utilised. They have usually few storeys, increasing their rooftop availability per m^2 of living surface, and thus not imposing any restriction on the collectors' surface.
- ✓ **Healthcare buildings**. They show a very high energy demand (for DHW as well), and they usually have a large number of storeys, and important restrictions on the rooftop availability. Therefore, the SolBio-Rev system can be applied for covering only heating and cooling and work together with their backup devices (e.g. gas boilers).
- ✓ **Sports buildings**. They usually have 1-2 storeys with large rooftop area. Their specific volume (volume per m^2 of surface) is high, resulting to high heating and cooling needs. They also have very high DHW demand, but low electricity needs (mostly for lighting). Therefore, the SolBio-Rev system is suitable to supply all heating and cooling and a significant fraction of electric needs, with an energy share > 75%.
- ✓ **Industrial buildings**. Their energy needs are similar to sports buildings (without considering the energy for industrial processes) with a main difference their very low DHW needs. Therefore, the SolBio-Rev system can be applied either for all heating and cooling or additionally a fraction of electricity.

The SolBio-Rev flexibility is valuable in the case of renovations, as presented in § 1.3.4, making it possible to include many parts of the existing infrastructure (e.g. gas boiler, PV), and proceed to minimal interventions. This introduces an energy share penalty, which can be minimised with higher loading of the heat pump-based configuration and the fine-tuning of the controller to take into account the standard components, and their smooth integration in the overall solution. This flexibility is also welcomed in high-rise buildings, requiring to either install collectors at the façade or use any other heating source (e.g. district heating, gas boiler), in order to hold a high energy share.

The **SolBio-Rev solution is intended for a variety of buildings, new or renovated,** and depending on their rooftop availability and energy needs, different system versions can be applied, owing to its high modularity and flexibility. Integration in buildings will be examined in WP7, supported with the system simulation results for different building types and locations, to identify the energy share potential.

[45] DG for Internal Policies: Economic and Scientific Policy – Boosting Building Renovation: What potential and value for Europe?

1.4.4 Innovation potential

The main features of the commercial and state-of-the-art technology and of the SolBio-Rev innovative aspects are highlighted in Table 8, demonstrating the innovation potential of SolBio-Rev solution.

Table 8. Improvement and target values of the SolBio-Rev solution and its key components

Component	Parameter		Commercial/state-of-the-art	SolBio-Rev
Cascade adsorption chiller/heat pump (FAHREN, DAIKIN)	Specific cooling power of adsorber HEX at specified conditions (kW/m^3)		50-75 (FAHREN and other state of the art adsorption chillers)	> 90
	Electric COP for cooling (-)		3.5-4 (electrical heat pump) 4.5-5 (cascade chiller/HP)	6-6.5
	Thermal COP for cooling (-)		0.3-0.5 (thermal chiller) 0.4-0.5 (cascade chiller/HP)	0.5-0.6
	Cost at specified conditions (€/kW)		900-1,000 (FAHREN and other state of the art adsorption chillers)	800-850
Reversible heat pump/ORC (DAIKIN)	Electric COP for heating (-)		< 4 (for geothermal heat pumps) < 3.5 (for standard heat pumps)	> 4.5 (solar-assisted)
	Cost (€/kWth)		300-350 (for real-sized units)	320-360 (reversible mode)
Solar thermal collectors with TEGs (AKOTEC, KIT)	Cost of collector (€/m²)		300-350 (vacuum tube collector) > 250-300 (PV/T collector)	340-360 (with TEGs for electricity production)
	Annual energy yield in Germany (kWh/m^2)		451 (vacuum tube collector, heat only) 300 (PV/T, 220/80 of heat/electricity)	481-501 (451/30-50 of heat/electricity)
Biomass boiler for CHP (OKOFEN)	CHP efficiency (%)		85-90	> 94
	Cost (€/kWth)		400-600	500-600
	Emissions (mg/kWh) at typical 13% O_2	NOx	250-300 (OKOFEN and SoA boilers)	180-220
		CO	200-220 (OKOFEN and SoA boilers)	< 200
		PM	28-35 (OKOFEN and SoA boilers)	< 25
		Total	478-555 (OKOFEN and SoA boilers)	< 445
SolBio-Rev solution (all industrial partners)	Energy share covered by renewables in buildings[46] (%)		< 50 (STC and biomass-CHP in MFBs) < 40 (STC with chiller) < 40 (PVs and heat pumps) < 35 (geothermal heat pumps)	Up to 85 (respecting the rooftop availability)
	PBP (years) compared to reference solutions in 2025		> 13 (STC and biomass-CHP in MFBs) 8-10 (STC with chiller) 7-11 (PVs and heat pumps) 9-15 (geothermal heat pumps)	New buildings: 4-7 in MFBs, 2-12 in offices Renovated buildings: 4-11 in MFBs, 15-18 in offices

It becomes clear that the SolBio-Rev solution outperforms the commercial and state-of-the-art ones, having higher compactness mainly due to the heat pump-based configuration, and high performance. These features result in a similar cost compared to other renewable energy-based systems with lower energy share, making it possible to be successfully commercialised after the technology validation and further development stages.

1.4.5 Freedom to operate

A patent search has been already carried out that showed that there is "freedom to operate". The industrial and research partners have secured their background knowledge/IP (thermoelectric materials, HEXs, heat pumps), see § 2.2.3. Permission to use any of the IP belonging to a partner by any other partner will be defined in the Consortium Agreement. The solar-TEG concept and the principle of combining solar with biomass heat for supplying a heat pump-based configuration are state of the art and free of patents. The coating technology on the adsorber HEX belongs to ITAE and UNIME, and KIT holds a patent on the TEG production process. It is planned to generate new IP and/or utility models in the solar-TEGs, the reversible heat pump/ORC, and the heat pump-based configuration, which can lead to their protection through joint patent(s) application.

[46] Urchueguía JF, et al. Common Implementation Roadmap for Renewable Heating and Cooling Technologies. European Technology Platform on Renewable Heating and Cooling, 2014.

2. Impact

2.1 Expected impacts

2.1.1 Work programme impact

The work is in alignment with the ambitions of EU in the field of "*Low Carbon Economy*" for developing new renewable energy-based systems with a very high energy share for heating, cooling and electricity in buildings. The expected impacts of the work programme and how they are addressed by the SolBio-Rev project are described next.

Develop solutions that will **reduce the dependence on fossil fuels** …

The very high energy share of the SolBio-Rev solution results to a **reduction of the dependence on fossil fuels by up to 70%**, thus aiding on EU energy security of supply, for: (1) **heating** with gas commonly used in EU, with boiler efficiency of 90%, (2) **cooling** with standard electrical chillers or air-conditioners (powered by grid electricity generated from fossil fuels), with an average COP of 2.5, and (3) **electricity needs** from gas-fired power plants, with a typical thermal efficiency of 40%, including transmission and conversion losses.

The fossil fuel dependence (equivalent to gas and energy for presentation purposes) of the two reference buildings of Table 1 is shown in Table 9. The required gas amount to cover their energy needs is about 10,000 m^3/year for the MFB and 17,000 m^3/year for the commercial building. These amounts have been calculated based on the average conversion factor of the gas heating value (34.58 MJ/Nm^3), according to the gas produced in countries that supply Europe (e.g. Algeria, Russia, Norway, Netherlands).

Table 9. Fossil fuel dependence of the two reference buildings of 1,000 m^2

Buildings without SolBio-Rev	**New multi-family residential**			**New commercial building**		
	Athens	**Berlin**	**Stockholm**	**Athens**	**Berlin**	**Stockholm**
Gas for heating (MWh/year)	39.0	53.9	66.7	36.7	51.1	61.1
Gas for electricity (MWh/year)	50.0	40.6	37.5	130.0	110.0	100.0
Total gas-equivalent (MWh/year)	89.0	94.5	104.2	166.7	161.1	161.1
Gas amount (1,000-m^3/year)	9.3	9.8	10.8	17.4	16.8	16.8

In order to evaluate the reduction of fossil fuel consumption, two versions of the SolBio-Rev system are considered, as previously: (1) one for covering all heating and cooling, and (2) another that additionally covers the maximum share of electricity according to the rooftop availability, as presented in § 1.3.4. The required gas amounts for these two versions are given in Table 10, as well as the resulting reduction of gas consumption.

Table 10. Fossil fuel dependence of two SolBio-Rev versions in the two reference buildings of 1,000 m^2

Buildings with SolBio-Rev	**New multi-family residential**			**New commercial building**		
For heating and cooling only	**Athens**	**Berlin**	**Stockholm**	**Athens**	**Berlin**	**Stockholm**
Gas for heating (MWh/year)		-			-	
Gas for electricity (MWh/year)		37.5			100.0	
Gas amount (1,000-m^3/year)		3.9			10.4	
Reduction (%)	57.9	60.3	64.0	40.0	38.0	37.9
For heating, cooling and max. el. share	**Athens**	**Berlin**	**Stockholm**	**Athens**	**Berlin**	**Stockholm**
Gas for heating (MWh/year)		-			-	
Gas for electricity (MWh/year)	27.4	30.7	30.0	89.0	96.0	90.0
Gas amount (1,000-m^3/year)	2.8	3.2	3.1	9.3	9.9	9.4
Reduction (%)	69.9	67.3	71.3	46.6	41.1	44.1

The **fossil fuel reduction** is about 60% in MFBs for covering only heating/cooling, while it reaches to 70%, when also covering a fraction of electricity. This reduction is lower in commercial buildings, in the range of 38-46%, due to their high electric needs.

Cost competitiveness with traditional solutions is expected to be achieved by 2025 considering also the effect of economies of scale.

Detailed PBP calculations have been presented in § 1.4.2, demonstrating the cost competitiveness of the SolBio-Rev versions compared to traditional solutions, such as the use of solar thermal collectors or PVs.

The positive findings are further supported by the expected increase of energy prices, making the proposed system even more competitive and decreasing the PBP presented previously. Moreover, a cost decrease of some system parts is expected as of 2025, such as of the chiller, the heat pump and most importantly the TEGs, leading to a total cost reduction of over 20% by 2025, decreasing accordingly the PBP and enhancing the cost-effectiveness of SolBio-Rev. This combined cost reduction is about 30-35% in 2025.

Finally, the **building size** has a direct effect on system sizing. Buildings as of 1,000 m^2 are large enough, with economies of scale only having a minor effect on the PBP. The effect is shown in Fig. 27 for a new MFB in Berlin (similar in other locations) with size from 500 m^2 (very small MFB, 5 dwellings) up to 10,000 m^2 (very large MFB, 100 dwellings). PBP remains nearly the same and equal to 5.8 years for MFBs with sizes larger than 2,000 m^2. The calculations for commercial buildings, which are usually of larger size than MFBs, follow a similar trend with the PBP converging again for a size of over 2,000 m^2.

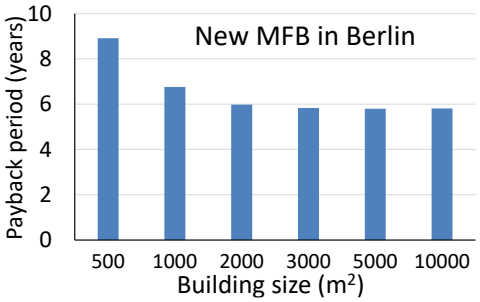


Fig. 27. *PBP of new MFBs of various sizes*

All the above ensure that **SolBio-Rev has a great potential to become very competitive**. The engagement, implementation, and large-scale promotion by SolBio-Rev's stakeholders will enforce successful commercialisation.

2.1.2 Other strategic project impact

SolBio-Rev also has a significant impact on several other social challenges except from reducing the dependency on fossil fuels and introducing cost-efficient solutions. Below, the impacts are presented relevant to the environment/climate, industrial capacity with new business opportunities and growth, and society.

Environmental and climate change mitigation impact

The technologies developed will have extended lifetime expectancy of at least 20 up to 40 years: (1) extremely high cyclic stability of the sorption material of the chiller with corrosion-free HEXs guarantee the chiller lifetime of over 30-40 years, (2) TEGs have similar lifetime over 30-40 years, not having any moving parts, (3) solar thermal collectors, biomass boiler and storage tanks exhibit long lifetime of more than 25-30 years, and the (4) highly innovative reversible heat pump/ORC is expected to reach a similar lifetime of over 20-25 years, since its reliable operation is guaranteed by the employment of parts and components with proven stability. Moreover, SolBio-Rev's materials and components will be selected to maximise their (re-)useability or recyclability, contributing to the circular economy.

Reducing air pollutant emissions: SolBio-Rev solution reduces air pollutants emitted for heating (e.g. from gas/oil boilers) and for electricity production (e.g. from power plants), including cooling production. The air pollutants from biomass will be minimised due to its high combustion efficiency and EGR operation. The overall result is reduced emissions of particulate matter (PM) (almost all from cooling), CO (almost all form heating), NO_X (similar from cooling and heating) and SO_X emissions (almost all from cooling), compared to the same mix of heating and electricity generation from fossil fuels (using a typical energy mix for electricity generation in EU).

The emissions of air pollutants with & without the use of the SolBio-Rev for covering the whole heating & cooling and the maximum share of electricity, are shown in Table 11 for the reference new MFB of 1,000 m^2 in Athens. For these calculations, typical conversion factors, considering EU average values for specific emissions from electricity were taken from a NTUA report, and the expected emissions from the biomass boiler (see § 1.4.4).

Table 11. Air pollutants and reduction in the new MFB in Athens

Reference new MFB of 1,000 m^2 in Athens	Air pollutants (kg/year)				
	NOx	SOx	CO	PM	Total
Without SolBio-Rev	14.28	127.8	10.29	0.79	**153.17**
With SolBio-Rev	6.16	70.18	3.34	0.40	**80.08**
Reduction (%)	**56.9**	**45.1**	**67.6**	**49.4**	**47.7**

Using the SolBio-Rev system, the total avoided air pollutants are 73 kg/year in the MFB in Athens, almost 50% for this building. The reduction of the air pollutants in other locations for the two reference buildings is shown in Fig. 28. It is clear from the different trend between the MFB and the commercial building that a large amount of pollutants results from electric needs. Overall, the pollutants reduction ranges from 20 up to 50% for the MFB and up to 33% for the commercial building.

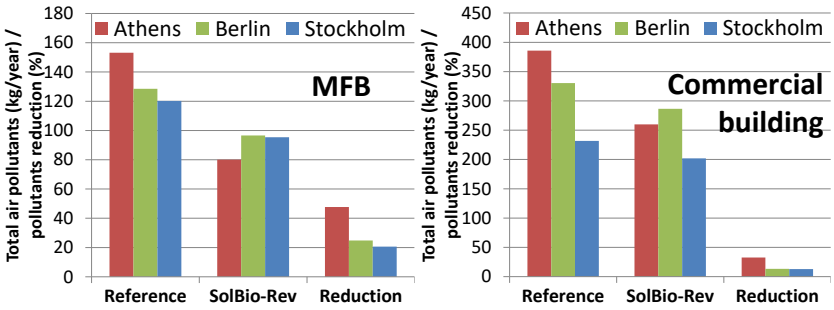


Fig. 28. *Air pollutants and their reduction with the SolBio-Rev system in the reference buildings in the three locations*

Reducing CO_2 emissions: A similar study for CO_2 emissions has been also conducted. The calculations show that the SolBio-Rev reduces these emissions by about 70% in the reference MFB and by 45% in the commercial building. In order to extrapolate these results to all targeted EU buildings (in terms of CO_2 mitigation and energy savings), a simplified analysis based on the building stock is presented next.

The total building stock of multi-family residential buildings in EU is ~7 million, according to the average building by BPIE (similar to the above reference building, according to ENTRANZE) and the dwelling stock (115 million) by Odyssee-Mure data. The number of EU non-residential buildings stock is about 15 million with a large variation of types and sizes. The addressable building stock is lower since some of those buildings are not appropriate for applying the SolBio-Rev, possibly due to: (1) high shading and inappropriate orientation, (2) high-rise buildings or buildings with a very small rooftop, (3) residential buildings with no permanent occupancy (e.g. country houses), and (4) buildings with extremely high electricity demand and low heating/cooling needs. It is estimated that the addressable market size is thus reduced by a conservative 50%, ending up to a total stock of 11 million buildings.

The buildings sector in EU accounts for a primary energy demand of about 430 Mtoe/year, shared to 93 Mtoe for MFBs (1,081 TWh/year), 150 Mtoe (1,744 TWh/year) for non-residential ones and the rest to single-family houses (EU buildings data). The energy demand and emissions of the addressable stock are the half, and considering typical energy requirements in EU buildings and emissions conversion factors based on the average EU grid electricity, the CO_2 equivalent emissions amount 124 Mtons CO_2/year for the MFBs and 220 Mtons CO_2/year for the non-residential ones (344 Mtons of CO_2/year in total), which correspond to about 35 tons of CO_2/year per building of either type in average. This is compared to the total CO_2 emissions of the EU building sector equal to about 1,200 Mtons/year.

Assuming this entire building stock with the mix of MFBs and non-residential buildings replaces its existing systems with the SolBio-Rev one, the total primary energy savings are almost 2,000 TWh/year, leading to a reduction of CO_2 emissions by 170 Mton/year. In other words, **the use of the SolBio-Rev system in EU buildings** of various sizes and types could lead to the **reduction of primary energy consumption of the whole building sector (including single-family houses) by 40% (compared to the current energy consumption of 430 Mtoe/year) and 15% of CO_2 emissions**.

Finally, the **emissions for the equipment production** are similar to standard solutions, and a refrigerant with **ultra-low GWP** in accordance to all current and future regulations (*F-Gas ready*), will be used in the heat pump. A detailed LCA, LCC and CBA study will be conducted to identify the entire environmental and economic performance of SolBio-Rev (from production to operation and disposal) and compare it with the one of alternative solutions.

European based research leadership creating strong bonds impacting to effectively solve societal challenges

Enabled to test their ideas along with researchers from industry, the partner universities (NTUA, FAU, UDL, UOS, KIT, and UNIME) and research institute (ITAE) will prove the validity of their ideas and strengthening their industrial credibility. Results will attract other companies to collaborate with them, expanding their number of industry related projects and attract young researchers working in close collaboration with industry.

For all research partners - all well-embedded in EU collaborative projects - SolBio-Rev enables not only to solidify their industrial bonds, it also enables to strengthen collaborative activities with universities and research institutes in new domains. The collaboration amongst universities and research institutes allows both of them to intensify contacts, learning from each other and defining joint new ideas in other research projects. The collaboration will allow them to engage faster in future projects based on their expertise, while strengthening each other. SolBio-Rev enables to create bonds for future projects and exchange of staff & students. Continued participation in EU research projects has an important added value to prove to the outside world their capabilities, **endorsing their thought leadership**.

Participating in large-scale EU projects enables also the industrial partners FAHREN, TEAVE, AKOTEC, DAIKIN, DBC, OKOFEN and STRABAG and the association TECH to strengthen their collaborative activities with universities, research institutes and other companies EU-wide enforcing their research and innovation activities.

Growth of industrial capacity at partner level impacting positively investment increase and job creation

For FAHREN, TEAVE, AKOTEC, DAIKIN, DBC, OKOFEN & STRABAG participating in SolBio-Rev enables to acquire knowledge in highly innovative fields and add innovative products & concepts to their portfolio. For the smaller entities, such as OKOFEN, AKOTEC & FAHREN, it is of great importance to develop a broad portfolio of innovative products, add unique selling propositions (USPs) enforcing their market relevance. This allows them to grow their companies to become European Champions in their respective fields.

For FAHREN & AKOTEC, already well acquainted with EU funded projects, SolBio-Rev is important to prove their continued R&D efforts, so clients can always rely on being offered beyond state-of-the-art technology. For OKOFEN, SolBio-Rev will enable to reach an EU-wide research and industrial community and grow their business importantly

relying on the technologies developed in the project. It will allow STRABAG to enforce the industry relevance of SolBio-Rev's research efforts, helping to align with large industrial applicability. For STRABAG, the project is important to incorporate at an early stage innovative technologies in its building concepts, enforcing their reputation as innovator. SolBio-Rev enables DAIKIN, a large company well known for its innovative solutions, to keep ahead of their competitors, engaging important efforts in R&D. The reversible heat pump/ORC will be an important new product in their portfolio, remaining on top of technology offerings.

SolBio-Rev will enable all industrial technology partners AKOTEC, DAIKIN, FAHREN, OKOFEN, TEAVE and STRABAG to enforce and expand their activities, increase their investments, grow their companies and attract technicians, engineers, administrative personnel, sales and marketing people and blue collars. Along with them, their service providers will be able to grow their business as well.

Last but not least, SolBio-Rev will also allow TECH and DBC to expand their activities. TECH is getting more and more involved in EU-wide projects, promoting the need for installers to be part of research projects as of an early stage. They are the missing link in many cases to bring technology really to the application level. Promoting their participation is an important task for TECH. It will enable installers to expand their activities, implement new business models (e.g. offering energy savings-based design build and maintain – DBM - contracts). Vice versa, it allows TECH to get into contact at an early stage with innovative technologies and be known as an industry relevant organisation actively supporting its members. For DBC, participating, as an engineering consultant, is important for growing their business, proving not only their technical but as well their practical knowledge and research capabilities. In charge of communication and dissemination supports them to promote the industry relevance of the results.

In summary, the involved technologies are based on the products of the industrial partners, who are already active in the building sector and have the capacity to commercialise the solution with an anticipated **high growth**. Especially for the 4 SMEs partners (FAHREN, AKOTEC, TEAVE, OKOFEN) a growth by over 30-40% in the period 2025-2030 is anticipated. SolBio-Rev will enable them to strengthen their **European industrial technology base**, in particular the technology for energy systems in buildings, Once this technology is commercialised and all IP shared, its competitive advantages over other heating/cooling appliances or energy-efficiency measures (reduced price, high energy share, user friendliness and compactness) can ensure the growth of the industrial partners and of any other organisation that can benefit from the project results (e.g. technology providers of HVAC sector, mostly in buildings, or installers), since a new validated technology platform with superior features will be available, creating at the same time many direct and indirect jobs.

Industrial capacity and technology base in Europe

Once all specific objectives are met, the technology roadmap will define the next development steps and collaboration opportunities with other enterprises (e.g. PV panel manufacturers, building construction companies), supporting the uptake of the technology by a broad range of both industrial and research organisations, while safeguarding the IP of the consortium partners. The consortium already includes key European industrial partners that can handle its further development with the research partners, and the inclusion of other key organisations, according to the research outcomes and exact needs. Moreover, it is expected results will be picked up by the broad industrial & research community leading to new developments and expanding the concept, offering similar solutions. The final aim is to validate this technology and reduce its technological risks, while overcoming the market barriers, in order then to optimise the commercialisation plan of the innovative SolBio-Rev system.

The research results can be also applied in other systems/applications of the industrial partners, such as: (1) Waste heat recovery with TEGs for exploiting low temperature heat sources (KIT), (2) Advanced solar collectors for protection from heat overloading and high lifetime (AKOTEC), (3) Innovative adsorption chiller with high-performing adsorber HEX for heating/cooling applications (FAHREN), (4) Control of renewable energy systems in buildings (TEAVE), (5) advanced biomass boiler with high efficiency & reduced air pollutants (OKOFEN), (6) innovative heat pump with additional features, operating in reverse for electricity production (DAIKIN), and (7) Sustainable building design & construction (STRABAG). The above open more opportunities for product development and market uptake in similar segments, further strengthening the innovation potential of the industrial partners.

Finally, this technology can be also applied in **regions outside EU** with weather conditions similar to the three main climatic zones presented here, making it appropriate to directly address markets in countries, such as USA, Japan, Australia, China, India, and even countries of Latin America, Middle East, and North Africa. Therefore, market opportunities exist in many countries around the world, requiring a detailed commercialisation plan by the industrial partners of the consortium, once this solution reaches the market.

Societal impact

As already mentioned, the SolBio-Rev project will produce technology-based insights, which will be linked to social impacts and perceptions from the very beginning of the project, for enhancing its market potential. The starting point will consist of the analysis of other case studies in buildings with similar low-carbon energy systems that will generate lessons and insights for both national and EU policy. The state-of-the art investigation of social perceptions of heating/cooling/electricity will be carried out and the key societal awareness drivers will be identified, with the aim to also inform and engage investors, energy suppliers, and other stakeholders involved in designing business models and financing flows for the building sector. These activities will be mainly handled by UOS and TECH, receiving input from the other partners as well.

With the introduction of strict energy performance standards (Directive 2010/31/EU), all buildings should include local renewables, resulting to higher initial costs compared to today's conventional solutions. The SolBio-Rev system shows similar costs than its competing solutions (see cost-benefit analysis, § 1.4.2) with much higher energy savings, mitigating the market barrier that could impose constraints in its future commercialisation, and supporting end-users to alleviate to up-front cost of energy saving technologies. To engage more end-users to adopt the proposed technology, suitable business models will be defined and suggested, such as through Energy Service Companies (ESCOs), offering an optional contracting or hire-purchase solution (similar to solar leases of rooftop PV panels). These issues will be properly handled in Task 8.4, by assessing all suitable business models.

Finally, some key features of the system specifications directly linked to the user needs are described next:

- ✓ **Surface needed.** The system is designed to easily fit on rooftops and in buildings, considering their availability. The compact heat pump-based configuration allows for a trigeneration with a limited footprint and simplified hydraulics. The estimated sizing shows that it will not need more room than 8-10 m^3, surface of about 4-6 m^2, in the boiler room of a medium-sized MFB (including the storage tanks), increasing to 10-12 m^2 with the boiler and the pellet tank.
- ✓ **Ease and time of installation.** The high compactness allows reducing installation effort (time and cost), since less collectors are required and the heat pump configuration needs few connections and piping. AKOTEC will include its advanced quick-clip technique of the tubes in the collector manifold that allows to greatly decrease installation time and handling effort, enabling also easy replacement, while the TEG module will come pre-installed on each collector, requiring only a cable connection.
- ✓ **System reliability.** Reliability will be considered in the system design, reducing the need for frequent maintenance or replacement of expensive parts (e.g. HEXs, HP compressor), supported with the built-in remote monitoring of the control unit, preventing any major malfunctions. Moreover, the new system does not require any dedicated maintenance that differs from other solar, biomass or heat pump systems causing less hesitation for installers and end-users to implement the technology.
- ✓ **Operation effort.** This effort is minimised due to automated operation handled by the controller, supervising the solar field, the heat pump, the boiler, and all hydraulics. Both these aspects will be examined in WP3 and their results included in the design process.
- ✓ **Integration in buildings.** Initial integration studies have been conducted mainly concerning the available surface in the building and on rooftops. A detailed study will be conducted in existing buildings (in WP7) that makes it possible for a smooth installation, as well as to exploit as much as possible some parts and components of existing installations in buildings (e.g. heating/cooling appliances, hydraulics, boilers).

The above attractive features, combined with the potential of reaching a competitive cost, increase user acceptance and societal awareness. This eliminates an important market barrier, while any other existing barrier will be examined, making the technology extremely attractive for the end-users. It should be emphasised that end-users in buildings are already familiar with the energy solutions supplied by solar energy, biomass and heat pumps, so the barrier of implementing the technology is low. This detailed analysis will be conducted through the Life Cycle Cost (LCC) analysis and Cost Benefit Analysis (CBA) in WP7 and dedicated business models in WP8. Thus, a clear business opportunity exists for the industrial partners that will invest their resources at a later stage to bring the system to the market (see § 2.2.1), once this technology is validated.

2.1.3 Market barriers and framework conditions

Market barriers: These barriers are mainly linked to the conservative building sector itself, slow uptake of innovative energy systems by installers and low public awareness, as a direct effect of the lack of appropriate training/expertise of technology providers/installers. One of the innovative aspects of this project is to spread the potential of the approach, through a dedicated effort in the targeted Dissemination & Communication tasks (WPs 8 and 9). Table 12 describes and summarises how the SolBio-Rev project addresses the main barriers.

Table 12. Identified barriers and SolBio-Rev contribution

Barriers		SolBio-Rev contribution
Technical/ Technological	• Performance of HP-based configuration • Integration of main components • Smart and user-friendly control interface	• Energy specialised researchers (FAU, ITAE, KIT, UDL, NTUA), manufacturers (DAIKIN, FAHREN, AKOTEC, OKOFEN), building constructor (STRABAG) and experts in ICT and control (UDL, TEAVE).
Industrial	• System efficiency and cost • High complexity for building applications	• Technical innovations reducing complexity and number of parts, enhancing system efficiency and lowering costs.
Economic	• Competitors' market positions • Complex concept to be realised in real buildings.	• Innovation and functionalities offering. • Market analysis, business model generation and industry relevant results to facilitate post-project investment, development and uptake.
Technology providers/ installers/ construction companies	• No appropriate expertise of installers, blacking the promotion of new techno-logies to their customers • Reduced profit margin, preferring the installation of other energy systems	• TECH will involve installers through its network. Other key associations will get involved in future actions. • STRABAG will proceed to demo installations. • Include installer's contribution and direct contacts with customers in the business models to be generated.
Societal	• Trust and reliable information concerning new renewable energy-based systems • Not adequately informed by installers • The components are more expensive	• SolBio-Rev stakeholder community (SHAB) created and engaged throughout the project. • Introduction of stakeholder knowledge/needs in the design process by UOS and TECH. • High system efficiency and long-life bring a short PBP.
Regulatory	• Differences in national standards slow components standardisation and uptake • Regulations for public decision promote lowest prices, not best performances • Missing tools to assist market uptake • Uncertainty on future energy performance standards in buildings.	• Exploitation and dissemination strategy and associations will help the standardisation. • Introduction of incentive schemes for sustainable solar/biomass energy-based solutions. • Conduct techno-economic studies as a function of the building's energy performance, to conclude to overall system sizing in each climatic zone.

Innovative products traditionally struggle to gain the attention and confidence of the conservative building sector. Early adopters are inclined to go for new technologies and are often more environmentally conscious. They will more easily be convinced of the SolBio-Rev system's advantages. For the majority however, financial advantages offered need to be communicated and highlighted. For both new and renovated buildings, when addressing these market barriers (e.g. providing trainings to installers) there should be major benefits in adopting the proposed system that offers a high energy share, limited space requirements, easy installation & maintenance and low total cost of ownership. The market barrier of low public awareness of SolBio-Rev system will be addressed in WPs 8 and 9, supported by the surveys of WP6 with the aim to:

- ✓ Spread the main concepts of this technology and its features and interact with the wider society and receive feedback on the SolBio-Rev system and its features.
- ✓ Inform end-users, architects, building construction companies and other stakeholders of the pressing need to minimise energy consumption and adopt energy efficient products.
- ✓ Focus on technology providers/installers that come in direct contact with end-users, and engage them. TECH will introduce this stakeholder knowledge in the project so that in future innovation actions, providers at both local and European level (e.g. HVAC or building construction associations, BUILD UP portal) will be directly involved for the final development stages. A list of relevant stakeholders will be produced during the project and considered in the business model generation and technology roadmap.

Framework conditions: Strict regulations about energy performance of buildings has just started to take effect (Directive 2010/31/EU, and according to national targets and energy strategies). By 2030 this Directive will probably be amended, considering even more ambitious goals. Since no concrete long-term policy data are currently available, these goals will be included in a sensitivity analysis. This issue will be examined in WP2 and included in the simulation work of WP3, in order to conclude to appropriate sizing for any future Directive and/or national legislation, imposing energy performance targets in EU buildings. Moreover, more strict regulations on emissions from biomass boilers are expected to be formulated, introducing NO_X emissions limits, currently not regulated. Relevant policy directions/regulations will be considered. This is ensured for the envisaged biomass boiler since already the commercial OKOFEN boiler is characterised by low emissions, which will be further reduced in the project.

Finally, the influence of grants and incentives throughout Europe on the overall system cost will be assessed. This analysis will take into account various climatic conditions relying on the simulation results.

2.1.4 Total Addressable Market size (TAM) – Serviceable addressable market (SAM)

The total addressable building stock includes 3.5 million multi-family residential buildings, and another 7.5 million non-residential ones, amounting to a total 11 million buildings, as presented in § 2.1.2. An average construction rate of 1% year and refurbishing rate of 3% year is considered, according to ZEBRA2020 data tool. These values are rather conservative, especially for the refurbishments, having in mind the strict rules for energy performance in buildings that will come shortly into force, and the established target for a rate of 3% in public buildings.

With the above figures, the TAM in the EU building sector concerns ~**0.14 million MFBs and 0.3 million non-residential ones per year**. Assuming a system price of 70,000 € (a mix of systems at various regions & sizes) the full market potential for the SolBio-Rev system accounts to **30.8 billion €**. However, considering that the initial commercialisation will focus on few EU countries, with some possible ones being Germany, Belgium, Spain, Italy and Greece (defined with detail at a later stage), the initial SAM is estimated at about one third of the TAM, i.e. at **10.3 billion €**. With a conservative (*low*) rate of 0.5% and an optimistic one (*high*) of 2% of addressable buildings installing the SolBio-Rev system after 2025, the resulting potential sales and revenues are shown in Fig. 29. This initial plan considers expansion in more EU countries, as the technology becomes established, driving the growth of the industrial partners exploiting it. After 2040 it is projected that business activities could cover all EU countries and expansion outside Europe will have been initiated[47].

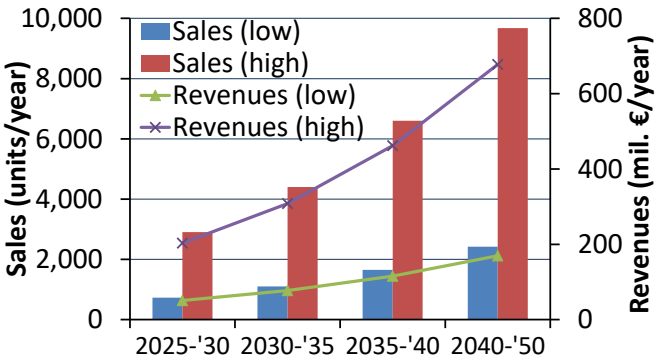


Fig. 29. *Potential sales and revenues*

The market potential is extremely high, even with the very conservative approach of this analysis. In the *period 2025-2030*, few EU target countries are considered, with potential annual sales > 700, **ensuring revenues ≥ 50 M€/year**. The potential gradually increases, as expansion in more EU countries and in non-EU countries is on-going, reaching revenues > 170 M€/year *after 2040* and be present in all EU countries.

2.2 Measures to maximise impact

2.2.1 Dissemination and exploitation of results

Draft dissemination plan: During the project, the knowledge developed will be disseminated following a strategy targeted for each type of stakeholder, as shown in Table 13.

Table 13. Dissemination strategy applied to each targeted stakeholder

Target groups	Strategic objectives	Dissemination tools
Professionals (designers, technology providers/installers, energy advisors)	Capacity building of the huge potential of renewables in buildings. Collect feedback on market needs and appropriate required expertise.	✓ Visits, sem/webinars, conferences & videos ✓ Training courses, workshops, networking ✓ Involve technology providers and installer associations in future innovation actions
Construction and engineering companies	Increased knowledge integrating SolBio-Rev in buildings & synergies with other systems.	✓ Visits, sem/webinars, conferences & videos ✓ Workshops, exhibitions, networking
Manufacturers (ICT, BEMS, heating/-cooling appliances)	Foster synergies between their products and SolBio-Rev.	✓ Articles and scientific papers ✓ Visits, sem/webinars/conferences & videos ✓ Training courses, workshops. networking
Building owners/ facility managers	Realise strategies for promoting renewables. Consider installation of SolBio-Rev solution.	✓ Visits, sem/webinars, conferences & videos ✓ Training courses, workshops, networking
Government (building and energy regulators, standardisation bodies)	Knowledge of potential benefits of user engagement to include specification in regulation/labelling.	✓ Articles and scientific papers ✓ Visits, sem/webinars, conferences & videos ✓ Training courses, workshops, networking
Academia, scientific community	Ensure knowledge transfer and capitalise results for further RTD tasks.	✓ Articles and scientific papers ✓ Visits, sem/webinars, conferences & videos ✓ Training courses, workshops, networking
End-users	To identify early adopters. Include their needs in the design process.	✓ Visits, sem/webinars, conferences & videos ✓ Surveys, interviews.

[47] S Serrano, et al. Heating & cooling energy trends and drivers in Europe. Energy 2017;119:425-34.

While the communication activities - creating project awareness - such as the project website, press releases, social media, videos and leaflets (see also § 2.2.4) will support the dissemination activities, the latter are focussed on realising technology uptake. Dissemination activities comprise presenting the project outcomes via articles, scientific papers, exhibition fairs & networking events, and involving stakeholders actively during workshops, open-info days at the two pilot buildings, seminars, roundtables in events and trainings (see WP8). SolBio-Rev's dissemination strategy will focus on the large diversity of stakeholders (see Table 13) to support market uptake. The implementation and testing of the SolBio-Rev system in the two pilot buildings will allow the creation of use cases dedicated to training and knowledge exchange. To enforce the dissemination plan, the SolBio-Rev will focus on understanding stakeholder needs. The following actions are foreseen during the project:

- ✓ **Strong in-depth user needs assessment** (Tasks 6.1-6.3) to ascertain the most effective method of approaching them. By having a clear vision of the desired features from the beginning, the development will be on the right track early on. Our strong multi-disciplinary consortium will always highlight the perspectives of the users.
- ✓ **Engagement of stakeholder community** (Task 1.2) by establishing a continuous feedback loop with the main stakeholder organisations (e.g. sustainable building associations, building construction companies, research organisations) early in the development trajectory. Their points of view will be ascertained through literature/report reviews, discussions with relevant umbrella organisations, and expert interviews. This community will be informed, engaged and invited to major events, and to project meetings on an annual basis. They will support in making sure that the developments are in line with their needs and will be our first critical early adopters.
- ✓ **Market synergies** (Task 8.4) to elucidate the conditions influencing the development and possible synergistic strategies for different sectors (e.g. HVAC systems, solar collectors, smart control) to be exploited for different building types and climates, energy, cultural, and regulatory contexts. It will also be the basis for developing relevant business models, exploitation plans and commercialisation paths.

Draft exploitation plan: Prior to the project submission, the SolBio-Rev consortium performed a market analysis to assess the ***commercial potential*** (see also § 2.1.4). It became clear that the TAM and SAM are large enough to ensure high market penetration in diverse segments in both new and existing buildings, such as: (1) MFBs, (2) commercial (e.g. offices, retail and wholesale, hotels), (3) public (e.g. offices and educational), and (4) industrial (e.g. manufacturing workshops and warehouses). Upon this positive outcome, a draft exploitation plan was designed relying on the cost-benefit analysis (see § 1.4.2) and the promising markets in all three EU climatic zones, focussing on MFBs and offices, which show a very high energy consumption. The exploitation potential depends on the nature of the consortium partners (research / commercial organisations) and their commercial activities. In Table 14 is presented an overview of the ***potential exploitation activities***, which will be regularly updated during the project.

Table 14. Exploitation activities of the consortium partners

Partners	Exploitation activities
Research partners (universities, research organisation)	**All (NTUA, FAU, ITAE, UDL, UOS, KIT, UNIME):** publications in key journals and conferences, expose large student body to the ideas and methods emerging from the project, knowledge transfer to industrial partners and future collaborative projects (RIA/IA) further expanding the project concept (e.g. synergies with other components, such as PVs, for increasing the electricity share, or with district networks). Attracting visibility with the two pilot systems, the centrepiece of the dissemination work during and after the project, serving as reference installations for reaching various stakeholders. Finally, NTUA intends to create its spin-off company during or after the project and exploit the reversible HP/ORC technology, in collaboration with the relevant industrial consortium partners.
Industrial partners (technology providers, professionals)	**FAHREN**: exploiting the complete system, focusing on the cascade chiller in buildings (new/retrofitted). Knowledge/technology transfer to its thermal chiller product. **DBC**: serving as commercial and resell agent across its networks of sustainability professionals and organisations. Focus on business strategy and commercialisation plan. **AKOTEC**: exploiting the complete system, focussing on the solar collector. Knowledge/technology transfer to its solar collector for integrating TEGs for overloading protection. **TEAVE**: expanding the business towards innovative solutions for smart controllers in building applications. **DAIKIN**: exploiting the complete system focusing on the heat pump configuration in buildings. **OKOFEN**: exploiting the complete system, focussing on the biomass boiler. Knowledge/technology transfer to its products for integrating an internal HEX and EGR for CHP applications. **STRABAG**: providing designs and feasibility studies for building constructions and consulting services, aiming at developing buildings for its customers with extremely high energy performance.
Association	**TECH**: will provide installers & construction companies advice relevant to system integration in buildings.

