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ANNEX 1 (part A)

Research and Innovation action

NUMBER — 637268 — RIBuild

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1.1. The project summary

Project Number [1]	637268	Project Acronym [2]	RIBuild

One form per project

General information	
Project title [3]	Robust Internal Thermal Insulation of Historic Buildings
Starting date [4]	01/01/2015
Duration in months [5]	60
Call (part) identifier [6]	H2020-EE-2014-1-PPP
Topic	EE-03-2014 Energy strategies and solutions for deep renovation of historic buildings
Fixed EC Keywords	Energy efficient buildings, Renovation
Free keywords	Internal thermal insulation, decision guidelines, probabilistic, building physics, life cycle impact assessment, durability,

Abstract [7]

RIBuild will strengthen the knowledge on how and under what conditions internal thermal insulation is to be implemented in historic buildings, without compromising their architectural and cultural values, with an acceptable safety level against deterioration and collapse of heavy external wall structures. The general objective of RIBuild is to develop effective, comprehensive decision guidelines to optimise the design and implementation of internal thermal insulation in historic buildings across the EU. RIBuild focuses on heavy external walls made of stone, brick and timber framing, as most historic buildings are made of these materials. The general objective is achieved through three main activities

• To obtain a thorough knowledge level to characterise the eligibility of the building for a deep internal thermal insulation renovation. This knowledge is obtained through screening of historic buildings, investigation of material properties and threshold values for failure

• To determine the conditions under which different internal insulation measures are reliable and affordable measures based on probabilistic modelling of the hygrothermal performance, the environmental impact and the cost/benefit

• To develop a set of comprehensive decision guidelines, which are demonstrated in a number of buildings. RIBuild addresses the most difficult retrofitting measure of historic buildings: internal thermal insulation. The adaption of knowledge developed by RIBuild contributes to sustainable historic buildings with improved energy efficiency implying an easier conversion of energy supply from inefficient fossil fuels to efficient renewable energy sources. RIBuild also assesses the hygrothermal performance of the building construction, thus no collateral damage occurs; in case of failure an easy roll back of the measures is possible. The guidelines developed in RIBuild strongly support the deep and holistic retrofitting approach which historic buildings face in the coming years.

1.2. List of Beneficiaries

Project Number [1]	637268	Project Acronym [2]	RIBuild

List of Beneficiaries

No	Name	Short name	Country	Project entry date[8]	Project exit date
1	AALBORG UNIVERSITET	AAU	Denmark		
2	RIGAS TEHNISKA UNIVERSITATE	RTU	Latvia		
3	TECHNISCHE UNIVERSITAET DRESDEN	TUD	Germany		
4	KATHOLIEKE UNIVERSITEIT LEUVEN	KU Leuven	Belgium		
5	UNIVERSITA POLITECNICA DELLE MARCHE	UNIVPM	Italy		
6	DANMARKS TEKNISKE UNIVERSITET	DTU	Denmark		
7	SP SVERIGES TEKNISKA FORSKNINGSINSTITUT AB	SP	Sweden		
8	HAUTE ECOLE SPECIALISEE DE SUISSE OCCIDENTALE	HES-SO	Switzerland		
9	INTRO FLEX APS	IFLEX	Denmark		
10	ERIK MOLLER ARKITEKTER AS	EMA	Denmark		

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	Pre-renovation assessment	2 - RTU	46.00	1	12
WP2	Material characterisation coupled with eligible renovation	1 - AAU	124.00	4	60
WP3	Case studies and laboratory measurement	3 - TUD	122.00	4	48
WP4	Probabilistic assessment of interior insulation solutions	4 - KU Leuven	100.00	3	48
WP5	Development of cost/benefit and environmental impact assessment	5 - UNIVPM	68.00	13	42
WP6	Application and evaluation of assessment tools	6 - DTU	111.00	25	58
WP7	Communication and dissemination	1 - AAU	47.00	1	60
WP8	Project management	1 - AAU	28.00	1	60
		Total	646.00		

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	Report on historical building types and combinations of structural solutions	WP1	2 - RTU	Report	Public	9
D1.2	Report on state-of-the-art	WP1	2 - RTU	Report	Public	12
D2.1	Report on material properties	WP2	1 - AAU	Report	Public	36
D2.2	Report on threshold values for failure	WP2	7 - SP	Report	Public	48
D2.3	Impact of water repellent agents on hygric properties of porous building materials	WP2	4 - KU Leuven	Report	Public	60
D3.1	Closed technology loop of laboratory experiments and simulation models in the field of internal insulation testing	WP3	3 - TUD	Report	Public	36
D3.2	Monitoring data basis of European case studies	WP3	3 - TUD	Report	Public	48
D4.1	A methodology for the efficient hygrothermal assessment of building components	WP4	4 - KU Leuven	Report	Public	36
D4.2	A methodology for the efficient probabilistic evaluation of building performances	WP4	4 - KU Leuven	Report	Public	36
D5.1	Report and tool: Probability based Life Cycle Impact Assessment	WP5	5 - UNIVPM	Report	Public	36
D5.2	Report and tool: Probability based Life Cycle Cost	WP5	5 - UNIVPM	Report	Public	42
D6.1	Assessment Methodology	WP6	6 - DTU	Report	Public	56
D6.2	Risk assessment guidelines for insulation of historic buildings	WP6	6 - DTU	Report	Public	58

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D6.3	Evaluation of methodology	WP6	6 - DTU	Report	Public	58
D7.1	Procedure for evaluating research results	WP7	1 - AAU	Report	Public	6
D7.2	Mapping of networks	WP7	1 - AAU	Report	Public	6
D7.3	Formation of network partnerships	WP7	1 - AAU	Report	Public	6
D7.4	Information kit on project results	WP7	1 - AAU	Report	Public	60
D7.5	Report on first workshop/seminar	WP7	1 - AAU	Report	Public	12
D7.6	Report on final conference	WP7	1 - AAU	Report	Public	60
D7.7	Report on jounal and papers	WP7	1 - AAU	Report	Public	60
D7.8	Project website	WP7	1 - AAU	Websites, patents filling, etc.	Public	3
D7.9	First press release on the project	WP7	1 - AAU	Report	Public	6
D7.10	Final press release on the project	WP7	1 - AAU	Report	Public	60
D8.1	Data Management Plan	WP8	1 - AAU	ORDP: Open Research Data Pilot	Confidential, only for members of the consortium (including the Commission Services)	6

1.3.3. WT3 Work package descriptions

Work package number [9]	WP1	**Lead beneficiary** [10]	2 - RTU
Work package title	Pre-renovation assessment		
Start month	1	**End month**	12

Objectives

The main objective of WP1 is to examine most commonly found historic building structural elements, determine their physical properties, classify them by different types, observe and describe main historic building envelope deterioration symptoms and study their possible causes.

Description of work and role of partners

WP1 - Pre-renovation assessment [Months: 1-12]
RTU, AAU, TUD, KU Leuven, UNIVPM, DTU, SP, HES-SO
Historic buildings inherit cultural significance, therefore possibilities of energy efficiency improvements associated with insulation of building envelope is strictly restricted by number of options and are governed by several rules of thumb.

In WP1 information concerning internal post-insulation of historic buildings is gathered as a basis for the activities in the following WP's.

Task 1.1 Survey of historic building stock
Lead: RTU
Participants: AAU, TUD, KUL,UNIVPM, DTU, SP, HES-SO
This part of the work package will be dedicated to survey of historic building stock in the countries of the participants regarding building materials used in external walls and joints with adjoining building elements (ceiling/roof, suspended floor, and foundations) (D1.1). The survey will be limited to buildings with heavy walls (stone, brick, timber framing), thus excluding wooden buildings.

Each partner contributing to this part of the work package will have to examine the historic buildings in their country providing short description of each surveyed building and detailed description of historical building structural elements which would allow to characterise the most commonly used structural building elements.

Set of benchmarks will be developed to compare different buildings from different partner countries. All involved partners should provide conditioned space area, energy consumption and country specific climate date, so that the task leader could analyse received data and provide information on average energy consumption based on climate corrected data. This activity is expected to make use of the long-term national strategies for mobilising investment in the renovation of residential and commercial buildings, prescribed by EU, including an overview of the national building stock, identification of cost-effective approaches to renovations etc. The main interest of research will be focused on the quantification of physical parameters of each building structural element and most commonly observed signs of building structural element deterioration and their main causes. Summarization on different building structural element U-values will also be provided,separately also indicating the different wall thickness observed in each building and heat conductivity values. Overview of the combination of different structures in the buildings depending on building practice will also be provided. It is also necessary to specify the use of the building and information on internal parameters – is the space conditioned or unconditioned, it the space is conditioned, internal temperature in cooling and heating periods.

Task 1.2 Screening of case studies on renovation of historic buildings
Lead: RTU
Participants: AAU, TUD, KUL,UNIVPM, DTU, SP, HES-SO
To observe the potential effects of internal insulation application to structural elements of historic buildings, selection of 3-5 case studies of ongoing or finished internal insulation projects for each participant country will be required. Information on structures, renovation measures, pre and post energy usage etc. must be available including cost of investment, maintenance and operation. Also, basic building information is obtained e.g. year of construction, floor area, use. Registration and field investigation of typical defects when implementing renovation measures should also be investigated.

Initially it is recommended to contact municipalities to see if they have any municipality owned historic buildings, which recently had undergone any kind of renovation. If the buildings can't be selected from municipalities, then private owners should be contacted. After identification of appropriate buildings, the evaluation process will begin.

The evaluation process for each of the partners will include data analysis of pre and post renovation energy consumption, investigation of materials used for renovation, finding considerations which need to be taken into account planning for the renovation, obtaining information on specific renovation materials chosen and why. The evaluation process will also include inspection of the building with fault detection and finding the cause of detected faults. Task 1.2 will provide information on main driving forces which promote the renovation of historic buildings. The project leader will gather information, including questionnaires, from each project partner on the main motivational aspects. The deliverable will include description on main driving forces behind each of the motivational assumptions as well as other aspects which could have contributed to the decision making.

The deliverable (D1.1) will include answers from questioners given to building managers as well as independent view of each project partner:
- What were the objectives and motivation for executing the renovation (energy savings, maintenance, profitability, legislation etc.)? #
- What kind of renovation measures were implemented and how?
- What kind of planning and design tools or guidelines were used?
- What was the aim of the renovation and was it reached?

Task 1.3 Screening of existing internal insulation technologies
Lead: RTU
Participants: AAU, TUD, KUL,UNIVPM, DTU, SP, HES-SO

Existing methods and materials for insulation are investigated with emphasis on internal insulation materials installed in historic buildings.

The study will be done on extensive review of available literature sources and recently published scientific papers. In addition insulation material producers and suppliers will be contacted to obtain practical information on insulation and finishing trim materials used for historic building retrofit. A state-of-the-art on insulation materials for historic building retrofit projects will be provided (D1.2). The materials will be characterized depending on their intended use (insulation, protective layer, etc.). Main physical parameters for each insulation material will be provided along with short description on material advantages, disadvantages and potential application possibilities.

This part of the work package will include not only description of the insulation materials available for energy efficiency improvements, but also decoration materials and finishes which are used to hinder further deterioration of restored building envelope thus ensuring longevity of the renovation and achieved energy efficiency levels. Also, if possible, corresponding case study of historical building will be indicated, in which the examined methods and materials have already been applied.

Task 1.4 Review of existing guidelines and decision making tools on internal insulation Lead: RTU
Participants: AAU, TUD, KUL,UNIVPM, DTU, SP, HES-SO

This part of the WP will be devoted to review of assumptions, methodologies and other guidelines and decision making tools related to internal insulation of historic buildings (D1.2). A comparison of different strategies will be made indicating their advantages and disadvantages between one and another. Also main considerations which should be taken into account when performing historical building retrofit will be provided. Main motivational aspects (e.g. economy, legislation profitability, LCIA, CO2, probabilistic modelling etc.) driving the decision making on improving the historic building envelope will also be examined. One of the factors influencing decision making are economic aspects which have to be evaluated by weighting the possible long-term gains of improved energy efficiency, rise in monetary value and retention of historic building fabrics against the whole capital investments of the historic building renovation process. All the findings will be part of the background for decision guidelines developed in WP5.

The main information source to evaluate existing guidelines and decision making tools will be scientific publications, software provider web-pages, previous EU projects regarding historical buildings and other adequate sources with high level of competence.