The sales projections and the resulting revenues presented in § 2.1.4, although preliminary and rather conservative, exhibit the potential of SolBio-Rev. Even if they have high uncertainty, they demonstrate the high chances for growth

of the industrial partners, and especially for the SMEs, who will experience a significant increase of their turnover and business cycle by more than 30-40%. This fraction will be much lower for the two large enterprises (DAIKIN and STRABAG). All industrial partners will be integrating the new designs and innovations in their existing products (e.g. FAHREN for its adsorption chiller, AKOTEC for its solar collector, DAIKIN for its heat pump, OKOFEN for its biomass boiler, TEAVE for its building control units), maximising impact.

Based on the potential exploitation activities and the results of the commercialisation analysis of the envisaged solution all partners have made initial individual exploitation plans. The overall and individual plans will be updated at the start of the project and afterwards they will be assessed and updated every year. The industrial partners that showed interest for its exploitation or the delivery of some key components are mostly SMEs (FAHREN, AKOTEC, OKOFEN and TEAVE) together with large companies (DAIKIN and STRABAG). DBC and TECH are strategic partners of this alliance and deal with market and business aspects (DBC) and building integration issues (TECH). This industrial base will be enriched with additional companies that will either adopt this solution in their buildings or will be included in this partnership at a later stage.

SWOT analysis: An initial SWOT analysis has been prepared, shown in Fig. 30. The solution's technical features account for its strong points, with some weaknesses such as development risks introducing large uncertainties, while existing solutions already in the market narrow the potential buyers. The business opportunity is obvious, due to the new environmental regulations put into action and increasing energy prices, while the low interest of users and market entry barriers could be a threat to its market introduction.

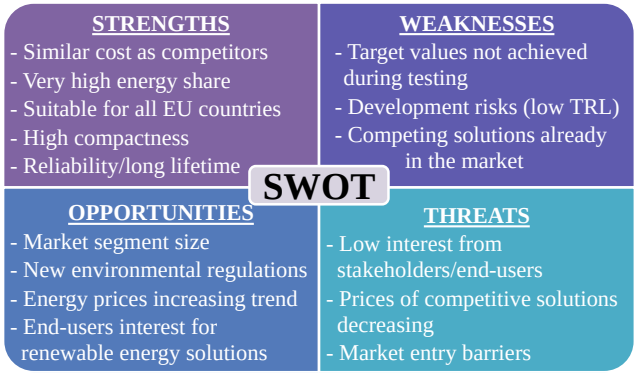


Fig. 30. *Initial SWOT analysis*

To maximise the exploitation potential, the project approach tackles two important steps, described below.

Step 1: Preparing exploitation during development

The foreground of many RIA projects enters the valley of death, because it is not clear who is the responsible/can benefit from its exploitation and there are no solid business models or plans for exploitation and commercialisation. SolBio-Rev is different, since there is a strong focus on all necessary steps for reaching the market, including:

- ✓ Competence assessment and matching of developments with customer/market needs. One of the most complex aspects when carrying out research and innovation is to find the ideal match between the desired and the delivered features/benefits. Therefore, as soon as the foreground of each partner is identified, the business model will include a SWOT analysis highlighting extraordinary features & limitations, with feedback from surveys of WP6.
- ✓ Protection of IP and management of foreground. After the foreground is identified, the involved partners will start discussing agreements with the support of NTUA and DBC. Additionally, before dissemination starts, we will perform a thorough patent search, IP protection and arrive at agreements among involved partners and possibly with external ones as well, if required. Only after an innovation is protected and agreements are reached, dissemination will occur. The IP manager assigned for each foreground will receive support by the Dissemination and Exploitation Board (chaired by DBC) along all the steps.

Step 2: Market preparation activities

The road to the market will start to get prepared close to the project end, when the two pilot systems are tested and validated (reaching TRL5). At that moment, the future development stages of the technology will be scheduled (for going initially from TRL5 to TRL6-7, and at a later stage to TRL8), and in parallel a suitable market preparation task will be conducted by DBC, as described next:

- ✓ Solid exploitation plan and business models. Based on experience, stakeholder analysis, and discussion among interested partners (e.g. FAHREN, DAIKIN, UOS, AKOTEC, OKOFEN, STRABAG) appropriate business cases will be defined for each development task. The exploitation plans and business models will be refined, as soon as the foreground is clearly assessed and agreed.
- ✓ All steps for preparing market introduction will be identified, and the feedback from the stakeholders will ensure that our foreground will be well positioned. These steps will be included in the technology roadmap in WP8, which also examines business-related aspects except from technological ones.
- ✓ Dissemination and education of market and users. The developed SolBio-Rev system and the pilot buildings will be followed-up throughout the project targeting specific audiences, in order to receive feedback from stakeholders (e.g. users, installers, construction companies), and the external advisory board.

2.2.2 Management of research data

Data management will follow the Guidelines on Open Access to Scientific Publications and Research data of Horizon H2020. Within the management structure, the Management Board will be responsible for data management. The types of data generated in the SolBio-Rev project are:

- ✓ Technical specifications of the prototypes and pilot systems.
- ✓ Simulation parameters & results related to the prototypes in various environments & operating conditions.
- ✓ Performance characteristics related to the lab and pilot testing of the components and the system.

Project exploitable results are identified early in the project and it is already foreseen that some partners will protect results via patent applications (e.g. NTUA for the reversible HP/ORC). This identification and patenting will make clear what information/data cannot be disseminated. Instead, in the event of a decision to disseminate/share the results, data will be generally treated as follows: results related to data that support the dissemination, exploitation and future branding of the SolBio-Rev will be treated with GOLD open-access. Instead, results that are related to competitive aspects for the future development and exploitation of the results (e.g. component pricing, process and integration knowledge) will be RED (restricted). The project will establish a knowledge repository and the treatment of data within the repository for use after the project will be detailed in Data Management Plan. All publications will employ a GOLD open-access strategy and the treatment of data to produce them will be also outlined in this Plan. The decision to disseminate/share or exploit/protect the results is handled in Task 8.5.

Publication of results: The partners are entitled to publish research results and development results obtained from the project in the usual scientific forms. However, all concept publications must be submitted to all partners prior to submission together with a request for permission to publish.

The research partners are entitled to use knowledge or results from the project that either have been published or have been declassified, for research, training and teaching purposes. However, in order to protect the commercial interests of the industrial partners, which are facing strong competitive pressures from the USA and Far East, publication of the results will be selective, except for submission of contractually required reports and information to the EC. In this case, the IP manager (provides advices on the management of knowledge and of IP and of other innovation-related activities arising in the project, see § 3.2) will decide which parts of the results are to be protected by patents, copyright or trade secrets and which parts are suitable for dissemination. One of the pages of the project website will contain an overview and archive of all published information: scientific articles, publications, press releases, conference papers, and others. The Coordinator will make sure that all publications related to the project are made available in Open Access publications or via an online repository. More details on these issues will be described in the Consortium Agreement. In general, the non-commercially sensitive results will be of open-access, published mainly by the research organisations, while there will be a restriction of giving away commercially-related results.

2.2.3 Intellectual Property (Rights) (IP(R)) management and protection

The IPR and exploitation issues will be handled by the Management Board, chaired by the Coordinator, who has wide relevant experience, and access to internal and external specialists and IP-lawyers in patent and legal affairs. Besides, most other partners have their own legal departments and specialists for in-house support.

All partners have agreed that the **"background"** relevant IP belongs to the companies or research institutions that have developed it. However, access rights to this "background" may be requested by any participant if necessary for carrying out its own work under the project. Access rights to the "background" for implementing the project will be granted on a royalty-free basis, for the duration of the project.

Within the project, the IP of the **"foreground"** will belong to the partners or group of partners that develop it. These partners might choose to protect it by applying for patents. If access to this know-how is necessary to the other partners for developing and commercialising a product, this will be granted or licensed on fair and reasonable conditions that will be negotiated between the involved parties. All partners will have access rights to the "foreground" on a royalty-free basis as long as it is necessary for implementing the project. Any owner of any result will be free to use such result and to commercialise and distribute it. In case of joint ownership, each owner will be free to use such result and to commercialise and distribute it, provided all its joint owners agree. Such agreement will not unreasonably be withheld. Project results will be made available free of charge to consortium partners for research purposes within the scope and the duration of the project.

During the Grant Agreement preparation phase, a **Consortium Agreement** based on the latest DESCA version will be prepared and signed between all partners that will regulate with detail the IP and other collaboration conditions. The IP rights on background and foreground of all partners are described in Table 15, as defined during the proposal preparation phase.

Table 15. IP ownership of background and foreground of each partner

Partner	IP on background	IP on foreground
NTUA	Operation and control of heating/cooling equipment for buildings. Development and testing of HP/ORC trigeneration systems. Simulation and optimisation of energy systems in buildings, including dynamic models and user behaviour.	Development and testing of the reversible HP/ORC unit. Operation, control and testing of solar/biomass energy systems. Simulation and sizing of SolBio-Rev system at various locations and building types. Pilot system performance and validation in Greece.
FAU	Design and testing of biomass boilers. Domestic heating technologies.	Advanced biomass boiler for CHP operation. System performance and validation in Germany.
FAHREN	Existing adsorption chiller product, control and coupling with a heat pump.	Design and production of the advanced cascade chiller, with the new HEXs. Business models.
ITAE	Design and testing of heating/cooling equipment.	Design of advanced components (adsorbers, evaporator/condenser) for the innovative cascade chiller with HP. Testing of cascade chiller/HP.
TEAVE	Smart system control for various applications.	Development of smart control for SolBio-Rev with advanced features, aiming at user-friendliness.
AKOTEC	Existing solar collector product. Solar tank design and know-how. Control of solar field and temperature of heat production.	The advanced solar collector including TEGs suitable to be integrated in the SolBio-Rev system. Collector testing indoors and outdoors.
UDL	Thermal energy storage. Building energy efficiency. Building materials. Control strategies and artificial intelligence. LCA and LCC.	Storage tanks design/sizing according to energy indicators. Advanced system control. LCA, LCC, and CBA
DAIKIN	Expert in heat pump technology. High expertise in heating and cooling solutions in buildings.	Heat pump-based configuration. System control.
UOS	Policy and social acceptance of energy efficiency products linked to business strategy.	Policy and social acceptance linked to SolBio-Rev system. Business models.
DBC	Market expert on energy systems in buildings. Business plan development.	Market analysis of sustainable energy systems in buildings. Dedicated business models. Policies.
TECH	Technical expertise on HVAC and electrical installations in buildings.	Integration aspects of SolBio-Rev in new and existing buildings. Installer needs/requirements.
KIT	Expert in thermoelectric materials and devices with bulk or printed TEGs for various applications and temperatures.	Development, design and production of TEG system to be mounted in the solar collector.
OKOFEN	Existing biomass boilers and CHP solutions.	Development, design and production of the biomass boiler for CHP.
STRABAG	Building design and construction.	SolBio-Rev integration in buildings and sustainable building design.
UNIME	Direct synthesis of SAPO-34 onto metallic HEX and production process optimisation.	Adsorbent coating technology optimisation through improved post-synthesis procedure.

2.2.4 Communication activities

The communication is based on an outcome-oriented approach, as detailed in WP9 and it is a key element to reach impacts. At the macro-level, the strategy is influenced by the three goals of EU research and innovation policy defined in 2016: (1) Open Innovation, (2) Open Science, and (3) Open to the world, and outlined by tasks which in a simplified manner are: (i) to **plan** strategic communication activities, (ii) to **conduct** workshops and conferences that link SolBio-Rev to a much broader scientific and building sector stakeholder audience, and (iii) to **leverage** the unique capacities of the partners to achieve maximum possible dissemination to the relevant audiences. Communication processes (newsletters, dissemination contacts) and high-quality baseline materials (e.g. website, logo, web-videos) will be underlying and constant throughout the project.

A workshop series is scheduled for **targeting various stakeholder groups**. Maximum possible benefit will be sought from the industrial and pilot system development activities, which will be promoted for media coverage, with coverage of partner facilities, prototyping, and innovations to be sought afterwards. **Communication multipliers** in the form of **platforms** will be used to maximise outreach.

The methods and routes for communication of the SolBio-Rev project include:

- ✓ The internal communication of the results between partners will be made by circulating technical documents and memoranda that will be treated as confidential, in case they include any commercially sensitive information.
- ✓ Communication to the Commission will be carried out by frequent reports by the Coordinator.
- ✓ General communication to a variety of stakeholders (e.g. final users, society, industry, and academia) will be made through project leaflets, project website, workshops, and videos production.

More in detail for the general communication, it requires a large effort, in order to reach a diversified audience. The relevant activities and communication means are described next:

- ✓ **Leaflets**. Two project (4-page) leaflets will be produced by DBC in Month 3 and 30, and distributed in the planned events and to the public. About 5,000 leaflets are estimated to be distributed during the project.
- ✓ **Website**. A project website will be developed by Month 2 by NTUA and regularly updated to report the latest research activities and major findings. All partners will be granted access to update information and the latest developments related to their work. The website, as a communication tool, will allow broad access to the public. The number of website visits is expected to exceed 10,000 over the project duration.
- ✓ **Three workshops** will be organised during the project to engage different stakeholder groups, as follows:
  1. A research and innovation workshop for the EU building research community and innovative companies, exhibiting the pilot building with the installed prototype SolBio-Rev system at FAU with anticipated participants number of 100-150. Month: 36-39, location: Germany, organised by FAU.
  2. An industry workshop for the building industry stakeholder to showcase the operating prototype system at NTUA, with anticipated participants number of 80-100. Month: 40-43, location: Greece, organised jointly by NTUA and DAIKIN.
  3. A policy-related workshop for future renewable energy systems in buildings within the EU Sustainable Energy Week (EUSEW) in Brussels. The processed results of the surveys in WP6 will be also presented in this event. During the last year of the project, location: Belgium, organised jointly by DBC and UOS.
- ✓ **Events**. The Consortium members will present the project results in at least 15 international conferences, industry fairs and congresses, focussing on energy efficiency in buildings, renewable energy systems, and heating/cooling systems for buildings. The tentative list of the most attractive events in which consortium partners will participate is: World Building Sustainable Forum, EnerSTOCK, The Sustainable Building Conference, Eco-Build Conference, International Conference on Sustainable Construction and Design, EUSEW, ISES World Conference. Finally, the pilot systems at NTUA and FAU will attract visibility, and presented to various stakeholders (e.g. researchers, technology providers, building associations, end-users) during open-info days, organised in parallel to other events.
- ✓ **Scientific/Technical publications**. At least 12 open-access scientific publications related to the novel technologies and the testing results are expected. These will be published in peer-reviewed, high-impact factor, international journals, such as Solar Energy Materials and Solar Cells, Renewable Energy, Energy and Buildings, Solar Energy, Applied Energy, Int Journal of Energy Research, Energies, and Energy.
- ✓ **Two conceptual videos** (Month 6 and 42) illustrating the concepts, activities and testing facilities, developed by the consortium partners. These will be uploaded in the project website and advertised in known portals, press publications, social networks, YouTube, Twitter, LinkedIn, and other social media.

Mr. Konstantinos Tsiakataras from DBC (WP9 leader) will manage various communication related issues, including: (1) determination of the targeted groups for communication; (2) collection/identification of the research results that are suitable for communication; (3) planning/organisation of the communication activities/events over the project duration; and (4) development of the methods/policies applicable to the communication implementation. The targeted groups for communication of the project results are:

- ✓ Local authorities & EU/national/regional public bodies.
- ✓ Policy makers at energy efficiency and environmental related departments of local/national/EU agencies.
- ✓ Building Technical Systems companies (also including SMEs, large manufacturers, and contractors).
- ✓ Energy efficiency associations (e.g. BPIE, Ecofys, Kiwa, EHI, EHPA), innovation platforms (e.g. RHC).
- ✓ End users, owners and building managers/operators.
- ✓ Technology providers and installers and their professional associations and portals (e.g. BUILD-UP).
- ✓ Practitioners, building systems manufacturers: Architects, HVAC professionals, and professional associations.
- ✓ Academia, researchers and students in areas of sustainable development, energy, building energy systems.
- ✓ Energy services companies and related professionals.

3. Implementation

3.1 Work plan – Work packages and deliverables

The SolBio-Rev project has a duration of **48 months** and includes **9 WPs** to integrate the diverse sectors, skills, and capabilities of the consortium and to achieve the project objectives. These links between the WPs are presented in the PERT chart of Fig. 31.

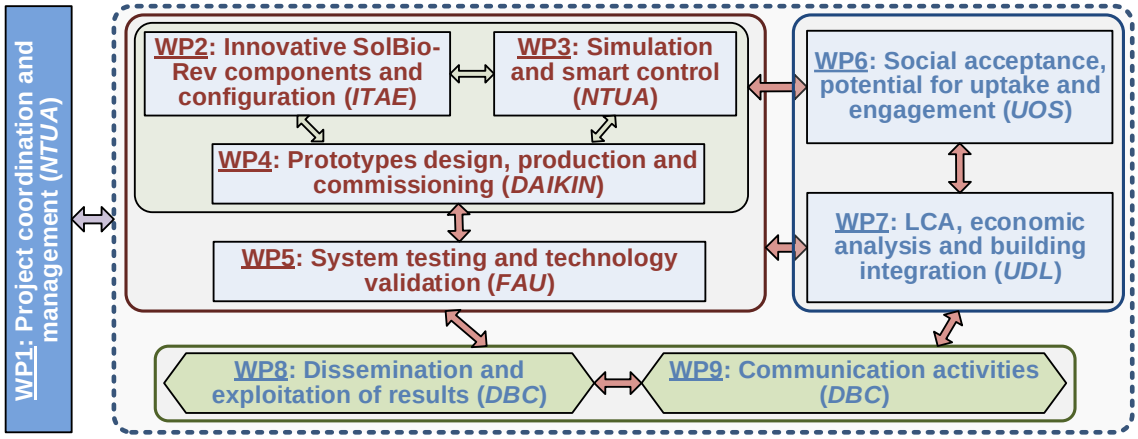


Fig. 31. *PERT chart of the SolBio-Rev project*

The WPs are briefly presented next, indicating the WP leaders.

- ✓ WP1: Project coordination and management (NTUA). The aim is to ensure efficient project management & coordination, mitigate risks, enforce the innovation potential, ensure data protection & handling and secure IP management.
- ✓ WP2: Innovative SolBio-Rev components and configuration (ITAE). Development of the key components, respecting the feedback from installers/users securing future integration. These components will be then tested at the lab for validation purposes and production of numerical sub-models to feed WP3.
- ✓ WP3: Simulation and smart control (NTUA). Development of the numerical tool with optimisation features for annual simulations of building energy flows, according to the local weather data, building specifications, components' sub-models (from WP2), behavioural models, and control strategies. The work will lead to the development of the dedicated controller, tested at the lab by TEAVE under simulated conditions.
- ✓ WP4: Prototypes design, production and commissioning (DAIKIN). Design and manufacture the prototype building at FAU to host the SolBio-Rev. Design two versions of SolBio-Rev prototype systems, due to different energy needs in the installation sites. They will be then produced and commissioned in Greece (NTUA) and Germany (FAU), followed by extensive commissioning tests.
- ✓ WP5: System testing and technology validation (FAU). The testing of the two prototype systems in Greece and in Germany for a whole year will allow to extract reliable conclusions from the monitored data, leading to the technology validation.
- ✓ WP6: Social acceptance, potential for uptake and engagement (UOS). Social science research will be conducted through interaction with various stakeholders groups. Case studies and in-depth interviews will be supported with the outcomes of web-based surveys, gaining a better understanding of user and installer needs and requirements, and providing input to the development/design process.
- ✓ WP7: LCA, economic analysis and building integration (UDL). LCA and life cycle costing will be conducted, accompanied by cost-benefit analysis for a variety of buildings. Building integration issues of SolBio-Rev will be identified that could introduce constraints, as well as feedback from installers for considering their needs for fine-tuning the SolBio-Rev system.
- ✓ WP8: Dissemination and exploitation of results (DBC). The dissemination and exploitation will develop a strategy and platform for fostering the proposed RIA on several audiences: designers, installers, customers, technicians, industries, academics, by encouraging their participation as long-term goal of the project. Market analysis and business models will be generated. Contribution to standardisation will be also a critical task of WP8.
- ✓ WP9: Communication activities (DBC). Communication of project activities and results to a wide audience is scheduled. The technology roadmap will be developed and communicated, together with the project website, logo and two videos.

Figure 32 shows the Gantt chart, which includes the timing of WPs and tasks, all milestones and deliverables, and the three reporting periods (ending at Month 18, 30 and 48). The 9 WPs are presented with detail next.

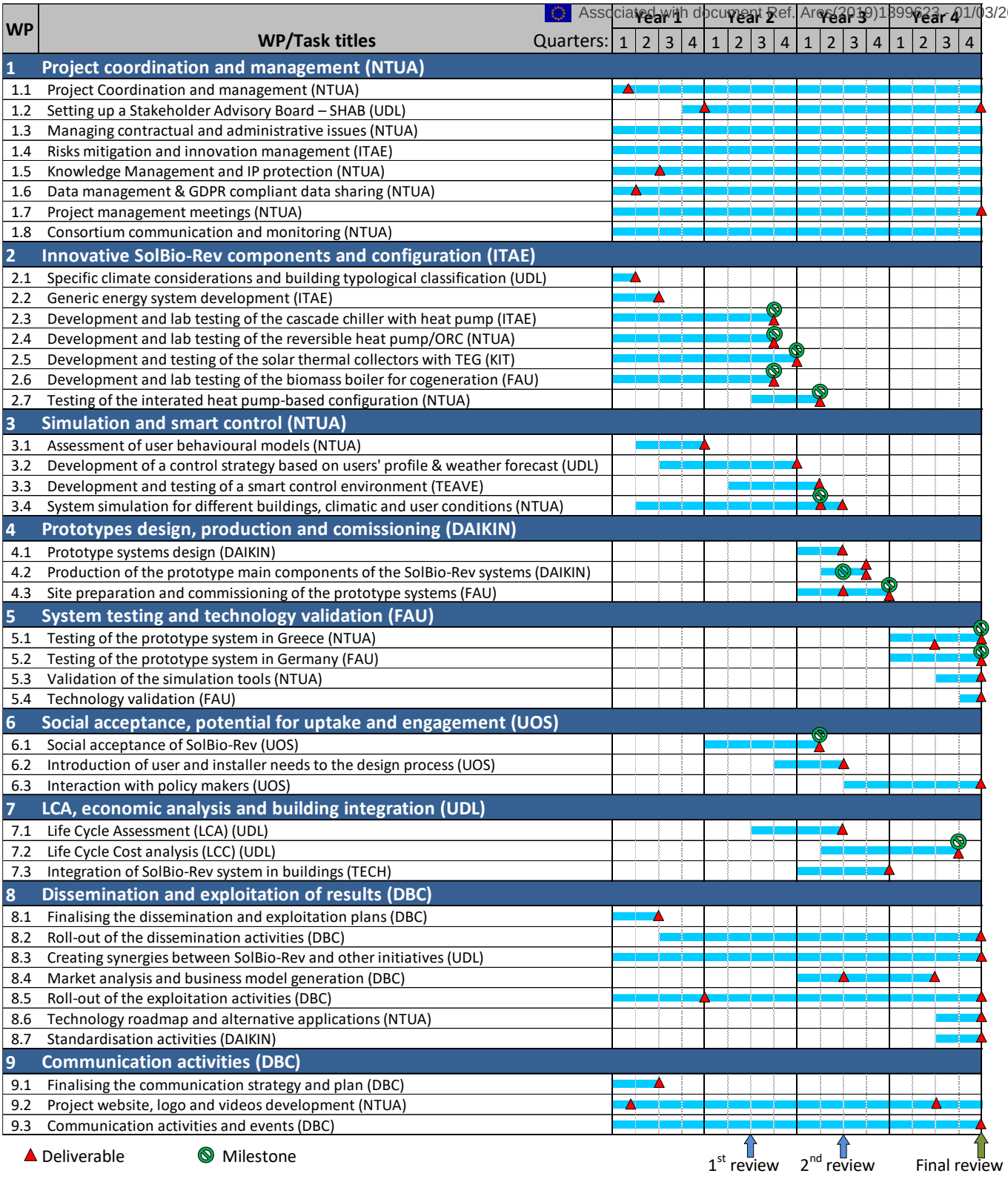


Fig. 32. *Gantt chart of the SolBio-Rev project*

3.2 Management structure, milestones and procedures

Project management is in accordance to EC rules for achieving the project objectives within the agreed high quality of work, budget and time scale. Its main aim is the strategic control of each WP, implying coordination of the activities and implementation of quality control mechanisms. **Project Management** includes: Coordination of project's research activities; overall legal, contractual, financial and administrative management; Preparing the Consortium Agreement (CA), using the latest DESCA model; Coordination and management of knowledge and risks; Managing the exploitation and dissemination activities. Consortium communication and monitoring will ensure the high-quality work, using appropriate methods, such as frequent contact between the coordinator and the WP Leaders and briefing of their progress, technical meetings on demand through the web, and updates to all partners once milestones or deliverables are accomplished. **Management Structure** (see Fig. 33) is adapted to the project size, and already implemented with success in projects of similar scale. The management bodies are presented next.

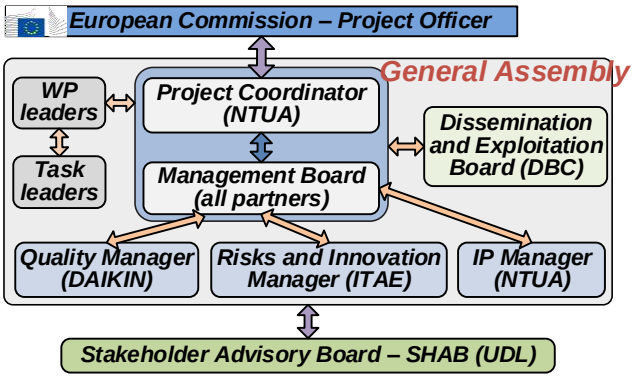


Fig. 33. *Management structure*

General Assembly (GA): The General Assembly is the high-level management body of SolBio-Rev. It is the governing body in the decision-making process of this collaborative project. The GA comprises one senior representative from each Partner, with budget responsibility, able to make consistent decisions and to represent the partner's interests. A representative from the SHAB participates in the General Assembly. The GA is chaired by the Coordinator and meets every semester. The role of the GA is to ensure the follow-up of the project and to take the major decisions mainly on contractual aspects, such as Grant Agreement and CA amendment, contract termination and actions against underperforming partners. Decisions will be taken by consensus whenever possible; in case of conflict, decision will be taken by voting. Each Partner owns a voting right and has one vote.

Management Board (MB): The MB is responsible for the overall project management, including quality assurance and risk management. All WP leaders are part of this board, which is chaired by the Coordinator by means of his activities and responsibilities in WP1. The MB is composed by one person per partner, who is technically involved in the project and meet every semester. The MB has the responsibility for the overall technical project progress and results in full conformance with the Description of Action (DoA) and the decisions of the GA. The MB decides on the overall project strategy, including technical, financial, dissemination, planning and any control matter that does not need approval by the General Assembly, and on actions in case of deviations from project plan, and any changes of legal project documents. Decisions will be taken by consensus whenever possible. No voting will occur within MB. In case of conflict, the MB escalates it to the GA.

Project Coordinator: The Project Coordinator (Assoc. Prof. Sotirios Karellas, NTUA) has more than 13 years of experience on managing both industrial and research projects. He takes care of all the communication channels within the consortium and provides the EC with all required information, assisted by the MB and supported by the NTUA research office. His main tasks are: preparation of the GA, production of the meetings' minutes and follow-up of their decisions, the collection of audit certificates and distribution of EC contribution.

Quality Manager: This Manager will periodically review the technical progress, ensuring high innovation standards, and being open to collaborations, making sure that the project results are of high quality. It has been decided by the consortium members that Mr. N. Barmparitsas from DAIKIN will be the Quality Manager, having great experience on quality control.

WP Leaders: Each WP has a technical coordinator, who has high expertise on the corresponding field and ensures coordination among WP contributors and the timely delivery of WP results and deliverables.

IP Manager: The IP Manager will assess all IP relevant information that are brought or developed in the project. In accordance to the Grant Agreement and the CA rules and based on the ownership of IP, access rights and use of results shall be determined and regulated. The IP manager will: (a) propose to the Management Board the updating of the Pre-Existing Know-How list, (b) assist in identifying knowledge that could be the subject matter of protection, use or dissemination, based on publications and activity reports issued by activity leaders, (c) assist the partners in proposing measures in connection with the protection of knowledge and their dissemination, and (d) submit on demand a proposal to the Management Board and to the concerned partners on the allocation of co-ownership shares over knowledge obtained by several partners. The IP Manager has been decided to be Professor E. Kakaras from NTUA with more than 25 years of experience on IP management, assisted by an IP lawyer.

Risks Mitigation and Innovation Manager: The Risks Mitigation and Innovation Manager will be asked periodically to review the project progress and the risks items table to ensure that the project remains in-line with its main technical objectives (Task 1.4). This manager will be also responsible for the extension of project results, by investigating their potential applications, in close collaboration with the SHAB. Other tasks of this manager are: (1) identify market opportunities that could involve partially or the entire developed system, (2) ensure the consistency between scientific/technical and market preferences, and (3) screen existing and potential competitors and identify the advantages and disadvantages of the SolBio-Rev compared to them. This will enable the consortium to respond to any opportunity that could arise for further research or exploitation of some parts. The Risks Mitigation and Innovation Manager will be Dr. A. Frazzica from ITAE, leading the relevant Task 1.4, being involved in many technical tasks of SolBio-Rev system and being familiar with both scientific and market aspects. He will be assisted by representatives from the industrial partners, who have excellent background on the market status and innovation level of commercial products.

Dissemination and Exploitation Board: It supports the exploitation of the knowledge generated and interacts as closely as possible with key actors. It supports the project with advice on engaging stakeholders and to promote the results to potential customers. This board will be chaired by Mr. Tsiakataras (DBC) and co-chaired by Mr. Nikolaos Barmparitsas (DAIKIN) and Prof. Luisa F. Cabeza (UDL), and will also include one member from each partner.

Stakeholder Advisory Board (SHAB): An external advisory board will contribute to the project activities. Its members will be finalised during the kick-off meeting and then invited under terms of confidentiality, in order to provide guidance and advices. The members of this board will usually meet during the General Assembly every 12 months (in M13, M25, M37, and M48). The remote participation of SHAB member(s) in these meetings will be possible, in case of limited availability. Their travel costs will be covered from the budget of the Coordinator, while its members will not receive any other financial support from the project. Prof. L.F. Cabeza (UDL) will be chairing the SHAB meetings, and will be responsible for inviting its members and providing their valuable feedback. The coordinator will assist and participate in the SHAB meetings.

Conflict resolution: The success of the project relies on the efficient and fast decision making on technical, administrative, financial and project result presentation and exploitation issues. A clear decision-making procedure allows a simple conflict resolution process. When a conflict occurs, consensus seeks to solve the problem. Decision making for technical issues is the main responsibility of the WP-Leaders and the participants within the corresponding WP. If the problem cannot be solved it is escalated to the Management Board: the WP leader prepares a description of the problem and its possible solutions. If consensus cannot be reached within the Management Board, it is escalated to the General Assembly and a vote occurs, requiring a simple majority. In practice, the conflict resolution process can be very fast, as: Extraordinary GA meetings can be organised using audio-conference (with the terms and delay defined in the CA), while E-mail voting is allowed (again according to the rules defined in the CA).

Decision making: It is the main responsibility of the Coordinator concerning administrative issues with the support of the Management Board. Of course, any major decisions shall be approved by the General Assembly. Specific financial issues are the responsibility of each partner, while the overall financial monitoring and decision making is the responsibility of the project Coordinator, who in collaboration with the EC Officers seeks the best solutions for fulfilling the project objectives under the approved financial plan.

Project communication: The communication between the different bodies of the management structure will flow both bottom-up and top-down. Typical communication methods will be put in place (e.g. meetings, phone, e-mail, Skype). The organisational structure is such that the lead partners on the various WPs are experts in that area. They are also supported by a team of experts from other partners for the effective WP progress and completion of all deliverables within the time frame. The deliverables allow for close supervision of progress and timekeeping. The introduction of the management board containing the partners will allow them to understand the issues pertaining to the WPs, and gain a holistic perspective of the project and their participation within the consortium with shared responsibility.

Milestones: Milestones have been identified, in order to monitor the project and proceed to appropriate actions, in case of any deviation. The milestones have been placed at critical junctions, when the work package results are presented and critical decisions made for the next step in the project.

Risks: The critical risks have been identified with detail, as well as mitigating measures. There are implementation risk (WP1), technical risks (WPs 2-5), and social/exploitation risks (WPs 6, 8).

3.3 Consortium as a whole

For the development of this next generation energy system **a diverse group of experts has been formed** with significant interdisciplinary research activities and expertise: from materials to heat transfer and building physics, and from thermodynamics to ICT and applied social and behavioural research on energy efficiency. The joint effort of this multi-disciplinary team of scientists (chemists, physicists, social), engineers (mechanical, energy, thermal, materials, civil, architects), and practitioners with complementary expertise, ensures that all research aspects are approached with a systematic and synergistic way for achieving the objectives.

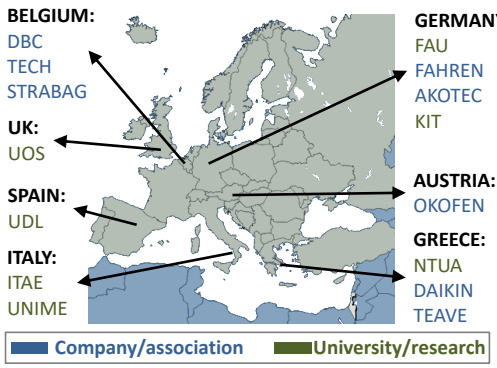


Fig. 34. *Partners map*

This high-quality consortium gathers academia (UNI), research organisations (RTO), industrial partners (IND, including two large enterprises – DAIKIN and STRABGAG, and SMEs) and a professional association (ASSOC) from all over Europe, as shown in Fig. 34, bringing in their expertise and know-how. The relevant skills, activities and main involvement of each partner is presented in Table 16.

Table 16. Partners' skills, activities and main roles in the SolBio-Rev project

Partner	Type	Dedicated highly recognised skills/expertise and industrial activity (industrial partners)	Main roles
NTUA	UNI	Heating and cooling systems expert (certification body for heating boilers), including heat pumps. Highly expert on ORC systems development. Expert on EE in buildings. High expertise on complex simulation and multi-parameter optimisation tasks. Experienced EC project coordinator.	Coordinator, **WPs 1, 3 leader**. Simulation & validation of system performance. Development and testing of the reversible heat pump/ORC. Pilot testing of a prototype in Greece. Technology roadmap.
FAU	UNI	Biomass boiler expert. ORC and heat pump expert. Expert on heating and CHP systems in buildings.	**WP5 leader**. Development and testing of the biomass boiler. Integration with the ORC. Pilot testing of a prototype in Germany.
FAHREN	SME	European leader in adsorption chiller development and manufacturing for domestic applications.	Cascade chiller with heat pump development. Exploitation activities.
ITAE	RTO	Sorbent materials. HEX. Extensive expertise on development of adsorption machines. Control and management of integrated energy systems.	**WP2 leader**. Sorbent material and cascade chiller key components development and lab testing.
TEAVE	SME	Automation control expert (DDC & PLC). Integrator/installer BEMS. Facility management & integration in unified control platforms.	Development of smart controller with advanced features. Exploitation activities.
AKOTEC	SME	Solar collector with vacuum tubes manufacturer. Complete solar system provider.	Co-development of integrated TEGs on the solar collector. Design/delivery of storage tanks for the pilot systems. Exploitation.
UDL	UNI	Thermal energy storage. Building energy efficiency. Building materials. Control strategies. LCA and LCC.	**WP7 leader**. TES components design. LCA and LCC analysis. System control. Dissemination/communication. SHAB chair.
DAIKIN	IND	Expert in heat pump technology. High expertise in heating and cooling solutions in buildings.	**WP4 leader**. Co-development of the heat pump-based configuration. New refrigerant. Exploitation activities.
UOS	UNI	Sociotechnical systems analysis, social acceptance, public policy mechanisms, expert solicitation & qualitative social science techniques.	**WP6 leader**. Case studies of the rapid diffusion of new renewable energy systems and the survey of public attitudes about SolBio-Rev. Business model generation.
DBC	SME	Expert in bridging the research & market implementation gap. Integrated and multi-disciplinary consulting company, accelerator for bringing technologies and services to the market.	**WPs 8, 9 leader**. Dissemination, exploitation and communication. Market analysis and business models.
TECH	ASSOC	Association of electrical and HVAC installers of Belgium.	Installers' needs and requirements and their integration in the design process.

KIT	UNI	TEG and materials expert for heat recovery applications. TEG and heat flows control.	Development of TEGs for the solar collector, focusing on thermal integration.
OKOFEN	SME	Expert in pellet heating systems. Biomass boiler (including biomass-CHP) manufacturer.	Development and production of prototype biomass boilers. Exploitation activities.
STRABAG	IND	Expert in including new technologies in buildings. Construction company with strong innovation profile	System building integration. Renovation aspects. Exploitation activities.
UNIME	UNI	Development and characterisation of sorbent materials. Adsorbent coating manufacturing technologies.	Optimisation of adsorbent coating technique for HEX modules for the cascade chiller, by an optimised post-synthesis process.

Industrial/commercial involvement: Several non-academia partners are included in the consortium and their specific skills and roles in the project are described in the above Table 15. Their participation is essential, in order to get engaged with the SolBio-Rev system from the very beginning, and thus secure their IP.

Other countries and international organisations participation: There is not any non-EU partner in the consortium and no international organisation participates in the SolBio-Rev project. However, there is the possibility to include experts from non-EU organisations in the SHAB, for considering the needs of non-EU stakeholders in the development phase.

3.4 Resources to be committed

The project budget is about **4.79 million €**. Around 44% of the budget and 39% of the total PMs belong to industrial partners and the rest to research partners, while the share of PMs on the main activities is shown in Fig. 35. In addition to the staff effort, there are also costs for consumables, materials and other costs given in Table 3.4b. Personnel costs have been calculated according to rates of participation in previous EU projects and gross salaries. Travel costs include transport and lodging for meetings, conferences and events, and site visits for enhancing synergies and cross-fertilisation among partners. The estimation of the different other direct costs is based on previous experience on EC funded projects, geographical spread of the partners (covering locations from south to central/north Europe) and estimates of the consumables/services costs of the industrial partners.

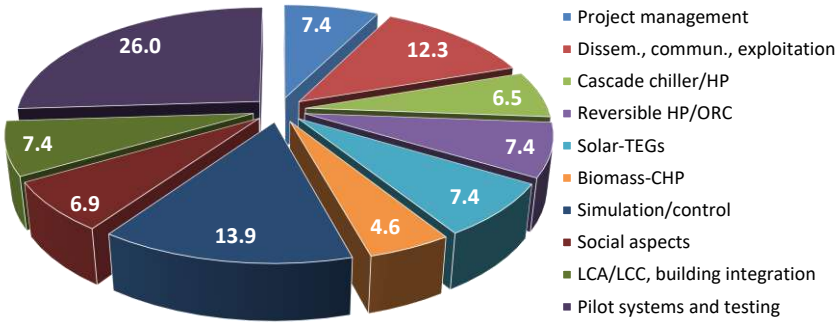


Fig. 35. *Share of PMs (%) on the main project activities*

All depreciation costs for equipment, infrastructure or other assets in the project will be recorded in the appropriate beneficiary's accounts, purchased in accordance with Article 10 of the grant agreement and written off in accordance with international accounting standards and the beneficiary's usual accounting practices.

Table 3.4b: 'Other direct cost' items (travel, equipment, other goods and services)

1. NTUA	Cost (€)	Justification
Travel	35,000	Travel cost for 7 project meetings, 2 persons/meeting (14,000€), and for 5 conferences/events (5,000€). Short visits to other partners for testing, 1-2 persons (6,000€). SHAB travel costs (10,000€).
Other goods and services	170,000	Organisation of 2 project meetings (4,000€), conference fees (6,000€), WP9: website, logo and videos development (10,000€), WP8: dissemination material (1,000€), WP1: two financial certificates (6,000€), WP3: software licenses for EnergyPlus and dynamic simulation (15,000€), WP2: parts for the reversible heat pump/ORC and its test-rig with measurement instruments, control and connections (44,000€), test-rig for the heat pump-based configuration with measurement instruments, control and connections (25,000€). WP5: Preparation of the pilot building: sensors, indoor modifications, heating/electricity loads, hydraulic connections with heating/cooling appliances (32,000€). WP8: Fees for 6-7 Open-access publications (19,000€), WP9: organisation of 1 workshop in Athens (5,000€).
Total	**205,000**	

2. FAU	Cost (€)	Justification
Travel	12,000	Travel cost for 8 project meetings, 1 person/meeting (8,000€), and for 4 conferences/events (4,000€).

Other goods and services	106,000	WP2: Consumables for testing the biomass-CHP boiler (e.g. fuels, installation material, maintenance gas analysis) and shipping costs (10,000€). WP4: Consumables and materials for the prototype containerised pilot building and its installation at FAU (47,000€), heating/electricity loads, monitoring sensors, loggers and minor consumables for the pilot building (30,000€). WP8: 2 Open-Access publications (4,000€), WP1: Auditing costs (5,000€), organisation of one meeting (2,000€) and one workshop in Germany in WP9 (5,000€). WP8: Registration fees for 4 conferences (3,000€).
Total	**118,000**	

3. FAHREN	**Cost (€)**	**Justification**
Travel	20,000	Travel cost for 8 project meetings, 1 person/meeting (8,000€), and for 6 exhibitions/events/workshops (6,000€), site visits for chiller installation, and testing at ITAE and NTUA (6,000€).
Other goods and services	41,000	Production of prototype small-scale adsorber HEXs of 250 W cooling capacity in WP2 and shipping to ITAE (10,000€). Consumables, components and materials for the integrated evaporator/condenser HEX and the cascade chiller equipped with sensors in WP2 and shipping to ITAE (20,000€). WP2: Adsorbent materials for testing the adsorber HEX and shipping to ITAE (5,000€). WP8: Dissemination material, registration fees for 4 exhibitions (6,000€).
Total	**61,000**	

4. ITAE	**Cost (€)**	**Justification**
Travel	20,000	Travel cost for 8 project meetings, 2 persons/meeting (16,000€), and for 4 conferences (4,000€).
Other goods and services	47,000	WP1: workshop/meeting organisation (4,000€); WP2: small-scale HEXs for lab-scale coating technology testing (5,000€), HEXs for integrated evaporator/condenser (10,000€), thermophysical sensors for cascade chiller implementation (5,000€), vacuum components for prototype realisation (5,000€), consumables for components and prototype testing (5,000€), shipping of chiller to Greece (3,000€); WP8: conference fees (2,000€), 2-3 open access publications (7,000€); WP9: communication material (1,000€).
Total	**67,000**	

5. TEAVE	**Cost (€)**	**Justification**
Travel	15,000	Travel cost for 7 project meetings, 1 person/meeting (7,000€), and for 6 exhibitions/events/workshops (6,000€). Site visits of 1 person at FAU for controller setting (2,000€).
Other goods and services	21,500	WP3: Consumables and parts for two prototype controllers (20,000€), and shipping one to Germany in WP4 (1,500€).
Total	**36,500**	

6. AKOTEC	**Cost (€)**	**Justification**
Travel	18,000	Travel cost for 8 project meetings, 1 person/meeting (8,000€), and for 4 exhibitions/events/workshops (4,000€). Site visits for collectors installation, and testing at NTUA and at FAU (6,000€).
Other goods and services	54,500	WP2: Components and consumables to manufacture the prototype collectors (30,500€), including the vacuum tubes, the prototype manifolds for integrating the TEGs, sensors and test equipment. WP2: Test-rig for testing the prototype collector with TEGs (5,000€). WP4: Materials and consumables for the solar field installation in the two pilot buildings and shipment (11,000€). Four storage tanks (two per pilot building) (6,000€). WP8: Fees for 4 exhibitions (2,000€).
Total	**72,500**	

7. UDL	**Cost (€)**	**Justification**
Travel	20,000	Travel cost for 8 project meetings, 2 persons/meeting (16,000€), and for 4 conferences/workshops/site visits (4,000€).
Other goods and services	30,000	WP3: Computer for control supervision and software licences (TRNSYS, SIGMAPRO, other) (12,000€). WP8: Conference and exhibition fees (5,000€), WP1: organisation of one meeting (3,500€), WPs 8,9: dissemination and communication material (9,500€).
Total	**50,000**	

8. DAIKIN	**Cost (€)**	**Justification**
Travel	13,000	Travel cost for 7 project meetings, 1 person/meeting (7,000€), and for 4 exhibitions/events/workshops (4,000€). Site visits for installation and testing at FAU (2,000€).

Other goods and services	66,000	Consumables, components and materials for the two new heat pumps at the ITAE and NTUA labs in WP2 and shipping one HP in Italy (24,000€). WP2: Modified compressor/expander and materials of the reversible HP/ORC test-rig (10,000€). WP4: Preparation of the pilot building at NTUA for the installation of the heat pump-based configuration (5,000€). WP4: Parts, materials and consumables for the prototype reversible unit for the pilot system at FAU, and shipping to Germany (13,000€). WPs 8,9: Dissemination material, registration fees for 4 events (6,000€).
Total	**79,000**	

9. UOS	**Cost (€)**	**Justification**
Travel	28,260	Travel cost for 9 project meetings, 1-2 persons/meeting (9,040€), and for the workshop in Brussels (3,350€). Field work for data collection in four European countries (15,870€).
Other goods and services	16,219	WP6: Design and printing of policy briefing (744€), WP8: 3 open-access publication fees (7,440€), WP6: transcription costs for 90 interviews (8,035€).
Total	**44,479**	

12. KIT	**Cost (€)**	**Justification**
Travel	18,000	Travel cost for 8 project meetings, 1-2 person2/meeting (16,000€), and for 4 conferences/events/workshops (2,000€).
Other goods and services	44,000	WP2: Prototype development: chemicals and consumables for ink modification, printing screens of specially tailored TEG, consumables for the customisation of the printing process, user charges for printing tests on the roll-to-roll printing machine, tools for TEG processing, components for electronics (14,000€), components for test rig, heater for hot water cycle, pumps, valves, air fans, pipes, insulation, collecting basin, various sensors, data logger, computer system, various TEGs for testing, components for power electronics, thermal paste, components of adjusting flow conditions (13,000€). WP2: Prototypes production: Small scale synthesis of active inks, consumables for printing and assembly of prototypes, user charges for the roll-to-roll printing machine, electronics consumables for the TEG module and shipment (5,500€), components for power electronics (3,000€). WP4: Other: shipment of prototypes (national/international) (500€), WP8: registration fees for 4 conferences/exhibitions (4,000€), 1 open-access publication fee (3,000€), WP1: organisation of 1 meeting (1,000€).
Total	**62,000**	

13. OKOFEN	**Cost (€)**	**Justification**
Travel	9,000	Travel cost for 8 project meetings, 1 person/meeting (8,000€), and for 2 exhibitions/events/workshops (1,000€).
Other goods and services	34,500	WP2: Consumables for developing the prototype biomass-CHP boiler (e.g. fuels, installation material, measurement equipment, such as valves, thermocouples etc.) (10,000€). WP4: Consumables and materials for two prototype boilers (20,000€), shipping costs (3,000€), WP8: registration fees for two exhibitions (1,500€).
Total	**43,500**	

15. UNIME	**Cost (€)**	**Justification**
Travel	10,000	Travel cost for 8 project meetings, 1 person/meeting (8,000€), and for 2 conferences/events/workshops (2,000€).
Other goods and services	27,000	WP2: thermophysical parameters sensors (4,000€), washing/calcination set-up (10,000€), chemicals for adsorbent coating preparation (2,000€), consumables for washing/calcination prototypes (5,000€), WP8: registration fees for 2 conferences (1,000€), 2 open access publications (5,000€).
Total	**37,000**	

Finally, no partner has large research infrastructure costs under Article 6.2 of the Model GA.

4. Members of the consortium

The consortium includes **15 partners** in total, with participants from both academic, research and industrial sectors, as well as one association. The consortium guarantees the successful development of the novel SolBio-Rev system as the fields of activity and technical expertise of its members encompass the combined integration of renewables for achieving high energy shares in EU buildings. Furthermore, the consortium partners have the necessary infrastructure to manufacture and test the involved technological components, as well as the excitement to pursuit additional future possibilities for further developing the concept and fulfilling its market potential.

The SolBio-Rev project partners come from **7 European countries** covering all the main climatic zones of Europe (Greece, Germany, Italy, Spain, Belgium, Austria and UK), thus ensuring its wide geographical scope of application and dissemination of the project activities. The main skills and roles of all partners are presented in Table 1, indicating the work package of their main involvement. The consortium partners are presented in the following § 4.1.

Table 1. Partners' skills, activities and main roles in the SolBio-Rev project

Partner	Dedicated highly recognised skills/expertise (all partners) *Field of industrial activity* (industrial partners)	Main roles in WPs								
		1	2	3	4	5	6	7	8	9
NTUA	• Heating and cooling systems expert, including heat pumps • ORC systems development recognised expert • EE in buildings expert • Complex simulation & multi-parameter optimisation skills • Experienced EC project coordinator	X	X X	X		X				
FAU	• Biomass boiler expert • ORC and heat pump expert • Expert on heating and CHP solutions in buildings		X X			X				
FAHREN	• European leader in adsorption chiller development • *Production of advanced chillers for domestic applications*		X			X				
ITAE	• Sorbent material expert • Development of dedicated HEXs • Extensive expertise development of adsorption machines • Control and management of integrated energy systems		X X X	X						
TEAVE	• Automation control expert (DDC & PLC) • Integrator/installer BEMS • *Facility management & integration in unified control platforms*			X X		X				
AKOTEC	• Solar collector with vacuum tubes manufacturer • *Complete solar system provider*		X			X				
UDL	• Thermal energy storage • Building energy efficiency • Building materials and LCA/LCC/CBA • Control strategies and artificial intelligence			X	X	X		X		
DAIKIN	• Expert in heat pump technology • *Leader for heating & cooling (HVAC-R) systems in buildings*		X		X	X				
UOS	• Sociotechnical systems analysis, social acceptance, public policy mechanisms, expert solicitation & qualitative social science • Business models generation for new technologies						X		X	
DBC	• Expert in bridging the research & market implementation gap • *Integrated and multi-disciplinary consulting company, accelerator for bringing technologies and services to the market*								X	X
TECH	• Experts in bridging the product and installation gap, in bridging between the producers and the electrical and HVAC installers • *Association addressing the needs and requirements of installers for innovative energy technologies in buildings*				X		X	X		

KIT	• TEG and materials expert for heat recovery applications • TEG and heat flows control		X	X		X				
OKOFEN	• Expert in pellet heating systems • *Biomass boiler (including biomass-CHP) manufacturer*.		X			X				
STRABAG	• Expert in including new technologies in buildings • *Building construction company with strong innovation profile*							X	X	
UNIME	• Development and characterisation of sorbent materials • Adsorbent coating manufacturing technologies		X X							

4.1. Participants

4.1.1 Participant 1: National Technical University of Athens (NTUA) (Coordinator, Greece)

Website: http://www.lsbtp.mech.ntua.gr

The National Technical University (NTUA) is the oldest and most prestigious educational institution in Greece in the field of technology and has contributed unceasingly to the country's scientific, technical & economic development since its foundation in 1836. NTUA is divided into nine academic Schools, eight engaging in **engineering sciences** and one in **general sciences**. The personnel includes about 1,000 people as academic staff. These nine Schools are divided into 33 Departments or Sections. The "Laboratory of Steam Boilers and Thermal Plants" belongs to the Thermal Engineering Department of the School of Mechanical Engineering, and is the coordinator of the SolBio-Rev project.

The Laboratory of Steam Boilers and Thermal Plants of NTUA has a wide experience and is active for over 30 years in the field of **thermal energy conversion** technologies, focusing among other topics on **energy efficiency** assessment and evaluation, energy savings in industrial processes and power plants, **process simulation/optimisation, experimental testing and development of heat pump units**, thermodynamic modelling and development of advanced cycles for power generation and innovative **domestic tri-generation systems** for heating and cooling production.

The laboratory is global leader in ORC technology and has a long experience and expertise in the thermodynamic optimisation, design, development and experimental testing of **ORC system**s. More specifically, the laboratory has issued numerous research publications on the thermodynamic design/integration and heat transfer of ORC applications, on their thermo-economic evaluation/optimisation, on the study of advanced configurations, on the thermodynamic and economic investigation of ORC-based biomass and solar-driven domestic multi-generation systems, as well as on the experimental testing of ORC components (see also *"Relevant recent publications"* below).

NTUA is an active member of the Knowledge Centre of Organic Rankine Cycle (KCORC) organisation, being also the organiser and host of the upcoming International Seminar on ORC Power Systems to be held in September 2019 in Athens (ORC2019). NTUA is additionally a recognised partner of several ***ORC technology*** focused projects (see also "*Relevant recent projects"*):

- ✓ SORC: NTUA contributed to the thermodynamic optimisation and heat transfer investigation of a novel micro-scale supercritical ORC prototype.
- ✓ BioTRIC: development and testing of an innovative domestic solar-/biomass-driven trigeneration system based on the integration of a supercritical ORC along with a vapour compression cycle.
- ✓ Marine ORC: NTUA undertook the development and experimental investigation of a micro ORC prototype aimed at waste heat recovery from marine diesel engines.
- ✓ SunClim: development of a solar driven trigeneration system based on an ORC and an ejector cooling cycle.

The laboratory has also coordinated/participated in ***heat pump*** oriented projects (see also "*Relevant recent projects"*):

- ✓ EXP-Heat: development of a two-phase expander for replacing the heat pump throttle valve.
- ✓ HYBUILD: focusing on the smart domestic integration of storage with heat pump units.

NTUA has extensive experience and research activity in the field of ***energy efficiency*** interventions and renewable energy sources in various building types (residential & non-residential ones) mainly in Greece. The NTUA staff participated in forming both the initial and recast Greek Technical Guidelines 20701-1, -2, -3, -4, and the corresponding training programme for energy inspectors, under the supervision of the Technical Chamber of Greece (TEE-TCG).

Furthermore, the NTUA experts performed more than 2.5 million simulations, using behavioural modelling and user energy profiles in typical buildings in Greece. The simulation tools were developed by the members of the Laboratory and are in accordance with European standards (e.g. ELOT EN ISO 13790 E2 (2009), ELOT EN 15316 (2008), ELOT EN 15193 (2008), etc.). Additionally, similar simulations of techno-economic analysis were also executed, as defined in Directive 2010/31/EC and the delegated Regulation (EC) no. 244/2012.

NTUA is especially suited as a **coordinator** in the SolBio-Rev project having wide experience in similar works covering a large range of involved technologies. NTUA has a very high participation in several EU projects dealing with renewable energy systems, heating-cooling systems, and industrial processes, with the aim to work together with industrial partners and bring to the market innovative technologies.

In addition to the ORC and heat pump related projects, NTUA participates in the H2020 Biofficiency project and coordinates the H2020-FTI project ZEOSOL, which deals with the development of a solar cooling and heating unit,

being highly relevant to the SolBio-Rev project, as well as the H2020 project SWS-HEATING, which is focused on sorbent material embedded in a compact multi-modular sorption STES unit supplied by solar thermal energy for single-family houses.

Furthermore, NTUA is a certified body for heating systems and hot water boilers (including tri-generation systems), providing the "CE" marking. It has certified over 90% of the small, medium and large co- (tri-) generation plants operating nowadays in Greece (the rest 10% have been certified by TÜV-Hellas), providing its expertise on heating and tri-generation systems in buildings. A complete testing facility for boilers' certification according to the EU prototype EN ISO/IEC 45011 (EC certifier for oil- and natural gas fired boilers) is available in the laboratory. The facility is suitable for testing central heating systems fed with solid, liquid, gas fuel or electricity driven heat pumps or ion exchange boilers with maximum nominal heat output of 400 kW.

Finally, NTUA has developed so far numerous **energy-related prototype and demonstration units** proving its know-how on complex thermal engineering processes. A sample of those is given next:

- A power plant of 200 kWe.
- A tri-generation plant for electricity production of 1.5 MWe and thermal-cooling production of 1.6 MWth (cooling is produced with absorption chillers).
- A small-scale heat-to-power unit (~ 5 kWe) based on the Organic Rankine Cycle (ORC) for electricity production.
- A hybrid tri-generation unit for cooling, heating & power, based on ORC (heat from biomass/solar).
- Environmental measurements infrastructure according to EN ISO/IEC 17025:2005.
- Two Fluidised Bed facilities for biomass combustion or gasification: an Atmospheric Circulating Fluidised Bed Combustor (ACFBC) (150 kW), an Atmospheric Bubbling Fluidised Bed (ABFB) (lab-scale). These installations are used for the research and assessment of this combustion technology.
- A 2 kWe PEM Fuel Cell for domestic use using hydrogen.
- Assembled test-rig of open cell SOFC (100 cm^2 surfaces, testing of solid membranes and catalysts).
- Fixed bed test rig for gas cleaning with solid sorbents before methanation process.

Main tasks in the project

NTUA will be the project **coordinator** (WP1) and will be responsible for the development of the **reversible heat pump/ORC** component and its integration within the heat pump-based configuration in WP2. It will also handle the development of the **numerical platform and its validation**, when test data become available (WPs 3 and 5). NTUA has a central role in WP5, being **in charge of one pilot site testing** at its premises.

NTUA will work together with the other partners and provide its expertise on thermal processes for the heat sink specifications of the solar-TEGs and work together with FAU in fine-tuning the temperature of the biomass heat in WP2. NTUA will also participate in the development of the control strategies in WP3, directly linked to its simulation tasks. Finally, NTUA will be actively involved in other activities as well, such as the LCC in WP7, and dissemination, communication and exploitation in WPs 8 and 9.

Key personnel involved in this project

Assoc. Prof. Dr.-Ing. Sotirios Karellas (M). Associate Professor at the School of Mechanical Engineering of NTUA, visiting Professor at the Technische Universität München, specialist on energy systems, energy storage, solar-thermal energy, biomass, ORC technology, decentralised energy systems, heat pumps, and tri-generation systems. He has over 100 relevant publications in scientific Journals and Conferences. He is currently supervising 5 Ph.D. students at NTUA working in the field of energy production/conversion and energy performance in buildings. He has participated in a high number of projects in NTUA (2006-present) and in Technische Universität München (2001-2006), having both technical and coordination responsibilities. He has industrial experience in power production plants, co/tri-generation systems, heat pumps, building heating systems and chillers. He is full member of the editorial board of 5 scientific journals dealing with energy systems and renewable energy sources.

Prof. Dr.-Ing. Emmanuel Kakaras (M). Professor at the School of Mechanical Engineering of NTUA and the Director of the Laboratory of Steam Boilers and Thermal Plants, since 1995. He is also director of the Chemical Process and Energy Resources Institute of the Centre for Research and Technology Hellas (CERTH). He has more than 25 years of experience on power production, energy systems modelling, and heating/cooling systems and over 450 publications in scientific Journals and Conferences.

Christina Hatzilau (F). Physicist M.Sc. – Ph.D. candidate. Associate researcher at NTUA. Her research interests include the Day ahead Electricity Generation Planning with integration of variable RES (PhD theme), Pollution abatement technology, Clean Technologies in Industry, Emissions Trading and application of Environmental & Energy Policy measures. She has been involved in projects concerning decentralised energy generation and combined solar water and space heating. She has been an EU-ETS Emissions Trading Agent in Greece of an EU Brokerage House from 2011 to 2016 and has acted as external Assistant to several private companies, the Centre for Research and Technology Hellas (CERTH), Centre for Renewable Energy Sources (CRES), and the Public Power Corporation of Greece (PPC).

Platon Pallis (M). He is a Ph.D. candidate in the field of Waste Heat Recovery with the use of Organic Rankine Cycle systems. He graduated from the School of Mechanical Engineering of NTUA in 2002 and since 2003 holds a M.Sc. in Energy Production and Management. He is certified by IRCA as Auditor/ Lead Auditor of Energy Management Systems according to the requirements of ISO 50001: 2011 and of Environmental Management Systems according to ISO 14001: 2004. From 2002 to 2007 he worked as a research associate in the Laboratory of Steam Boilers and Thermal Plants and participated in EC-funded research projects. The research objectives of most of these projects were in the field of heat production by hot water boilers (design, laboratory measurements and techno economic analysis), but also in experimental fluidised bed combustion plants. As a member of the permanent staff of the lab, he provides for administrative and technical support to the accredited laboratory services as a certification body of Heat Production Systems and Environmental Measurements and Sampling Department Unit in line with the requirements set by ISO17025:2005.

Konstantinos Braimakis (M). He graduated from the School of Mechanical Engineering of NTUA in 2013. He is a Ph.D. candidate on the "Computational and experimental investigation of low grade waste heat utilisation systems for power production" and a research associate at the Laboratory of Steam Boilers and Thermal Plants. His research interests include Organic Rankine Cycle, low grade waste heat utilisation for production of power and heat, cogeneration and tri-generation systems, decentralised power production, process modelling, analysis and simulation of hybrid power generation systems, thermal plants, Renewable Energy Sources, Biomass supply chains. He has 7 publications in Journals and 6 in Conferences.

Tryfon Roumpedakis (M). He graduated from the School of Mechanical Engineering of NTUA in 2014, and has been working as research assistant at NTUA for the last 3 years. In 2016, he finished his postgraduate studies in "Energy Production and Management" at NTUA. In 2017, he pursued his second master degree in "Sustainable Processes and Energy Technologies" in the Process & Energy Department at TU Delft, Netherlands. Since 2018, he is a Ph.D. candidate at NTUA, focusing on solar thermal cooling applications. His main fields of expertise are the design and testing of adsorption chillers, heat-to-power conversion technology mostly with Organic Rankine Cycle, as well as modelling of heat transfer mechanisms and equipment. He has contributed to several researches and publications being conducted over the past years at NTUA, while at the moment he is a main member of a team working on publishing a book regarding Solar Cooling Technologies.

Ioannis Mandilaras (M). Post-Doc researcher, energy expert. Dr. Ioannis Mandilaras is a Post-doc Research Associate at NTUA. He received his Diploma in Mechanical Engineering (2004), his M.Sc. in Automation Systems (2006) and his Ph.D. (2015) from NTUA. He has been working for the past 10 years on the development of experimental methods to characterise building materials in terms of thermal conductivity, heat capacity, humidity effects and thermal bridges and monitoring and numerical methods to characterise the energy performance of buildings. He has 26 publications in peer-reviewed journals and international conferences.

Antonios Charalampidis (M). He is a Ph.D. student at the Laboratory of Steam Boilers and Thermal Plants of NTUA, working on trigeneration systems based on the reversible organic Rankine cycle. His research interests are mainly focused on the analysis and the design of organic Rankine cycle systems for cogeneration and trigeneration, especially for small scale applications, participating in relevant projects of the Laboratory.

Charalampos Mavrakis (M). Technical engineer. Mr. Charalampos Mavrakis is a technical engineer (technical education in mechanical engineering) with 20 years of experience in lab-testing of mechanical and electrical systems.

Despina Magiri–Skouloudi (F). She holds an M.Eng. in Chemical Engineering from the University of Patras and an M.Sc. in Energy Production and Management from NTUA. She has over two years of professional experience in the thermodynamic modelling of industrial processes, energy production and heat integration, as well as biomass and biofuel industrial applications. She is a research associate of the Laboratory of Steam Boilers and Thermal Plants of NTUA since May 2018. Her research interests include life cycle analysis of power generation technologies, waste heat valorisation and socioeconomic analysis of renewable energy sources deployment.

Vassiliki–Ioanna Barmparitsa (F). She has studied in the National and Kapodistrian University of Athens, Department of Philosophy, and afterwards acquiring an 18-month of experience in public administration in the "*Greek Manpower and Employment Organisation*". She is a member of the Laboratory of Steam Boilers and Thermal

Plants of NTUA administration since 2014. Her duties include project management and dissemination activities for EU and national funded projects, preparation and evaluation of legal documents, resource allocation, organisation of seminars and summer schools and dissemination of laboratory announcements through public media and university platforms.

Relevant recent publications

1. Braimakis K, Karellas S. *Exergetic optimisation of double stage Organic Rankine Cycle (ORC)*. Energy 2018;149:296-313 **(2018)**.
2. Braimakis K, Karellas S. *Integrated thermoeconomic optimisation of standard and regenerative ORC for different heat source types and capacities*. Energy 2017;121:570-98 **(2017)**.
3. Braimakis K, Thimo A, Karellas S. *Technoeconomic Analysis and Comparison of a Solar-Based Biomass ORC-VCC System and a PV Heat Pump for Domestic Trigeneration*. Journal of Energy Engineering 2017;143(2):04016048 **(2017)**.
4. Karellas S, Braimakis K. *Energy–exergy analysis and economic investigation of a cogeneration and trigeneration ORC–VCC hybrid system utilizing biomass fuel and solar power*. Energy conversion and management 2016;107:103-13 (**2016**).
5. Leontaritis AD, Pallis P, Karellas S, Papastergiou A, Antoniou N, Vourliotis P, Kakalis NM, Dimopoulos G. *Experimental study on a low temperature ORC unit for onboard waste heat recovery from marine diesel engines*. In: 3rd International Seminar on ORC Power Systems, 2015 Oct 12 (p. 1) (**2015**).

Relevant recent projects

1. SWS-HEATING, Coordinator: *Development and Validation of an Innovative Solar Compact Selective-Water-Sorbent-Based Heating System*, H2020-LCE-07-2018 (**2018-2022**)
2. ZEOSOL, Coordinator: *Integrated solar heating and cooling unit based on a novel zeolite chiller and heat pump*, H2020-FTI-2016 (**2017-2019**)
3. HYBUILD, Partner: *Innovative compact HYbrid electrical/thermal storage systems for low energy BUILDings*, H2020-EEB-2017 (**2017-2021**)
4. EXP-HEAT, Coordinator: *Energy Recovery in new and retrofitted heat pumps using a dedicated expander concept*, FP7-SME-2013 (**2014-2017**)
5. BioTric, Coordinator: *Detailed investigation and optimisation of the operation and design of a small-scale hybrid Bio-TRI-generation system powered by a supercritical ORC*, Programme Aristeia II (Excellence). Project nr. 4988, Greek General Secretariat of Research and Technology (**2014-2015**)

The above mentioned relevant projects are just a sample of those that NTUA has participated/is participating during the last 4 years (either as a coordinator or as a partner) and are indicative of its experience in research, innovation and applied engineering projects in the field of heating/cooling, energy conversion technologies, and industrial processes.

Significant infrastructure/technical equipment, relevant to the proposed work

Major equipment of the Lab. of Steam Boilers and Thermal Plants of NTUA will be used for the tests of the reversible heat pump/ORC, and the heat pump-based configuration in WP2. The existing equipment that will be used includes the following:

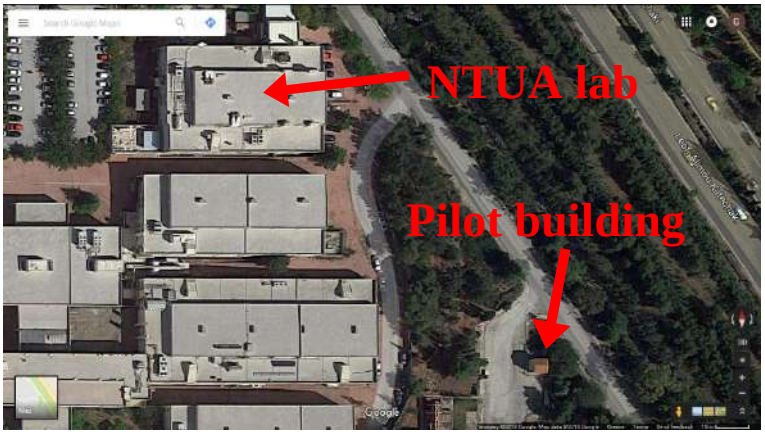
- Equipment for the determination of the efficiency grade of heat exchangers, hot water boilers, cooling towers etc. Portable energy meter for the determination of heat flows.
- Supplementary measuring instruments concern: pressure transducers, flow-meters, torque-meters, thermo-couples.
- Electric load measurements / Power measurements (current & voltage, active power, reactive power, power factor, frequency), for the determination of compressor/motor electric efficiency and power consumptions.
- Various sensors (flow-meters, thermo-elements, etc.).
- Flow rate measurement for a variety of fluids by the help of a modern energy flow meter without the need for altering the installation or seizing its operation.
- Data logging equipment.
- A portable unit for environmental measurements and instrument calibration.

The available software packages of NTUA that can be used in WPs 2, 3 are as follows:

- Energy systems packages (in-house or commercial) specialised for thermodynamic cycle calculations: EES, ENBIPRO, IPSEpro, ASPENplus, Gate Cycle, Refprop, CoolProp, Matlab, Simulink, Dymola, OpenModelica, APROS.
- In-house heat-pump and ORC design numerical tools.
- Other general-purpose software: heat transfer programs for HEX design (in-house tool based on RefProp 8 from NIST) in subcritical and supercritical conditions and also software for stochastic modelling, risk management and economic evaluations, such as multi-criteria parametric analyses.

A figure from the laboratory is shown below, where the certification of heating systems is implemented.

A top view of the NTUA lab and of the **pilot building** are shown in the next figure. The pilot building has a perfect orientation facing south. Further details of this building are provided in the methodology description of § 1.3.7.



4.1.2 Participant 2: Friedrich-Alexander University of Erlangen-Nürnberg (FAU) (Germany)

Website: https://www.evt.tf.fau.de/

FAU is a pioneering research university with an international perspective and one of the largest universities in Germany, with 39,780 students, 265 degree programmes, 4,000 academic staff (including over 579 professors), near 200 million € third-party funding, and 500 partnerships with universities all over the world. Teaching at the University is closely linked to research and focuses on training students in both theory and practice to enable them to think critically and work independently. The research itself also meets the perfect balance between a theoretical approach and practical application.

Combustion, gasification and synthesis gas utilisation and carbon capture are the main focuses of FAU's Chair of Energy Process Engineering. The institute deals with traditional thermal engineering, such as steam and gas turbine power plant processes, district heating systems, combined heat and power plants, synthesis gas production and utilisation. Special focus is given on **biomass combustors**, fluidised bed combustion and gasification of biomass and coal, and the conversion of biogenic syngas and tars in fuel cells by means of a catalyst. The institute operates a complete 100 kW SNG process chain with an allothermal gasifier (i.e. Heatpipe reformer), hot gas cleaning, CO_2 removal and catalytic fixed bed methanation. Recent research projects focus on biological methanation and the interdisciplinary evaluation of renewable gas technologies.

The institute has a large experience in **development, installation and testing of thermal processes** as well as their **integration in buildings and field-test environments**. At the moment, FAU provides a prototype of a small-scale fluidised bed combustion chamber for field-tests with different solid biofuels and residues (project "*BioWasteStirling*"). This design was developed in the last years for coupling with Stirling engine to realise micro-scale CHP units.

Recently, the project "*HomeORC*" with a focus on the integration of **small-scale ORC in domestic environments with smart control units** was successfully finalised. FAU had a special focus on the thermal coupling of combustion and ORC, testing innovative combustion technologies as a heat source in order to reach higher temperature levels. Key objective was the monitoring and prediction of electricity and heat demand, trying to improve the full-load operation hours and an intelligent control system realising an overall energy management of domestic buildings. Moreover, FAU has an on-going research activity on **heat pumps**, focusing on domestic heating applications.

Since 2012, the institute belongs to the activities of the research centre "***Energy Campus Nürnberg***". Due to its interdisciplinary approach, it brings together scientists and initiates projects in the fields of:

- Engineering
- building physics
- energy economy
- infrastructure

Within the second founding period started in 2017, the institute is involved in different projects concerning storage, especially in the development and testing of a reversible HP/ORC system for high-temperature storage.

Finally, FAU has developed various prototype energy installations and has an extended know-how on developing new technologies. A sample of these ***energy installations*** include:

- Large varieties of biomass combustors based on fluidised bed and grate combustion technology
- Thermal engines (3 kW Stirling engine, 1 kW ORC module) and SOFC test rigs for the evaluation of CHP concepts.
- Process chains for production of SNG in 5 and 100 kW (Heat pipe reformer) scale
- Heat pipe production and testing facilities

Main tasks in the project

FAU will be involved especially in the technological aspects and the pilot testing of the SolBio-Rev system. FAU will closely collaborate with NTUA concerning the development and testing of the reversible heat pump/ORC. In parallel, FAU will work together with OKOFEN for realising an internal HEX in **biomass boilers** and for optimising the combustion technology regarding emissions and efficiency with the use of exhaust gas recirculation (both in WP2). FAU will be **in charge of the second pilot system** testing in Germany (WP5 leader), closely following all the activities during the project duration. Finally, FAU will be actively involved in other activities as well, and dissemination, communication and exploitation in WPs 8 and 9, organising one project workshop at its premises.

Key personnel involved in this project

Prof. Dr.-Ing. Jürgen Karl (M) is a full professor at the Chair for Energy Process Engineering at the University of Erlangen-Nuremberg, Germany. His main research interests involve bioenergy, combustion and gasification, solid oxide fuel cells (SOFCs) and methane synthesis. He coordinated several European projects, namely the FP5 projects "BioHPR", "BioHPR NAS", the FP6 project "BioCellus", and the RFCS projects "CO2freeSNG" & CO2freeSNG2.0 and joined also a project with focus on solar ORC processes (FP6: RO-SOLAR-RANKINE). Recently, the leadership of another RFCS-project "i3Upgrade" with a focus on upgrade of carbon sources in steel mills started. Since 2011, Prof. Karl is the head of the newly founded Chair for Energy Process Engineering at the University of Erlangen-Nuremberg in Germany. He was an evaluator for the 6th and 7th European Framework program and is a member of the European Commission's TGC3 technical advisory group of the Research Fund Coal and Steel. In 2007 he founded the start-up company Agnion Inc. in order to commercialise the Heatpipe-Reformer, an innovative gasification technology producing synthesis gas from biomass. The company erected four Heatpipe reformer plants with a total capacity of 4.5 MWth between 2008 and 2013.

Dr.-Ing. Dominik Müller (M) leads the "Combustion and gasification of biomass" research group at the Chair for Energy Process Engineering. In his research, he developed an innovative concept for micro-scale CHP with Stirling engines and fluidised bed combustion. He coordinates several ongoing research projects which focus on CHP concepts with Stirling engines or ORC and plasma assisted gasification processes.

Sebastian Staub (M), M.Sc., is a researcher with expertise in small-scale ORC technology. He worked on the previously mentioned project HomeORC, integrating a 1 kW ORC to domestic buildings. Currently he is developing heat transfer solutions for supplying ORCs with heat in a temperature range up to 200 °C based on heat pipe technology.

Tanja Schneider (F) M.Sc., started her career as researcher in 2017 within the national funded project "BioWasteStirling - Power generation from biogenic residuals in a fluidised bed fired Stirling engine". At the moment, she is commissioning a pilot plant for field-tests in the environment of an energy provider. Starting from autumn 2018, the consortium will perform long-term tests with different biogenic fuels.

Relevant recent publications

1. Staub S, Bazan P, Braimakis K, Müller D, Regensburger C, Scharrer D, Schmitt B, Steger D, German R, Karellas S, Pruckner M, Schlücker E, Will S, Karl J. *Reversible Heat Pump–Organic Rankine Cycle Systems for the Storage of Renewable Electricity*. In: Energies 2018, 11(6), 1325, May 2018. doi:10.3390/en11061352. (**2018**)
2. Plankenbühler T, Müller D, Karl J. *Slagging prevention and plant optimisation by means of numerical simulation*. EUBCE 2017, Stockholm, Sweden, 12.-15.06.2017. (**2017**)
3. Staub S, Bauer J, Müller D, Franke J, Karl J. *CO_2-Neutral Generation of Heat and Power in Smart Homes by Organic Rankine Cycle Powered Combined Heat and Power Micro Plants*. In: AEF (Advanced Engineering Forum) 19 (2016), S. 10-19. (**2016**)
4. Müller D, Plankenbühler T, Karl J. *Small-scale CHP with Stirling Engines based on fluidized-bed combustion of biomass*. 17th International Stirling Conference, Newcastle, 24.-26.08.2016 (**2016**)
5. Reißner F. *Development of a Novel High Temperature Heat Pump System*. Dissertation, Friedrich-Alexander-University Erlangen-Nürnberg (**2015**)

Relevant recent projects – all as coordinator

1. HP/ORC, Coordinator: Upgrade of low-temperature heat with reversible HP/ORC systems. National project - Energy Campus Nürnberg, (**2017-2021)**
2. BioWasteStirling, Coordinator: *Power generation from biogenic residuals in a fluidized bed fired Stirling engine*, National project of German Federal Ministry for Economic Affairs and Energy, **(2017-2020)**
3. HomeORC, Coordinator: *Micro CHP with Organic Rankine Cycles*, National project E|Home Center, (**2015-2018)**
4. FuelBand, Coordinator: *Broadening the range of fuels in modern biomass combustion chambers*, National project of German Federal Ministry for Economic Affairs and Energy, **(2012-2015)**

Significant infrastructure/technical equipment, relevant to the proposed work

Equipment relevant to the proposed work will be used for the tests of biomass boilers and the pilot testing of the SolBio-Rev system in its dedicated environment.

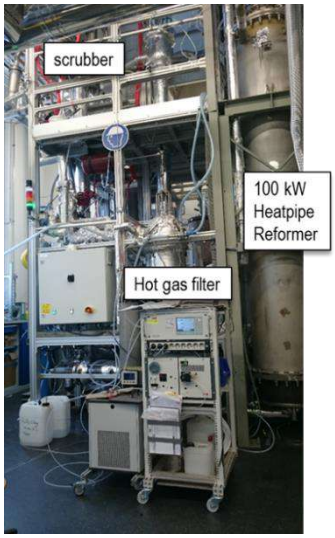
The existing equipment that will be used in the project for the **boiler development and testing** in WP2 includes the following:

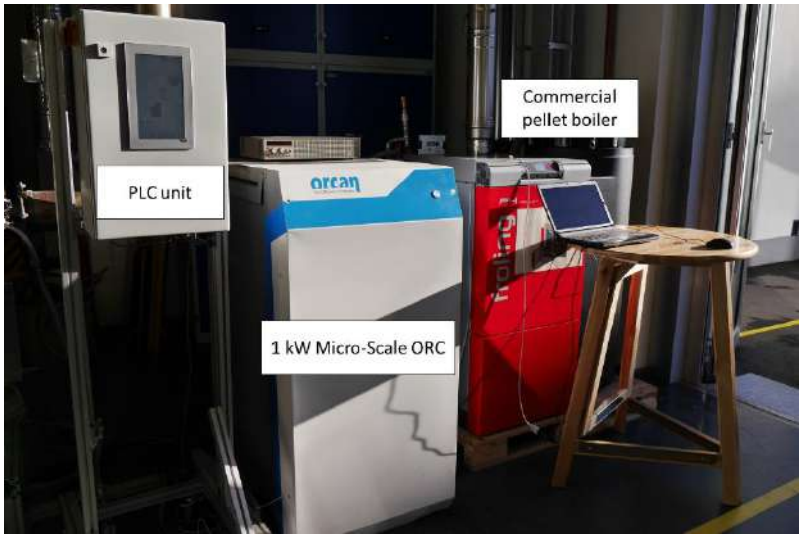
- PLC units for process control and data logging
- Cooling systems to reproduce relevant environments for boiler/CHP tests
- Flue gas analytics (dust emissions, gas composition, tar measurements)
- Fuel and ash analysis
- Air compressors (up to 10 bar), series of bottled gases, pressure reducers and connectors with a variety of mass-flow-controllers and gas condition units.