Participation per Partner

Partner number and short name	WP1 effort
1 - AAU	4.00
2 - RTU	21.00
3 - TUD	4.00
4 - KU Leuven	1.00
5 - UNIVPM	4.00
6 - DTU	4.00
7 - SP	4.00
8 - HES-SO	4.00
Total	46.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D1.1	Report on historical building types and combinations of structural solutions	2 - RTU	Report	Public	9
D1.2	Report on state-of-the-art	2 - RTU	Report	Public	12

Description of deliverables

D1.1 : Report on historical building types and combinations of structural solutions [9]

Including main driving forces promoting renovation of historic buildings based on case studies

D1.2 : Report on state-of-the-art [12]

- Insulation materials for historic building retrofit projects - Existing main strategies and methodologies used for retrofit of historic buildings

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	Report on historical building types and combinations of structural solutions	2 - RTU	9	D1.1
MS2	Report on main driving forces promoting renovation of historic buildings based on case studies	2 - RTU	9	D1.2
MS3	State-of-the-art on insulation materials for historic building retrofit projects	2 - RTU	12	D1.2

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS4	State-of-the-art on existing main strategies and methodologies used for retrofit of historic buildings	2 - RTU	12	D1.2

Work package number [9]	WP2	**Lead beneficiary** [10]	1 - AAU
Work package title	Material characterisation coupled with eligible renovation		
Start month	4	**End month**	60

Objectives

The main objective of WP2 is to provide data for material properties and threshold values for historic building materials and existing insulation materials as a background for material characterisation models and guidelines for safe renovation measures.

Description of work and role of partners

WP2 - Material characterisation coupled with eligible renovation [Months: 4-60]
AAU, RTU, TUD, KU Leuven, UNIVPM, DTU, SP, HES-SO, IFLEX
The behavior of external walls of historic buildings after adding internal insulation depends on the properties of the historic building materials and the insulation materials and how the insulation materials are installed.

Determining numerous material properties for many materials would take long time. The work can be reduced with effective material characterisation models, as many properties can be calculated from such models. Furthermore, to be able to make risk assessments material characterisation models must be further developed to include modes of failure, based on material properties and failure mechanisms.

In WP2 existing material characterisation models are evaluated, refined and validated as such models are necessary to evaluate existing structures (Task 2.1), ensuring the longevity of the post-renovation structure. Building materials used in historic buildings are investigated as regards material properties (Task 2.2). Ultimate and serviceability limit state of the materials as a result of changed hygro-thermal conditions is determined based on material properties and characterization models (Task 2.3). This helps understand the quality and eligibility of the existing structures for installing internal insulation.

The participants of WP2 have laboratory facilities for materials testing. Developing a standard for testing procedures makes it possible to test specific materials in countries where they are mostly used. In depth testing e.g. in climate simulators will mainly be performed by the task leaders.

Task 2.1 Evaluation, refinement and validation of material characterisation models Lead: AAU
Participants: RTU, KUL, SP

Existing models for calculating the effect of adding internal insulation on the hygrothermal conditions of external walls are evaluated and compared. First step in hygrothermal material characterization is measuring material parameters in the laboratory (T2.2). However, to reduce the number of testing a material characterisation model is needed to evaluate existing structures and their eligibility for renovation measures, depending on type of measure and thermal insulation (e.g. characterised by the thermal conductivity of insulation material). Further it is needed for the risk assessment (WP4).

The material functions must be calibrated in order to describe the material's behaviour correctly. The material characterisation comprises a whole concept from single basic parameters up to simulation models. The current state material characterisation captures to some extent a number of important processes, such as a consistent description vapour and liquid water transport processes, the hysteresis of the moisture storage function and other effects. However, thermal insulation materials with fundamental different properties (e.g. capillary active or not) are new to the market and different building structures are mixed with different insulation materials. Some of these simulations show deviations from measurements. The project will gain relevant information on the required accuracy of the calculation results which has to be translated into performance requirements of the input data. Task 2.1 is carried out in close coordination with WP1 and the other tasks in WP2. The material characterisation models will be validated by subjecting them to series of on-site measured and fictional data (D2.1). Adjustments will be incorporated if necessary.

Task 2.2 Material property data for historic building materials
Lead: AAU
Participants: RTU, TUD, KUL, UNIVPM, DTU, SP, HES-SO, IFLEX

Evaluation and/or development of models for calculation and simulation of the hygrothermal effect of adding thermal insulation on external walls (T2.1, WP4) requires material property data. In T2.2 such data will be provided either by review of databases etc. or by conducting laboratory experiments under sufficiently controlled conditions (D2.1).

Significant parameters for building materials related to insulation of historic buildings will be defined. Priority is given to parameters which influence the hygro-thermal behaviour and service life of the building materials and are relevant as input data for calculation tools, e.g. the water uptake coefficients of façade materials exposed to wind driven rain. As minimum the following parameters will be included: density, thermal conductivity, sorption characteristics, water vapour permeability, and porosity. A review of e.g. simulation tools and data bases including previous EU projects on historical buildings will be made for obtaining material property data as such sources may contain relevant data on building materials used in historic buildings. Measurements in the laboratory, if necessary, concentrates on building materials used in heavy external walls of historic buildings made of stone, brick, timber framing etc. and joints with adjoining building elements.

This will include moisture content measurements of building materials, which have been subjected to different climate conditions and are simulated under controlled conditions in a laboratory. The laboratory tests for determination of the material properties should follow a certain standard procedure which has to be agreed and worked out during the project (D2.1). Aim is the consolidation and harmonization of testing procedures in order to reduce the inter-laboratory systematic errors. The expected benefit is a higher quality in hygrothermal material property measurements, a broader data basis and support of knowledge exchange. Furthermore, the standard procedure may later be described in the final guidelines to help users to gain sufficient data for simulating materials which have not been tested or simulated in the project.

Task 2.3 Limit and threshold for failure Lead: SP
Participants: AAU, KUL, UNIVPM, DTU

Before deciding whether external walls in a historic building is eligible for internal insulation it is necessary to point out the critical areas in the construction (based on the survey and screening performed in WP1)
- what can go wrong when installing internal insulation (failure modes based on WP1) the criticality at failure (risk assessment; WP4)
- Whether a specific construction has critical areas at certain external conditions depends on the composition of the construction. Therefore, the ultimate and serviceability limit state for different building materials will be determined under varying climate conditions based on laboratory measurements (controlled conditions e.g. bio-lab for testing of critical moisture conditions regarding mould growth) (D2.2). This activity should be seen together with the activities in WP4. Failure in the construction related to overrun of a limit state are related to those occurring as a result of changed hygro-thermal conditions in the structures as a result of introducing internal insulation. Failure is for instance expressed as freeze-thaw damage of stone and brick used for the external wall or mould growth or rot in wooden parts of a suspended floor that rest on the inner part of the external wall.
Threshold values for failure will be very important to develop decision guidelines for eligible renovation measures (WP6). Threshold values for failures related to the specific building materials need to be translated to threshold values for specific compositions of external walls as the inter-relation between the different building materials in external walls and the adjoining elements is one of the most important factors that determines whether internal insulation is possible and under which conditions. Threshold values for failure for specific composition of external walls need further to be developed into threshold values for the building as such, e.g. internal RH and temperature values, induced by the insulation intervention, as it often is difficult or even impossible to measure the conditions in the wall itself. Threshold values also need to be linked to types of building structure and thermal bridges.

Task 2.4: Impact of water repellent agents on hygric material properties
Lead: KUL
Participants: DTU, TUD, IFLEX, AAU

Following RIBuild's 'Report on historical building types and combinations of structural solutions' (deliverable D1.1), many of the structural damages experienced in relation to internal insulation are linked to moisture. Exemplary illustrations are frost spalling of the exterior brick, fungal decay of structural wooden elements, or mould growth at surfaces or interfaces. Moisture inside the internal insulation material may moreover reduce its thermal resistance, thus (partially) compromising the thermal retrofit that is intended. The harmful impacts of moisture on internally insulated walls are closely linked to the absorption of rain water at the exterior surface. When changes of the exterior appearance of the building are considered undesirable, then only water repellent agents can applied to limit this rain water absorption. Hydrophobisation should hence be regarded as a possible element in the spectrum of internal insulation solutions.

In order to include hydrophobisation in the hygrothermal performance simulations of WP4, in the life cycle assessments of WP5 and in the assessment tool development of WP6, the impact of water repellent agents on the moisture behaviour of (internally insulated) walls is to be evaluated. To that aim the changes in the basic hygric properties of building materials caused by the water repellent agents are to be quantified. Selected historic building materials from Task 2.2 are considered, as well as other relevant porous building materials, to widen the extent of the resulting findings. A representative range of water repellent agents is used, to obtain outcomes relevant for a wide range of products. Firstly, fully hydrophobised material samples are subjected to the characterisation procedure developed in Task 2.2, to measure the basic moisture storage and transport properties. Complementarily, the relation between the hydrophobisation protocol – manner of application, time of contact, temperature, … – and the impregnation depth of the water repellent agent is investigated, as the impregnation depth has an important influence on the drying behaviour. In a second step, the impact of the water repellent agents on the hygric properties is correlated to the penetration of the agent in the different pore ranges of the material, to enable generalisation of our findings on a limited set of building materials and water repellent agents. It can be considered to connect these pore penetration findings to the hygric property outcomes by means of pore-network modelling. In conclusion, the findings of the previous stages are validated by comparison of numerical and experimental results of drying tests on building materials. That final step will moreover form the transition to the inclusion of hydrophobisation in WP4, WP5 and WP6.

Participation per Partner

Partner number and short name	WP2 effort
1 - AAU	19.00
2 - RTU	9.00
3 - TUD	4.00
4 - KU Leuven	50.00
5 - UNIVPM	10.00
6 - DTU	10.00
7 - SP	16.00
8 - HES-SO	2.00
9 - IFLEX	4.00
Total	124.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D2.1	Report on material properties	1 - AAU	Report	Public	36
D2.2	Report on threshold values for failure	7 - SP	Report	Public	48
D2.3	Impact of water repellent agents on hygric properties of porous building materials	4 - KU Leuven	Report	Public	60

Description of deliverables

D2.1 : Report on material properties [36]

The deliverable includes: -# Material properties of building materials used in historic buildings -# Validated material characterisation models -# Standard laboratory procedure for determining material properties

D2.2 : Report on threshold values for failure [48]

The failure values will be linked to types of building structure and failure modes

D2.3 : Impact of water repellent agents on hygric properties of porous building materials [60]

The deliverable concerns an analysis of the impact of selected hydrophobisation agents on the hygric material properties of several porous building materials as well as an investigation of how to generalise the findings to the wide spectrum of historic and modern porous building materials.

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS5	Standard laboratory procedure for determining material properties	1 - AAU	36	D2.1
MS6	Validated material characterisation models	1 - AAU	36	D2.1
MS7	Material properties of building materials used in historic buildings	1 - AAU	36	D2.1
MS8	Threshold values for failure, linked to types of building structure and failure modes	1 - AAU	48	D2.2

Work package number [9]	WP3	Lead beneficiary [10]	3 - TUD
Work package title	Case studies and laboratory measurement		
Start month	4	**End month**	48

Objectives

The primary objective of WP3 is to support the research and development works in the project with high quality measurement data from both laboratory experiments and on-site monitoring of test buildings (case studies). Laboratory measurements are conducted under well controlled boundary conditions and on-site measurements in case studies reflect real scenarios. Both are needed to validate the concepts and models developed during the project.

The laboratory measurements will be driven by the industrial partner's product developments. The laboratory measurements are complementarily conducted by the research partners who have well developed research laboratories. The case studies will be selected and jointly operated by the research and industrial partners. The selection of the case studies aims at representation of different building styles and different climate zones across Europe.

Description of work and role of partners

WP3 - Case studies and laboratory measurement [Months: 4-48]
TUD, AAU, RTU, KU Leuven, UNIVPM, DTU, SP, IFLEX
The decision guidelines for probabilistic hygrothermal assessment of interior insulation solutions need to be worked out on the basis of high quality measurement data from laboratory experiments and on-site monitoring. Since models are used to support the development of decision guidelines, the laboratory experiments must comply with the model's modelling assumptions (e.g. non-isothermal, 3D, anisotropic).

The measurement strategy in the project scales up from smaller to larger units. The smallest unit is a single material test as planned under WP 2. The laboratory experiments under WP 3 focus on material composites, building constructions and components.

The monitoring concepts of the case studies will deliver relevant data on hourly or sub-hourly basis on critical boundary conditions (e.g. realistic internal and external climate conditions for dimensioning of insulation systems). In addition, they will deliver information on performance criteria of internal insulation systems under real use case scenarios (especially critical physical state quantities, as temperatures, heat fluxes, moisture contents and condensation at selected positions in constructional cross sections of test inhabited buildings).

Task 3.1 Design of appropriate laboratory test methods
Lead: TUD
Participants: AAU, RTU, KUL, DTU, SP, INTRO FLEX

Since material composites behave differently than single materials, it is planned to develop tests at different scales to control processes under well-defined boundary conditions. The experiments will be designed for testing of wall constructions retrofitted with internal insulation systems with variable constructions, materials and dimensions. Critical 2D/3D-building construction details need particular testing. The laboratory tests will be designed application of standard and extreme interior and exterior climates to the building's envelope construction. In order to have reference cases, the tests will include situations before and after renovation. In addition, physical processes need to be tested step-by-step in order to minimize overlapping influences. This means, that the laboratory tests need to start first at simple, abstract levels and go later up to more complex levels (e.g., first "academic" cases, later more realistic scenarios). The focus of the experiments will be on critical physical processes with high damaging potential, e.g. the water penetration into wooden beams with defined rain loads (D3.1) or the moisture accumulation due to convective air flows. The change of material dimensions due to hygrothermal shrinking and swelling will be an important side effect to be taken into account.