The relevant software packages used for the boiler **simulation purposes** (WP2) and **system evaluation** (WP5) are:

- Thermodynamic simulation and power plant engineering: IPSEpro, ASPENplus, FactSAGE
- Other general-purpose software/equipment: CAD tools, computational infrastructure (server solutions), PLC programming

Some figures of the institute, the 100kW Heatpipe reformer and the previous coupling of a pellets boiler with a 1 kW ORC are shown below. All of them were designed, erected and commissioned in-house at FAU.





Left: Heatpipe reformer. Right: Biomass-CHP experimental unit

FAU lab and envisaged installation location of the pilot building

4.1.3 Participant 3: Fahrenheit GmbH (FAHREN) (Germany)

Website: www.fahrenheit.cool

Fahrenheit GmbH is based in Germany, with headquarters in Munich and manufacturing plant in Halle with 33 employees in total. Fahrenheit is the leading developer and manufacturer in the **adsorption technology industry**. The company is well-known for its professional, complete solutions in the field of thermal chillers, proved by its numerous recognitions and awards.

Fahrenheit was founded in 2002 (initially named SorTech AG) as a spin-off company of Fraunhofer Institute of Solar Energy Systems (ISE). From the very beginning, research and technological excellence have been the company's pillars. Fahrenheit is the pioneering company in small/medium capacity adsorption chillers. Since its foundation, the R&D base is the core of Fahrenheit's business, which is demonstrated with the 22 national and international patent families on thermal refrigeration and technological solutions utilising solid sorbents like silica gel and zeolite. FAHREN quickly evolved to be the market and innovation leader for adsorption cooling. The technology, initially intended as a solution for solar cooling, has since become established in numerous applications, such as in industry, automotive and data centres.

Since market introduction, Fahrenheit has sold more than 600 adsorption chillers units of capacities from 10 to over 100 kW based on silica gel – water. Based on the R&D work, a second product based on zeolite-water has been developed and has been launched in the market in 2015, with **on-going research work** aiming to improve the adsorption chiller in terms of both performance and cost-effectiveness (see "*Relevant recent projects*" below).

Main tasks in the project

Fahrenheit will be mainly involved in the development and production of the **adsorption chiller** to be included in the **cascade chiller/heat pump** component in close cooperation with ITAE and DAIKIN (WP2). Moreover, it will collaborate with TEAVE providing **input for the controller development** (WP3), and will contribute in the system operation and performance optimisation. Fahrenheit will also support the evaluation of test results of the entire system in the pilot site at NTUA, focusing on the cascade chiller (WP5). Finally, Fahrenheit will actively get involved in other activities as well, such as dissemination, communication and exploitation in WPs 8 and 9, with the aim to further develop this technology and bring it to the market in 2025.

Key personnel involved in this project

Ralph Herrmann (M). He studied and received a PhD (1995) in chemistry in University of Halle. As a senior scientist, he worked about different topics of zeolite chemistry in Erlangen before he joined Fahrenheit in 2004 for the development of the Partial-Support-Transformation Zeolite coating technique. He is head of the materials development department and responsible for scale-up of this process, and adsorbents development and characterisation. Currently, he is inventor or co-inventor of 4 patents held by Fahrenheit GmbH.

Matthias Hoene (M), CEO, has been in charge of leading Fahrenheit since 2017. He started his career as a software developer with Trilogy Software in Austin/Texas, and went on to become a project manager with BMW in their logistics division. He then joined McKinsey as a consultant to automotive, high-tech, and healthcare clients. In 2010, Matthias Hoene co-founded ZebraMobil GmbH in Munich, the first free-floating car sharing operator in a major city. After selling the car sharing operations of ZebraMobil, he returned to McKinsey to run Horizon360, an internal startup which offers data and standard tools to help with IT and Digital transformations. Matthias Hoene graduated from ETH Zurich with a degree in Industrial Management and Production Engineering, and holds an undergraduate diploma in Mechanical Engineering.

Steffen Kühnert (M). He is Technical Director at Fahrenheit. He joined the company in 2007 as development engineer. Since then, he took on responsibility for both product development and manufacturing. Prior to joining Fahrenheit, Steffen Kühnert had been working for engineering companies. He started his career by serving seven years in the German armed forces. Steffen Kühnert completed an apprenticeship as a cutting machine operator and holds a diploma in Mechanical Engineering.

Relevant recent publications

1. Wittstadt U, Füldner G, Laurenz E, Warlo A, Große A, Herrmann R, Schnabel L, Mittelbach W. *A novel adsorption module with fiber heat exchangers: Performance analysis based on driving temperature differences*. Renewable Energy 2017;110:154-61 **(2017)**
2. Wittstadt U, Füldner G, Vasta S, Volmer R, Bendix P, Schnabel L, Mittelbach W. *Adsorption Heat Pumps and Chillers–Recent Developments for Materials and Components*. 12th IEA Heat Pump Conference K.4.3.1. **(2017)**
3. Wittstadt U, Füldner G, Andersen O, Herrmann R, Schmidt F. A *new adsorbent composite material based on metal fiber technology and its application in adsorption heat exchangers*. Energies 2015;8(8):8431-46 **(2015)**
4. C Weber, F Mehling, A Fregin, I Daßler, P Schossig. *On standardizing solar cooling – field test in the small capacity range.* International Conference on Solar Heating and Cooling for Buildings and Industry IEA Solar Heating and Cooling (SHC) Conference, Freiburg, Germany **(2013)**
5. A Kühn (Ed.). *Thermally driven heat pumps for heating and cooling*. Universitätsverlag der TU Berlin, ISBN (online) 978-7983-2596-8 **(2013)**

Relevant recent projects

1. SWS-HEATING, Partner: *Development and Validation of an Innovative Solar Compact Selective-Water-Sorbent-Based Heating System,* H2020-LCE-2016-17 **(2018-2022)**
2. GEOFIT, Partner: *Deployment of novel GEOthermal systems, technologies and tools for energy efficient building retrofitting,* H2020-LCE-2017 **(2018-2022)**
3. HYBUILD, Partner: *Innovative compact HYbrid electrical/thermal storage systems for low energy BUILDings*. H2020-EEB-2016-2017 **(2017-2021)**
4. ZEOSOL, Partner: *Integrated solar heating and cooling unit based on a novel zeolite chiller and heat pump*. H2020-FTI-2016 **(2017-2019)**
5. Heat4cool, Partner: *Smart building retrofitting complemented by solar assisted heat pumps integrated within a self-correcting intelligent building energy management system*. H2020-EEB-2016 **(2016-2020)**

Significant infrastructure/technical equipment, relevant to the proposed work

The infrastructure used for the production of the prototype cascade chiller/heat pump unit (WP2), according to the design and its quality control is described next.

Zeolite Coating Plant for adsorber HEXs

Production line: Currently, Fahrenheit produces between 100 to 150 adsorption chillers per year at its factory workshop in Halle, Germany. The standard parts of the prototype unit will be produced in this workshop. The production line includes the following processes:

- Coating of heat exchangers with zeolite and silica gel.
- Manual assembly and stainless steel welding (WIG) of the adsorption modules.
- Semi-automatised activation of the adsorption module (bake-out, evacuation and filling with process water under vacuum).
- Manual assembly of the hydraulic system, the controller and the casing.
- Fully automatised final quality control of chiller operation and performance data.

Station for Final Quality Control of a silica gel chiller (eCoo)

Laboratory: For R&D, Fahrenheit operates a laboratory including three parallel test rigs to measure performance of adsorption chillers, two test rigs to measure adsorber, evaporator or condenser performance independently, a series of smaller experimental installations for the measurement of data of adsorption materials (adsorption equilibria, kinetics and cycle stability) and a full scale chemical laboratory.

The integration of the chiller with the heat pump in WP2 will be conducted in the laboratory, as well as its quality control.

4.1.4 Participant 4: Consiglio Nazionale delle Ricerche (CNR), Institute for Advanced Energy Technologies (ITAE) (Italy)

Website: http://www.itae.cnr.it/

The National Research Council (CNR) is the main Italian public research organisation. Its duty is to carry out, promote, spread, transfer and improve research activities in the main sectors of knowledge growth and of its applications for the scientific, technological, economic and social development of the Country. To this end, the activities of the organisation are divided into macro areas of interdisciplinary scientific and technological research, concerning several sectors: biotechnology, medicine, materials, environment and land, information and communications, advanced systems of production, judicial and socio-economic sciences, classical studies and arts.

CNR is active all over Italy through a network of institutes aiming at promoting a wide diffusion of its competences throughout the national territory and at facilitating contacts and cooperation with local firms and organisations. From the financial point of view, the main resources come from the State, but also from the market: 30% of its balance sheet, an extraordinary result, is the result of revenues coming from external job orders for studies and activities of technical advice as well as from agreements with firms, contracts with the European Union and with the other international organisations.

The Institute for Advanced Energy Technologies (ITAE) was established in Messina in 1980 by CNR. The ITAE has long proven experience in environmentally friendly production, **storage and use of energy**. It has been contributing to development and penetration of technologies related to energy saving, low polluting energy production, renewable energy sources, hydrogen and fuel cells in Italy and Europe since the early 80's. The research activity is based on multidisciplinary knowledge, such as chemistry, physics, engineering, and is aimed at the study of the synthesis and material properties of the processes as well as the realisation of prototypes and their application. The ITAE carries out its scientific activities in the framework of national and European programs, in cooperation with industry and research groups. Currently, about 100 researchers, technicians and post-doctors are employed. The ITAE is also active in the integration of different technologies (with special emphasis on wind, solar cell, solar cooling and biomass). Since 2000 ITAE has increased progressively its activities in technology transfer, education and training.

ITAE is a recognised partner in a series of ***sorption chillers and storage*** focused projects, all relevant to the SolBio-Rev project (see also "*Relevant recent projects"*):

- ✓ ZEOSOL, dealing with the development of a hybrid heat pump for solar heating and cooling.
- ✓ HYBUILD, dealing with the development of innovative hybrid electric/thermal storages for residential buildings.
- ✓ GEOFIT, dealing with testing and validation of innovative geothermal solutions for heating and cooling applications.
- ✓ HYCOOL, dealing with the validation of innovative solutions to increase the share of solar thermal energy in industrial applications.
- ✓ SWS-HEATING, dealing with innovative sorption storage concepts for thermal energy storage applications.

In the field of **thermally driven adsorption heat pumps and chillers**, the research activity concerns several fields, covering the different levels of development of the adsorption machine, in particular: preparation and characterisation of new adsorbent materials and their integration with the heat exchanger, simulations of adsorption systems, design and test of prototypes with improved COP and heating/cooling power density, integration of the thermally driven heat pump with RES sources (Solar Cooling), thermal energy storage, combined heat and power (CHP) and energy savings in buildings.

Main tasks in the project

ITAE will be in charge for the **risk management** task (WP1) throughout the project. ITAE will lead WP2 and will be mainly in charge for the definition of the generic energy system and the development and testing of the **adsorption part of the cascade chiller**. In WP4 it will support the design of the prototype system at NTUA and its realisation. In WP5, it will support the testing of the technology in the pilot site in Greece and the technology validation. In WP7, it will support LCA and building integration analysis of the developed technology. Finally, ITAE will actively get involved in other activities as well, such as dissemination, communication and exploitation in WPs 8 and 9.

Key personnel involved in this project

Dr. Andrea Frazzica (M). He graduated in Materials Engineering at the University of Messina, Italy, in 2008 and completed his PhD in Chemical and Materials Engineering at the University of Messina in 2012. Currently he is working as senior researcher at CNR-ITAE, Messina. He was in charge for the scientific coordination of industrial cooperation with Toyota Motor Corporation (Japan). He is currently managing the activities of CNR-ITAE in 5 H2020 ongoing/approved projects. His scientific activity is mainly focused on the development and characterisation of adsorbent materials and components for thermally driven heat pumps and on advanced materials, components and systems for thermal energy storage. He has published more than 70 printed papers. He is currently member of the IEA HPT Annex 43, IEA ECES Annex 30 and IEA SHC/ECES Task 58/Annex 33 on gas driven heat pumps and thermal energy storage development.

Dr. Vincenza Brancato (F). Graduated in Material Engineering at the University of Messina, Italy, in 2009 and completed her PhD in Chemical and Materials Engineering at the University of Messina in 2013. Currently she is working as researcher fellow at CNR-ITAE, Messina. The scientific activity of Dr.-Eng. Vincenza Brancato is mainly focused on development & characterisation of adsorbent materials, processing & characterisation of thermoplastic & thermoset materials and on characterisation of systems for thermal energy storage. She has published over 30 printed papers.

Dr. Valeria Palomba (F). She graduated in Materials Engineering at the University of Messina in 2013. She completed her PhD in a joint collaboration between University of Messina and CNR-ITAE, in Chemical and Materials Engineering in 2017. Her scientific activity focuses on the modelling and realisation of innovative sorption technologies for thermal energy storage and conversion. She has published more than 40 printed papers.

Dr. Salvatore Vasta (M). He received his Degree in Mechanical Engineering (Energy branch) in 2001 at the Faculty of Engineering of the University of Catania and a Ph.D. in Engineering and Materials Chemistry at the University of Messina. Since 2011 he is a permanent staff researcher of the National Research Council at the Institute for Advanced Technologies for Energy (CNR-ITAE) in Messina. Currently, he is scientific coordinator of research projects with private foreign companies and in charge for the CNR ITAE activity in a H2020 ongoing project. He has participated in research programs related to the development of advanced energy technologies, development of heat pumps driven by thermal energy both for stationary and mobile purpose, thermal energy storage systems and solar thermal systems. He has published about 40 printed works, including papers for international journals, national and international conference proceedings and book chapters. He carried out his scientific activity within national and international research programs, in collaboration with industries and research groups.

Relevant recent publications

1. S. Vasta, V. Palomba, D. La Rosa, W. Mittelbach. *Adsorption-compression cascade cycles: An experimental study. Energy Conversion and Management*, Volume 156, pp. 365-375 **(2018)**
2. L. Calabrese, V. Brancato, L. Bonaccorsi, A. Frazzica, A. Caprì, A. Freni, E. Proverbio. *Development and characterisation of silane-zeolite adsorbent coatings for adsorption heat pump applications*. Applied Thermal Engineering, Volume 116, pp. 364-371 **(2017)**
3. A. Freni, G. Maggio, A. Sapienza, A. Frazzica, G. Restuccia, S. Vasta. *Comparative analysis of promising adsorbent/adsorbate pairs for adsorptive heat pumping, air conditioning and refrigeration*. Applied Thermal Engineering, Volume 104, pp. 85-95 **(2016)**
4. A. Freni, L. Bonaccorsi, L. Calabrese, A. Caprì, A. Frazzica, A. Sapienza. *SAPO-34 coated adsorbent heat exchanger*. Applied Thermal Engineering, Volume 82, pp. 1-7 **(2015)**
5. A. Frazzica, G. Fuldner, A. Sapienza, A. Freni, L. Schnabel. *Experimental and theoretical analysis of the kinetic performance of an adsorbent coating composition for use in adsorption chillers and heat pumps*. Applied Thermal Engineering, Volume 73, pp. 1022-1031 **(2014)**

Relevant recent projects

1. SWS-HEATING, Partner: *Development and Validation of an Innovative Solar Compact Selective-Water-Sorbent-Based Heating System*, H2020-LCE-07 (**2018-2022**)
2. GEOFIT, Partner: *Deployment of novel GEOthermal systems, technologies and tools for energy efficient building retroFITting*, H2020-LCE-2017 **(2018-2022)**
3. HYCOOL, Partner: *Ind. Cooling through Hybrid system based on Solar Heat*, H2020-LCE-2017 **(2018-2021)**
4. HYBUILD, Partner: *Innovative compact HYbrid electrical/thermal storage systems for low energy BUILDings*, H2020-EEB (**2017-2021**)
5. ZEOSOL, Partner: *Integrated solar heating and cooling unit based on a novel zeolite chiller and heat pump*, H2020-FTI-2016 (**2017-2019**)

Significant infrastructure/technical equipment, relevant to the proposed work

Different equipment available in the ITAE labs will be used for the development of the activities within the project in WPs 2 and 3. In the following, main equipment relevant for the activities are listed.

Material development and characterisation lab:

- Thermogravimetric apparatus for measurement of ad/absorption and co-ad/absorption of vapours on solids and liquids from room up to 400°C with relative pressure from 0.01 up to 0.95 (DVS Vacuum)
- HF-DSC for phase transition and specific heat measurements from -50 °C up to 800 °C (Mettler DSC-1)
- TG/DSC apparatus working under pure saturated vapour conditions, from room temperature up to 600 °C (Setaram Labsys-Evo)
- Test rig for hydrothermal ageing of adsorbent materials. Temperature range from 30 °C to 90 °C and relative pressure from 0.1 to 0.99. Able to perform up to 150 ageing cycles per day.
- Transient plane thermal conductivity apparatus (Mathis-TCi).

Components development and characterisation lab:

- Test rig for single adsorber adsorption machines testing up to 1 kW of cooling/heating power.
- Test rig for sorption kinetic measurements of small scale adsorber configurations.
- Test rig for small scale evaporator/condenser testing under saturated pure vapour working conditions.
- 24 kW heating power test rig for thermal energy storages.

Thermally driven systems characterisation lab:

- Test rig for thermally driven heat pumps/chillers up to 20 kW heating power and 10 kW cooling power.
- Test rig for thermally driven heat pumps/chillers up to 60 kW heating power and 40 kW cooling power.

Available software packages at the ITAE lab:

- FEM software: Comsol-MultiPhysics 5.2.
- Energy systems simulation, TRNSYS 17.
- General purpose software: Mathematica 11.0, Matlab 2016, Origin 2015; Dymola/Modelica.

Two figures from the thermally driven systems characterisation lab at ITAE are shown below, where the testing facilities in WP2 will be conducted.

Left: Small-scale adsorption chiller prototype testing. Right: Adsorber HEX characterisation testing-rig

4.1.5 Participant 5: Techniki Eteria Antiprosopion Viomichanikoy Exoplismoy Ltd. (TEAVE) (Greece)

Website: www.teabe.gr

Techniki Eteria Antiprosopion Viomichanikoy Exoplismoy (TEABE Ltd/TEAVE) is an Engineering company and SME, founded in 1985. Its main activities are Control Systems in Commercial, Residential and Industrial sites. About 80% of its activities are in the Building Market and 20% in Industrial sector. TEAVE is partner of Schneider Electric, a global leader in the Electrical World and is utilising products from the latest system platform EcoStruxure for Buildings, Energy and Power and Industrial **control and automation**. TEAVE has certified engineers in the above mentioned control products, specialising in Bacnet communication, Modbus and KNX protocols.

The TEAVE team is focused on offering **Integrated Solutions** to its customers, throughout all the phases of a project. Depending on the status of a project, from inspiration to tested operation, the team can deliver the required services. The experience and expertise of its engineers contribute to successful solutions at the right time. The Design and Specification of a system, the supply of the required products, the construction and implementation, the operation and maintenance of a project, belong to the range of the services offered.

Main tasks in the project

TEAVE is responsible for **realising the control strategy of the SolBio-Rev** system into a unified controller (WP3) that will allow: (a) the optimised control of the process, (b) monitor and log running parameters, (c) integrate the system to stand-alone GUI through web-interface, and (d) integrate the controller to Commercial Building Management Systems. TEAVE has a significant role in WP5 as well (controller tuning-operation). Finally, TEAVE will actively get involved in other activities as well, such as dissemination, communication and exploitation in WPs 8 and 9.

Key personnel involved in this project

Klearchos N. Chalikakis (M). Electrical Engineer and Computer Science from NTUA (Greece), Technical Manager of TEAVE Ltd. He has 23 years of experience in Building Automation and Control Systems, having direct and indirect involvement in BMS and SCADA installations around Greece in a variety of sectors, including Commercial, Residential and Industrial projects. In the last 15 years has been project manager for all construction projects in TEAVE.

Dionysia N. Chalikaki (F). Chemical Engineer from NTUA (Greece), Sales Manager of TEAVE. She has 15 years of experience in Building Automation and Control Systems both from technical and commercial view. She has participated in construction and hand-over of more than 15 BMS projects. She is EcoStruxure for Buildings Certified from Schneider Electric and KNX Partner.

Relevant recent products and services

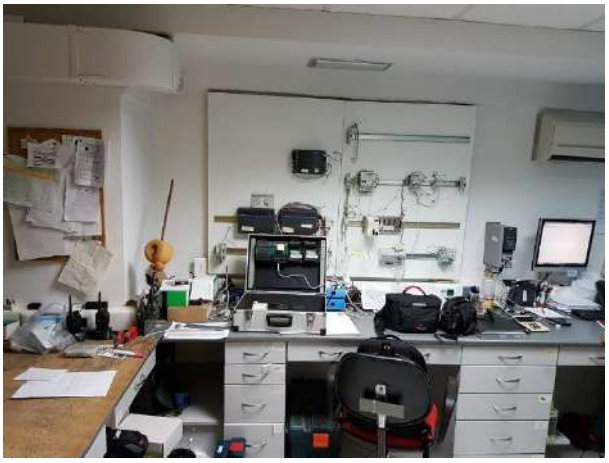
- Building Management Systems for both residential and non-residential buildings, even of high complexity.
- SCADA and PLC control.
- Building automations combined with a user-friendly interface.
- Integrated facility management systems (HVAC, Light, Security, and Energy Efficiency).
- Variable speed drives for enhancing energy efficiency, coupled to suitable control systems.

Relevant recent projects

1. SWS-HEATING, Partner: *Development and Validation of an Innovative Solar Compact Selective-Water-Sorbent-Based Heating System*, H2020-LCE-07 **(2018-2022)**
2. Camp IT, Partner: *An integrated smart indoor – outdoor web based Energy Management System for University Campuses*. National project funded by the General Secretary for Research and Technology **(2013-2016)**
3. New Surgical Wing of Evangelismos Hospital, Athens, Greece. Building Management System **(2014-2017)**
4. Integrated Building Management System and Power Monitoring and Targeting System in Stavros Niarchos Foundation Cultural Center **(2014-2016)**
5. National Bank of Greece, Several Building Management Systems and Power monitoring systems **(2015)**

Significant infrastructure/technical equipment, relevant to the proposed work

TEAVE owns facilities for developing and testing control panels at its Head Offices in Paleo Faliro, Athens, which will be used for the system controller development in WP3. The workshop has the capacity to build three control panels for BMS and/or SCADA systems simultaneously. The workshop offers testing facilities and simulation devices to prepare Factory Acceptance Tests prior to product shipments. For the programming and testing of systems, TEAVE has a DELL R330 server with Enterprise Server from Schneider Electric installed, in order to offline program and debug control algorithms.



Workshop for producing and testing controllers and automation equipment

DELL server for programming and testing

4.1.6 Participant 6: AkoTec Produktionsgesellschaft mbH (AKOTEC) (Germany)

Website: www.akotec.eu

AkoTec is an SME founded in 2008. The company develops and manufactures one of the most efficient full **vacuum tube collectors** worldwide, proved by its Solar Keymark specifications. The collectors are applied for private use, such as for domestic water heating and heating support, as well as for industrial use, such as for solar cooling and process heat up to 110 °C. Akotec is based on the high expertise of its CEO, who has over 30 years of experience with **solar thermal products and system concepts**, ensuring continuous development and high quality products.

AKOTEC NARVA vacuum collector

Beside the vacuum tubes, an integral part of the solar collector is the collecting manifold. The core know-how of AkoTec lies in the development and manufacturing of different collecting manifolds. The automated processing of collector elements maintains the quality standards. Akotec is also involved in commissioning complete solar systems, which include various components, such as thermal storage tanks, controllers, expansion vessels and other accessories.

The centrepiece of AkoTec is the NARVA tube with its vacuum technology (shown in the next figure). Additionally, the full vacuum tube is patented for its unique glass metal connection and highly resistant against hail, and combined with its quick-clip system for easy assembly and installation provides an important competitive advantage to its products. AkoTec sells its products worldwide as a system supplier and has received Solar Keymark certification, as well as many awards and recognitions.

Main tasks in the project

Akotec will be responsible for the development of the **prototype solar collectors with integrated TEGs** (WP2), focusing on the dynamic response once combined with the other system components. Also, Akotec will handle in WP3 the integration of its **solar control within the system controller**. In WP4, AkoTec will **produce the prototype collectors** for both pilot systems, as well as design and provide the storage tanks for the pilot systems. Finally, Akotec will actively get involved in other activities as well, such as dissemination, communication and exploitation in WPs 8 and 9.

Key personnel involved in this project

Reinhold Weiser (M). Dipl.-Ing. precision engineering, founder and General Manager of AkoTec. He has started his career as plant manager and technical superintendence in a crafts enterprise in Ufe Heizung Sanitär GmbH, while then he became the owner of an engineering firm for building services. He has high expertise on solar collectors and he has been the inventor of 2 patents in solar collector technology.

Björn Rücker (M). He is a Mechanical Engineer and he is working at AkoTec since 2012. His main focus is on the collector development and production and he will be in charge of the development of the prototype collector and testing.

Adrian Rompel (M). He is a Mechanical Engineer and he is working at AkoTec since 2014. His main focus is on development and production of solar field control units, software, system solutions and storages.

Niels Harborth (M). M.Sc. Regenerative Energy Systems. He is working as Project manager and mechanical Engineer at AkoTec since 2017. Before he worked at the *Rainer Lemoine Institut GmbH*, as team leader and laboratory head.

Relevant recent publications, products and services

1. Reinhold Weiser. *Decentralised heat production from solar heat*, 2014, Brandenburger Energietag conference, lecture **(2014)**
2. Reinhold Weiser. *Efficient solar heat from full-vacuum tube collectors*, 2013, Universität Eberswalde, lecturem **(2013)**
3. Reinhold Weiser. *Solar Cooling*, Kälte Luft Klimatechnik, Ausgabe August/September 2011, S. 48f. **(2011)**
4. Products: Vacuum tube solar collectors of both direct flow and with heat pipes, for domestic and industrial applications.
5. Products: Complete solar systems with collectors, storage tanks, solar station/controller, expansion vessel and all other auxiliaries.

Relevant recent projects

1. SWS-HEATING, Partner: *Development and Validation of an Innovative Solar Compact Selective-Water-Sorbent-Based Heating System*, H2020-LCE-07 (**2018-2022**)
2. ZEOSOL, Partner: *Integrated solar heating and cooling unit based on a novel zeolite chiller and heat pump*, H2020-FTI-2016 (**2017-2019**)
3. SysNet, Partner: *System optimisation of the solarheat in local and district heating networks*, DBU 33658/01-24 **(2017-2019)**
4. *Solar tracking system in combination with a very efficient full-vacuum tube collector for process heating*, Federal R&D-project, funded by Bundeswirtschaftsministerium (BMWi) **(2013-2015)**
5. Solarthermie2000plus, Partner: *Solar supported climatisation project of Deutsche Telekom AG in Rottweil in range of benefit concept*, Federal Environment Ministry **(2011)**

Significant infrastructure/technical equipment, relevant to the proposed work

The technical equipment of AkoTec is distinguished by the special purpose machines of the production line for the collectors and the endurance test equipment. AkoTec makes full vacuum tube collectors and disposes of several multistage assembly-line row productions. The single stations are decoupled by buffer storages. Special purpose machines are in use, handled by the workers. Those machines are modifiable in use, by change of the software or by mechanical settings and new device, making it possible to produce **prototype manifolds** for the solar-TEG system in WP2.

The most important special purpose machines are the punch and saw machine (for different pipe lengths and the punching of the pipe departures), the pressure test arrangement, the manifold machining centre (for the complete treatment of the manifold) and the arc brazing machine (coupling piece and manifold are soldered automatically), as shown in the next figures. In particular, these machines will be used within the scope of this project for the production of the **complete solar-TEG system** in WPs 2 and 5.

In addition, the endurance test equipment will be relevant to the proposed R&D work. With the endurance test equipment new connections can be tested and the load changes of decades be simulated. All parts are tested up to the break and from these results the life span is then derived.

<table>
<tr><td>  </td><td>  </td></tr>
<tr><td>Punch and saw machine</td><td>Arc brazing machine</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Buffer storage</td><td>Endurance test equipment</td></tr>
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4.1.7 Participant 7: Universidad de Lleida (UDL) (Spain)

Website: www.udl.cat – www.grea.udl.cat

Universidad de Lleida (UDL) is a public university with education and research as its main objectives with about 12,000 students and almost 1,200 teaching and research staff. UDL combines its success as a long-standing university with a young and dynamic structure that is committed to high quality training based on advanced methods. UDL offer includes training and research activities with the aim of transferring knowledge to the fields of engineering, computer science, the health and life sciences, the educational sciences, law, economics and the arts. To do so, the UDL is actively engaged in delivering high quality courses in all these fields.

The research group GREiA – former GREA – of UDL, headed by Prof. Dr. Luisa F. Cabeza, has long experience in **thermal energy storage technologies**, **buildings energy efficiency**, artificial intelligence applied to control strategies, advanced **control strategies** implementation, and LCA/LCC of energy efficiency systems. Since its foundation in 1999, the group has been developing TES concepts and systems for different applications, such as solar water tanks, building envelops, buildings HVAC systems, industrial applications, and CSP plants. Moreover, UDL has developed the **LCA of different systems** such as energy efficiency buildings, energy efficiency HVAC systems, waste management systems, and others. UDL expertise on artificial intelligence includes **predictive control and deep-learning** in hybrid energy systems (e.g. TES, PV, electricity grid) that allow planning the operations in an optimum way. With an efficient coding of the problem and a correct integration of the optimisation tools and automatic learning an optimal control of the systems in real time is achieved. Using this knowledge, UDL has published extensive publications about intelligent control for different applications from ventilated facades to condenser defrosting.

UDL created the Spanish Network of Thermal Energy Storage in 2006, pooling up storage research in Spain, such as through the INNOSTORAGE FP7-project successfully coordinated by UDL. UDL is active in several Tasks of the International Energy Agency (IEA), as well as the RHC European Technology Platform and the SPIRE PPP.

Main tasks in the project

UDL will develop appropriate **control strategies** to be included in the system simulation (WP3) and provide its support in the design and sizing of the **storage tanks** (WP4) of the pilot systems at NTUA and FAU. UDL is leading the **LCA/LCC work in WP7**, directly linked with its control/simulation activities in WP3. Finally, UDL will be in-charge of the external stakeholder advisory board (WP1) and will get involved in other activities as well, such as dissemination, communication and exploitation in WPs 8 and 9.

Key personnel involved in this project

Prof. Dr. Luisa F. Cabeza (F). She is a full professor since 2006 at UDL. She graduated in Chemical engineering in 1993 and Industrial engineering in 1992 at the Universitat Ramon Llull (Barcelona, Spain). She got a MBA in 1995 and Ph.D. in 1996 from the same university. After a post-doctorate appointment at the USDA-ARS-ERRC lab in Philadelphia, US, she joined the UDL in 1999. She has devoted the last 16 years in developing new materials and systems for thermal energy storage in different applications. She is a member of the Executive Committee of the Storage Program of the International Energy Agency (ECES IA – IEA) and is contributing to the SREEN and AR5 preparation of IPCC.

Dr. Cèsar Fernández (M) (Ph.D., associate professor at UDL). He graduated in Telecommunications engineering in 1987 and PhD in 2001, both at Universitat Politècnica de Catalunya (Barcelona, Spain). After a post-doctorate appointment at Cornell University (US) he worked as communications engineer at Inisel Espacio. He joined UDL as Associate professor in 1992. His research is focused in the development and application of machine learning technics to the optimisation of industrial processes. He has published 55 papers and participated in over 30 congresses. He has participated in 15 research projects funded in public competitive calls, being the main researcher in 6 of them. Within his management activities, he was coordinator for the implementation of the communication network (1995-1997), vice rector of infrastructures and new technologies (2003-2007) and director of the research centre "Centre de computació de ponent" (2009-2013).

Dr. Carles Mateu (M) (Ph.D., associate professor at UDL), PhD in Engineering from UDL. He was responsible for information and communication systems, as responsible for UDL's communications network and computer security. Later, he became director of IT services of the UDL. In 2009, after a period as a researcher at the Institute of Artificial Intelligence Research of CSIC, he joined as a lecturer at UDL, until 2014. Currently, he is Associate professor. His interests are based on: the study and design of computationally complex optimisation solutions, especially in the field of computational sustainability and energy efficiency; the study of contents in social networks for the extraction of information, for the modelling of social opinion and discussion; the deployment of intelligent sensor networks and

the use of social networks for the analysis of the behaviour of tourists and visitors, for the detection of deambulation patterns for optimisation of transportation routes.

Dr. Gabriel Zsembinszki (M) (Ph.D., post-doctoral researcher at UDL), holds a Ph.D. degree in physics from the Autonomous University of Barcelona, Spain. Since 2010 he has been part-time lecturer at the Department of Computer Science and Engineering at UDL, where he is been involved in teaching different subjects of the Mechanical Engineering degree. Currently, he is a postdoctoral researcher at the research group GREiA at UDL, on topics related to thermal energy storage based on the use of phase change materials, energy optimisation in industrial processes, energy systems, and modelling of refrigeration systems. So far he has published a total of 17 articles in scientific journals, and reached an h-index of 7 according to Scopus, and 8 according to Google Scholar. He participated in different European projects, being currently involved in the coordination of the EU H2020 funded project INPATH-TES (H2020-CSA No 657466).

Dr. Alvaro de Gracia (M) (Ph.D., TECNIOSpring post-doctoral researcher at UDL). Today TECNIOSpring+ post-doctoral researcher (MSC fellow) at UDL, in the last two year has been a post-doctoral researcher (Juan de la Cierva) at SUSCAPE research group at Universitat Rovira i Virgili (Tarragona, Spain). He studied Mechanical Engineering at UDL and Industrial Engineering at Universitat Politècnica de Catalunnya. In 2013 he presented his Ph.D. at UDL and then spent one year as post-doc at the University of Antofagasta (Chile). His research interests are thermal energy storage for industrial processes and buildings. He has 57 papers published, h-index 18 and over 1700 citations in Scopus.

Dr. Eduard Oró (M) (Ph.D., Juan de la Cierva Incorporación post-doctoral researcher at UDL). Recently Dr. Oró has joined UDL as post-doctoral researcher but he has spent the last four and a half years working at the Catalonia Institute for Energy Research (Barcelona, Spain) as senior researcher, involved in different EU funded projects and leading the greenIT research line. He studied Mechanical Engineering at UDL and Industrial Engineering at Universitat Politècnica de Catalunnya. In 2013 he presented his Ph.D. at UDL about thermal energy storage solutions. His research interests are energy efficiency, renewable energy and thermal energy storage for industrial processes, IT sector and buildings. He has more than 30 papers published, h-index 18 and over 1700 citations in Scopus.

The rest of the GREiA group at UDL might also be involved in the project.

Relevant recent publications

1. Maldonado JM, Zsembinszki G, de Gracia A, Moreno P, Albets X, González MA, Cabeza LF. *Control strategies for defrost and evaporator fans operation in walk-in freezers*. International Journal of Refrigeration 91, 101-110 **(2018)**
2. Romaní J, Belusko M, Alemu A, Cabeza LF, de Gracia A, Bruno F. *Control concepts of a radiant wall working as thermal energy storage for peak load shifting of a heat pump coupled to a PV array*. Renewable Energy 118, 489-501 **(2018)**
3. Naves AX, Barreneche C, Fernández AI, Cabeza LF, Haddad AN, Boer D. *Life cycle costing as a bottom line for the life cycle sustainability assessment in the solar energy sector: A review*. Solar Energy, in press **(2018)**
4. de Gracia A, Barzin R, Fernández C, Farid MM, Cabeza LF. *Control strategies comparison of a ventilated facade with PCM – energy savings, cost reduction and CO2 mitigation*. Energy and Buildings 130, 821-828 **(2016)**
5. Cabeza LF, Rincón L, Vilariño V, Pérez G, Castell A. *Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review*. Renewable and Sustainable Energy Reviews 29, 394-416 **(2014)**

Relevant recent projects

UDL has participated in different local, national and European projects, most of them related to energy efficiency of buildings, energy systems and storage technologies. Examples of the different European projects are:

1. SWS-HEATING, Partner: *Development and Validation of an Innovative Solar Compact Selective-Water-Sorbent-Based Heating System*, H2020-LCE-07 (**2018-2022**)
2. HYBUILD, Partner: *Innovative compact HYbrid electrical/thermal storage systems for low energy BUILDings*, H2020-EEB-06-2017 (**2017-2021**)
3. INNOVA MicroSolar, Partner: *Innovative Micro Solar Heat and Power System for Domestic and Small Business Residential Buildings*. H2020-EE-04 **(2016-2020)**
4. INPATH-TES, Coordinator: *Innovation pathways to TES*, H2020-LCE-20-2014 **(2015-2018)**
5. MERITS, Partner: *More Effective use of Renewables Including compact seasonal Thermal energy Storage*, FP7-COOPERATION Grant 295983 **(2012-2016)**

Significant infrastructure/technical equipment, relevant to the proposed work

The research group GREiA at UDL has available software licenses for the simulation of energy systems (e.g. TRNSYS, Matlab), and the implementation of LCA (e.g. EcoInvent database) in WP7. In-house software is developed and applied for designing storage equipment (in WP4), LCC analysis (in WP7), and optimising control strategies of complex energy systems (in WP3).

4.1.8 Participant 8: Daikin Air-Conditioning Hellas SA (DAIKIN) (Greece)

Website: https://www.daikin.gr

Daikin Greece was establish as a Sales Office of Daikin Europe in 2004 and became a full Affiliate in 2006. From 2013 onwards is responsible for the areas of Greece and Cyprus. The parent company Daikin Industries Ltd. started in 1924 in Japan as a manufacturer of air-conditioning systems. The company now **leads the industry for HVAC-R systems** worldwide: solutions for heating and cooling, ventilation and air-conditioning. It is about heating using **energy-efficient heat pump technology** and climate systems for the residential market, as well as cooling and freezer systems, chillers and solutions for air treatment for professional and industrial environments.

In Europe, the company invariably adapted the Japanese technology to suit the requirements of the EU local markets. That resulted in a very specific approach. The expertise of the company ensures that DAIKIN can offer the most fitting total solutions in each of those markets. Innovation, sustainability and energy-efficiency receive top priority. That is evident from the growing local development of residential, commercial and industrial applications, among other things, that deal more efficiently with energy and release less CO_2.

DAIKIN is a market leader focusing at various applications like heating, residential, commercial, and refrigeration. Its product portfolio consists of different solutions that mainly aim to save energy, to reduce the environmental impact, and at the same time to increase the comfort for the end users. The modular units enable the selection of the right mix of equipment and technology to ensure that the optimal balance of temperature, humidity and air freshness for the perfect comfort zone with maximum energy efficiency and cost effectiveness is achieved. Furthermore, the combination of the above solutions can be combined with renewable and/or sustainable energy sources like:

- Energy Saving Condensing Technology
- Heat Pumps and geothermal heat pumps with increased seasonal and nominal efficiencies
- Solar energy for hot water and heating
- Rainwater utilisation
- Underfloor heating.

The company is currently supporting the full range of Daikin products and solutions in the sectors of Air conditioning, Heating, Refrigeration and Applied Solutions. The support offered starts from the design of the project, the selection of the proper equipment, the pre commissioning check, the commissioning of the installation, the maintenance of the installation, the ad hoc visits that may occur, but also can be extended in measuring the actual energy performance of the installation, allowing the proper optimisation. The organisation in Greece consists of engineers and technicians with great knowledge over the HVAC-R applications.

Daikin heat pumps in combination with in-house inverter technology offer unparalleled indoor heating comfort and process efficiency. Inverter control reduces unit start up time and varies compressor output to match precise system load requirements. Also, when linked with Daikin DC compressor motors, it allows Daikin equipment to achieve the highest COP ratings in the market. Similarly, advanced computerised control packages ensure optimum system efficiency at all times and allow remote monitoring via the internet.

Main tasks in the project

DAIKIN will participate in the development of the reversible heat pump/ORC unit, leading to the **heat pump-based configuration**, based on one of its heat pumps (in WP2). Moreover, it will **lead WP4 for designing and producing** the components and configurations of the two pilot systems and take active part in the pilot testing (in WP5). DAIKIN will get involved in other activities as well, such as dissemination, communication and exploitation in WPs 8 and 9.

Key personnel involved in this project

Nikolaos Barmparitsas (M). Senior Expert Engineer. Assistant manager of the After Sales Department of Daikin Greece Affiliate with high skill and experience in the evaluation of current heating, ventilation and Air- Conditioning systems and also in developing custom-made solutions for each installation by utilising the different available technologies. Member of the scientific committee of the Greek Division of CECED. He has also knowledge over the current National and European legislation related to HVAC efficiency and F-Gases.

Dimitris Kalogeras (M). Senior Expert Engineer. Assistant manager of the Sales Department of Daikin Greece Affiliate with high skill and experience in the evaluation of current heating, ventilation and Air- Conditioning systems and also in the field of supporting consultants in developing custom-made solutions for each installation by utilising the different available technologies. He has also deep knowledge in the field of Energy Efficiency in the Building Sector.

Relevant recent projects

1. Athens Mall: Application of 280 VRV heat pump outdoor units of 10HP each. The units are mainly utilised for the air-conditioning of the different shops. The specific design not only allows increased efficiency but also offer flexibility in possible changes of the layout of the shops.
2. Makedonia Palace: One of the most prestigious hotels in Thessaloniki with 30 VRV heat pump outdoor units of 14HP. The outdoor units installed at the specific project utilises Daikin breakthrough technology of Variable Refrigerant Temperature that adjust the operation of the outdoor unit on the actual request of the site. Furthermore the installed outdoor units utilise an innovation of Daikin that allows the outdoor unit to produce heating even during defrost – continuous heating.
3. Nokia Headquarters in South Europe: 19 VRV outdoor units of 12HP. The outdoor units installed at the specific project utilises Daikin breakthrough technology of Variable Refrigerant Temperature that adjust the operation of the outdoor unit on the actual request of the site.
4. The Headquarters of the Greek Navy: 44 VRV outdoor units of 10HP. The outdoor units installed at the specific project utilises Daikin breakthrough technology of Variable Refrigerant Temperature that adjust the operation of the outdoor unit on the actual request of the site.
5. The Headquarters of the National Bank of Greece in Thessaloniki: 19 VRV outdoor units of 10HP. The outdoor units installed at the specific project utilises Daikin breakthrough technology of Variable Refrigerant Temperature that adjust the operation of the outdoor unit on the actual request of the site.

Significant infrastructure/technical equipment, relevant to the proposed work

As heat pump manufacturer, Daikin has access to all our production plants in Europe and to the laboratories that they have for testing and monitoring of equipment.

4.1.9 Participant 9: Science Policy Research Unit (SPRU), University of Sussex (UOS) (United Kingdom)

Website: http://www.sussex.ac.uk/spru/

The University of Sussex (UOS) is a higher education institution established in August 1961 for the advancement of learning and knowledge by teaching and research. Over 75 per cent of Sussex research activity is rated as world leading, internationally excellent or internationally recognised. In the 2018-19 Times Higher University World Rankings, Sussex was ranked 19th in the UK, 68th in Europe, and 147th in the world. It has a dynamic and thriving research culture with strengths across the sciences, arts, social sciences and medicine with a focus on interdisciplinary research. It currently has over 15,000 students and 2,100 staff from all over the world. It has had 3 Nobel Prize winners, 14 Fellows of the Royal Society, 12 Fellows of the British Academy and a winner of the prestigious Crafoord Prize on its faculty. In the financial year 2016/2017 the total income was £286 million and the value of the University's total portfolio of external project research income was £36 million, ranging from commercial funders to charities and public-sector organisations (including governmental departments).

The University of Sussex has experience in dealing with all European Research and Innovation programme matters. In FP7 it was awarded over 100 grants totalling over £33m. This included 5 European Research Council Advanced Investigator grants, 12 Starting Investigator grants, 1 Consolidator grant, 33 Marie Curie fellows and the coordination of numerous Collaborative Projects and Marie Curie Initial Training Networks. In 2014 the University became a partner in the FET Flagship Human Brain Project (HBP). In H2020, Sussex has already been successful in securing 50 grants: 4 FET, 18 ERC, 15 Marie Skłodowska-Curie and 13 Societal Challenges projects.

The Science Policy Research Unit (SPRU) at the University of Sussex is a world-leading department which combines research, consultancy and high-level policy advice with postgraduate teaching in science, technology, and innovation policy and management. Founded in 1966 by Christopher Freeman, SPRU was the first interdisciplinary research centre in the field of science and technology policy and management. Today, with over 70 faculty members, more than 70 doctoral students, over £7m of on-going Research Council projects, as well as hosting the leading journal in its field, *Research Policy*, SPRU remains at the forefront of new ideas, problem-orientated research, inspiring teaching, and creative, high impact engagement with decision makers across government, business and civil society. With a community of more than 200 MSc and doctoral students from all over the world, SPRU is also well known for its high quality, research-led teaching programmes. The multidisciplinary nature of SPRU means that students have access to an extensive range of expertise, whilst also contributing directly to SPRU research as part of their training and development. The Sussex Energy Group (SEG) at SPRU undertakes rigorous, inter-disciplinary research on **energy and climate policy**, focusing upon the challenge created by the transition to low carbon energy systems, and **social sciences**. SEG currently has 50 researchers and 25 doctoral students and is funded from an array of public and private sector sources, including the UK Research Councils, UK government departments and the European Commission. SEG is a partner in the Tyndall Centre for Climate Change Research and the UK Energy Research Centre.

Main tasks in the project

UOS will be in charge of the **social science research** component undertaking qualitative research into perceptions and acceptance of existing renewable energy systems as well as future acceptance/perceptions of the SolBio-Rev concept (WP6). Moreover, UOS will support the **business model generation** in WP8. Finally, UOS will get involved in other activities as well, such as dissemination, communication and exploitation in WPs 8 and 9.

Key personnel involved in this project

Dr. Mari Martiskainen (F). She is a Research Fellow at Science Policy Research Unit (SPRU). She has over 15 years' experience from the energy sector having worked in the renewable energy sector before joining SPRU. Mari has worked on a range of research projects including topics such as building energy efficiency policies, innovation processes linked to community energy, influences on household energy consumption and the diffusion of small scale renewable energy technologies. Mari has authored several articles in journals such as *Energy Research & Social Science, Environmental Innovation and Societal Transitions, Environment and Planning A, Journal of Cleaner Production, Local Environment* and *Research Policy*. She has worked with a range of stakeholders and partners, including community groups, not-for-profit organisations, businesses and consultants. Mari has experience from various communication channels, ranging from TV and radio to social, print and online media. Mari completed a PhD in Science and Technology Policy Studies at SPRU in 2014, she has an MSc in Environmental Technology from Imperial College London and a BA in Social Sciences from the University of Helsinki, Finland.

Mr. Donal Brown (M). She is a Research Associate at the Centre on Innovation and Energy Demand (CIED) based at the Science Policy Research Unit (SPRU) at the University of Sussex and is also Sustainability Director at the Sustainable Design Collective. Donal holds a First-class BSc in Environmental Science and distinction in Climate

Change and Policy MSc and is currently completing a PhD in domestic retrofit. Donal has worked for over 10 years in all aspects of the construction industry. A sustainable energy and energy demand specialist in low carbon housing - Donal researches and provides consultancy on energy efficiency, renewable energy and sustainable building solutions.

Dr. Paula Kivimaa (F). She is a Senior Research Fellow at SPRU, Senior Researcher at the Finnish Environment Institute and has an affiliation of Docent at Aalto University, Finland. She has over ten years' experience in research dealing with the interface between environmental innovations and climate, energy, transport and environmental policies. Her recent research is focused on analysing transport and energy policy as well as intermediary organisations from the perspective of sustainability transitions. She has experience in managing several projects funded by Finnish research funding agencies. She has published scientific articles in journals such as *Research Policy*, *Environmental Policy and Governance*, *Environmental Politics*, *Journal of Cleaner Production*, and *Transport Geography* as well as research reports issued, for example, by the Nordic Council of Ministers and the Partnership for European Environmental Research.

Relevant recent publications

1. Brown, D. *Business models for residential retrofit in the United Kingdom; a critical assessment of 5 key archetypes*. Energy Efficiency 1–26. **(2018)**
2. Kivimaa P, Martiskainen M. *Dynamics of policy change and intermediation: The arduous transition towards low-energy homes in the United Kingdom*. Energy Research & Social Science 44, 83–99 **(2018)**
3. Martiskainen M, Kivimaa P. *Creating innovative zero carbon homes in the United Kingdom – intermediaries and champions in building projects*. Environmental Innovation and Societal Transitions 26, 15-31 **(2018)**
4. Kivimaa P, Martiskainen M. *Innovation, low energy buildings and intermediaries in Europe: systematic case study review*. Energy Efficiency 11(1), 31-51 **(2018)**
5. Kern F, Kivimaa P, Martiskainen M. *Policy packaging or policy patching? The development of complex energy efficiency policy mixes*. Energy Research & Social Science 23, 11–25 **(2017)**

Relevant recent projects

1. SET, Partner: *The Smart Energy Transition consortium (SET) analyses the ongoing global transition and its impacts on Finnish society, in particular the potential benefits for cleantech, digitalisation and bioeconomy.* Funded by Academy of Finland (**2015-2020**)
2. CIED, Partner: *Centre on Innovation and Energy Demand (CIED), Research Centre on End Use Energy Demand*, RCUK Energy Programme. Grant EP/K011790/1, United Kingdom. (**2013-2018**)
3. Community Innovation for Sustainable Energy, Partner: *Sussex and East Anglia proposal to UK Engineering and Physical Science Research Council (EPSRC) and the European Centre Laboratories for Energy Efficiency Research (ECLEER) of EdF Energy* (**2010-2014**)
4. Energy Demand Research Project (EDRP), Partner: *Joint project with EdF Energy. Examining the impact of feedback measures on household energy consumption.* Funded by UK Government (**2007-2010**)

Significant infrastructure/technical equipment, relevant to the proposed work

Not applicable for UOS.

4.1.10 Participant 10: DBC Europe SA (DBC) (Belgium)

Website: www.dbceurope.eu

DBC Europe S.A. was established in 2015 and its mission is to provide premium quality ser-vices and contribute in a constructive way to customers' development efforts. The personnel of the company possesses extensive experience in the management of projects financed by the European Bank of Investment (EBI), EU (European Union) and World Bank (WB) for nation-wide public organisations in various countries, i.e. Greece, Turkey, Serbia, Kyrgyzstan, Montenegro, Georgia, northern part of Cyprus, providing a complete range of specialised services in :

- Regional development and economic cooperation
- Sustainable economic development of local communities
- Public Administration Reform
- Renewable Energy/Energy storage
- Environment protection
- Coastal development/Aquaculture
- Development of Small Medium Enterprises (SMEs)
- Information, Communication and Technology (ICT)

DBC Europe is in close partnership with a number of credible academic institutions, research centres and organisations all over Europe and its team has been successful at developing and exploiting institutional reform projects.

DBC Europe S.A. has the unique advantage of being able to provide high level expertise in all specific sub-sectors of this project. At the same time, the staff of the Company has extensive experience in the development of strategic and operational planning. The company has a strong network of high calibre experts with experience in Energy, Environment, Training, ICT Development, e-Governance, GIS development and implementation, Public administration, Monitoring and evaluation, Performance Measurement, Institutional development, Capacity building, Interoperability, Financing Plan and Public–private partnership (PPP). Relevant to the latter, DBC assists government authorities in the development of strategies and the implementation of programmed and budgeted operational actions, as well as in establishing co-ordination mechanisms between central and local authorities. The company's staff has extensive experience in using widespread applications, to which DBC has acquired an absolute know-how through their intensive use in the implementation of the projects.

Main tasks in the project

DBC is leading WP8 (**Dissemination and exploitation of results**) and WP9 (**Communication activities**), and participates in WP6 for the stakeholder engagement. In WP8 will develop a strategy and platform for fostering the proposed RIA on several audiences: designers, installers, customers, technicians, industries, academics, by encouraging their participation as long-term goal of the project. In WP9 will organise one workshop in Brussels during the last year of the project. Finally, DBC will lead the **market analysis** and **business model** generation in WP8.

Key personnel involved in this project

Konstantinos Tsiakataras (M). CEO and Partner. He has a high-level academic background in statistics, economics and finance and more than 15 years of professional experience as Project Director and Team Leader of multi-million projects and programmes. As Project Director, he has successfully completed over 15 EC funded projects for public authorities (including ministries and regional authorities), utilities and public companies. As Team Leader he has managed multidisciplinary teams in more than 10 technical assistance projects and worked in close relationship with Ministers, State Secretaries and NGO's. He has accumulated valuable experience in: public administration reform, employment programmes, development of Operational and Regional Programmes funded by ERDF and ESF, institutional capacity building at national and regional levels, monitoring and evaluation of CSF projects and programmes, business planning, Information Society development and ICT consulting.

Sarah Charles (F). Ms. Charles has spent the last 9 years working in the international development and cooperation sector through projects and programmes spread worldwide, with a focus on communication and knowledge for sustainable development – increasing project/activity visibility, raising awareness on development issues and managing knowledge for more effective action. She is currently studying towards a M.Sc. in Sustainable Development (specialised in Communication & Knowledge for Development) at the University of London's School of Oriental and African Studies (SOAS). Her practical experience & skills acquired include multi-party internal communication and liaison, stakeholder engagement at all levels, local and international press liaison,

communication strategy implementation and adaptation, website content population and management, preparation of visibility items, information of dissemination products and social media strategy and account management. Her technical reporting work includes drafting of communication strategies, communication and visibility sections of proposals, and project reporting for the EU. She is familiar with the EU Communication and Visibility guidelines and adheres to them for all EU funded assignments. She has specific recent experience in communication and event management for the EU funded CES-MED programme and the EU Technical Assistance Facility (TAF) under the wider SE4ALL Programme. She currently has a year-long contract with the UN's International Trade Centre as communication expert for the development of the Coconut Industry in the Caribbean, including capacity building and empowerment of actors across the value chain, to increase their competitiveness on the international market, attract investors and make stakeholders more resilient with more sustainable production and incomes.

George Sidiras (M). Mr. Sidiras obtained a BSc in Marketing and Communication as well as a Master of Business Administration (MBA) from Athens University of Economics and Business. He is experienced in the management and implementation of large scale World Bank and EU-funded projects and has successfully delivered projects in countries like Turkey, Croatia, Romania, Montenegro, Cyprus, Kyrgyzstan and Georgia over the last years. Mr. Sidiras is very well acquainted with the PRAG rules and EC Project Cycle Management and he also has experience in Business Process Reengineering projects and as a Public Relations officer.

Emmanuel Stamatakis (M). He holds a Ph.D. in Chemical Engineering and a Master in Production Management. He works as a freelance Researcher & Consultant over the last 15 years and has been involved in various Environmental & Energy related European projects. In the past, he was the Assistant Project Manager of the Green Island – "Ai Stratis" Project for the installation and operation of a hybrid power system comprising Renewable Energy Technologies and Energy Storage Devices, as well as, the project Manager Leading Greek demo for the FCH JU project SHEL - Sustainable Hydrogen Evaluation in Logistics. He was also actively involved in the EU projects: STORIES (Addressing barriers to storage technologies for increasing the penetration of intermittent energy sources) and H2SusBuild (Development of a clean and energy self-sustained building). He is consultant of DBC.

Relevant recent services

1. Development of Software for Financial Processing and Analysis, which predicts financial figures and ratios based on alternative scenarios.
2. Development of a Business intelligence Software to support of business decisions.
3. Design and implementation of Energy related strategies (Feasibility & Impact assessment studies, Market-based pricing, Cost effectiveness analyses, Development of decision analytical models).
4. Multi stakeholders consultations, Public awareness, Research surveys and Social studies on Energy & Environmental issues.
5. Design and delivery of training programmes and organisation of specialised seminars, workshops, conferences and communication campaigns at national and regional level.

Relevant recent projects

1. Technical Assistance to build the capacities of business support organisation and enhance the competitiveness of the private sector (2015 – ongoing). Provision of Business Development Services (Business Plan/Organisational Structure) in tourism sector, in Karpas and Lefke regions – Capacity building for the bodies related to the development of the clusters & Technical Assistance during the Cluster development & implementation.
2. Sustainable Economic Development and ICT Sector Programme (2010 – 2013). Business Development Services to 90 SMEs, Business Support Organisations (SME Development Centre (KOBIGEM), Chamber of Commerce, Cyprus Turkish Chamber of Industry (CTCI), Turkish Cypriot Chamber of Shopkeepers and Artisans (TCCSA), CTCI Young Professionals (CTCI-YP), Young Businessmen Association (GIAD), Cyprus Turkish Science and Technology Association (BILTED), Investment Development Agency (YAGA) Degirmenlik Environment & Promotion Association, Business Women Association in company restructuring, efficiently planning, marketing.
3. "Technical Assistance to 10 municipalities for the submission of applications in the framework of the Programme regarding the adoption of energy saving measures for public buildings", Greece (250,000 €); National funds.
4. "E-Governance Facility in Georgia"; European Commission.
5. Provision of Consultancy services – analysis of financing methods for Sustainable Development investments in prefecture of Epirus, in the context of the project "ALTERENERGY".

Significant infrastructure/technical equipment, relevant to the proposed work

Not applicable for DBC.

4.1.11 Participant 11: Techlink (TECH) (Belgium)

Website: http://www.techlink.be/

Techlink (previously known as Fedelec and ICS) has been the most prominent **professional federation for electrotechnical and HVAC operators** in the whole of Belgium for years. Techlink now brings around 3,000 companies together: self-employed, SMEs and large enterprises, active in all areas of installation technology.

The operation is based on a strong national structure, 10 provincial departments, Sector Councils, Sector Committees and an integrated collaboration with the Construction Confederation umbrella organisation (national, regional and local).

Techlink is recognised as a national professional federation by the FPS Economy, SMEs, Self-employed and Energy. Therefore, Techlink also has two mandates within the High Council for the Self-employed and SMEs, more specifically in Commission 4 - "Construction": *A spokesperson for the electrical and HVAC installation sector*.

Techlink defends sectoral interests with the government, economic policymakers and construction partners. By being present at the local, regional, national and European level, Techlink represents the electrical and HVAC installation sector with numerous organisations and authorities such as the sectoral joint committees (149.01), technical committees, political institutions, administrations and prescribers. Techlink defends the electrical and HVAC installation companies in numerous consultation and advisory bodies that directly or indirectly influence the interests of the installation companies.

Through the collaboration with the Construction Confederation umbrella organisation, which includes 15,000 entrepreneurs, the position of Techlink becomes even stronger. That's how the regional federations, the Flemish Construction Confederation (VCB), the Construction Confederation of Brussels-Capital (CBB-H) and the Construction Confederation of Wallonia (CCW) defend the interests of the affiliated members together with the regional authorities and advise them optimally in their areas of competence (energy, environment, training and recruitment, waste, regional permits, etc.).

Techlink represents the installation companies as a sector federation. From their role as sector organisations, they recognise the need for installers to respond to more innovative technologies and proactively approach the market. As a sector organisation for installation companies, they obviously understand the characteristics of this sector like no other. They have extensive experience in organising events and information sessions for installers and ensure that the best approach of the target group can be followed to achieve maximum impact.

A reactive and proactive approach characterises the integrated operation of Techlink:

- In the field of individual services, an average of 60 questions are handled on a daily basis. The technical questions are firstly handled by Techlink itself. For technical questions that require much deeper expertise, these are solved through collaboration with the WTCB and Tecnolec sectoral knowledge centres.
- At a proactive level, Techlink performs extensive information dissemination (+ knowledgebase for members on the website), awareness raising, knowledge transfer and vocational training in which innovation and energy technology is central. The federation is active in various relevant technical committees of the sectoral technical knowledge centres, actively follows standardisation and regulation, and is an important stakeholder in energy consultations (e.g. EPB, NZE buildings, and installation requirements in renovation).
- With regard to energy technology, the interaction with the installers is realised through so-called sector committees that determine a common position for the professional federation:
    - Sectoral Committee for CHP installations;
    - Sectoral Committee for Photovoltaic installations;
    - Sectoral Committee for Solar thermal installations;
    - Sectoral Committee for Heat pump installations;

Main tasks in the project

The main involvement of Techlink is in WP7, concerning the **integration of the SolBio-Rev solution in buildings**, both new and existing ones, and the possible use of existing infrastructure. Techlink will also get involved in the prototype system design in WP4, bringing its expertise in the implementation of innovative installations, including the use of renewable energy systems. Moreover, it will support the activities in WP6, **engaging installer companies** through its network in Belgium, in order to introduce their needs in the SolBio-Rev solution. Finally, Techlink will get involved in other activities as well, such as dissemination, communication and exploitation in WPs 8 and 9, focusing mainly on installer companies.

Key personnel involved in this project

Jan Lhoëst (M) is an industrial engineer of process techniques and obtained a postgraduate degree in Real Estate at KU Leuven. He has extensive experience in project work for SMEs from previous positions at Lessius Hogeschool and ODE Vlaanderen, with various successful subsidy files within IWT (Collective Research, HOBU, TETRA, and IDEG). After working for several years in the private sector for heat pump and heating boiler manufacturers, he started work at the beginning of 2015 as director of the ICS professional federation and subsequently became commercial director of Techlink. He is now a director at ODE Vlaanderen (formerly, he also managed the European Heat Pump Association-EHPA for several years). Through his experience in both the private sector and the federations and education, he has insight into the problems of SMEs in the installation sector. As a result, he has the necessary skills and applied technological insight to provide the necessary support and knowledge transfer adequately.

Kris Van Dingenen (M) is an electrotechnical industrial engineer and obtained a postgraduate degree in business administration at KU Leuven. From prior positions at Tecnolec (the technical knowledge centre of the electrical sector), he has extensive experience in project work for SMEs with various successful IWT-VIS subsidy files within the TIS, TD, TR and TR-IV programs. After 5 years as an advisor-coordinator, he was director of Tecnolec for 12 years (formerly known as VEI). After 17 years at Tecnolec, in 2014 he started working at the professional federation Fedelec (STS umbrella) as Director Special Techniques and is now a director at Tecnolec and Vormelek. He is currently Director of Technology & Certification at Techlink. Through his experience within the Tecnolec Technological Services, he has insight into the problems of SMEs in the installation sector. As a result, he has the necessary skills and applied technological insight to provide the necessary support and knowledge transfer adequately.

Relevant services

- Response to technical questions to our members.
- Information and awareness to our members, such as access to technical databases, latest developments of the construction sector, and activities of committees and working groups.
- Networking and promoting.
- Vocational training to its members.
- Various E-tools for designing and installation.

Relevant recent projects

1. HBC.2017.0023, Coordinator: *Slagkracht voor de vernieuwende installateur*.
2. E13-001: Certification of installers of small scale renewable energy systems: implementation of Belgian *system*

Significant infrastructure/technical equipment, relevant to the proposed work

Not applicable for Techlink.

4.1.12 Participant 12: Karlsruhe Institute of Technology (KIT) (Germany)

Website: http://www.lti.kit.edu/english/index.php

Karlsruhe Institute of Technology (KIT) is a higher education and research organisation with about 9,500 employees, 26,000 students. It bundles the missions of a university of the state of Baden-Wuerttemberg and of a large-scale research institution of the Helmholtz Association. Within these missions, KIT is operating along the three strategic fields of action of research, teaching, and innovation. In establishing innovative research structures, the KIT is pursuing joint strategies and visions. KIT is devoted to top research and excellent academic education as well as to be a prominent location of academic life, life-long learning, comprehensive advanced training, exchange of know-how, and sustainable innovation culture.

The Light Technology Institute (LTI) and its **Thermoelectric Technologies** division is part of the electrical engineering faculty. The Institute of Lighting Technology of the Karlsruhe Institute of Technology has many years of experience in the field of printed electronics. From modelling, design, implementation and automation of printed electronics and their materials, the LTI's expertise and research activities cover a broad spectrum.

A key technology of the institute that has been developed from these research efforts over the last 8 years is a liquid processable production method for **thermoelectric generators** (TEGs). As a result of these research activities, the spin-off Otego GmbH was founded, which specialises in the development, production and marketing of printed TEG technology for energy harvesting applications.

The innovative core of this new technology is the use of specially developed, environmentally friendly and liquid processable semiconductor materials. These materials, which form the basis of the TEGs, are optimised to have particularly good thermoelectric properties. They are then applied to a thin carrier foil in a large industrial roll-to-roll printing process before being fully automatically wound and folded in further steps (patent pending). With this approach, a very cost-effective and scalable TEG can be produced.

Furthermore, the LTI and the Karlsruhe location provide an optimal environment for printed thermoelectrics with close collaborations in the near vicinity with the InnovationLab GmbH (partially owned by KIT) in Heidelberg providing industrial printing machines.

Besides the experience gathered in the field of printed TEG technology, the LTI does also have experience on commercial bulk TEGs, as those are currently representing the benchmark technology in the field of thermoelectric generators.

Like the interdisciplinary research field of thermoelectrics itself, the LTI thermoelectric research group is made up of a team of researchers coming from different disciplines including researchers with an electrical engineering background as well as physicists and mechanical engineers. The group is an active member in the thermoelectric research community, thus participating and giving presentations at conferences, such as the "*International Conference on Organic and Hybrid Thermoelectrics (ICOT)*" or the "*Material Research Spring Meeting (MRS)*".

Main tasks in the project

The KIT will develop in cooperation with AKOTEC a vacuum tube collector with **integrated TEGs**. This includes the conceptual design of the TEG-System, and the thermal coupling of the TEGs into the solar heat cycle (WP2). The relevant power management and **control strategies** will be defined in WP3. Finally, KIT will get involved in other activities as well, such as dissemination, communication and exploitation in WPs 8 and 9.

Key personnel involved in this project

Prof. Dr. re. nat. Uli Lemmer (M). Uli Lemmer received the diploma degree in physics from RWTH Aachen University in 1990 and a Ph.D. from the University of Marburg in 1995. From 1995 to 1996, he held a postdoctoral position with the University of California at Santa Barbara. He was with the University of Munich from 1996 to 2002. In 2002, he was appointed a full Professor and director of the Light Technology Institute, Karlsruhe Institute of Technology (KIT). Since 2006 he is also the coordinator of the Karlsruhe School of Optics & Photonics (KSOP) and he is also heading the device physics competence centre within the InnovationLab in Heidelberg. His research interests are in the technology and the applications of printable organic and inorganic semiconductors.

Andres Georg Rösch (M). He graduated from the faculty of Electrical Engineering at the Karlsruhe Institute of Technology (KIT) in 2017. His specialisation lies in micro- and nano-electronics and he completed his studies with a thesis on printed thermoelectrics. Since then he is Ph.D. candidate on the topic of "Design and modelling of thermoelectric materials and generators". He has developed a software, for the simulation and optimisation of printed thermoelectrics for thermal and electrical impedance matching of printed TEGs.

Leonard Franke (M). He graduated from the faculty of Mechanical Engineering at KIT in 2017 and in parallel pursued a degree in Energy and Environment from the Buenos Aires Institute of Technology (ITBA). He is a Ph.D. candidate at KIT on the topic of "Printed and large surface thermoelectric generators for low and medium grade waste heat recovery". In his work he concentrates on the conceptual design and simulation of waste heat recovery systems with integrated printed TEGs.

Relevant recent publications

1. Karlsruhe Institute of Technology (KIT), 2018. Organische Halbleiter, *Verfahren zu ihrer Herstellung und ihre Verwendung Inventors* : Silas Mehmet ASLAN, Frederick LESSMANN, André GALL, Matthias Jan Frederik Hecht, Uli LEMMER, Danny WAGNER, Stefan Bräse. 28.06.2018. Anmeldung: 23.12.2016. DE 10 2016 125 644 A1. **(2018)**
2. Lemmer U, Gall A, Hecht M, Aslan S, Lessmann F, Schendel V. *Hybrid electronic systems powered by printed thermoelectric generators* In: Hybrid Memory Devices and Printed Circuits 2017 (Vol. 10366, p. 103660B). International Society for Optics and Photonics **(2017)**
3. Karlsruhe Institute of Technology (KIT), 2015. *Wound and folded thermoelectric systems and method for producing same*. Inventors: Ulrich LEMMER, Siegfried KETTLITZ, André GALL, Marcel GÜLTIG. 22.04.2015. EP 2 862 208 B1 **(2015)**
4. Manfred Scholdt, Hung Do, Johannes Lang, Andre Gall, Alexander Colsmann, Uli Lemmer, Jan D. Koenig, Markus Winkler and Harald Boettner. *Organic Semiconductors for Thermoelectric Applications*. Journal of electronic materials 39(9):1589-92 **(2010)**

Relevant recent projects

1. PANAMAT: *PEDOT and inorganic nanoscale materials for printed thermoelectric*. Call: ProMat_KMU, 03XP0161A **(2018-2020)**
2. PRINTTEG: *Roll-to-Roll printing of organic thermoelectric generators, Development of a scalable and automatable production process for organic TEGs (printing/wrapping/folding)* **(2011-2014)**
3. EXIST RESEARCH TRANSFER: *Commercialisation of printed organic thermoelectric generators, Foundation of the spin-off company OTEGO, Commercialisation of printed TEGs for Energy Harvesting* **(2011-2014)**

Significant infrastructure/technical equipment, relevant to the proposed work

The KIT relies for the development of the lab prototype TEG system in WP2 on the following infrastructure and technical equipment:

- In-house mechanical and electrical workshop.
- TEG measurement setup to determine temperature dependant Seebeck effect and thermal conductivity.
- Setup for full characterisation of thermoelectric thin films (Seebeck effect, thermal conductivity, electrical conductivity).
- Equipment for electric load measurements / power measurement.
- Various sensors for temperature, flow velocity, pressure, etc.

The KIT provides the following software packages for the development of TEG system in WP2:

- CAD-Systems: Creo Parametric 4.0, Autodesk Inventor, SolidWorks.
- Simulation software for energy systems Matlab, Simulink/Simscape, Modelica/OpenModelica.
- Computational mechanics software: COMSOL Multiphysics, OpenFOAM, ANSYS FLUENT.
- In-house software for TEG simulation based on Modelica modelling language.
- In-house software for design optimisation of printed TEGs.

The production process of printed TEGs and the relevant equipment for testing and characterisation are shown in the next figures.

Gallus printing press used in the TEG production process at Innovation Lab

White light interferometer (WLI) and profilometer for surface characterisation of printed TEGs at KIT

4.1.13 Participant 13: ÖkoFEN Forschungs- und Entwicklungs GmbH (ÖKOFEN) (Austria)

Website: www.okofen.com

The name ÖkoFEN stands since its foundation in 1989 for ecological research and development of environmentally friendly pellet heating systems. Today, the company is known worldwide as the specialist in pellet heating. The specialisation in the fuel pellets is the basis for innovation in the field of pellet heating and storage technology from ÖkoFEN. Since the presentation of the first type-tested fully automatic pellet boiler in 1997, ÖkoFEN has become the innovator and large exporter in the pellet boiler industry.

Currently, ÖkoFEN is one of the world's leading manufacturers of **pellet heating systems** with more than 70,000 pellet heating systems delivered to industrial, commercial and residential customers. The export share of the company is currently more than 90%. The products are distributed by the headquarters in Niederkappel, Austria, via regional partners to professional tradesmen in less than 17 different countries worldwide. ÖkoFEN has subsidiaries in Germany, France, Italy, Spain, Belgium and Switzerland.

ÖkoFEN has won numerous business and innovation awards including the Energy Genius, and in 2001 the Energy Globe Award. These awards stand for the continuous development of the product range on the cutting edge of technology. 100% of the innovations derived from their in-house research and development department, which ensures ÖkoFEN´s technological advance.

ÖkoFEN pellet heating systems are suitable both for the new construction and for the renovation of large and small buildings. From a single family home to large commercial and public buildings, as a **specialist for wood pellet boilers**, ÖkoFEN offers the right solution in the range of 6 to 256 kilowatts for every requirement.

Main tasks in the project

OKOFEN together with FAU will develop a **prototype biomass boiler** equipped with EGR for reduced emissions and an internal HEX for high-temperature heat supply to the ORC (WP2). Afterwards, ÖKOFEN will provide **two biomass boiler prototypes** (WP4) for the integration in the pilot systems at FAU and NTUA and assist in the testing activities (WP5). Finally, OKOFEN will get involved in other activities as well, such as dissemination, communication and exploitation in WPs 8 and 9.

Key personnel involved in this project

Dipl.-Ing. (FH) Stefan Ortner (M) is the CEO of ÖkoFEN Forschungs- und Entwicklungs-GmbH. He has a degree in Marketing and Management, received during his studies at the University for Applied Science in Wels and San Diego State University, USA. Since 2011, he is member of the OKOFEN management, responsible for research and development, product & quality management and business development.

Dipl.-Ing. (FH) Roland Pargfrieder (M) started his activities in the energy sector as electrician at Alstom before he began his education in energy engineering at the University for Applied Science in Wels. He is engineer at ÖkoFEN since 2006 with a focus on combustion and software development. Starting from 2016, he is division manager of research and development within the ÖkoFEN Forschungs- und EntwicklungsgesmbH.

Relevant recent products and services

1. Production of pellet boilers and plants (of conventional and condensing technology) with an output of 4 to 256 kW
2. Production of Pellet-CHP with an integrated Stirling engine for small-scale applications, such as in single family houses.
3. Production of solutions for pellet storage and conveying.
4. Electronic controllers for heat and electricity management.
5. Production of auxiliary parts of biomass boilers, such as buffer tanks, and pump sets.

Relevant recent projects

1. Pelletskessel mit Stirlingmotor, National project of Energie-Technologie-Programm Upper Austria, **(2010-2012)**

Significant infrastructure/technical equipment, relevant to the proposed work

ÖkoFEN has its research and development centre, its test laboratory and prototyping in Lembach im Mühlkreis (Upper Austria), near the headquarters in Niederkappel. For the proposed work in **boiler development and testing** (WP2) and **prototype production (WP4)** the following infrastructure and equipment is available.

- Test lab specialised on continuous tests of wood pellet heating systems
  - Fuel characterisation
  - Emission measurements and reduction strategies
  - Efficiency improvements
- Test lab for CHPs and battery systems
  - Long-term testing
  - Integration to buildings
  - Control strategies
- Prototyping
  - Manufacturing
  - Electrical and measuring equipment
  - Commissioning and operation

Figures of the laboratory during prototype boiler tests are shown below.

4.1.14 Participant 14: N.V. STRABAG Belgium SA (STRABAG) (Belgium)

Website: www.strabag.be

STRABAG is an EU-based technology group for construction services, leader in innovation and financial strength, spanning all areas of the construction industry. STRABAG adds value for its clients by integrating the most diverse services and assuming responsibility for them. Relying on close to 73,000 employees, services are offered along the entire construction value chain – from design to planning, from construction to property and facility services, from operation all the way to demolition. As such, an annual output volume of more than € 14 billion is realised. A dense network of numerous subsidiaries in many European countries and on other continents expands operation far beyond the borders of Austria and Germany.

As a technology-focused company, innovation is embraced to remain competitive in the long term. STRABAG's provision of research and development funding by the company: amounts € ~11 million, with 23 out of 100 with at least one person responsible for innovation: On average, about 100 development projects annually are carried out in the group which encompass the entire construction value chain: from the measurement of topographical data using drones to the analysis of traffic data by our subsidiary EFKON AG, from the development and adaptation of tools for model-based working methods for design and construction logistics to facility management, where we are working together with Microsoft on the use of the HoloLens data glasses. Innovation is further promoted through the STRABAG platform connect, which allows our employees to exchange ideas and propose solutions quickly across organisational and geographic boundaries.

STRABAG's team concept enables to join various competencies at an early stage, increasing project efficiency and optimisation of the end result. The team concept also guarantees cost transparency and risk management. In all stages of the construction process, partners work on each other with the same focus.

Over the past decade, STRABAG's function of general **building contractor** has shifted to that of customer-oriented service provider. Collaborative forms such as Public Private Partnerships and Design & Build projects are already very well embedded in STRABAG's offerings.

STRABAG Belgium is one of the leading Belgian construction companies, striving for a strong position in non-residential and industrial buildings as well as in civil engineering. STRABAG Belgium counts on 400 enthusiastic employees, realising an annual turnover of more than € 200 million. The order portfolio comprises building schools, hospitals, residential care centres, offices, industrial sites and Designer Outlet Centres. STRABAG Belgium's international anchoring offers, technically sophisticated innovative solutions and a strong financial basis. The concentration of competence, capacity and know-how available within STRABAG guarantees an integrated approach to projects. As a result, STRABAG is able to complete larger and more complex projects.

While at EU level the technical competence of several hundred specialists is grouped at "Zentrale Technik", within the Benelux, technical expertise is combined in the Central Services (CS) department in order to be able to respond better to the needs. The team of more than 40 engineers, architects, BIM employees, project managers, etc. supports their colleagues in the Benelux with the designs, technical studies and various specialised work areas. CS works closely with the client, the architect and the engineering firm to continuously fine-tune each construction project. The department uses the most up-to-date software for drawing up calculation notes, plans, BIM models, risk analyses or optimisations. Lessons learned are inventoried and disseminated to the employees. As a result, the organisation is always ready to respond to changing market situations and ever-changing standards, requirements and specifications.

STRABAG stands for quality and reliability with an integrated management system in accordance with ISO 9001, ISO 14001 and VCA. Within the group, STRABAG can call on its BREEAM specialists, contributing to corporate social responsibility.

Main tasks in the project

The main involvement of STRABAG is in WP7, providing its expertise on building construction, focusing on the **integration of the SolBio-Rev solution in a variety of buildings**. STRABAG will also get involved in the prototype system design in WP4, bringing its expertise in the implementation of innovative installations. Finally, STRABAG will get involved in other activities as well, such as dissemination, communication and exploitation in WPs 8 and 9, focusing mainly on the **future exploitation** of the SolBio-Rev solution in sustainable buildings.

Key personnel involved in this project

Danny Goossens (M) has a track record of 27 years at STRABAG with functions ranging from technical employee, technical commercial representative, senior project manager until now in charge of the central services. For 3 years, Danny is Technical Director Central Services providing all necessary support for projects of STRABAG Belgium and Netherlands (the STRABAG entity in the Netherlands is referred to as Züblin Netherlands). He leads a team of 40 collaborators, i.e. architects, engineers, design coordinators, BIM-specialists, cost estimators and project preparators, supporting projects in execution, as well as projects in tendering phase. Danny is an experienced project manager showing leadership to steer and motivate his team to focus and execute with high professionalism. He is an experienced Fellow in Legal Expertise and has a broad network in the building and energy world. He has been in charge of challenging projects realising building projects using energy saving technologies. Danny motivates his team to assess and where techno-economically possible incorporate renewable energies.