Task 3.2 Installation, test and operation of laboratory facilities
Lead: TUD
Participants: AAU, RTU, KUL, DTU, SP, INTRO FLEX

In parallel with the design phase of the experiments, the basic laboratory equipment of the participating partners needs to be completed, installed and tested. The basic equipment configuration will be available in the research laboratories according to the current scientific standards. Additional required equipment needs to be purchased on a case to case basis. All components, especially the sensors, need to be properly calibrated and tested. Measurements of relevant state variables (relative humidity, temperatures, moisture contents, heat flux, etc.) need be done at selected positions in the constructions. Therefore, the layout of the test facilities must include methodology how to place sensors properly with minimal impact on the measurement itself.

The hygrothermal climate conditions (temperature, moisture, air pressure) at the boundaries will be defined and adjusted either as constant or variable values. This requires well insulated rooms which allow well-controlled boundary conditions within the given limits. Suitable technology for providing adjusted climates needs to be tested and operated. The test specimens, which range from single material samples up to complete walls, are prepared for testing in co-operation between the industrial and academic partners. A well-tuned collaboration between scientific and industrial laboratories is here essential. In the result, the laboratory measurements will provide the necessary data for hygrothermal analysis of different processes (e.g. accumulation and redistribution of condensate, frost, durability, deterioration processes, etc.) (D3.1).

Task 3.3 Laboratory data evaluation, inverse analysis
Lead: TUD
Participants: AAU, RTU, KUL, DTU, SP, INTRO FLEX

In order to gain the expected knowledge from the laboratory measurements, a professional data management and post-processing needs to be applied. Appropriate laboratory standards need to be further developed, agreed and distributed among the partners. The behaviour of the material composites, building constructions and components can only be properly understood when the loop between laboratory experiments and model simulations is consistently closed. Heat, air and moisture flows are coupled hygrothermal processes. Therefore, the methodology for data evaluation involves also hygrothermal simulation of the conducted experiments. This allows inverse analysis of the process parameters. With the adjusted process parameters and the simulation models in combination, it will be possible to describe the measured processes at sufficient accuracy (calibration step). The validation step has succeeded, if the same processes under different boundary conditions can be predicted at sufficient accuracy. Then, a substantial contribution to the new knowledge on the safe dimensioning of internal insulation systems can be generated (D3.1).

Task 3.4 Selection and documentation of the test buildings
Lead: RTU
Participants: TUD, DTU, UNIVPM

The research activities in the project will be stimulated and accompanied by several case studies which will be selected and jointly operated by the research and industrial partners. The purpose of the case studies is testing of newly developed internal insulation systems under practical conditions. Case studies should be inhabited historical buildings which have been renovated and equipped with monitoring systems for measurement of the external local climate, indoor climate, user behaviour (operation of windows, shadings, setpoints of HVAC-systems) and hygrothermal response of the insulated walls. The selection of the case studies aims at representation of different building styles and different climate zones across Europe. Therefore, the case studies shall be conducted in different partner countries which represent different climatic conditions, different use case scenarios and different interventions. In order to streamline the process, a methodology will be formulated for selection of case-study buildings (D3.2). For example, TUD will contribute a building ensemble in the City centre of Weimar (D3.2). This consists of six historical buildings with preserved facades from the early 20th Century; each with 8-12 apartments. The basis of the case studies is a good documentation. In particular, proper documentation is needed on diagnosis including specification of materials and existing constructions, intervention needs, feasibility studies, and monitoring measures. The status of the post-intervention will also be documented in this way, which includes all structural changes to the building's design and their impact on the building's behaviour (D3.2). The methodology will consist of set of questions on buildings legal status, type and short assessment of structural elements, heat energy source type, heat energy consumption and heated floor area.

Task 3.5 Conceptual design, installation and operation of monitoring systems
Lead: TUD
Participants: RTU, DTU, UNIVPM

This task comprises the development and installation of monitoring concepts for measurement of all relevant building parameters at sufficient time resolution. Since the installation of the sensors has to be partly done in parallel with the renovation of the buildings (e.g. external walls), again, a well-tuned collaboration between scientific and industrial laboratories is essential. The insulation systems will be delivered by the industrial partners. The renovation of the buildings has to be co-ordinated with all involved partners. The measurements are done at hourly or sub-hourly time intervals according to the physical quantities (signals) to be measured. Monitoring concepts include the measurement of the local external weather conditions, the building's energy efficiency (energy demand/consumption status), the indoor climate; the occupants' and the building's envelope construction behaviour (e.g. critical construction details like thermal bridges, beam heads, etc.) The standard climate conditions in current regulations in Europe are not sufficient for a save dimensioning of internal insulation measures. Therefore, realistic boundary conditions need to be provided which allow the design of internal insulation systems with appropriate safety factors. The internal boundary conditions depend much on the user behaviour which has a stochastic nature. Therefore, stochastic physical quantities need to be packaged into applicable rules for development of new design guidelines. Especially, realistic internal moisture loads and air ventilation rates are of specific interest in this context. Similar to the laboratory experiments, the basic equipment of the participating partners needs to be completed, installed and tested. Additional required equipment needs to be purchased on a case to case basis. The measurements of relevant state variables need be done at selected critical positions in the construction. The methodology how to place sensors with minimal impact on the measurements can be adapted from the laboratory.

Task 3.6 Monitoring data collection and analysis, evaluation of insulation systems
Lead: TUD
Participants: RTU, DTU, UNIVPM

The monitoring data from the test buildings will be compiled in data bases by help of specially developed software which provides pinpoint consolidation and scientific analysis. The raw data needs to be checked on consistency, plausibility and correctness. In order to detect sensor outages, the data must have individual validity periods and outliers must be automatically eliminated. Consistent generation of data at equidistant time intervals must be provided for convenient and error-free analysis and visualisation. However, measured data can be wrong. The sources of measurement errors can be manifold. Therefore, the monitoring campaign needs to be accompanied by simulations. Correct conclusions are only possible on the basis of a good agreement of both, monitoring and simulation data. This will lead to a sound evaluation of the applied insulation systems and a certified quality assurance. The conclusions will be compiled as recommendations for future building projects (pre-normative work and guidance development) (D3.2).

Participation per Partner

Partner number and short name	WP3 effort
1 - AAU	8.00
2 - RTU	20.00
3 - TUD	31.00
4 - KU Leuven	16.00
5 - UNIVPM	11.00
6 - DTU	18.00
7 - SP	8.00
9 - IFLEX	10.00
Total	122.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D3.1	Closed technology loop of laboratory experiments and simulation models in the field of internal insulation testing	3 - TUD	Report	Public	36
D3.2	Monitoring data basis of European case studies	3 - TUD	Report	Public	48

Description of deliverables

D3.1 : Closed technology loop of laboratory experiments and simulation models in the field of internal insulation testing [36]

An iterative approach are used to fit measured data, where a series of lab experiments and numerical simulations are done in parallel for each material

D3.2 : Monitoring data basis of European case studies [48]

Including sound performance evaluation of internal insulation systems under different realistic boundary conditions

Schedule of relevant Milestones

Milestone number[18]	**Milestone title**	**Lead beneficiary**	**Due Date (in months)**	**Means of verification**
MS9	Design of tests at different scales in order to control hygrothermal processes under defined laboratory boundary conditions	3 - TUD	12	D3.1
MS10	Measurements of hygrothermal processes which lead to accumulation and redistribution of condensate, frost, durability loss, deterioration	3 - TUD	24	D3.1
MS11	Proper understanding of hygrothermal behaviour of the material composites, building constructions and components	3 - TUD	36	D3.1
MS12	Methodology for selection of case-buildings for full-scale tests	3 - TUD	12	D3.2
MS13	Documentation on materials and existing constructions, intervention needs, feasibility studies, and monitoring measures of test buildings	3 - TUD	12	D3.2
MS14	Development and installation of monitoring concepts for measurement of all relevant building parameters	3 - TUD	36	D3.2
MS15	Sound evaluation of the applied insulation systems and a certified quality assurance	3 - TUD	48	D3.2

Work package number [9]	WP4	Lead beneficiary [10]	4 - KU Leuven
Work package title	Probabilistic assessment of interior insulation solutions		
Start month	3	**End month**	48

Objectives

The key target of WP4 is the development of an efficient strategy for the probabilistic hygrothermal assessment of interior insulation solutions.

Description of work and role of partners

WP4 - Probabilistic assessment of interior insulation solutions [Months: 3-48]
KU Leuven, AAU, TUD, HES-SO
Van Gelder et al. recently presented a comprehensive methodology for probabilistic hygrothermal assessment, but its application to interior insulation solutions requires further developments with relation to its numerical efficiency. At present, the computational costs of such assessment of interior insulation solutions would far exceed the time restraints of this research project.
Such probabilistic hygrothermal assessment can indeed only be managed via numerical simulation, since a multitude of scenarios need to be judged quickly and cheaply. WP4 is however founded on the experimental characterisation of buildings and materials performed in WP1, WP2 and WP3, and will furthermore be validated experimentally through the case studies included in WP3.
The currently available methodology revolves around Monte-Carlo-based repetitions of heat, air and mois- ture transfer simulations, and the developments towards an efficient strategy cover both fields. Tasks 4.1 and 4.2 relate to the efficient one-, two- and three-dimensional simulation of heat, air and moisture transfer in built structures, Tasks 4.3 and 4.4 connect to the probabilistic assessment of hygrothermal performances based on these simulations. In a final Task 4.5, the developments of Tasks 4.1 to 4.4 will be brought together in an application example.
TU Dresden (TUD) is the main developer of the Delphin environment for the hygrothermal simulation of building components, and they will as such take the lead in Task 4.1, which relates to the further perfection of the Delphin environment. The KU Leuven (KUL) is one of the main coordinators as well as contributors to the currently ongoing IEA Annex 55 on the theme of probabilistic hygrothermal assessment. They will thus take up Tasks 4.2, 4.3 and 4.4. In the last Task 4.5, TUD, and KUL, together with AAU and HES-SO will collaborate toward a number of final exemplary applications, as inspiration and methodology for the widespread application in WP6.
Task 4.1 Numerical efficiency of hygrothermal simulation
Lead: TUD
Currently, the one- and two-dimensional simulation of heat, air, moisture transfer in built structures can be considered state-of-the-art, and several research and engineering models with this capability are available. A dependable hygrothermal evaluation of interior insulation solutions does however require three-dimensional capability, to e.g. study the impact on embedded wooden beam ends. As these three-dimensional simulations notably inflate the computational load, numerical efficiency developments are an intrinsic complementary prerequisite. Since the Delphin simulation environment – developed by TUD – presently sits at the apex of simulation efficiency, physical reliability and user friendliness, the developments focus on this tool.
Major necessary improvements involve extension of the physical and geometrical model that forms the basis of Delphin. With respect to the latter, pre- and post-processing procedures are to be adapted to support three-dimensional geometries and related model specifications. In relation to the former, integration and simulation of three-dimensional air flow paths and incorporating ice formation probability models for assessment of frost damage risks are envisaged.
The extension towards three-dimensional transient simulation models complementarily necessitates optimisation of the numerical solution procedures. Substitution of direct equation system solvers by iterative methods (GMRES, BiCGStab, ...) with suitable preconditioners (ILU, SSOR, ...) is mandatory to achieve an acceptable computational performance. Further improvements will be evaluated, for example block-based matrix algorithms and parallel solver implementation, in order to attain an even better numerical efficiency (D4.1).

Task 4.2 Reduced-order models in hygrothermal simulation
Lead: KUL
Even after numerical optimisation, conventional hygrothermal simulation will still require substantial computational efforts, due to the relatively fine spatial and temporal discretisation of the relatively large calculation domain, caused by the strongly transient and non-linear nature of the issue at hand. In Task 4.2, further efforts in relation to

numerical efficiency focus on external measures, in particular reduced-order- modelling, which aim at replacing highly-dimensional problems with a lower-dimensional model, in order to decrease the computational effort (D4.1).
Within the framework of this research project, both a posteriori and a priori methods are evaluated. An a posteriori method, like proper orthogonal decomposition, needs an initial solution to build the reduced order model. Two extension approaches are gauged: from an initial solution covering only a short time interval to a reduced-order-model for simulations of longer time intervals, and from an initial solution covering a long time interval to a reduced-order model applicable for differing boundary conditions and/or material properties. Both methods can be beneficial in combination with the probabilistic assessment. A major disadvantage of these a posteriori methods is the need for an initial solution, which is not required by a priori methods like proper generalised decomposition. Therefore, these techniques are equally examined. In this approach, the solution is assumed to be a sum of a number of tensorial products of unidimensional functions, which are initially not known. Starting from an initial function that satisfies the boundary and initial conditions, extra 'modes' are developed via iterative enrichment, until the residual deviation is assumed negligible.