Patrick Deketele (M) started his career at STRABAG Belgium in 1996, starting as site employee having since then been in various positions such as site manager, project manager and head of project management. Since 2003 Patrick has been in different director positions and for the last three years (since 2015) is the CEO of STRABAG Belgium – Züblin Netherlands. As head of project management, Patrick was in charge of many large-scale challenging projects. As CEO he not only oversees current projects and acts as a visionary for future development, above all he inspires people to create team works, creating added value by integrating the most diverse services and assuming responsibility for them. He facilitates to bring together people, materials and machines at the right place and at the right time in order to realise even the most complex construction projects – on schedule, of the highest quality and at the best price. Patrick is well embedded in the building, construction and energy world, bridging innovation and implementation.

Peter Krammer (M), STRABAG SE Management Board member acts as a sponsor of innovation and digitalisation within the group. He motivates innovation managers at the divisions and central divisions, collects development proposals and approves their realisation in line with the strategic alignment of their business field. He assists in how to recognise relevant trends; on questions pertaining to the systematic development of new solutions, public funding or development partnerships; and on the in/external rollout and reporting on the group-wide innovation activities.

Relevant recent products

1. **EnergyVille at the science park "Thorpark" (KULeuven, VITO, IMEC) (Genk, Belgium)** - construction of the new "smart grid" Flemish knowledge Centre for energy research. The building is energy neutral and therefore strives for a BREEAM Excellent certificate: a minimal environmental impact with a high degree of user satisfaction. Energyville wants to become the most sustainable building in Flanders as regards the energy consumption. Furthermore, the centre is closely related to its environment by exchanging warmth and electricity and using optimised transport facilities on site. STRABAG was responsible for the closed carcass, the finishing, the landscaping and the full coordination. The new design is a mix of innovative architectural insights and similarities with the original static building. The façade is finished using special grilles and big windows to bring nature into the project. The laboratory utilities include a LV-AC & DC test grid, a home lab, a battery test lab and a sound isolating test cell. A multifunctional matrix space, charging infrastructure for electrical vehicles and climate rooms is integrated too. Furthermore, Energyville is equipped with a chemical lab, an electronics lab and a 300 m² photovoltaic test field of the roof. The concrete structure is mainly characterised by the use of "green concrete": a high-tech concrete with recycled non-ferrous snails from Umicore. The Excavated sand was re-used on site to make stabilised sand according to the "Cradle-to-Cradle" principle. Site accommodations used LED-lights, motion detectors and HVAC timers to minimise the energy consumption on site (***Total area 14,500 m², € 11.5 million,* 11/2013 - 06/2016**).

2. **Greenwal (IFAPME) (Gembloux, Belgium)** - situated at the industrial park "Creafys" which is divided in a "practical zone" with workshops (e.g. for trainings on ecological & natural materials and special technical installations), and a ''theoretical zone'' with classes, offices and an auditorium. STRABAG Belgium was responsible for the realisation of the carcass and the landscapes works. The abuilding is an example of an environment-friendly performance and smart energy solution. The project is built according to the passive house concept. A wood/concrete combination is used during the realisation of the project. The project includes the construction of the "greenwal" information and advice centre: an initiative to boost sustainable construction projects. (***Total area 5,205 m², € 3.6 million*, 09/2014 - 04/2016**)

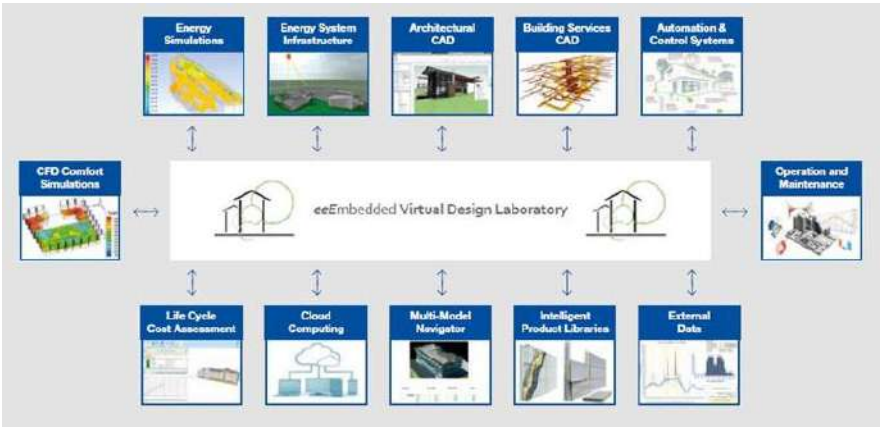
3. **Care campus de Maasmeander (OCM) (Maasmechelen, Belgium)** - a new district in the neighbourhood of the central park combining 3 main functions: caring, living and working. The care program involves 120 single rooms, 2 double rooms, 10 rooms for short stay and 35 service flats on 4 aboveground levels (9,750 m²). The residents and their visitors can use the underground car park and a bicycle parking (2,000 m²). The building fits into the surrounding environment: sustainable but sober. Sand-coloured bricks were used for the façade and reflect the warm colour palette. Furthermore, the design team centralised the client as well as the end user in its design. On the one hand the building is functionally and efficiently manageable by the client and on the other hand it gives the residents a comfortable and welcoming feeling. The main part of the building construction is made out of prefabricated elements such as sandwich elements. An intensive pre-study with detailed BIM modulation was the basis of the execution file, resulting in a shorter construction period. (***Total area 2,000 m², € 14.25 million,* 05/2011 - 12/2013**)

4. **Vertical city, De Rotterdam (DRCV combination of OVG / MAB Bouwfonds) (Rotterdam, The Netherlands)** - a unique, sustainable, multifunctional energy-efficient building, with frugal consumption and maximum use of daylight and an optimal air conditioning system. The project consists of three linked 149 m high towers. This "Design & Build" project includes: high-quality offices (72,000 m²), 220 luxury apartments, a 4-star hotel with 280 bedrooms, extensive conference facilities, shops, cafes, restaurants, fitness facilities, 684 parking spaces and cultural functions. The building has been erected in the form of a vertical town where 3,000 to 4,000 people live, work, and shop & relax every day. Use is made of public power generation with city heating, a bio oil-fired combined heat and power system. Water from the River Maas is used to cool the building. The ventilation systems is used to recover heat, and there is high output lighting and daylight switching using movement sensors. The building has dropped 20 cm during the construction period with differential differences of 14 cm. using the jacking technique: measuring of settlement differences between jacking columns and their adjacent columns by means of a monitoring system. The towers jump out on height of 80 meters with a difference of 8 meters. 4,500 employees realised this impressive project. (***Total area 162,000 m², € 162.75 million,* 12/2010 - 11/2013**).

5. **Bio heating installation (44 MW) (Stadsverwarming Purmerend) (Purmerend, The Netherlands)** – providing 80% of the total sustainable heat for 25,000 customers. The Design & Build project included all construction and civil-technical works. STRABAG's 5D Design division and its Central Services department used the Building Information Model (BIM), combination of 3D, 4D and 5D plans, in order to optimise understanding of the common tasks between contractor and client. After the testing period (04/2014 - 08/2014), the bio heating installation was operational**. (*Total area 3,500 m², € 8.3 million*, 01/2013 – 03/2014)**

Relevant recent projects

1. **eEmbedded - Collaborative holistic design laboratory and methodology for energy-efficient embedded buildings** – In eeEmbedded, the building design process has been divided into three phases: In Urban Design, the building shape and its very basic room concept is optimised. In Early Design, the concepts of HVAC (heating, ventilation & air conditioning) and BACS (building automation and control systems) are determined, including a more detailed elaboration of the building structure, while the BIM modelling approach migrates to the state of the art procedure in Detailed Design. With the multi-model approach and automated data connection of every involved software program, the central server provides the possibility to manage various design options. Graphical evaluations assist the decision process between these alternatives at the end of each planning phase (**FP7 - October 2013 - September 2017**).



2. **PreComBo - Sensor-based commissioning and optimisation of building services** – In this project a previously developed open-source measuring system has been enhanced in further cooperation with the Steinbeis Transferzentrum Building Technology (STZ BT). A prototype of the developed measuring system has been used in the "Office 2020"-area in the ZÜBLIN-Haus. Different possibilities for visualisation and analysis of the measured values have been tested (**in-house project, 2016 – 2017**).
3. **Accelerated introduction of BIM.5D® at STRABAG** - With every realised project the number of application fields increases such that further developments in the field of BIM are planned for the next years to master future challenges in construction projects that are becoming ever more complex (July 2015 until December 2016).
4. **SolConPro, Holistic integration of energy generating facade components (building-integrated photovoltaics and solarthermal systems) in construction processes** – Analysis of the requirements of a holistic BIM approach where every software user reads and edits the data required for the corresponding application only. Within SolConPro, the focus is on approaches that allow parallel data handling. Extended concepts for filtering and pre-processing units have been developed in the project, which allow format adjustments while maintaining data synchronisation. The concepts are currently extended to semantic web structures while further activities in buildingSMART and ENCORD are intended in the near future (**April 2015 - March 2018**).
5. **Innovative energy concepts and downhole hammer technology for medium-depth geothermal systems**. Drilling cost is decisive for the economic feasibility of medium depth geothermal systems. The technique of using water instead of air as an energy carrier in down-the-hole (DTH) drill hammers has been known for years in the mining and geotechnical industry. Recent technical developments in terms of tooling and drilling fluid circulation systems now enable the utilisation of this drilling method for medium-depth geothermal energy applications. The water powered DTH hammer drilling method can be utilised with small truck-based drill rigs and corresponding small site requirements resulting in lower prices for medium deep drilling operations compared to conventional rotary mud drilling (**Intern project, March 2015 – December 2018**).

Significant infrastructure/technical equipment, relevant to the proposed work

Not applicable for STRABAG.

4.1.15 Participant 15: Universita Degli Studi di Messina (UNIME) (Italy)

Website: www.unime.it

University of Messina, founded in 1548, is a higher education and research institution counting 24,000 students and 1,200 research staff members. Nowadays, it offers 72 active degree courses in different areas, 12 doctorates programs and several educational programs. UNIME has expertise in the participation and management of EU funded projects, under FP7 & H2020.

Over 5 academics and researchers at Department of Engineering, Materials Science Laboratory are active in many fields of energy materials (composite solid adsorbents, phase change materials, chemical heat storage) and the related sustainable issues, e.g. materials design and synthesis of functional materials for energy systems applications.

The facilities of UNIME are used for materials preparation, chemical-physical characterisation, structural and morphological characterisation (XRD, SEM, TEM, Surface Area, Particle size distribution, mechanical testing), thermal analysis (TGA, DSC), as well as for dip coating and spray coating systems for large HEX applications (up to 30L volume).

Main tasks in the project

UNIME will develop and optimise the **post-synthesis process** of SAPO 34-based adsorbent coating, defining the improved process for the realisation of the full-scale adsorber to be employed in the cascade adsorption chiller with heat pump in WP2. UNIME will participate in the **validation of this technology** during the pilot tests in WP5. Finally, UNIME will also be involved in other activities such as dissemination, communication and exploitation in WPs 8 and 9.

Key personnel involved in this project

Dr. Luigi Calabrese (M). Luigi Calabrese was born in 1974. He graduated from Material Engineering in 1998 and obtained his Ph.D. in Materials Chemistry and Engineering at University of Messina, in 2002. Currently, he is a researcher in the field of Material Science and technology at the Department of Engineering of the University of Messina and associate professor at the CNR-ITAE in Messina. His main research activities are focused on: - Synthesis and characterisation of adsorbent materials; - Advanced composites and functional materials for industrial applications. Up to date, he has published over 90 articles in indexed international journals. 5 Chapters on scientific books. 1 Book on Springer Scientific series and 4 patents.

Prof. Edoardo Proverbio (M), born in 1963, obtained his Master's degree (MEng) cum laude in Nuclear Engineering at the University of Rome "La Sapienza", Rome, Italy. He was from 4/1991 to 10/1998 Assistant Professor in Science and Technology of Materials at the University of Rome "La Sapienza", Rome, Italy, and from 11/1998 to 06/2005 Associate Professor of Science and Technology of Materials at the University of Messina, Italy. He is currently full Professor of Science and Technology of Materials at the University of Messina. His main research fields are on synthesis, characterisation and durability in materials science. He was coordinator of about 10 research projects on materials science field. He is author of 115 peer-reviewed publications on materials science, physics and engineering area. His publications gained 1028 citations and are ranked with an h-index of 19.

Relevant recent publications

1. L Calabrese, L Bonaccorsi, A Freni, E Proverbio. *Silicone composite foams for adsorption heat pump applications*. Sustainable materials and technologies 12, 27-34 (**2017**)
2. A Freni, L Bonaccorsi, L Calabrese, A Caprì, A Frazzica, A Sapienza. *SAPO-34 coated adsorbent heat exchanger for adsorption chillers*. Applied thermal engineering 82, 1-7 (**2015**)
3. L Calabrese, L Bonaccorsi, D Di Pietro, E Proverbio. *Effect of process parameters on behaviour of zeolite coatings obtained by hydrothermal direct synthesis on aluminium support*. Ceramics International 40 (8), 12837-12845 (**2014**)
4. L Bonaccorsi, L Calabrese, A Freni, E Proverbio, G Restuccia. *Zeolites direct synthesis on heat exchangers for adsorption heat pumps*. Applied Thermal Engineering 50 (2), 1590-1595 (**2013**)
5. L Bonaccorsi, L Calabrese, A Freni, E Proverbio. *Hydrothermal and microwave synthesis of SAPO (CHA) zeolites on aluminium foams for heat pumping applications*. Microporous and Mesoporous Materials 167, 30-37 (**2013**)

Relevant recent projects

1. INCAS: Integration of Nanoreactor and multisite CAtalysis for a Sustainable chemical production. FP7-NMP (**2010-2014**)
2. MSE - National Project. *Adsorption solar air conditioning* **(2012-2014)**
3. CHEMWATER: *Coordinating European Strategies on Sustainable Materials, Processes and Emerging Technologies Development in Chemical Process and Water Industry across Technology Platform*. FP7-NMP (**2011-2013**)
4. NEXT-GTL: *Innovative Catalytic Technologies & Materials for Next Gas to Liquid Processes*. FP7-NMP (**2009-2013**)
5. MSE - National Project. *Use of solar energy for summer conditioning*. 5.4.1.3, Thematic Group: Innovative Components and Plants **(2010-2011)**

Significant infrastructure/technical equipment, relevant to the proposed work

Different equipment available in the UNIME labs will be used for the development of the activities in WP2. In the following, the main relevant equipment is listed.

Material development and characterisation lab:

- Microwave oven for microwave assisted synthesis and continuous flow reactions (Milestone FlowSynth)
- 3D digital microscope/profilometer (Hirox KH8700)
- Dual Beam SEM/FIB electron microscope (Zeiss Crossbeam 540), see next figure
- Environmental Scanning Electron Microscope (ESEM-Fei Quanta 250)
- Dynamic Dual Vapor/Gas Thermogravimetric Sorption Analyser for measurement of ad/absorption and co-ad/absorption of vapours on solids and liquids from room up to 400 °C with relative pressure from 0.01 up to 0.95 (DVS Vacuum)
- Universal Testing Machine (UTM) for mechanical performances evaluation (tensile, flexural, compression, adhesion, friction tests) (Zwich - ZwichLine 5kN)
- High Impedance BiPotentiostat/galvanostat/EIS instrument equipped with low current module for measurement of corrosion and performances of coatings and surfaces (Biologic SP-300).
- Gloves chamber at controlled atmosphere. It guarantees the material synthesis and development without contaminants.
- Fully automated optical tensiometer for characterising surface tension and contact angle (Attension Theta)
- TG/DSC working under specific heat measurements from 30 °C up to 1500 °C (TA Instruments SDT Q600)

Components development and characterisation lab:

- Manufacturing rig for spray coating technology on small- and large scale heat exchangers
- Manufacturing rig for dip coating technology on small- and large scale heat exchangers
- Climatic Chamber (volume 224L) for prototype curing ageing. Temperature range from -40 °C to 180 °C. relative humidity range from 10% to 98% (Angelantoni ACS Challenge CH250)
- Universal oven (volume 750L) for prototype curing cycles, temperature range from 30 °C to 300 °C
- Vertical furnace (Lenton UAF 17/12M) for materials calcination. Volume 12L and temperature range from 30 °C to 1150 °C. It is equipped with inlet and outlet for air/gas flow, see next figure.

The available furnace that will be used for the calcination process and the electron microscope equipment for the evaluation of the morphology of the synthesized material and post-treated coated HEX are shown in the next two figures.

Left: Lenton UAF 17/12M vertical Furnace used for the calcination process. Right: Zeiss Crossbeam 540, Dual Beam SEM/FIB electron microscope

4.2. Third parties involved in the action (including use of third party resources)

No third parties are involved in the SolBio-Rev project.

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	**No**
-	
Does the participant envisage that part of its work is performed by linked third parties	**No**
-	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	**No**
-	

5. Ethics and Security

5.1 Ethics

In terms of personal data, the project will adhere to UOS Research Data Management Policy (UOS is WP leader of social science research and stakeholder engagement, WP6), the Information Security Policy and the Code of Practice for Research. The research activities will adhere to the latest "General Data Protection Regulation" (GDPR, Regulation (EU) 2016/679). The interview and survey data collection will be conducted according to the UOS Research Ethics Committee approval and guidelines. All data during collection and processing will be therefore **anonymised**.

5.2 Security

All activities planned in the framework of the SolBio-Rev project raise no security issues. No background information, neither any results delivered within the project are considered as classified in the terms of national/european safety and/or security.

Thus, the SolBio-Rev project will involve:

- activities or results raising security issues: NO
- EU-classified information' as background or results: NO

Finally, no dual-use items, listed in Annex I and in Annex IV of Council Regulation No 428/2009, nor dangerous materials and substances are going to be used in the project.

ESTIMATED BUDGET FOR THE ACTION

Associated with document Ref. Ares(2019)1399623 - 01/03/2019

	Estimated eligible[1] costs (per budget category)										EU contribution			Additional information		
	A. Direct personnel costs				B. Direct costs of subcontracting	*[C. Direct costs of fin. support]*	D. Other direct costs		E. Indirect costs[2]	Total costs	Reimbursement rate %	Maximum EU contribution[3]	Maximum grant amount[4]	Information for indirect costs	Information for auditors	Other information:
	A.1 Employees (or equivalent) A.2 Natural persons under direct contract A.3 Seconded persons *[A.6 Personnel for providing access to research infrastructure]*		A.4 SME owners without salary A.5 Beneficiaries that are natural persons without salary				D.1 Travel D.2 Equipment D.3 Other goods and services *[D.4 Costs of large research infrastructure]*	D.5 Costs of internally invoiced goods and services						Estimated costs of in-kind contributions not used on premises	Declaration of costs under Point D.4	Estimated costs of beneficiaries/ linked third parties not receiving funding/ international partners
Form of costs[6]	Actual	Unit[7]	Unit[8]		Actual	Actual	Actual	Unit[9]	Flat-rate[10] 25%							
	a	Total b	No hours	Total c	d	*[e]*	f	Total g	h = 0,25 x (a +b+c+f+g +*[i1]*[13]+*[i2]*[13]-n)	j = a+b+c+d +*[e]*+f+g+h +*[i1]*+*[i2]*	k	l	m	n	Yes/No	
1. NTUA	470 400.00	0.00	0.00	0.00	0.00	0.00	205 000.00	0.00	168 850.00	844 250.00	100.00	844 250.00	844 250.00	0.00	No	n/a
2. FAU	345 600.00	0.00	0.00	0.00	0.00	0.00	118 000.00	0.00	115 900.00	579 500.00	100.00	579 500.00	579 500.00	0.00	No	n/a
3. FAHREN	120 000.00	0.00	0.00	0.00	0.00	0.00	61 000.00	0.00	45 250.00	226 250.00	100.00	226 250.00	226 250.00	0.00	No	n/a
4. ITAE	192 000.00	0.00	0.00	0.00	0.00	0.00	67 000.00	0.00	64 750.00	323 750.00	100.00	323 750.00	323 750.00	0.00	No	n/a
5. TEAVE	190 000.00	0.00	0.00	0.00	0.00	0.00	36 500.00	0.00	56 625.00	283 125.00	100.00	283 125.00	283 125.00	0.00	No	n/a
6. AKOTEC	186 000.00	0.00	0.00	0.00	0.00	0.00	72 500.00	0.00	64 625.00	323 125.00	100.00	323 125.00	323 125.00	0.00	No	n/a
7. UDL	200 000.00	0.00	0.00	0.00	0.00	0.00	50 000.00	0.00	62 500.00	312 500.00	100.00	312 500.00	312 500.00	0.00	No	n/a
8. Daikin	163 020.00	0.00	0.00	0.00	0.00	0.00	79 000.00	0.00	60 505.00	302 525.00	100.00	302 525.00	302 525.00	0.00	No	n/a
9. UOS	175 152.00	0.00	0.00	0.00	0.00	0.00	44 479.00	0.00	54 907.75	274 538.75	100.00	274 538.75	274 538.75	0.00	No	n/a
10. DBC	195 000.00	0.00	0.00	0.00	0.00	0.00	28 500.00	0.00	55 875.00	279 375.00	100.00	279 375.00	279 375.00	0.00	No	n/a
11. TECH	119 600.00	0.00	0.00	0.00	0.00	0.00	12 000.00	0.00	32 900.00	164 500.00	100.00	164 500.00	164 500.00	0.00	No	n/a
12. KIT	219 076.00	0.00	0.00	0.00	0.00	0.00	62 000.00	0.00	70 269.00	351 345.00	100.00	351 345.00	351 345.00	0.00	No	n/a
13. OKOFEN	118 332.00	0.00	0.00	0.00	0.00	0.00	43 500.00	0.00	40 458.00	202 290.00	100.00	202 290.00	202 290.00	0.00	No	n/a
14. STRABAG	126 720.00	0.00	0.00	0.00	0.00	0.00	11 500.00	0.00	34 555.00	172 775.00	100.00	172 775.00	172 775.00	0.00	No	n/a
15. UNIME	83 550.00	0.00	0.00	0.00	0.00	0.00	37 000.00	0.00	30 137.50	150 687.50	100.00	150 687.50	150 687.50	0.00	No	n/a
Total consortium	2 904 450.00	0.00		0.00	0.00	0.00	927 979.00	0.00	958 107.25	4 790 536.25		4 790 536.25	4 790 536.25			0.00

[1] See Article 6 for the eligibility conditions.
[2] Indirect costs already covered by an operating grant (received under any EU or Euratom funding programme; see Article 6.5.(b)) are ineligible under the GA. Therefore, a beneficiary/linked third party that receives an operating grant during the action's duration cannot declare indirect costs for the year(s)/reporting period(s) covered by the operating grant, unless it can demonstrate that the operating grant does not cover any costs of the action (see Article 6.2.E).
[3] This is the theoretical amount of EU contribution that the system calculates automatically (by multiplying all the budgeted costs by the reimbursement rate). This theoretical amount is capped by the 'maximum grant amount' (that the Agency decided to grant for the action) (see Article 5.1).
[4] The 'maximum grant amount' is the maximum grant amount decided by the Agency. It normally corresponds to the requested grant, but may be lower.
[5] Depending on its type, this specific cost category will or will not cover indirect costs. Specific unit costs that include indirect costs are: costs for energy efficiency measures in buildings, access costs for providing trans-national access to research infrastructure and costs for clinical studies.
[6] See Article 5 for the forms of costs.
[7] Unit : hours worked on the action; costs per unit (hourly rate) : calculated according to the beneficiary's usual accounting practice.
[8] See Annex 2a 'Additional information on the estimated budget' for the details (costs per hour (hourly rate)).
[9] Unit and costs per unit : calculated according to the beneficiary's usual accounting practices.
[10] Flat rate : 25% of eligible direct costs, from which are excluded: direct costs of subcontracting, costs of in-kind contributions not used on premises, direct costs of financial support, and unit costs declared under budget category F if they include indirect costs (see Article 6.2.E).
[11] See Annex 2a 'Additional information on the estimated budget' for the details (units, costs per unit).
[12] See Annex 2a 'Additional information on the estimated budget' for the details (units, costs per unit, estimated number of units, etc).
[13] Only specific unit costs that do not include indirect costs.
[14] See Article 9 for beneficiaries not receiving funding.
[15] Only for linked third parties that receive funding.

ANNEX 2a

ADDITIONAL INFORMATION ON THE ESTIMATED BUDGET

- **Instructions and footnotes in blue will not appear in the text generated by the IT system (since they are internal instructions only).**
- **For options *[*in square brackets*]*: the applicable option will be chosen by the IT system. Options not chosen will automatically not appear.**
- **For fields in [grey in square brackets] (even if they are part of an option as specified in the previous item): IT system will enter the appropriate data.**

⚠ **Transitory period: Until SyGMa fully supports Annex 2a, you must prepare it manually (using this template by choosing and deleting the options/entering the appropriate data).**
For the 'unit cost tables': either fill them out manually or use currently existing tables from Annex 1 or the proposal.
The document can then be uploaded in SyGMa and attached to the grant agreement.

Unit cost for SME owners/natural beneficiaries without salary

1. Costs for a *[*SME owner*][*beneficiary that is a natural person*]* not receiving a salary

Units: hours worked on the action

Amount per unit ('hourly rate'): calculated according to the following formula:

{the monthly living allowance for researchers in MSCA-IF actions / 143 hours}
multiplied by
{country-specific correction coefficient of the country where the beneficiary is established}

The monthly living allowance and the country-specific correction coefficients are set out in the Work Programme (section 3 MSCA) in force at the time of the call:

- for calls *before* Work Programme 2018-2020:
  - for the monthly living allowance: **EUR 4 650**
  - for the country-specific correction coefficients: see Work Programme 2014-2015 and Work Programme 2016-2017 (available on the Participant Portal Reference Documents page)
- for calls *under* Work Programme 2018-2020:
  - for the monthly living allowance: **EUR 4 880**
  - for the country-specific correction coefficients: see Work Programme 2018-2020 (available on the Participant Portal Reference Documents page)

[additional OPTION for beneficiaries/linked third parties that have opted to use the unit cost (in the proposal/with an amendment): For the following beneficiaries/linked third parties, the amounts per unit (hourly rate) are fixed as follows:

- beneficiary/linked third party [short name]: EUR [insert amount]
- beneficiary/linked third party [short name]: EUR [insert amount]

[same for other beneficiaries/linked third parties, if necessary] *]*

Estimated number of units: see Annex 2

Energy efficiency measures unit cost

2. Costs for energy efficiency measures in buildings

Unit: m^2 of eligible 'conditioned' (i.e. built or refurbished) floor area

Amount per unit*: see (for each beneficiary/linked third party and BEST table) the 'unit cost table' attached

* Amount calculated as follows:
{EUR 0.1 x estimated total kWh saved per m^2 per year x 10}

Estimated number of units: see (for each beneficiary/linked third party and BEST table) the 'unit cost table' attached

Unit cost table (energy efficiency measures unit cost)[1]

Short name beneficiary/linked third party	BEST No	Amount per unit	Estimated No of units	Total unit cost (cost per unit x estimated no of units)

[1] Data from the 'building energy specification table (BEST)' that is part of the proposal and Annex 1.

Research infrastructure unit cost

3. Access costs for providing trans-national access to research infrastructure

Units[2]: see (for each access provider and installation) the 'unit cost table' attached

Amount per unit*: see (for each access provider and installation) the 'unit cost table' attached

* Amount calculated as follows:

$$\frac{\text{average annual total access cost to the installation (over past two years[3])}}{\text{average annual total quantity of access to the installation (over past two years[4])}}$$

Estimated number of units: see (for each access provider and installation) the 'unit cost table' attached

Unit cost table (access to research infrastructure unit cost)[5]

Short name access provider	Short name infrastructure	Installation		Unit of access	Amount per unit	Estimated No of units	Total unit cost (cost per unit x estimated no of units)
		No	Short name				

Clinical studies unit cost

4. Costs for clinical studies

Units: patients/subjects that participate in the clinical study

Amount per unit*: see (for each sequence (if any), clinical study and beneficiary/linked third party) the 'unit cost table' attached

* Amount calculated, for the cost components of each task, as follows:

For **personnel costs**:

For personnel costs of doctors: 'average hourly cost for doctors', i.e.:

{certified or auditable total personnel costs for doctors for year N-1

{1720 * number of full-time-equivalent for doctors for year N-1}

multiplied by

estimated number of hours to be worked by doctors for the task (per participant)**}**

For personnel costs of other medical personnel: 'average hourly cost for other medical personnel', i.e.:

{certified or auditable total personnel costs for other medical personnel for year N-1

{1720 * number of full-time-equivalent for other medical personnel for year N-1}

---

2 Unit of access (e.g. beam hours, weeks of access, sample analysis) fixed by the access provider in proposal.

3 In exceptional and duly justified cases, the Commission/Agency may agree to a different reference period.

4 In exceptional and duly justified cases, the Commission/Agency may agree to a different reference period.

5 Data from the 'table on estimated costs/quantity of access to be provided' that is part of the proposal and Annex 1.

multiplied by
estimated number of hours to be worked by other medical personnel for the task (per participant)**}**

For personnel costs of technical personnel: **'**average hourly cost for technical personnel', i.e.:

{certified or auditable total personnel costs for technical personnel for year N-1

{1720 * number of full-time-equivalent for technical personnel for year N-1}
multiplied by
estimated number of hours to be worked by technical personnel for the task (per participant)**}**

'total personnel costs' means actual salaries + actual social security contributions + actual taxes and other costs included in the remuneration, provided they arise from national law or the employment contract/equivalent appointing act

For **consumables**:

For each cost item: 'average price of the consumable', i.e.:

{{certified or auditable total costs of purchase of the consumable in year N-1

total number of items purchased in year N-1}
multiplied by
estimated number of items to be used for the task (per participant)**}**

'total costs of purchase of the consumable' means total value of the supply contracts (including related duties, taxes and charges such as non-deductible VAT) concluded by the beneficiary for the consumable delivered in year N-1, provided the contracts were awarded according to the principle of best value- for-money and without any conflict of interests

For **medical equipment**:

For each cost item: 'average cost of depreciation and directly related services per unit of use', i.e.:

{{ certified or auditable total depreciation costs in year N-1 + certified or auditable total costs of purchase of services in year N-1 for the category of equipment concerned}

total capacity in year N-1
multiplied by
estimated number of units of use of the equipment for the task (per participant)**}**

'total depreciation costs' means total depreciation allowances as recorded in the beneficiary's accounts of year N-1 for the category of equipment concerned, provided the equipment was purchased according to the principle of best value for money and without any conflict of interests + total costs of renting or leasing contracts (including related duties, taxes and charges such as non-deductible VAT) in year N-1 for the category of equipment concerned, provided they do not exceed the depreciation costs of similar equipment and do not include finance fees

For **services**:

For each cost item: 'average cost of the service per study participant', i.e.:

{certified or auditable total costs of purchase of the service in year N-1

total number of patients or subjects included in the clinical studies for which the service was delivered in year N-1**}**

'total costs of purchase of the service' means total value of the contracts concluded by the beneficiary (including related duties, taxes and charges such as non-deductible VAT) for the specific service delivered in year N-1 for the conduct of clinical studies, provided the contracts were awarded according to the principle of best value for money and without any conflict of interests

For **indirect costs**:

{{{cost component 'personnel costs' + cost component 'consumables' + cost component 'medical equipment'}

minus

{costs of in-kind contributions provided by third parties which are not used on the beneficiary's premises + costs of providing financial support to third parties (if any)}**}**

multiplied by

25%**}**

The estimation of the resources to be used must be done on the basis of the study protocol and must be the same for all beneficiaries/linked third parties/third parties involved.

The year N-1 to be used is the last closed financial year at the time of submission of the grant application.

Estimated number of units: see (for each clinical study and beneficiary/linked third party) the 'unit cost table' attached

Unit cost table: clinical studies unit cost[6]

Task, Direct cost categories	**Resource per patient**	**Costs year N-1 Beneficiary 1 [short name]**	**Costs year N-1 Linked third party 1a [short name]**	**Costs year N-1 Beneficiary 2 [short name]**	**Costs year N-1 Linked third party 2a [short name]**	**Costs year N-1 Third party giving in-kind contributions 1 [short name]**
Sequence No. 1						
Task No. 1 Blood sample						
(a) **Personnel costs:** - Doctors	n/a					
- Other Medical Personnel	Phlebotomy (nurse), 10 minutes	8,33 EUR	11,59 EUR	10,30 EUR	11,00 EUR	9,49 EUR
- Technical Personnel	Sample Processing (lab technician), 15 minutes	9,51 EUR	15,68 EUR	14,60 EUR	15,23 EUR	10,78 EUR
(b) **Costs of consumables**:	Syringe	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
	Cannula	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
	Blood container	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
(c) **Costs of medical equipment**:	Use of -80° deep freezer, 60 days	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
	Use of centrifuge, 15 minutes	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
(d) **Costs of services**	Cleaning of XXX	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
(e) **Indirect costs** (25% flat-rate)		XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
Task No. 2						
…						
Amount per unit (unit cost sequence 1):		**XX EUR**	**XX EUR**	**XX EUR**	**XX EUR**	**XX EUR**
Sequence No. 2						
Task No. 1						

[6] Same table as in proposal and Annex 1.

XXX						
(a) **Personnel costs:** - Doctors	XXX	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
- Other Medical Personnel	XXX	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
- Technical Personnel	XXX	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
(b) **Costs of consumables**:	XXX	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
	XXX	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
	XXX	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
(c) **Costs of medical equipment**:	XXX	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
	XXX	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
(d) **Costs of services**	XXX	XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
(e) **Indirect costs** (25% flat-rate)		XX EUR	XX EUR	XX EUR	XX EUR	XX EUR
Task No. 2						
…						
Amount per unit (unit cost sequence 2):		**XX EUR**	**XX EUR**	**XX EUR**	**XX EUR**	**XX EUR**
…						
Amount per unit (unit cost entire study):		**XX EUR**	**XX EUR**	**XX EUR**	**XX EUR**	**XX EUR**

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ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

FRIEDRICH-ALEXANDER-UNIVERSITAET ERLANGEN NUERNBERG (FAU), established in SCHLOSSPLATZ 4, ERLANGEN 91054, Germany, VAT number: DE132507686, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('2')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

FAHRENHEIT GMBH (FAHREN), established in SIEGFRIEDSTR 19, MUNCHEN 80803, Germany, VAT number: DE221337150, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('3')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

CONSIGLIO NAZIONALE DELLE RICERCHE (ITAE), established in PIAZZALE ALDO MORO 7, ROMA 00185, Italy, VAT number: IT02118311006, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('4')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

T.E.A.V.E LTD (TEAVE), established in 16, TAXIARCHON STR., PALEO FALIRO 17563, Greece, VAT number: EL095304865, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('5')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

AKOTEC PRODUKTIONSGESELLSCHAFT MBH (AKOTEC), established in GRUNDMUHLENWEG 3, ANGERMUNDE 16278, Germany, VAT number: DE258392653, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('6')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

UNIVERSIDAD DE LLEIDA (UDL), established in Placa Victor Siurana 1 1, LLEIDA 25003, Spain, VAT number: ESQ7550001G, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('7')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

DAIKIN AIRCONDITIONING HELLAS SA (Daikin), established in AGIOU KONSTANTINOU 50, MAROUSI 15124, Greece, VAT number: EL999211196, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('8')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

THE UNIVERSITY OF SUSSEX (UOS), established in SUSSEX HOUSE FALMER, BRIGHTON BN1 9RH, United Kingdom, VAT number: GB692712320, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('9')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

DBC EUROPE (DBC), established in ROND POINT ROBERT SCHUMAN 6, BRUXELLES 1040, Belgium, VAT number: BE0631731009, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('10')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

TECHLINK ASBL (TECH), established in JOSEPH CHANTRAINEPLANTSOEN 1, KORTENBERG 3070, Belgium, VAT number: BE0682796163, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('11')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

KARLSRUHER INSTITUT FUER TECHNOLOGIE (KIT), established in KAISERSTRASSE 12, KARLSRUHE 76131, Germany, VAT number: DE266749428, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('12')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

OKOFEN FORSCHUNGS-UND ENTWICKLUNGSG (OKOFEN), established in GEWERBEPARK 1, NIEDERKAPPEL 4133, Austria, VAT number: ATU23808501, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('13')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

STRABAG BELGIUM (STRABAG), established in NOORDERLAAN 139, ANTWERPEN 2030, Belgium, VAT number: BE0472028526, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('14')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

UNIVERSITA DEGLI STUDI DI MESSINA (UNIME), established in PIAZZA PUGLIATTI 1, MESSINA 98122, Italy, VAT number: IT00724160833, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('15')

in Grant Agreement No 814945 ('the Agreement')

between NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA **and** the Innovation and Networks Executive Agency (INEA) ('the Agency'), under the powers delegated by the European Commission ('the Commission'),

for the action entitled 'Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings (SolBio-Rev)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

ⓘ print format A4 landscape

Associated with document Ref. Ares(2019)1399623 - 01/03/2019

FINANCIAL STATEMENT FOR *[BENEFICIARY [name]/ LINKED THIRD PARTY [name]]* FOR REPORTING PERIOD [reporting period]

	Eligible[1] costs (per budget category)													Receipts	EU contribution			Additional information
	A. Direct personnel costs				B. Direct costs of subcontracting	*[C. Direct costs of fin. support]*	D. Other direct costs			E. Indirect costs[2]	*[F. Costs of …]*		Total costs	Receipts	Reimbursement rate %	Maximum EU contribution[3]	Requested EU contribution	Information for indirect costs :
	A.1 Employees (or equivalent) A.2 Natural persons under direct contract A.3 Seconded persons *[A.6 Personnel for providing access to research infrastructure]*		A.4 SME owners without salary A.5 Beneficiaries that are natural persons without salary			*[C.1 Financial support]* *[C.2 Prizes]*	D.1 Travel D.2 Equipment D.3 Other goods and services	*[D.4 Costs of large research infrastructure]*	D.5 Costs of internally invoiced goods and services		*[F.1 Costs of …]*	*[F.2 Costs of …]*		Receipts of the action, to be reported in the last reporting period, according to Article 5.3.3				Costs of in-kind contributions not used on premises
Form of costs[4]	Actual	Unit	Unit		Actual	Actual	Actual	Actual	Unit	Flat-rate[5] 25%	Unit		*[Unit][Lump sum]*					
	a	Total b	No hours	Total c	d	*[e]*	f	*[g]*	Total h	i=0,25 x (a+b+ c+f+*[g]* + h+ *[j 1]*[6] +*[j2]*[6] -p)	No units	Total *[j1]*	Total *[j2]*	k = a+b+c+d+*[e]* +*f* + *[g]* +h+ i + *[j1]* +*[j2]*	l	m	n	o	p
[short name beneficiary/linked third party]																		

The beneficiary/linked third party hereby confirms that:
The information provided is complete, reliable and true.
The costs declared are eligible (see Article 6).
The costs can be substantiated by adequate records and supporting documentation that will be produced upon request or in the context of checks, reviews, audits and investigations (see Articles 17, 18 and 22).
For the last reporting period: that all the receipts have been declared (see Article 5.3.3).

ⓘ Please declare all eligible costs, even if they exceed the amounts indicated in the estimated budget (see Annex 2). Only amounts that were declared in your individual financial statements can be taken into account lateron, in order to replace other costs that are found to be ineligible.

[1] See Article 6 for the eligibility conditions

[2] The indirect costs claimed must be free of any amounts covered by an operating grant (received under any EU or Euratom funding programme; see Article 6.2.E). If you have received an operating grant during this reporting period, you cannot claim indirect costs unless you can demonstrate that the operating grant does not cover any costs of the action.