Task 4.3 Sequential sampling in probabilistic assessment
Lead: KUL
Typically, the probabilistic assessment of hygrothermal performance requires application of Monte Carlo, a repeated execution of a deterministic simulation with differing parameters, due to the non-linear and transient nature of hygrothermal transfer processes. Such repeated simulation comes at a significant computational cost: restricting the number of needed repetitions is thus a must. A sequential sampling strategy with a convergence monitoring approach was proposed, however based on the iterative addition of blocks of repetitions.
This approach is further developed to arrive at a genuine sequential sampling approach, wherein additional repetitions can be added one by one until sufficient convergence of the Monte Carlo results is obtained. This requires the development of sequential sampling sequences derived from optimal Latin Hypercubes as well
as the formulation of a convergence monitoring technique based on error estimates of the progressive Monte Carlo results (D4.2).

Task 4.4 Surrogate modelling of hygrothermal performance
Lead: KUL
While efficient numerical solvers, reduced-order-models and sequential Monte-Carlo sampling are all already contributing to an efficient strategy for probabilistic assessment of hygrothermal performance, a final angle at improving numerical efficiency is the application of surrogate models. The applicability of simpler metamodels to replace complex original models was demonstrated63, but additional developments can further enhance their benefits.
A first option that is assessed is the development of dynamic neural network models, which are currently applied for forecasting of transient phenomena. Static neural networks have been successfully applied, but they lack in versatility and flexibility for highly transient or non-linear phenomena. In this development, the particular complexity of the parameterisation of climate variables in weather data sets is also investigated, to allow integration of climate dependencies in the surrogate modelling of hygrothermal performance.
Complementarily, this task builds upon the reduced-order-models of Task 4.2, by investigation of a potential relation between the stochastic simulation parameters and: 1) the snapshots from an initial solution used in a posteriori approaches or 2) the modes identified in the iterative enrichment procedure in a priori methods (D4.2). If such relation exists, then it can be exploited to facilitate the Monte-Carlo-based probabilistic assessment even further.

Task 4.5 Exemplary application on internal insulation case
Lead: KUL
Participants: AAU, TUD, HES-SO
WP6 targets a comprehensive comparative assessment of internal insulation solutions based on life cycle cost, combining the probabilistic assessment of hygrothermal performance developed in WP4 with the quantification of life cycle costs of internal insulation's benefits and damages formulated in WP5. To support the application of the WP4 techniques in such holistic evaluation, an illustrative application forms the concluding element of this work package. In this example, a number of internal insulation solutions for external walls with embedded wooden beams, openings in the building envelope such as windows and doors etc., are evaluated via the developed probabilistic hygrothermal assessment strategy (D4.2). Initial three-dimensional simulations are performed with the model resulting from Task 4.1, serving as input to and validation of the reduced-order-models stemming from Task 4.2. These reduced-order-models form the deterministic core of a Monte-Carlo-based probabilistic simulation succession, further enhanced by surrogate modelling based on reduced-order-modelling and climate parameterisation. This application example is to facilitate the integration with the life- cycle-costing of WP5 and the implementation of the overall methodology in WP6.

Participation per Partner

Partner number and short name	WP4 effort
1 - AAU	8.00
3 - TUD	16.00
4 - KU Leuven	72.00
8 - HES-SO	4.00
Total	100.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D4.1	A methodology for the efficient hygrothermal assessment of building components	4 - KU Leuven	Report	Public	36
D4.2	A methodology for the efficient probabilistic evaluation of building performances	4 - KU Leuven	Report	Public	36

Description of deliverables

D4.1 : A methodology for the efficient hygrothermal assessment of building components [36]
Based on direct three-dimensional simulations and indirect reduced-order-modelling approaches

D4.2 : A methodology for the efficient probabilistic evaluation of building performances [36]
Based on direct sequential-sampling methods and indirect surrogate-modelling techniques

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS16	A methodology for the efficient hygrothermal assessment of building components, based on direct three-dimensional simulations and indirect reduced-order-modelling approaches	4 - KU Leuven	36	D4.1
MS17	A methodology for the efficient probabilistic evaluation of building performances, based on direct sequential-sampling methods and indirect surrogate-modelling techniques	4 - KU Leuven	36	D4.2

Work package number [9]	WP5	**Lead beneficiary [10]**	5 - UNIVPM
Work package title	Development of cost/benefit and environmental impact assessment		
Start month	13	**End month**	42

Objectives

The objective of WP5 is to develop a probabilistic assessment methodology of the environmental impact and costs/ benefits of internal insulation solutions, based on Life Cycle Impact Assessment (LCA), Life Cycle Cost (LCC) and Cost-Optimal (CO) analysis.

Description of work and role of partners

WP5 - Development of cost/benefit and environmental impact assessment [Months: 13-42]
UNIVPM, AAU, RTU, DTU, HES-SO
Cost analysis (LCC) and Cost-Optimal (CO) levels of minimum energy performance calculation are not sufficient to correctly assess variations in energy use, environmental impact and costs/benefits related to functional performance of retrofitting measures in existing buildings. Actually, the environmental and economic impact due to performance variations and performance failure of building materials is not adequately considered.
Furthermore numerous uncertainties on the input data necessary for the analysis (such as the embodied energy of the materials, the durability of components, the market rates …) have strong influence on the results.
WP5 develops a probabilistic assessment methodology based on LCIA, LCC and CO analysis, able to take into account all the uncertainties related to the prediction of the variable involved. In particular, the impact of uncertainty on the performance, as the probabilities of benefits (reduced heat loss and energy consumption) and damages (deterioration due to mould growth, moisture damage …) of insulating solutions calculated in previous WPs, will serve as input to the LCIA, LCC and CO analysis. The work of WP5 will be carried out in three tasks. In the first task 5.1, all the participants will evaluate the energy saving potential of the insulation measures in the historic case-buildings selected in WP3. These data will be useful for the development of LCIA methodology in task 5.2 and its implementation and for LCC analysis in task 5.3. UNIVPM will coordinate the whole WP and particularly Tasks 5.2 and 5.3.
The effectiveness of the methodology developed will be validated in WP6 based on the functional performance of historical buildings retrofitted by internal insulation solutions (case studies of WP3).
Methods based on probability will provide important support for building retrofitting strategies and ensure an improvement in the prediction of energy performance, environmental impact, and cost benefits.