[3] This is the *theoretical* amount of EU contribution that the system calculates automatically (by multiplying the reimbursement rate by the total costs declared). The amount you request (in the column 'requested EU contribution') may be less,

[4] See Article 5 for the forms of costs

[5] Flat rate : 25% of eligible direct costs, from which are excluded: direct costs of subcontracting, costs of in-kind contributions not used on premises, direct costs of financial support, and unit costs declared under budget category F if they include indirect costs (see Article 6.2.E)

[6] Only specific unit costs that do not include indirect costs

ANNEX 5

MODEL FOR THE CERTIFICATE ON THE FINANCIAL STATEMENTS

- **For options [*in italics in square brackets*]: choose the applicable option. Options not chosen should be deleted.**
- **For fields in [grey in square brackets]: enter the appropriate data**

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Terms of Reference for an Independent Report of Factual Findings on costs declared under a Grant Agreement financed under the Horizon 2020 Research and Innovation Framework Programme

This document sets out the '**Terms of Reference (ToR)**' under which

[OPTION 1: [insert name of the beneficiary] ('the Beneficiary')] [OPTION 2: [insert name of the linked third party] ('the Linked Third Party'), third party linked to the Beneficiary [insert name of the beneficiary] ('the Beneficiary')]

agrees to engage

[**insert legal name of the auditor**] ('the Auditor')

to produce an independent report of factual findings ('the Report') concerning the Financial Statement(s)[1] drawn up by the *[Beneficiary] [Linked Third Party]* for the Horizon 2020 grant agreement [insert number of the grant agreement, title of the action, acronym and duration from/to] ('the Agreement'), and

to issue a Certificate on the Financial Statements' ('CFS') referred to in Article 20.4 of the Agreement based on the compulsory reporting template stipulated by the Commission.

The Agreement has been concluded under the Horizon 2020 Research and Innovation Framework Programme (H2020) between the Beneficiary and *[OPTION 1: the European Union, represented by the European Commission ('the Commission')][OPTION 2: the European Atomic Energy Community (Euratom,) represented by the European Commission ('the Commission')][OPTION 3: the [Research Executive Agency (REA)] [European Research Council Executive Agency (ERCEA)] [Innovation and Networks Executive Agency (INEA)] [Executive Agency for Small and Medium-sized Enterprises (EASME)] ('the Agency'), under the powers delegated by the European Commission ('the Commission').]*

The *[Commission] [Agency]* is mentioned as a signatory of the Agreement with the Beneficiary only. The *[European Union][Euratom][Agency]* is not a party to this engagement.

1.1 Subject of the engagement

The coordinator must submit to the *[Commission][Agency]* the final report within 60 days following the end of the last reporting period which should include, amongst other documents, a CFS for each beneficiary and for each linked third party that requests a total contribution of EUR 325 000 or more, as reimbursement of actual costs and unit costs calculated on the basis of its usual cost accounting practices (see Article 20.4 of the Agreement). The CFS must cover all reporting periods of the beneficiary or linked third party indicated above.

The Beneficiary must submit to the coordinator the CFS for itself and for its linked third party(ies), if the CFS must be included in the final report according to Article 20.4 of the Agreement.

The CFS is composed of two separate documents:

- The Terms of Reference ('the ToR') to be signed by the *[Beneficiary] [Linked Third Party]* and the Auditor;

[1] By which costs under the Agreement are declared (see template 'Model Financial Statements' in Annex 4 to the Grant Agreement).

- The Auditor's Independent Report of Factual Findings ('the Report') to be issued on the Auditor's letterhead, dated, stamped and signed by the Auditor (or the competent public officer) which includes the agreed-upon procedures ('the Procedures') to be performed by the Auditor, and the standard factual findings ('the Findings') to be confirmed by the Auditor.

If the CFS must be included in the final report according to Article 20.4 of the Agreement, the request for payment of the balance relating to the Agreement cannot be made without the CFS. However, the payment for reimbursement of costs covered by the CFS does not preclude the Commission *[Agency,]* the European Anti-Fraud Office and the European Court of Auditors from carrying out checks, reviews, audits and investigations in accordance with Article 22 of the Agreement.

1.2 Responsibilities

The *[Beneficiary] [Linked Third Party]:*

- must draw up the Financial Statement(s) for the action financed by the Agreement in compliance with the obligations under the Agreement. The Financial Statement(s) must be drawn up according to the *[Beneficiary's] [Linked Third Party's]* accounting and book-keeping system and the underlying accounts and records;
- must send the Financial Statement(s) to the Auditor;
- is responsible and liable for the accuracy of the Financial Statement(s);
- is responsible for the completeness and accuracy of the information provided to enable the Auditor to carry out the Procedures. It must provide the Auditor with a written representation letter supporting these statements. The written representation letter must state the period covered by the statements and must be dated;
- accepts that the Auditor cannot carry out the Procedures unless it is given full access to the *[Beneficiary's] [Linked Third Party's]* staff and accounting as well as any other relevant records and documentation.

The Auditor:

- *[Option 1 by default:* is qualified to carry out statutory audits of accounting documents in accordance with Directive 2006/43/EC of the European Parliament and of the Council of 17 May 2006 on statutory audits of annual accounts and consolidated accounts, amending Council Directives 78/660/EEC and 83/349/EEC and repealing Council Directive 84/253/EEC or similar national regulations*]*.
- *[Option 2 if the Beneficiary or Linked Third Party has an independent Public Officer:* is a competent and independent Public Officer for which the relevant national authorities have established the legal capacity to audit the Beneficiary*]*.
- *[Option 3 if the Beneficiary or Linked Third Party is an international organisation:* is an [internal] [external] auditor in accordance with the internal financial regulations and procedures of the international organisation*]*.

The Auditor:

- must be independent from the Beneficiary *[and the Linked Third Party]*, in particular, it must not have been involved in preparing the *[Beneficiary's] [Linked Third Party's]* Financial Statement(s);
- must plan work so that the Procedures may be carried out and the Findings may be assessed;
- must adhere to the Procedures laid down and the compulsory report format;
- must carry out the engagement in accordance with this ToR;
- must document matters which are important to support the Report;
- must base its Report on the evidence gathered;
- must submit the Report to the *[Beneficiary] [Linked Third Party]*.

The Commission sets out the Procedures to be carried out by the Auditor. The Auditor is not responsible for their suitability or pertinence. As this engagement is not an assurance engagement, the Auditor does not provide an audit opinion or a statement of assurance.

1.3 Applicable Standards

The Auditor must comply with these Terms of Reference and with[2]:

- the International Standard on Related Services ('ISRS') 4400 *Engagements to perform Agreed-upon Procedures regarding Financial Information* as issued by the International Auditing and Assurance Standards Board (IAASB);
- the *Code of Ethics for Professional Accountants* issued by the International Ethics Standards Board for Accountants (IESBA). Although ISRS 4400 states that independence is not a requirement for engagements to carry out agreed-upon procedures, the *[Commission][Agency]* requires that the Auditor also complies with the Code's independence requirements.

The Auditor's Report must state that there is no conflict of interests in establishing this Report between the Auditor and the Beneficiary *[and the Linked Third Party]*, and must specify - if the service is invoiced - the total fee paid to the Auditor for providing the Report.

1.4 Reporting

The Report must be written in the language of the Agreement (see Article 20.7).

Under Article 22 of the Agreement, the Commission*[, the Agency],* the European Anti-Fraud Office and the Court of Auditors have the right to audit any work that is carried out under the action and for which costs are declared from [*the European Union*] [*Euratom*] budget. This includes work related to this engagement. The Auditor must provide access to all working papers (e.g. recalculation of hourly rates, verification of the time declared for the action) related to this assignment if the Commission *[, the Agency]*, the European Anti-Fraud Office or the European Court of Auditors requests them.

1.5 Timing

The Report must be provided by *[*dd Month yyyy*]*.

1.6 Other terms

[*The [Beneficiary] [Linked Third Party] and the Auditor can use this section to agree other specific terms, such as the Auditor's fees, liability, applicable law, etc. Those specific terms must not contradict the terms specified above.*]

[legal name of the Auditor]	[legal name of the *[Beneficiary][Linked Third Party]*]
[name & function of authorised representative]	[name & function of authorised representative]
[dd Month yyyy]	[dd Month yyyy]
Signature of the Auditor	Signature of the *[Beneficiary][Linked Third Party]*

[2] Supreme Audit Institutions applying INTOSAI-standards may carry out the Procedures according to the corresponding International Standards of Supreme Audit Institutions and code of ethics issued by INTOSAI instead of the International Standard on Related Services ('ISRS') 4400 and the Code of Ethics for Professional Accountants issued by the IAASB and the IESBA.

Independent Report of Factual Findings on costs declared under Horizon 2020 Research and Innovation Framework Programme

(To be printed on the Auditor's letterhead)

To
[name of contact person(s)], [Position]
[[*Beneficiary's*] [*Linked Third Party's*] name]
[Address]
[dd Month yyyy]

Dear [Name of contact person(s)],

As agreed under the terms of reference dated [dd Month yyyy]

with *[OPTION 1: [insert name of the beneficiary] ('the Beneficiary')] [OPTION 2: [insert name of the linked third party] ('the Linked Third Party'), third party linked to the Beneficiary [insert name of the beneficiary] ('the Beneficiary')],*

we

[name of the auditor] ('the Auditor'),

established at

[full address/city/state/province/country],

represented by

[name and function of an authorised representative],

have carried out the procedures agreed with you regarding the costs declared in the Financial Statement(s)[3] of the *[Beneficiary] [Linked Third Party]* concerning the grant agreement [insert grant agreement reference: number, title of the action and acronym] ('the Agreement'),

with a total cost declared of
[total amount] EUR,

and a total of actual costs and unit costs calculated in accordance with the [*Beneficiary's*] [*Linked Third Party's*] usual cost accounting practices' declared of

[sum of total actual costs and total direct personnel costs declared as unit costs calculated in accordance with the *[Beneficiary's] [Linked Third Party's]* usual cost accounting practices] EUR

and **hereby provide our Independent Report of Factual Findings ('the Report')** using the compulsory report format agreed with you.

The Report

Our engagement was carried out in accordance with the terms of reference ('the ToR') appended to this Report. The Report includes the agreed-upon procedures ('the Procedures') carried out and the standard factual findings ('the Findings') examined.

[3] By which the Beneficiary declares costs under the Agreement (see template 'Model Financial Statement' in Annex 4 to the Agreement).

The Procedures were carried out solely to assist the *[Commission] [Agency]* in evaluating whether the *[Beneficiary's] [Linked Third Party's]* costs in the accompanying Financial Statement(s) were declared in accordance with the Agreement. The *[Commission] [Agency]* draws its own conclusions from the Report and any additional information it may require.

The scope of the Procedures was defined by the Commission. Therefore, the Auditor is not responsible for their suitability or pertinence. Since the Procedures carried out constitute neither an audit nor a review made in accordance with International Standards on Auditing or International Standards on Review Engagements, the Auditor does not give a statement of assurance on the Financial Statements.

Had the Auditor carried out additional procedures or an audit of the *[Beneficiary's] [Linked Third Party's]* Financial Statements in accordance with International Standards on Auditing or International Standards on Review Engagements, other matters might have come to its attention and would have been included in the Report.

Not applicable Findings

We examined the Financial Statement(s) stated above and considered the following Findings not applicable:

Explanation (to be removed from the Report):

*If a Finding was not applicable, it must be marked as '**N.A.**' ('Not applicable') in the corresponding row on the right-hand column of the table and means that the Finding did not have to be corroborated by the Auditor and the related Procedure(s) did not have to be carried out.*

The reasons of the non-application of a certain Finding must be obvious i.e.

i) if no cost was declared under a certain category then the related Finding(s) and Procedure(s) are not applicable;

ii) if the condition set to apply certain Procedure(s) are not met the related Finding(s) and those Procedure(s) are not applicable. For instance, for 'beneficiaries with accounts established in a currency other than euro' the Procedure and Finding related to 'beneficiaries with accounts established in euro' are not applicable. Similarly, if no additional remuneration is paid, the related Finding(s) and Procedure(s) for additional remuneration are not applicable.

List here all Findings considered not applicable for the present engagement and explain the reasons of the non-applicability.

….

Exceptions

Apart from the exceptions listed below, the *[Beneficiary] [Linked Third Party]* provided the Auditor all the documentation and accounting information needed by the Auditor to carry out the requested Procedures and evaluate the Findings.

Explanation (to be removed from the Report):

- *If the Auditor was not able to successfully complete a procedure requested, it must be marked as '**E**' ('Exception') in the corresponding row on the right-hand column of the table. The reason such as the inability to reconcile key information or the unavailability of data that prevents the Auditor from carrying out the Procedure must be indicated below.*
- *If the Auditor cannot corroborate a standard finding after having carried out the corresponding procedure, it must also be marked as '**E**' ('Exception') and, where possible, the reasons why the Finding was not fulfilled and its possible impact must be explained here below.*

List here any exceptions and add any information on the cause and possible consequences of each exception, if known. If the exception is quantifiable, include the corresponding amount.

….

Example (to be removed from the Report):

1. *The Beneficiary was unable to substantiate the Finding number 1 on … because ….*
2. *Finding number 30 was not fulfilled because the methodology used by the Beneficiary to calculate unit costs was different from the one approved by the Commission. The differences were as follows: …*
3. *After carrying out the agreed procedures to confirm the Finding number 31, the Auditor found a difference of _____ EUR. The difference can be explained by …*

Further Remarks

In addition to reporting on the results of the specific procedures carried out, the Auditor would like to make the following general remarks:

Example (to be removed from the Report):

1. *Regarding Finding number 8 the conditions for additional remuneration were considered as fulfilled because …*
2. *In order to be able to confirm the Finding number 15 we carried out the following additional procedures: ….*

Use of this Report

This Report may be used only for the purpose described in the above objective. It was prepared solely for the confidential use of the *[Beneficiary] [Linked Third Party]* and the [*Commission*] [*Agency*], and only to be submitted to the *[Commission] [Agency]* in connection with the requirements set out in Article 20.4 of the Agreement. The Report may not be used by the *[Beneficiary] [Linked Third Party]* or by the *[Commission] [Agency]* for any other purpose, nor may it be distributed to any other parties. The *[Commission] [Agency]* may only disclose the Report to authorised parties, in particular to the European Anti-Fraud Office (OLAF) and the European Court of Auditors.

This Report relates only to the Financial Statement(s) submitted to the *[Commission] [Agency]* by the *[Beneficiary] [Linked Third Party]* for the Agreement. Therefore, it does not extend to any other of the *[Beneficiary's] [Linked Third Party's]* Financial Statement(s).

There was no conflict of interest[4] between the Auditor and the Beneficiary *[and Linked Third Party]* in establishing this Report. The total fee paid to the Auditor for providing the Report was EUR _____ (including EUR_____ of deductible VAT).

We look forward to discussing our Report with you and would be pleased to provide any further information or assistance.

[legal name of the Auditor]
[name and function of an authorised representative]
[dd Month yyyy]
Signature of the Auditor

[4] A conflict of interest arises when the Auditor's objectivity to establish the certificate is compromised in fact or in appearance when the Auditor for instance:
- was involved in the preparation of the Financial Statements;
- stands to benefit directly should the certificate be accepted;
- has a close relationship with any person representing the beneficiary;
- is a director, trustee or partner of the beneficiary; or
- is in any other situation that compromises his or her independence or ability to establish the certificate impartially.

Agreed-upon procedures to be performed and standard factual findings to be confirmed by the Auditor

The European Commission reserves the right to i) provide the auditor with additional guidance regarding the procedures to be followed or the facts to be ascertained and the way in which to present them (this may include sample coverage and findings) or to ii) change the procedures, by notifying the Beneficiary in writing. The procedures carried out by the auditor to confirm the standard factual finding are listed in the table below.

If this certificate relates to a Linked Third Party, any reference here below to 'the Beneficiary' is to be considered as a reference to 'the Linked Third Party'.

The 'result' column has three different options: 'C', 'E' and 'N.A.':

- 'C' stands for 'confirmed' and means that the auditor can confirm the 'standard factual finding' and, therefore, there is no exception to be reported.
- 'E' stands for 'exception' and means that the Auditor carried out the procedures but cannot confirm the 'standard factual finding', or that the Auditor was not able to carry out a specific procedure (e.g. because it was impossible to reconcile key information or data were unavailable),
- 'N.A.' stands for 'not applicable' and means that the Finding did not have to be examined by the Auditor and the related Procedure(s) did not have to be carried out. The reasons of the non-application of a certain Finding must be obvious i.e. i) if no cost was declared under a certain category then the related Finding(s) and Procedure(s) are not applicable; ii) if the condition set to apply certain Procedure(s) are not met then the related Finding(s) and Procedure(s) are not applicable. For instance, for 'beneficiaries with accounts established in a currency other than the euro' the Procedure related to 'beneficiaries with accounts established in euro' is not applicable. Similarly, if no additional remuneration is paid, the related Finding(s) and Procedure(s) for additional remuneration are not applicable.

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
A	**ACTUAL PERSONNEL COSTS AND UNIT COSTS CALCULATED BY THE BENEFICIARY IN ACCORDANCE WITH ITS USUAL COST ACCOUNTING PRACTICE**		
	The Auditor draws a sample of persons whose costs were declared in the Financial Statement(s) to carry out the procedures indicated in the consecutive points of this section A. (*The sample should be selected randomly so that it is representative. Full coverage is required if there are fewer than 10 people (including employees, natural persons working under a direct contract and personnel seconded by a third party), otherwise the sample should have a minimum of 10 people, or 10% of the total, whichever number is the highest)* The Auditor sampled _____ people out of the total of _____ people.		

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
A.1	**PERSONNEL COSTS** For the persons included in the sample and working under an employment contract or equivalent act (general procedures for individual actual personnel costs and personnel costs declared as unit costs) To confirm standard factual findings 1-5 listed in the next column, the Auditor reviewed following information/documents provided by the Beneficiary: o a list of the persons included in the sample indicating the period(s) during which they worked for the action, their position (classification or category) and type of contract; o the payslips of the employees included in the sample; o reconciliation of the personnel costs declared in the Financial Statement(s) with the accounting system (project accounting and general ledger) and payroll system; o information concerning the employment status and employment conditions of personnel included in the sample, in particular their employment contracts or equivalent; o the Beneficiary's usual policy regarding payroll matters (e.g. salary policy, overtime policy, variable pay); o applicable national law on taxes, labour and social security and o any other document that supports the personnel costs declared. The Auditor also verified the eligibility of all components of the retribution (see Article 6 GA) and recalculated the personnel costs for employees included in the sample.	1) The employees were i) directly hired by the Beneficiary in accordance with its national legislation, ii) under the Beneficiary's sole technical supervision and responsibility and iii) remunerated in accordance with the Beneficiary's usual practices.	
		2) Personnel costs were recorded in the Beneficiary's accounts/payroll system.	
		3) Costs were adequately supported and reconciled with the accounts and payroll records.	
		4) Personnel costs did not contain any ineligible elements.	
		5) There were no discrepancies between the personnel costs charged to the action and the costs recalculated by the Auditor.	
	Further procedures if 'additional remuneration' is paid To confirm standard factual findings 6-9 listed in the next column, the Auditor: o reviewed relevant documents provided by the Beneficiary (legal form, legal/statutory	6) The Beneficiary paying "additional remuneration" was a non-profit legal entity.	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	obligations, the Beneficiary's usual policy on additional remuneration, criteria used for its calculation, the Beneficiary's usual remuneration practice for projects funded under national funding schemes…); o recalculated the amount of additional remuneration eligible for the action based on the supporting documents received (full-time or part-time work, exclusive or non-exclusive dedication to the action, usual remuneration paid for projects funded by national schemes) to arrive at the applicable FTE/year and pro-rata rate (see data collected in the course of carrying out the procedures under A.2 'Productive hours' and A.4 'Time recording system'). *'ADDITIONAL REMUNERATION' MEANS ANY PART OF THE REMUNERATION WHICH EXCEEDS WHAT THE PERSON WOULD BE PAID FOR TIME WORKED IN PROJECTS FUNDED BY NATIONAL SCHEMES.* *IF ANY PART OF THE REMUNERATION PAID TO THE EMPLOYEE QUALIFIES AS "ADDITIONAL REMUNERATION" AND IS ELIGIBLE UNDER THE PROVISIONS OF ARTICLE 6.2.A.1, THIS CAN BE CHARGED AS ELIGIBLE COST TO THE ACTION UP TO THE FOLLOWING AMOUNT:* *(A) IF THE PERSON WORKS FULL TIME AND EXCLUSIVELY ON THE ACTION DURING THE FULL YEAR: UP TO EUR 8 000/YEAR;* *(B) IF THE PERSON WORKS EXCLUSIVELY ON THE ACTION BUT NOT FULL-TIME OR NOT FOR THE FULL YEAR: UP TO THE CORRESPONDING PRO-RATA AMOUNT OF EUR 8 000, OR* *(C) IF THE PERSON DOES NOT WORK EXCLUSIVELY ON THE ACTION: UP TO A PRO-RATA AMOUNT CALCULATED IN ACCORDANCE TO ARTICLE 6.2.A.1.*	7) The amount of additional remuneration paid corresponded to the Beneficiary's usual remuneration practices and was consistently paid whenever the same kind of work or expertise was required.	
		8) The criteria used to calculate the additional remuneration were objective and generally applied by the Beneficiary regardless of the source of funding used.	
		9) The amount of additional remuneration included in the personnel costs charged to the action was capped at EUR 8,000 per FTE/year (up to the equivalent pro-rata amount if the person did not work on the action full-time during the year or did not work exclusively on the action).	
	Additional procedures in case "unit costs calculated by the Beneficiary in accordance with its usual cost accounting practices" is applied: Apart from carrying out the procedures indicated above to confirm standard factual findings 1-5 and, if applicable, also 6-9, the Auditor carried out following procedures to confirm standard	10) The personnel costs included in the Financial Statement were calculated in accordance with the Beneficiary's usual cost accounting practice. This methodology was consistently	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	factual findings 10-13 listed in the next column: o obtained a description of the Beneficiary's usual cost accounting practice to calculate unit costs;. o reviewed whether the Beneficiary's usual cost accounting practice was applied for the Financial Statements subject of the present CFS; o verified the employees included in the sample were charged under the correct category (in accordance with the criteria used by the Beneficiary to establish personnel categories) by reviewing the contract/HR-record or analytical accounting records; o verified that there is no difference between the total amount of personnel costs used in calculating the cost per unit and the total amount of personnel costs recorded in the statutory accounts; o verified whether actual personnel costs were adjusted on the basis of budgeted or estimated elements and, if so, verified whether those elements used are actually relevant for the calculation, objective and supported by documents.	used in all H2020 actions.	
		11) The employees were charged under the correct category.	
		12) Total personnel costs used in calculating the unit costs were consistent with the expenses recorded in the statutory accounts.	
		13) Any estimated or budgeted element used by the Beneficiary in its unit-cost calculation were relevant for calculating personnel costs and corresponded to objective and verifiable information.	
	<u>For natural persons included in the sample and working with the Beneficiary under a direct contract other than an employment contract, such as consultants (no subcontractors).</u> To confirm standard factual findings 14-17 listed in the next column the Auditor reviewed following information/documents provided by the Beneficiary: o the contracts, especially the cost, contract duration, work description, place of work, ownership of the results and reporting obligations to the Beneficiary; o the employment conditions of staff in the same category to compare costs and; o any other document that supports the costs declared and its registration (e.g. invoices, accounting records, etc.).	14) The natural persons worked under conditions similar to those of an employee, in particular regarding the way the work is organised, the tasks that are performed and the premises where they are performed.	
		15) The results of work carried out belong to the Beneficiary, or, if not, the Beneficiary has obtained all necessary rights to fulfil its obligations as if those	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
		results were generated by itself.	
		16) Their costs were not significantly different from those for staff who performed similar tasks under an employment contract with the Beneficiary.	
		17) The costs were supported by audit evidence and registered in the accounts.	
	<u>For personnel seconded by a third party and included in the sample (not subcontractors)</u> To confirm standard factual findings 18-21 listed in the next column, the Auditor reviewed following information/documents provided by the Beneficiary: o their secondment contract(s) notably regarding costs, duration, work description, place of work and ownership of the results; o if there is reimbursement by the Beneficiary to the third party for the resource made available (in-kind contribution against payment): any documentation that supports the costs declared (e.g. contract, invoice, bank payment, and proof of registration in its accounting/payroll, etc.) and reconciliation of the Financial Statement(s) with the accounting system (project accounting and general ledger) as well as any proof that the amount invoiced by the third party did not include any profit; o if there is no reimbursement by the Beneficiary to the third party for the resource made available (in-kind contribution free of charge): a proof of the actual cost borne by the Third Party for the resource made available free of charge to the Beneficiary such as a statement of costs incurred by the Third Party and proof of the registration in the Third Party's accounting/payroll;	18) Seconded personnel reported to the Beneficiary and worked on the Beneficiary's premises (unless otherwise agreed with the Beneficiary).	
		19) The results of work carried out belong to the Beneficiary, or, if not, the Beneficiary has obtained all necessary rights to fulfil its obligations as if those results were generated by itself..	
		If personnel is seconded against payment: 20) The costs declared were supported with documentation and recorded in the	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	○ any other document that supports the costs declared (e.g. invoices, etc.).	Beneficiary's accounts. The third party did not include any profit.	
		If personnel is seconded free of charge: 21) The costs declared did not exceed the third party's cost as recorded in the accounts of the third party and were supported with documentation.	
A.2	**PRODUCTIVE HOURS** To confirm standard factual findings 22-27 listed in the next column, the Auditor reviewed relevant documents, especially national legislation, labour agreements and contracts and time records of the persons included in the sample, to verify that: ○ the annual productive hours applied were calculated in accordance with one of the methods described below, ○ the full-time equivalent (FTEs) ratios for employees not working full-time were correctly calculated. If the Beneficiary applied method B, the auditor verified that the correctness in which the total number of hours worked was calculated and that the contracts specified the annual workable hours. If the Beneficiary applied method C, the auditor verified that the 'annual productive hours' applied when calculating the hourly rate were equivalent to at least 90 % of the 'standard annual workable hours'. The Auditor can only do this if the calculation of the standard annual workable	22) The Beneficiary applied method [*choose one option and delete the others*] [**A**: 1720 hours] [**B**: the 'total number of hours worked'] [**C**: 'standard annual productive hours' used correspond to usual accounting practices]	
		23) Productive hours were calculated annually.	
		24) For employees not working full-time the full-time equivalent (FTE) ratio was correctly applied.	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	hours can be supported by records, such as national legislation, labour agreements, and contracts. *BENEFICIARY'S PRODUCTIVE HOURS' FOR PERSONS WORKING FULL TIME SHALL BE ONE OF THE FOLLOWING METHODS:* ***A**. 1720 ANNUAL PRODUCTIVE HOURS (PRO-RATA FOR PERSONS NOT WORKING FULL-TIME)* ***B**. THE TOTAL NUMBER OF HOURS WORKED BY THE PERSON FOR THE BENEFICIARY IN THE YEAR (THIS METHOD IS ALSO REFERRED TO AS 'TOTAL NUMBER OF HOURS WORKED' IN THE NEXT COLUMN). THE CALCULATION OF THE TOTAL NUMBER OF HOURS WORKED WAS DONE AS FOLLOWS: ANNUAL WORKABLE HOURS OF THE PERSON ACCORDING TO THE EMPLOYMENT CONTRACT, APPLICABLE LABOUR AGREEMENT OR NATIONAL LAW PLUS OVERTIME WORKED MINUS ABSENCES (SUCH AS SICK LEAVE OR SPECIAL LEAVE).* ***C**. THE STANDARD NUMBER OF ANNUAL HOURS GENERALLY APPLIED BY THE BENEFICIARY FOR ITS PERSONNEL IN ACCORDANCE WITH ITS USUAL COST ACCOUNTING PRACTICES (THIS METHOD IS ALSO REFERRED TO AS 'STANDARD ANNUAL PRODUCTIVE HOURS' IN THE NEXT COLUMN). THIS NUMBER MUST BE AT LEAST 90% OF THE STANDARD ANNUAL WORKABLE HOURS.* *'ANNUAL WORKABLE HOURS' MEANS THE PERIOD DURING WHICH THE PERSONNEL MUST BE WORKING, AT THE EMPLOYER'S DISPOSAL AND CARRYING OUT HIS/HER ACTIVITY OR DUTIES UNDER THE EMPLOYMENT CONTRACT, APPLICABLE COLLECTIVE LABOUR AGREEMENT OR NATIONAL WORKING TIME LEGISLATION.*	*If the Beneficiary applied method B.* 25) The calculation of the number of 'annual workable hours', overtime and absences was verifiable based on the documents provided by the Beneficiary. 25.1) The Beneficiary calculates the hourly rates per full financial year following procedure A.3 (method B is not allowed for beneficiaries calculating hourly rates per month). *If the Beneficiary applied method C.* 26) The calculation of the number of 'standard annual workable hours' was verifiable based on the documents provided by the Beneficiary.	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
		27) The 'annual productive hours' used for calculating the hourly rate were consistent with the usual cost accounting practices of the Beneficiary and were equivalent to at least 90 % of the 'annual workable hours'.	
A.3	**HOURLY PERSONNEL RATES** I) For unit costs calculated in accordance to the Beneficiary's usual cost accounting practice (unit costs): If the Beneficiary has a "Certificate on Methodology to calculate unit costs " (CoMUC) approved by the Commission, the Beneficiary provides the Auditor with a description of the approved methodology and the Commission's letter of acceptance. The Auditor verified that the Beneficiary has indeed used the methodology approved. If so, no further verification is necessary. If the Beneficiary does not have a "Certificate on Methodology" (CoMUC) approved by the Commission, or if the methodology approved was not applied, then the Auditor: o reviewed the documentation provided by the Beneficiary, including manuals and internal guidelines that explain how to calculate hourly rates; o recalculated the unit costs (hourly rates) of staff included in the sample following the results of the procedures carried out in A.1 and A.2. II) For individual hourly rates: The Auditor: o reviewed the documentation provided by the Beneficiary, including manuals and internal guidelines that explain how to calculate hourly rates;	28) The Beneficiary applied [*choose one option and delete the other*]: [Option I: "Unit costs (hourly rates) were calculated in accordance with the Beneficiary's usual cost accounting practices"] [Option II: Individual hourly rates were applied] *For option I concerning unit costs and if the Beneficiary applies the methodology approved by the Commission (CoMUC):* 29) The Beneficiary used the Commission-approved methodology to calculate hourly rates. It corresponded to the organisation's usual cost accounting practices and was applied consistently for all	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	○ recalculated the hourly rates of staff included in the sample (recalculation of all hourly rates if the Beneficiary uses annual rates, recalculation of three months selected randomly for every year and person if the Beneficiary uses monthly rates) following the results of the procedures carried out in A.1 and A.2; ○ (only in case of monthly rates) confirmed that the time spent on parental leave is not deducted, and that, if parts of the basic remuneration are generated over a period longer than a month, the Beneficiary has included only the share which is generated in the month. *"UNIT COSTS CALCULATED BY THE BENEFICIARY IN ACCORDANCE WITH ITS USUAL COST ACCOUNTING PRACTICES":* *IT IS CALCULATED BY DIVIDING THE TOTAL AMOUNT OF PERSONNEL COSTS OF THE CATEGORY TO WHICH THE EMPLOYEE BELONGS VERIFIED IN LINE WITH PROCEDURE A.1 BY THE NUMBER OF FTE AND THE ANNUAL TOTAL PRODUCTIVE HOURS OF THE SAME CATEGORY CALCULATED BY THE BENEFICIARY IN ACCORDANCE WITH PROCEDURE A.2.* *HOURLY RATE FOR INDIVIDUAL ACTUAL PERSONAL COSTS:* *IT IS CALCULATED FOLLOWING ONE OF THE TWO OPTIONS BELOW:* *A) [OPTION BY DEFAULT] BY DIVIDING THE ACTUAL ANNUAL AMOUNT OF PERSONNEL COSTS OF AN EMPLOYEE VERIFIED IN LINE WITH PROCEDURE A.1 BY THE NUMBER OF ANNUAL PRODUCTIVE HOURS VERIFIED IN LINE WITH PROCEDURE A.2 (FULL FINANCIAL YEAR HOURLY RATE);* *B) BY DIVIDING THE ACTUAL MONTHLY AMOUNT OF PERSONNEL COSTS OF AN EMPLOYEE VERIFIED IN LINE WITH PROCEDURE A.1 BY 1/12 OF THE NUMBER OF ANNUAL PRODUCTIVE HOURS VERIFIED IN LINE WITH PROCEDURE A.2.(MONTHLY HOURLY RATE).*	activities irrespective of the source of funding.	
		For option I concerning unit costs and if the Beneficiary applies a methodology not approved by the Commission: 30) The unit costs re-calculated by the Auditor were the same as the rates applied by the Beneficiary.	
		For option II concerning individual hourly rates: 31) The individual rates re-calculated by the Auditor were the same as the rates applied by the Beneficiary. 31.1) The Beneficiary used only one option (per full financial year or per month) throughout each financial year examined. 31.2) The hourly rates do not include additional remuneration.	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
A.4	**TIME RECORDING SYSTEM** To verify that the time recording system ensures the fulfilment of all minimum requirements and that the hours declared for the action were correct, accurate and properly authorised and supported by documentation, the Auditor made the following checks for the persons included in the sample that declare time as worked for the action on the basis of time records: o description of the time recording system provided by the Beneficiary (registration, authorisation, processing in the HR-system); o its actual implementation; o time records were signed at least monthly by the employees (on paper or electronically) and authorised by the project manager or another manager; o the hours declared were worked within the project period; o there were no hours declared as worked for the action if HR-records showed absence due to holidays or sickness (further cross-checks with travels are carried out in B.1 below) ; o the hours charged to the action matched those in the time recording system. *ONLY THE HOURS WORKED ON THE ACTION CAN BE CHARGED. ALL WORKING TIME TO BE CHARGED SHOULD BE RECORDED THROUGHOUT THE DURATION OF THE PROJECT, ADEQUATELY SUPPORTED BY EVIDENCE OF THEIR REALITY AND RELIABILITY (SEE SPECIFIC PROVISIONS BELOW FOR PERSONS WORKING EXCLUSIVELY FOR THE ACTION WITHOUT TIME RECORDS).*	32) All persons recorded their time dedicated to the action on a **daily/ weekly/ monthly** basis using a **paper/computer-based** system. (*delete the answers that are not applicable)*	
		33) Their time-records were authorised at least monthly by the project manager or other superior.	
		34) Hours declared were worked within the project period and were consistent with the presences/absences recorded in HR-records.	
		35) There were no discrepancies between the number of hours charged to the action and the number of hours recorded.	
	<u>If the persons are working exclusively for the action and without time records</u> For the persons selected that worked exclusively for the action without time records, the Auditor verified evidence available demonstrating that they were in reality exclusively dedicated to the action and that the Beneficiary signed a declaration confirming that they have worked exclusively for the action.	36) The exclusive dedication is supported by a declaration signed by the Beneficiary and by any other evidence gathered.	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
B	**COSTS OF SUBCONTRACTING**		
B.1	**The Auditor obtained the detail/breakdown of subcontracting costs and sampled _____ cost items selected randomly** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is highest*). To confirm standard factual findings 37-41 listed in the next column, the Auditor reviewed the following for the items included in the sample: o the use of subcontractors was foreseen in Annex 1; o subcontracting costs were declared in the subcontracting category of the Financial Statement; o supporting documents on the selection and award procedure were followed; o the Beneficiary ensured best value for money (key elements to appreciate the respect of this principle are the award of the subcontract to the bid offering best price-quality ratio, under conditions of transparency and equal treatment. In case an existing framework contract was used the Beneficiary ensured it was established on the basis of the principle of best value for money under conditions of transparency and equal treatment). In particular, i. if the Beneficiary acted as a contracting authority within the meaning of Directive 2004/18/EC (or 2014/24/EU) or of Directive 2004/17/EC (or 2014/25/EU), the Auditor verified that the applicable national law on public procurement was followed and that the subcontracting complied with the Terms and Conditions of the Agreement. ii. if the Beneficiary did not fall under the above-mentioned category the Auditor verified that the Beneficiary followed their usual procurement rules and respected the Terms and Conditions of the Agreement..	37) The use of claimed subcontracting costs was foreseen in Annex 1 and costs were declared in the Financial Statements under the subcontracting category.	
		38) There were documents of requests to different providers, different offers and assessment of the offers before selection of the provider in line with internal procedures and procurement rules. Subcontracts were awarded in accordance with the principle of best value for money. *(When different offers were not collected the Auditor explains the reasons provided by the Beneficiary under the caption "Exceptions" of the Report. The Commission will analyse this information to evaluate whether these costs might be accepted as eligible)*	
		39) The subcontracts were not awarded to other Beneficiaries	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	For the items included in the sample the Auditor also verified that: o the subcontracts were not awarded to other Beneficiaries in the consortium; o there were signed agreements between the Beneficiary and the subcontractor; o there was evidence that the services were provided by subcontractor;	of the consortium.	
		40) All subcontracts were supported by signed agreements between the Beneficiary and the subcontractor.	
		41) There was evidence that the services were provided by the subcontractors.	
C	**COSTS OF PROVIDING FINANCIAL SUPPORT TO THIRD PARTIES**		
C.1	**The Auditor obtained the detail/breakdown of the costs of providing financial support to third parties and sampled _____ cost items selected randomly** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is highest*). The Auditor verified that the following minimum conditions were met: a) the maximum amount of financial support for each third party did not exceed EUR 60 000, unless explicitly mentioned in Annex 1; b) the financial support to third parties was agreed in Annex 1 of the Agreement and the other provisions on financial support to third parties included in Annex 1 were respected.	42) All minimum conditions were met	

D	OTHER ACTUAL DIRECT COSTS		
D.1	**COSTS OF TRAVEL AND RELATED SUBSISTENCE ALLOWANCES** **The Auditor sampled _____ cost items selected randomly** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is the highest*). The Auditor inspected the sample and verified that: o travel and subsistence costs were consistent with the Beneficiary's usual policy for travel. In this context, the Beneficiary provided evidence of its normal policy for travel costs (e.g. use of first class tickets, reimbursement by the Beneficiary on the basis of actual costs, a lump sum or per diem) to enable the Auditor to compare the travel costs charged with this policy; o travel costs are correctly identified and allocated to the action (e.g. trips are directly linked to the action) by reviewing relevant supporting documents such as minutes of meetings, workshops or conferences, their registration in the correct project account, their consistency with time records or with the dates/duration of the workshop/conference; o no ineligible costs or excessive or reckless expenditure was declared (see Article 6.5 MGA).	43) Costs were incurred, approved and reimbursed in line with the Beneficiary's usual policy for travels.	
		44) There was a link between the trip and the action.	
		45) The supporting documents were consistent with each other regarding subject of the trip, dates, duration and reconciled with time records and accounting.	
		46) No ineligible costs or excessive or reckless expenditure was declared.	
D.2	**DEPRECIATION COSTS FOR EQUIPMENT, INFRASTRUCTURE OR OTHER ASSETS** **The Auditor sampled _____ cost items selected randomly** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is the highest*). For "equipment, infrastructure or other assets" [from now on called "asset(s)"] selected in the sample the Auditor verified that: o the assets were acquired in conformity with the Beneficiary's internal guidelines and procedures;	47) Procurement rules, principles and guides were followed.	
		48) There was a link between the grant agreement and the asset charged to the action.	
		49) The asset charged to the action was traceable to the accounting records and the underlying documents.	

	○ they were correctly allocated to the action (with supporting documents such as delivery note invoice or any other proof demonstrating the link to the action) ○ they were entered in the accounting system; ○ the extent to which the assets were used for the action (as a percentage) was supported by reliable documentation (e.g. usage overview table); The Auditor recalculated the depreciation costs and verified that they were in line with the applicable rules in the Beneficiary's country and with the Beneficiary's usual accounting policy (e.g. depreciation calculated on the acquisition value). The Auditor verified that no ineligible costs such as deductible VAT, exchange rate losses, excessive or reckless expenditure were declared (see Article 6.5 GA).	50) The depreciation method used to charge the asset to the action was in line with the applicable rules of the Beneficiary's country and the Beneficiary's usual accounting policy. 51) The amount charged corresponded to the actual usage for the action. 52) No ineligible costs or excessive or reckless expenditure were declared.	
D.3	**COSTS OF OTHER GOODS AND SERVICES** **The Auditor sampled _____ cost items selected randomly** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is highest*). For the purchase of goods, works or services included in the sample the Auditor verified that: ○ the contracts did not cover tasks described in Annex 1; ○ they were correctly identified, allocated to the proper action, entered in the accounting system (traceable to underlying documents such as purchase orders, invoices and accounting); ○ the goods were not placed in the inventory of durable equipment; ○ the costs charged to the action were accounted in line with the Beneficiary's usual accounting practices; ○ no ineligible costs or excessive or reckless expenditure were declared (see Article 6 GA). In addition, the Auditor verified that these goods and services were acquired in conformity with	53) Contracts for works or services did not cover tasks described in Annex 1. 54) Costs were allocated to the correct action and the goods were not placed in the inventory of durable equipment. 55) The costs were charged in line with the Beneficiary's accounting policy and were adequately supported. 56) No ineligible costs or excessive or reckless expenditure were declared. For internal invoices/charges only the cost element was charged, without any mark-ups.	

	the Beneficiary's internal guidelines and procedures, in particular: o if Beneficiary acted as a contracting authority within the meaning of Directive 2004/18/EC (or 2014/24/EU) or of Directive 2004/17/EC (or 2014/25/EU), the Auditor verified that the applicable national law on public procurement was followed and that the procurement contract complied with the Terms and Conditions of the Agreement. o if the Beneficiary did not fall into the category above, the Auditor verified that the Beneficiary followed their usual procurement rules and respected the Terms and Conditions of the Agreement. For the items included in the sample the Auditor also verified that: o the Beneficiary ensured best value for money (key elements to appreciate the respect of this principle are the award of the contract to the bid offering best price-quality ratio, under conditions of transparency and equal treatment. In case an existing framework contract was used the Auditor also verified that the Beneficiary ensured it was established on the basis of the principle of best value for money under conditions of transparency and equal treatment); *SUCH GOODS AND SERVICES INCLUDE, FOR INSTANCE, CONSUMABLES AND SUPPLIES, DISSEMINATION (INCLUDING OPEN ACCESS), PROTECTION OF RESULTS, SPECIFIC EVALUATION OF THE ACTION IF IT IS REQUIRED BY THE AGREEMENT, CERTIFICATES ON THE FINANCIAL STATEMENTS IF THEY ARE REQUIRED BY THE AGREEMENT AND CERTIFICATES ON THE METHODOLOGY, TRANSLATIONS, REPRODUCTION.*	57) Procurement rules, principles and guides were followed. There were documents of requests to different providers, different offers and assessment of the offers before selection of the provider in line with internal procedures and procurement rules. The purchases were made in accordance with the principle of best value for money. *(When different offers were not collected the Auditor explains the reasons provided by the Beneficiary under the caption "Exceptions" of the Report. The Commission will analyse this information to evaluate whether these costs might be accepted as eligible)*	
D.4	**AGGREGATED CAPITALISED AND OPERATING COSTS OF RESEARCH INFRASTRUCTURE** The Auditor ensured the existence of a positive ex-ante assessment (issued by the EC Services) of the cost accounting methodology of the Beneficiary allowing it to apply the guidelines on direct costing for large research infrastructures in Horizon 2020.	58) The costs declared as direct costs for Large Research Infrastructures (in the appropriate line of the Financial Statement) comply with the methodology described in the positive ex-ante assessment report.	

	In the cases that a positive ex-ante assessment has been issued *(see the standard factual findings 58-59 on the next column)***,** The Auditor ensured that the beneficiary has applied consistently the methodology that is explained and approved in the positive ex ante assessment; ***In the cases that a positive ex-ante assessment has NOT been issued*** *(see the standard factual findings 60 on the next column),* The Auditor verified that no costs of Large Research Infrastructure have been charged as direct costs in any costs category; ***In the cases that a draft ex-ante assessment report has been issued with recommendation for further changes*** *(see the standard factual findings 60 on the next column),* • The Auditor followed the same procedure as above (when a positive ex-ante assessment has NOT yet been issued) and paid particular attention (testing reinforced) to the cost items for which the draft ex-ante assessment either rejected the inclusion as direct costs for Large Research Infrastructures or issued recommendations.	59) Any difference between the methodology applied and the one positively assessed was extensively described and adjusted accordingly. 60) The direct costs declared were free from any indirect costs items related to the Large Research Infrastructure.	
D.5	**Costs of internally invoiced goods and services** **The Auditor sampled cost items selected randomly** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is highest*). To confirm standard factual findings 61-65 listed in the next column, the Auditor: ○ obtained a description of the Beneficiary's usual cost accounting practice to calculate costs of internally invoiced goods and services (unit costs); ○ reviewed whether the Beneficiary's usual cost accounting practice was applied for the Financial Statements subject of the present CFS; ○ ensured that the methodology to calculate unit costs is being used in a consistent manner, based on objective criteria, regardless of the source of funding; ○ verified that any ineligible items or any costs claimed under other budget categories, in particular indirect costs, have not been taken into account when calculating the costs of	61) The costs of internally invoiced goods and services included in the Financial Statement were calculated in accordance with the Beneficiary's usual cost accounting practice. 62) The cost accounting practices used to calculate the costs of internally invoiced goods and services were applied by the Beneficiary in a consistent manner based on objective criteria regardless of the source of funding. 63) The unit cost is calculated using the actual costs for the good or service recorded in the Beneficiary's accounts, excluding any ineligible cost or costs included in other	

	internally invoiced goods and services (see Article 6 GA); ○ verified whether actual costs of internally invoiced goods and services were adjusted on the basis of budgeted or estimated elements and, if so, verified whether those elements used are actually relevant for the calculation, and correspond to objective and verifiable information. ○ verified that any costs of items which are not directly linked to the production of the invoiced goods or service (e.g. supporting services like cleaning, general accountancy, administrative support, etc. not directly used for production of the good or service) have not been taken into account when calculating the costs of internally invoiced goods and services. ○ verified that any costs of items used for calculating the costs internally invoiced goods and services are supported by audit evidence and registered in the accounts.	budget categories. 64) The unit cost excludes any costs of items which are not directly linked to the production of the invoiced goods or service. 65) The costs items used for calculating the actual costs of internally invoiced goods and services were relevant, reasonable and correspond to objective and verifiable information.	
E	**USE OF EXCHANGE RATES**		
E.1	a) For Beneficiaries with accounts established in a currency other than euros **The Auditor sampled _____ cost items selected randomly and verified that the exchange rates used for converting other currencies into euros were in accordance with the following rules established in the Agreement** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is highest)*: *COSTS RECORDED IN THE ACCOUNTS IN A CURRENCY OTHER THAN EURO SHALL BE CONVERTED INTO EURO AT THE AVERAGE OF THE DAILY EXCHANGE RATES PUBLISHED IN THE C SERIES OF OFFICIAL JOURNAL OF THE EUROPEAN UNION (https://www.ecb.int/stats/exchange/eurofxref/html/index.en.html), DETERMINED OVER THE CORRESPONDING REPORTING PERIOD.* *IF NO DAILY EURO EXCHANGE RATE IS PUBLISHED IN THE OFFICIAL JOURNAL OF THE EUROPEAN UNION FOR THE CURRENCY IN QUESTION, CONVERSION SHALL BE MADE AT THE AVERAGE OF THE MONTHLY ACCOUNTING RATES ESTABLISHED BY THE COMMISSION AND PUBLISHED ON ITS WEBSITE (http://ec.europa.eu/budget/contracts_grants/info_contracts/inforeuro/inforeuro_en.cfm),*	66) The exchange rates used to convert other currencies into Euros were in accordance with the rules established of the Grant Agreement and there was no difference in the final figures.	

	DETERMINED OVER THE CORRESPONDING REPORTING PERIOD.		
	b) For Beneficiaries with accounts established in euros **The Auditor sampled _____ cost items selected randomly and verified that the exchange rates used for converting other currencies into euros were in accordance with the following rules established in the Agreement** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is highest)*: *COSTS INCURRED IN ANOTHER CURRENCY SHALL BE CONVERTED INTO EURO BY APPLYING THE BENEFICIARY'S USUAL ACCOUNTING PRACTICES.*	67) The Beneficiary applied its usual accounting practices.	

[legal name of the audit firm]
[name and function of an authorised representative]
[dd Month yyyy]
<Signature of the Auditor>

ANNEX 6

MODEL FOR THE CERTIFICATE ON THE METHODOLOGY

- **For options [*in italics in square brackets*]: choose the applicable option. Options not chosen should be deleted.**
- **For fields in [grey in square brackets]: enter the appropriate data.**

TABLE OF CONTENTS

Terms of reference for an audit engagement for a methodology certificate in connection with one or more grant agreements financed under the Horizon 2020 Research and Innovation Framework Programme

This document sets out the '**Terms of Reference (ToR)**' under which

[OPTION 1: [insert name of the beneficiary] ('the Beneficiary')] [OPTION 2: [insert name of the linked third party] ('the Linked Third Party'), third party linked to the Beneficiary [insert name of the beneficiary] ('the Beneficiary')]

agrees to engage

[**insert legal name of the auditor**] ('the Auditor')

to produce an independent report of factual findings ('the Report') concerning the *[Beneficiary's] [Linked Third Party's]* usual accounting practices for calculating and claiming direct personnel costs declared as unit costs ('the Methodology') in connection with grant agreements financed under the Horizon 2020 Research and Innovation Framework Programme.

The procedures to be carried out for the assessment of the methodology will be based on the grant agreement(s) detailed below:

[title and number of the grant agreement(s)] ('the Agreement(s)')

The Agreement(s) has(have) been concluded between the Beneficiary and *[OPTION 1: the European Union, represented by the European Commission ('the Commission')][OPTION 2: the European Atomic Energy Community (Euratom,) represented by the European Commission ('the Commission')][OPTION 3: the [Research Executive Agency (REA)] [European Research Council Executive Agency (ERCEA)] [Innovation and Networks Executive Agency (INEA)] [Executive Agency for Small and Medium-sized Enterprises (EASME)] ('the Agency'), under the powers delegated by the European Commission ('the Commission').]*.

The *[Commission] [Agency]* is mentioned as a signatory of the Agreement with the Beneficiary only. The *[European Union] [Euratom] [Agency]* is not a party to this engagement.

1.1 Subject of the engagement

According to Article 18.1.2 of the Agreement, beneficiaries *[and linked third parties]* that declare direct personnel costs as unit costs calculated in accordance with their usual cost accounting practices may submit to the *[Commission] [Agency]*, for approval, a certificate on the methodology ('CoMUC') stating that there are adequate records and documentation to prove that their cost accounting practices used comply with the conditions set out in Point A of Article 6.2.

The subject of this engagement is the CoMUC which is composed of two separate documents:

- the Terms of Reference ('the ToR') to be signed by the *[Beneficiary] [Linked Third Party]* and the Auditor;

- the Auditor's Independent Report of Factual Findings ('the Report') issued on the Auditor's letterhead, dated, stamped and signed by the Auditor which includes; the standard statements ('the Statements') evaluated and signed by the *[Beneficiary] [Linked Third Party]*, the agreed-upon procedures ('the Procedures') performed by the Auditor and the standard factual findings

('the Findings') assessed by the Auditor. The Statements, Procedures and Findings are summarised in the table that forms part of the Report.

The information provided through the Statements, the Procedures and the Findings will enable the Commission to draw conclusions regarding the existence of the *[Beneficiary's] [Linked Third Party's]* usual cost accounting practice and its suitability to ensure that direct personnel costs claimed on that basis comply with the provisions of the Agreement. The Commission draws its own conclusions from the Report and any additional information it may require.

1.2 Responsibilities

The parties to this agreement are the *[Beneficiary] [Linked Third Party]* and the Auditor.

The *[Beneficiary] [Linked Third Party]:*

- is responsible for preparing financial statements for the Agreement(s) ('the Financial Statements') in compliance with those Agreements;
- is responsible for providing the Financial Statement(s) to the Auditor and enabling the Auditor to reconcile them with the *[Beneficiary's] [Linked Third Party's]* accounting and bookkeeping system and the underlying accounts and records. The Financial Statement(s) will be used as a basis for the procedures which the Auditor will carry out under this ToR;
- is responsible for its Methodology and liable for the accuracy of the Financial Statement(s);
- is responsible for endorsing or refuting the Statements indicated under the heading 'Statements to be made by the Beneficiary/ Linked Third Party' in the first column of the table that forms part of the Report;
- must provide the Auditor with a signed and dated representation letter;
- accepts that the ability of the Auditor to carry out the Procedures effectively depends upon the *[Beneficiary] [Linked Third Party]* providing full and free access to the *[Beneficiary's] [Linked Third Party's]* staff and to its accounting and other relevant records.

The Auditor:

- *[Option 1 by default: is qualified to carry out statutory audits of accounting documents in accordance with Directive 2006/43/EC of the European Parliament and of the Council of 17 May 2006 on statutory audits of annual accounts and consolidated accounts, amending Council Directives 78/660/EEC and 83/349/EEC and repealing Council Directive 84/253/EEC or similar national regulations].*
- *[Option 2 if the Beneficiary or Linked Third Party has an independent Public Officer: is a competent and independent Public Officer for which the relevant national authorities have established the legal capacity to audit the Beneficiary].*
- *[Option 3 if the Beneficiary or Linked Third Party is an international organisation: is an [internal] [external] auditor in accordance with the internal financial regulations and procedures of the international organisation].*

The Auditor:

- must be independent from the Beneficiary *[and the Linked Third Party]*, in particular, it must not have been involved in preparing the Beneficiary's *[and Linked Third Party's]* Financial Statement(s);
- must plan work so that the Procedures may be carried out and the Findings may be assessed;
- must adhere to the Procedures laid down and the compulsory report format;
- must carry out the engagement in accordance with these ToR;
- must document matters which are important to support the Report;
- must base its Report on the evidence gathered;
- must submit the Report to the *[Beneficiary] [Linked Third Party]*.

The Commission sets out the Procedures to be carried out and the Findings to be endorsed by the Auditor. The Auditor is not responsible for their suitability or pertinence. As this engagement is not an assurance engagement the Auditor does not provide an audit opinion or a statement of assurance.

1.3 Applicable Standards

The Auditor must comply with these Terms of Reference and with[1]:

- the International Standard on Related Services ('ISRS') 4400 *Engagements to perform Agreed-upon Procedures regarding Financial Information* as issued by the International Auditing and Assurance Standards Board (IAASB);
- the *Code of Ethics for Professional Accountants* issued by the International Ethics Standards Board for Accountants (IESBA). Although ISRS 4400 states that independence is not a requirement for engagements to carry out agreed-upon procedures, the Commission requires that the Auditor also complies with the Code's independence requirements.

The Auditor's Report must state that there was no conflict of interests in establishing this Report between the Auditor and the Beneficiary *[and the Linked Third Party]* that could have a bearing on the Report, and must specify – if the service is invoiced - the total fee paid to the Auditor for providing the Report.

1.4 Reporting

The Report must be written in the language of the Agreement (see Article 20.7 of the Agreement).

Under Article 22 of the Agreement, the Commission, *[the Agency]*, the European Anti-Fraud Office and the Court of Auditors have the right to audit any work that is carried out under the action and for which costs are declared from *[the European Union] [Euratom]* budget. This includes work related to this engagement. The Auditor must provide access to all working papers related to this assignment if the Commission*[, the Agency]*, the European Anti-Fraud Office or the European Court of Auditors requests them.

1.5 Timing

The Report must be provided by [dd Month yyyy].

1.6 Other Terms

[The [Beneficiary] [Linked Third Party] and the Auditor can use this section to agree other specific terms, such as the Auditor's fees, liability, applicable law, etc. Those specific terms must not contradict the terms specified above.]

[legal name of the Auditor]	[legal name of the [Beneficiary] [Linked Third Party]]
[name & title of authorised representative]	[name & title of authorised representative]
[dd Month yyyy]	[dd Month yyyy]
Signature of the Auditor	Signature of the *[Beneficiary] [Linked Third Party]*

[1] Supreme Audit Institutions applying INTOSAI-standards may carry out the Procedures according to the corresponding International Standards of Supreme Audit Institutions and code of ethics issued by INTOSAI instead of the International Standard on Related Services ('ISRS') 4400 and the Code of Ethics for Professional Accountants issued by the IAASB and the IESBA.

Independent report of factual findings on the methodology concerning grant agreements financed under the Horizon 2020 Research and Innovation Framework Programme

(To be printed on letterhead paper of the auditor)

To
[name of contact person(s)], [Position]
[[Beneficiary's] [Linked Third Party's] name]
[Address]
[dd Month yyyy]

Dear [Name of contact person(s)],

As agreed under the terms of reference dated [dd Month yyyy]

with *[OPTION 1: [insert name of the beneficiary] ('the Beneficiary')] [OPTION 2: [insert name of the linked third party] ('the Linked Third Party'), third party linked to the Beneficiary [insert name of the beneficiary] ('the Beneficiary')]*,

we

[name of the auditor] ('the Auditor'),

established at

[full address/city/state/province/country],

represented by

[name and function of an authorised representative],

have carried out the agreed-upon procedures ('the Procedures') and provide hereby our Independent Report of Factual Findings ('the Report'), concerning the *[Beneficiary's] [Linked Third Party's]* usual accounting practices for calculating and declaring direct personnel costs declared as unit costs ('the Methodology').

You requested certain procedures to be carried out in connection with the grant(s)

[title and number of the grant agreement(s)] ('the Agreement(s)').

The Report

Our engagement was carried out in accordance with the terms of reference ('the ToR') appended to this Report. The Report includes: the standard statements ('the Statements') made by the *[Beneficiary] [Linked Third Party]*, the agreed-upon procedures ('the Procedures') carried out and the standard factual findings ('the Findings') confirmed by us.

The engagement involved carrying out the Procedures and assessing the Findings and the documentation requested appended to this Report, the results of which the Commission uses to draw conclusions regarding the acceptability of the Methodology applied by the *[Beneficiary] [Linked Third Party]*.

The Report covers the methodology used from [dd Month yyyy]. In the event that the *[Beneficiary] [Linked Third Party]* changes this methodology, the Report will not be applicable to any Financial Statement[1] submitted thereafter.

The scope of the Procedures and the definition of the standard statements and findings were determined solely by the Commission. Therefore, the Auditor is not responsible for their suitability or pertinence.

Since the Procedures carried out constitute neither an audit nor a review made in accordance with International Standards on Auditing or International Standards on Review Engagements, we do not give a statement of assurance on the costs declared on the basis of the *[Beneficiary's] [Linked Third Party's]* Methodology. Had we carried out additional procedures or had we performed an audit or review in accordance with these standards, other matters might have come to its attention and would have been included in the Report.

Exceptions

Apart from the exceptions listed below, the *[Beneficiary] [Linked Third Party]* agreed with the standard Statements and provided the Auditor all the documentation and accounting information needed by the Auditor to carry out the requested Procedures and corroborate the standard Findings.

List here any exception and add any information on the cause and possible consequences of each exception, if known. If the exception is quantifiable, also indicate the corresponding amount.

…..

Explanation of possible exceptions in the form of examples (to be removed from the Report):

i. the [Beneficiary] [Linked Third Party] did not agree with the standard Statement number … because…;

ii. the Auditor could not carry out the procedure … established because …. (e.g. due to the inability to reconcile key information or the unavailability or inconsistency of data);

iii. the Auditor could not confirm or corroborate the standard Finding number … because ….

Remarks

We would like to add the following remarks relevant for the proper understanding of the Methodology applied by the [Beneficiary] [Linked Third Party] or the results reported:

Example (to be removed from the Report):

Regarding the methodology applied to calculate hourly rates …

Regarding standard Finding 15 it has to be noted that …

The [Beneficiary] [Linked Third Party] explained the deviation from the benchmark statement XXIV concerning time recording for personnel with no exclusive dedication to the action in the following manner: …

Annexes

Please provide the following documents to the auditor and annex them to the report when submitting this CoMUC to the Commission:

[1] Financial Statement in this context refers solely to Annex 4 of the Agreement by which the Beneficiary declares costs under the Agreement.

1. Brief description of the methodology for calculating personnel costs, productive hours and hourly rates;
2. Brief description of the time recording system in place;
3. An example of the time records used by the [*Beneficiary] [Linked Third Party*];
4. Description of any budgeted or estimated elements applied, together with an explanation as to why they are relevant for calculating the personnel costs and how they are based on objective and verifiable information;
5. A summary sheet with the hourly rate for direct personnel declared by the [*Beneficiary*] [*Linked Third Party*] and recalculated by the Auditor for each staff member included in the sample (the names do not need to be reported);
6. A comparative table summarising for each person selected in the sample a) the time claimed by the [*Beneficiary*] [*Linked Third Party*] in the Financial Statement(s) and b) the time according to the time record verified by the Auditor;
7. A copy of the letter of representation provided to the Auditor.

Use of this Report

This Report has been drawn up solely for the purpose given under Point 1.1 Reasons for the engagement.

The Report:

- is confidential and is intended to be submitted to the Commission by the [*Beneficiary*] [*Linked Third Party*] in connection with Article 18.1.2 of the Agreement;
- may not be used by the [*Beneficiary*] [*Linked Third Party*] or by the Commission for any other purpose, nor distributed to any other parties;
- may be disclosed by the Commission only to authorised parties, in particular the European Anti-Fraud Office (OLAF) and the European Court of Auditors.
- relates only to the usual cost accounting practices specified above and does not constitute a report on the Financial Statements of the [*Beneficiary*] [*Linked Third Party*].

No conflict of interest[2] exists between the Auditor and the Beneficiary *[and the Linked Third Party*] that could have a bearing on the Report. The total fee paid to the Auditor for producing the Report was EUR _____ (including EUR _____ of deductible VAT).

We look forward to discussing our Report with you and would be pleased to provide any further information or assistance which may be required.

Yours sincerely

[legal name of the Auditor]
[name and title of the authorised representative]
[dd Month yyyy]
Signature of the Auditor

[2] A conflict of interest arises when the Auditor's objectivity to establish the certificate is compromised in fact or in appearance when the Auditor for instance:
- was involved in the preparation of the Financial Statements;
- stands to benefit directly should the certificate be accepted;
- has a close relationship with any person representing the beneficiary;
- is a director, trustee or partner of the beneficiary; or
- is in any other situation that compromises his or her independence or ability to establish the certificate impartially.

Statements to be made by the Beneficiary/Linked Third Party ('the Statements') and Procedures to be carried out by the Auditor ('the Procedures') and standard factual findings ('the Findings') to be confirmed by the Auditor

The Commission reserves the right to provide the auditor with guidance regarding the Statements to be made, the Procedures to be carried out or the Findings to be ascertained and the way in which to present them. The Commission reserves the right to vary the Statements, Procedures or Findings by written notification to the Beneficiary/Linked Third Party to adapt the procedures to changes in the grant agreement(s) or to any other circumstances.

If this methodology certificate relates to the Linked Third Party's usual accounting practices for calculating and claiming direct personnel costs declared as unit costs any reference here below to 'the Beneficiary' is to be considered as a reference to 'the Linked Third Party'.

Please explain any discrepancies in the body of the Report.	
Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
A. Use of the Methodology I. The cost accounting practice described below has been in use since *[*dd Month yyyy*]*. II. The next planned alteration to the methodology used by the Beneficiary will be from [dd Month yyyy*]*.	**Procedure:** ✓ The Auditor checked these dates against the documentation the Beneficiary has provided. **Factual finding:** 1. The dates provided by the Beneficiary were consistent with the documentation.
B. Description of the Methodology III. The methodology to calculate unit costs is being used in a consistent manner and is reflected in the relevant procedures. *[Please describe the methodology your entity uses to calculate personnel costs, productive hours and hourly rates, present your description to the Auditor and annex it to this certificate]* *[If the statement of section "B. Description of the methodology" cannot be endorsed by the Beneficiary or there is no written methodology to calculate unit costs it should be listed here below and reported as exception by the Auditor in the main Report of Factual Findings:* - *…]*	**Procedure:** ✓ The Auditor reviewed the description, the relevant manuals and/or internal guidance documents describing the methodology. **Factual finding:** 2. The brief description was consistent with the relevant manuals, internal guidance and/or other documentary evidence the Auditor has reviewed. 3. The methodology was generally applied by the Beneficiary as part of its usual costs accounting practices.

Please explain any discrepancies in the body of the Report.	
Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
C. **Personnel costs** General IV. The unit costs (hourly rates) are limited to salaries including during parental leave, social security contributions, taxes and other costs included in the remuneration required under national law and the employment contract or equivalent appointing act; V. Employees are hired directly by the Beneficiary in accordance with national law, and work under its sole supervision and responsibility; VI. The Beneficiary remunerates its employees in accordance with its usual practices. This means that personnel costs are charged in line with the Beneficiary's usual payroll policy (e.g. salary policy, overtime policy, variable pay) and no special conditions exist for employees assigned to tasks relating to the European Union or Euratom, unless explicitly provided for in the grant agreement(s); VII. The Beneficiary allocates its employees to the relevant group/category/cost centre for the purpose of the unit cost calculation in line with the usual cost accounting practice; VIII. Personnel costs are based on the payroll system and accounting system. IX. Any exceptional adjustments of actual personnel costs resulted from relevant budgeted or estimated elements and were based on objective and verifiable information. *[Please describe the 'budgeted or estimated elements' and their relevance to personnel costs, and explain how they were reasonable and based on objective and verifiable information, present your explanation to the Auditor and annex it to this certificate].* X. Personnel costs claimed do not contain any of the following ineligible costs: costs related to return on capital; debt and debt service charges; provisions for future losses or debts; interest owed; doubtful debts; currency exchange losses; bank costs charged by the Beneficiary's bank for transfers from the Commission/Agency; excessive or reckless expenditure; deductible VAT or costs incurred during suspension of the implementation of the action. XI. Personnel costs were not declared under another EU or Euratom grant	**Procedure:** *The Auditor draws a sample of employees to carry out the procedures indicated in this section C and the following sections D to F.* *[The Auditor has drawn a random sample of 10 employees assigned to Horizon 2020 action(s). If fewer than 10 employees are assigned to the Horizon 2020 action(s), the Auditor has selected all employees assigned to the Horizon 2020 action(s) complemented by other employees irrespective of their assignments until he has reached 10 employees.].* For this sample: ✓ the Auditor reviewed all documents relating to personnel costs such as employment contracts, payslips, payroll policy (e.g. salary policy, overtime policy, variable pay policy), accounting and payroll records, applicable national tax , labour and social security law and any other documents corroborating the personnel costs claimed; ✓ in particular, the Auditor reviewed the employment contracts of the employees in the sample to verify that: i. they were employed directly by the Beneficiary in accordance with applicable national legislation; ii. they were working under the sole technical supervision and responsibility of the latter; iii. they were remunerated in accordance with the Beneficiary's usual practices; iv. they were allocated to the correct group/category/cost centre for the purposes of calculating the unit cost in line with the Beneficiary's usual cost accounting practices; ✓ the Auditor verified that any ineligible items or any costs claimed under other costs categories or costs covered by other types of grant or by other grants financed from the European Union budget have not been taken into account when calculating the personnel costs; ✓ the Auditor numerically reconciled the total amount of personnel costs used to calculate the unit cost with the total amount of personnel costs recorded in the statutory accounts and the payroll system.

Please explain any discrepancies in the body of the Report.	
Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
(including grants awarded by a Member State and financed by the EU budget and grants awarded by bodies other than the Commission/Agency for the purpose of implementing the EU or Euratom budget in the same period, unless the Beneficiary can demonstrate that the operating grant does not cover any costs of the action). <u>If additional remuneration as referred to in the grant agreement(s) is paid</u> XII. The Beneficiary is a non-profit legal entity; XIII. The additional remuneration is part of the beneficiary's usual remuneration practices and paid consistently whenever the relevant work or expertise is required; XIV. The criteria used to calculate the additional remuneration are objective and generally applied regardless of the source of funding; XV. The additional remuneration included in the personnel costs used to calculate the hourly rates for the grant agreement(s) is capped at EUR 8 000 per full-time equivalent (reduced proportionately if the employee is not assigned exclusively to the action). *[If certain statement(s) of section "C. Personnel costs" cannot be endorsed by the Beneficiary they should be listed here below and reported as exception by the Auditor in the main Report of Factual Findings:* *- …]*	✓ to the extent that actual personnel costs were adjusted on the basis of budgeted or estimated elements, the Auditor carefully examined those elements and checked the information source to confirm that they correspond to objective and verifiable information; ✓ if additional remuneration has been claimed, the Auditor verified that the Beneficiary was a non-profit legal entity, that the amount was capped at EUR 8 000 per full-time equivalent and that it was reduced proportionately for employees not assigned exclusively to the action(s). ✓ the Auditor recalculated the personnel costs for the employees in the sample. **Factual finding:** 4. All the components of the remuneration that have been claimed as personnel costs are supported by underlying documentation. 5. The employees in the sample were employed directly by the Beneficiary in accordance with applicable national law and were working under its sole supervision and responsibility. 6. Their employment contracts were in line with the Beneficiary's usual policy; 7. Personnel costs were duly documented and consisted solely of salaries, social security contributions (pension contributions, health insurance, unemployment fund contributions, etc.), taxes and other statutory costs included in the remuneration (holiday pay, thirteenth month's pay, etc.); 8. The totals used to calculate the personnel unit costs are consistent with those registered in the payroll and accounting records; 9. To the extent that actual personnel costs were adjusted on the basis of budgeted or estimated elements, those elements were relevant for calculating the personnel costs and correspond to objective and verifiable information. The budgeted or estimated elements used are: — (indicate the elements and their values). 10. Personnel costs contained no ineligible elements; 11. Specific conditions for eligibility were fulfilled when additional

Please explain any discrepancies in the body of the Report.	
Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
	remuneration was paid: a) the Beneficiary is registered in the grant agreements as a non-profit legal entity; b) it was paid according to objective criteria generally applied regardless of the source of funding used and c) remuneration was capped at EUR 8 000 per full-time equivalent (or up to up to the equivalent pro-rata amount if the person did not work on the action full-time during the year or did not work exclusively on the action).
D. Productive hours XVI. The number of productive hours per full-time employee applied is *[delete as appropriate]*: A. 1720 productive hours per year for a person working full-time (corresponding pro-rata for persons not working full time). B. the total number of hours worked in the year by a person for the Beneficiary C. the standard number of annual hours generally applied by the beneficiary for its personnel in accordance with its usual cost accounting practices. This number must be at least 90% of the standard annual workable hours. <u>If method B is applied</u> XVII. The calculation of the total number of hours worked was done as follows: annual workable hours of the person according to the employment contract, applicable labour agreement or national law plus overtime worked minus absences (such as sick leave and special leave). XVIII. 'Annual workable hours' are hours during which the personnel must be working, at the employer's disposal and carrying out his/her activity or duties under the employment contract, applicable collective labour agreement or national working time legislation. XIX. The contract (applicable collective labour agreement or national working time legislation) do specify the working time enabling to calculate the annual workable hours.	**Procedure (same sample basis as for Section C: Personnel costs):** ✓ The Auditor verified that the number of productive hours applied is in accordance with method A, B or C. ✓ The Auditor checked that the number of productive hours per full-time employee is correct. ✓ If method B is applied the Auditor verified i) the manner in which the total number of hours worked was done and ii) that the contract specified the annual workable hours by inspecting all the relevant documents, national legislation, labour agreements and contracts. ✓ If method C is applied the Auditor reviewed the manner in which the standard number of working hours per year has been calculated by inspecting all the relevant documents, national legislation, labour agreements and contracts and verified that the number of productive hours per year used for these calculations was at least 90 % of the standard number of working hours per year. **Factual finding:** <u>General</u> 12. The Beneficiary applied a number of productive hours consistent with method A, B or C detailed in the left-hand column. 13. The number of productive hours per year per full-time employee was accurate. <u>If method B is applied</u> 14. The number of 'annual workable hours', overtime and absences was

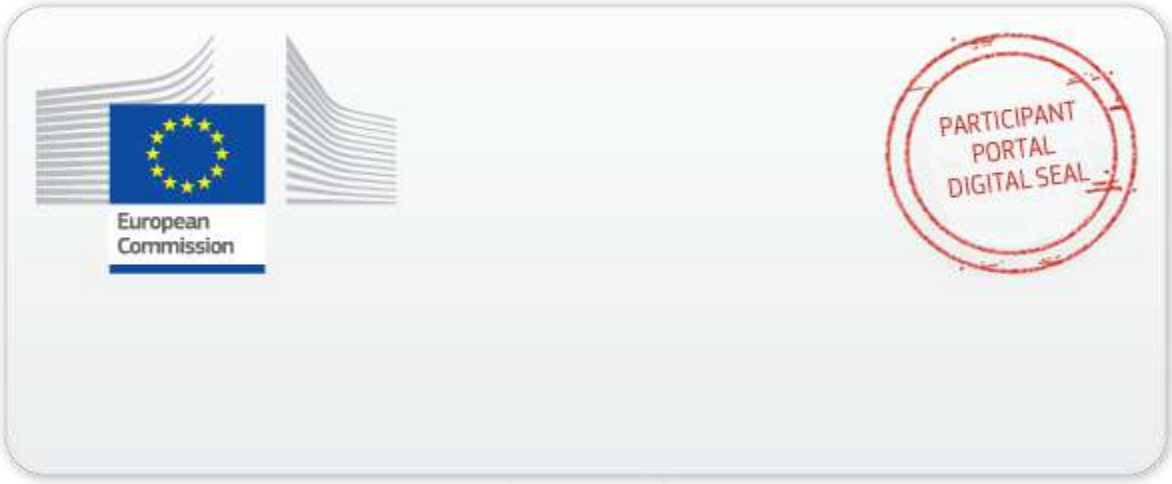
Please explain any discrepancies in the body of the Report.	
Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
If method C is applied XX. The standard number of productive hours per year is that of a full-time equivalent. XXI. The number of productive hours per year on which the hourly rate is based i) corresponds to the Beneficiary's usual accounting practices; ii) is at least 90% of the standard number of workable (working) hours per year. XXII. Standard workable (working) hours are hours during which personnel are at the Beneficiary's disposal preforming the duties described in the relevant employment contract, collective labour agreement or national labour legislation. The number of standard annual workable (working) hours that the Beneficiary claims is supported by labour contracts, national legislation and other documentary evidence. *[If certain statement(s) of section "D. Productive hours" cannot be endorsed by the Beneficiary they should be listed here below and reported as exception by the Auditor:* - *…]*	verifiable based on the documents provided by the Beneficiary and the calculation of the total number of hours worked was accurate. 15. The contract specified the working time enabling to calculate the annual workable hours. If method C is applied 16. The calculation of the number of productive hours per year corresponded to the usual costs accounting practice of the Beneficiary. 17. The calculation of the standard number of workable (working) hours per year was corroborated by the documents presented by the Beneficiary. 18. The number of productive hours per year used for the calculation of the hourly rate was at least 90% of the number of workable (working) hours per year.
E. Hourly rates The hourly rates are correct because: XXIII. Hourly rates are correctly calculated since they result from dividing annual personnel costs by the productive hours of a given year and group (e.g. staff category or department or cost centre depending on the methodology applied) and they are in line with the statements made in section C. and D. above. *[If the statement of section 'E. Hourly rates' cannot be endorsed by the Beneficiary they should be listed here below and reported as exception by the Auditor:* - *…]*	**Procedure** ✓ The Auditor has obtained a list of all personnel rates calculated by the Beneficiary in accordance with the methodology used. ✓ The Auditor has obtained a list of all the relevant employees, based on which the personnel rate(s) are calculated. For 10 employees selected at random (same sample basis as Section C: Personnel costs): ✓ The Auditor recalculated the hourly rates. ✓ The Auditor verified that the methodology applied corresponds to the usual accounting practices of the organisation and is applied consistently for all activities of the organisation on the basis of objective criteria irrespective of the source of funding. **Factual finding:**

Please explain any discrepancies in the body of the Report.	
Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
	19. No differences arose from the recalculation of the hourly rate for the employees included in the sample.
F. Time recording XXIV. Time recording is in place for all persons with no exclusive dedication to one Horizon 2020 action. At least all hours worked in connection with the grant agreement(s) are registered on a **daily/weekly/monthly** basis *[delete as appropriate]* using a **paper/computer-based system** *[delete as appropriate]*; XXV. For persons exclusively assigned to one Horizon 2020 activity the Beneficiary has either signed a declaration to that effect or has put arrangements in place to record their working time; XXVI. Records of time worked have been signed by the person concerned (on paper or electronically) and approved by the action manager or line manager at least monthly; XXVII. Measures are in place to prevent staff from: i. recording the same hours twice, ii. recording working hours during absence periods (e.g. holidays, sick leave), iii. recording more than the number of productive hours per year used to calculate the hourly rates, and iv. recording hours worked outside the action period. XXVIII. No working time was recorded outside the action period; XXIX. No more hours were claimed than the productive hours used to calculate the hourly personnel rates. *[Please provide a brief description of the time recording system in place together with the measures applied to ensure its reliability to the Auditor and annex it to the*	**Procedure** ✓ The Auditor reviewed the brief description, all relevant manuals and/or internal guidance describing the methodology used to record time. The Auditor reviewed the time records of the random sample of 10 employees referred to under Section C: Personnel costs, and verified in particular: ✓ that time records were available for all persons with not exclusive assignment to the action; ✓ that time records were available for persons working exclusively for a Horizon 2020 action, or, alternatively, that a declaration signed by the Beneficiary was available for them certifying that they were working exclusively for a Horizon 2020 action; ✓ that time records were signed and approved in due time and that all minimum requirements were fulfilled; ✓ that the persons worked for the action in the periods claimed; ✓ that no more hours were claimed than the productive hours used to calculate the hourly personnel rates; ✓ that internal controls were in place to prevent that time is recorded twice, during absences for holidays or sick leave; that more hours are claimed per person per year for Horizon 2020 actions than the number of productive hours per year used to calculate the hourly rates; that working time is recorded outside the action period; ✓ the Auditor cross-checked the information with human-resources records to verify consistency and to ensure that the internal controls have been effective. In addition, the Auditor has verified that no more hours were charged to Horizon 2020 actions per person per year than the number of productive hours per year used to calculate the hourly rates, and verified that

Please explain any discrepancies in the body of the Report.	
Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
present certificate[1]]. *[If certain statement(s) of section "F. Time recording" cannot be endorsed by the Beneficiary they should be listed here below and reported as exception by the Auditor:* - *…]*	no time worked outside the action period was charged to the action. **Factual finding:** 20. The brief description, manuals and/or internal guidance on time recording provided by the Beneficiary were consistent with management reports/records and other documents reviewed and were generally applied by the Beneficiary to produce the financial statements. 21. For the random sample time was recorded or, in the case of employees working exclusively for the action, either a signed declaration or time records were available; 22. For the random sample the time records were signed by the employee and the action manager/line manager, at least monthly. 23. Working time claimed for the action occurred in the periods claimed; 24. No more hours were claimed than the number productive hours used to calculate the hourly personnel rates; 25. There is proof that the Beneficiary has checked that working time has not been claimed twice, that it is consistent with absence records and the number of productive hours per year, and that no working time has been claimed outside the action period. 26. Working time claimed is consistent with that on record at the human-resources department.

[1] The description of the time recording system must state among others information on the content of the time records, its coverage (full or action time-recording, for all personnel or only for personnel involved in H2020 actions), its degree of detail (whether there is a reference to the particular tasks accomplished), its form, periodicity of the time registration and authorisation (paper or a computer-based system; on a daily, weekly or monthly basis; signed and countersigned by whom), controls applied to prevent double-charging of time or ensure consistency with HR-records such as absences and travels as well as it information flow up to its use for the preparation of the Financial Statements.

Please explain any discrepancies in the body of the Report.	
Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
[official name of the *[Beneficiary] [Linked Third Party]**]*** ***[name and title of authorised representative]*** ***[dd Month yyyy]*** ***<Signature of the*** *[Beneficiary] [Linked Third Party]>*	***[official name of the Auditor]*** ***[name and title of authorised representative]*** ***[dd Month yyyy]*** ***<Signature*** *of the Auditor>*



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