Task 5.1 Evaluation of the energy saving potential of interior insulation solutions depending on building practice
Leader: AAU
Participants: RTU, UNIVPM, DTU, HES-SO
In this task, dynamic energy simulations will be carried out historic buildings used as case studies in WP3.
Thanks to their expertise in building energy efficiency and as directly participating to the monitoring activities on the case-buildings selected in WP3, RTU, UNIVPM and DTU will analyse energy and thermal data of the case-buildings, in order to provide the potential energy saving of the internal insulation measures implemented. AAU and HES-SO, experts in building simulations, will then evaluate the potential energy saving [kWh/m2*year] and the comfort indoor (mean radiant temperature, relative humidity) induced by the implemented insulation strategies also varying their typology and thickness and depending on buildings typologies, features, uses, and climate conditions. As coordinator of this task, AAU will collect results that will be useful as input data for Tasks 5.2 and 5.3.

Task 5.2 Probabilistic Life Cycle Impact Assessment (LCIA) of the environmental impact of interior insulation solutions
Leader: UNIVPM
Participants: AAU, DTU, HES-SO
Life Cycle Impact Assessment (LCIA) is the most common and recognized method to determine the environmental burden of products and services. Several eco-design approaches and tools have been proposed and developed in recent years, but there is no defined methodology for LCIA of building renovation interventions. The methodology will be compliant with the state of the art approaches already existing for new buildings, but which need to be adapted for historical buildings renovation. Furthermore, in LCIA, the huge amount of data to be considered is subject to very many factors of uncertainty.
In Task 5.2, a probabilistic LCIA methodology based on Monte Carlo methods will be implemented by UNIVPM and HES-SO, who have considerable experience in the field, in order to account for uncertainties on all the necessary data on raw material extractions, energy acquisition, materials production, manufacturing, use, ultimate disposal or recycling

(D5.1). In the first phase of the WP, a so-called life cycle inventory (LCI) will be compiled, in order to calculate, as well as to interpret, indicators of the potential impacts of the natural environment on the insulation components. LCI will be performed to select the proper parameters that significantly influence the life cycle of the components and define the probability distribution functions of the inputs for the LCA of the insulation strategies. Secondly, the actual LCA of the buildings renovated in WP3 will be implemented in terms of embodied energy (at component scale) and operating energy (at global scale). The first one is sequestered in building materials during all processes of production, on-site construction, and final demolition and disposal, while the second one is required for indoor heating and cooling, lighting, and operating appliances.
Data on the operating energy of the buildings induced by the implemented insulation solutions will be obtained from Task 5.1 based on dynamic simulations on the historic buildings renovated in WP3.
All participants to this task (UNIVPM, AAU, DTU, HES-SO), highly competent in traditional LCIA methodologies, will then apply the new probabilistic LCIA methodology implemented to one among the selected buildings.
According to ISO 14040, results of this task will be presented in terms of functional unit (FU). FU is adescriptor or measure of the service or function performed by the material/product system under consideration. The purpose is to allow for the comparison of equivalent components. A FU suggested for insulation components is defined as mass (kg) of insulation material needed to cover an area (m2) providing an average thermal resistance (m2K/W) for a certain building service life (years).

Since the design of a product strongly predetermines its behaviour in the subsequent phases (included life cycle), Task 5.2 aims also to identify some specific methodological choices and outlies alternatives, where relevant, that can be adopted during the design phase of any internal insulation strategy.

Task 5.3 Probabilistic Life Cycle Cost (LCC) analysis and Cost-Optimal (CO) levels of minimum energy performance of interior insulation solutions Lead: UNIVPM
Participants: DTU, HES-SO
The importance of the determination of Cost-Optimal (CO) levels of minimum energy performance requirements for buildings is well established by European Directive 2010/31/EU on the energy performance of buildings (recast). The consequent Regulation (EU) No 244/2012 sets a comparative methodology framework for calculating Cost-Optimal levels, based on UNI EN 15459:2008. Nevertheless accurate Cost Analysis rely on quality of data. Unfortunately, data uncertainty is a well- recognised issue associated with deterministic calculation methods.
Uncertainties may be resulted from many cost items involved in a LCC analysis such as initial costs, maintenance costs and electricity rates and have a strong impact on results.
Thanks to the expertise of UNIVPM in the field with the significant contribution of HES-SO, Task 5.3 will develop a probabilistic method for LCC and CO analysis based on Monte Carlo simulation to account for data uncertainties through probability distribution functions (D 5.2). All the participants to this task will then apply the methodology on the case-buildings of WP3.
In general, LCC in term of Net Present Value (NPV) can be expressed as the sum of the initial, operation, maintenance, replacement and residual cost of a system under study. The analysis will particularly take into account:
- the probability distribution of uncertainties over the initial costs related to internal insulation solutions;
- the probability distribution of operation costs, related to the building energy performance with different internal insulation solutions and to the cost of energy;
- the probability distribution of replacement and maintenance costs related to the insulation functional performance and risk of failure (as determined in WP2 and WP4).
The potential energy saving induced by the implemented insulation measures will be obtained from Task 5.1, based on dynamic simulations on the historic buildings renovated in WP3.
Finally, the probability distribution of cost-optimal levels of the insulation strategies analysed in WP1, WP2 and WP4 will be determined, in order to find their cost-effective impact, also by varying their typology and thickness.
Durability and hygrothermal-related functional performance and their impacts on variations in Cost-Optimal levels of minimum energy performance will be particularly featured with the contribution of DTU.

Participation per Partner

Partner number and short name	WP5 effort
1 - AAU	11.00
2 - RTU	4.00
5 - UNIVPM	28.00

Partner number and short name	WP5 effort
6 - DTU	15.00
8 - HES-SO	10.00
Total	68.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D5.1	Report and tool: Probability based Life Cycle Impact Assessment	5 - UNIVPM	Report	Public	36
D5.2	Report and tool: Probability based Life Cycle Cost	5 - UNIVPM	Report	Public	42

Description of deliverables

D5.1 : Report and tool: Probability based Life Cycle Impact Assessment [36]
Includes energy saving potential of the internal insulation measures

D5.2 : Report and tool: Probability based Life Cycle Cost [42]
includes Cost-Optimal levels of the internal insulation measures

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS18	Sets of data on the energy performance of the alternative insulation strategies, depending on buildings typologies, features, uses, climate conditions	5 - UNIVPM	30	D5.1
MS19	Report on the energy saving potential of interior insulation solutions depending on building practice	5 - UNIVPM	30	D5.1
MS20	Report and tool: Probability based Life Cycle Assessment of the internal insulation solutions	5 - UNIVPM	36	D5.1
MS21	Report and tool: Probability based Life Cycle Cost and Cost-Optimal levels of the internal insulation solutions	5 - UNIVPM	42	D5.2

Work package number [9]	WP6	**Lead beneficiary [10]**	6 - DTU
Work package title	Application and evaluation of assessment tools		
Start month	25	**End month**	58

Objectives

The objective of WP6 is to develop and to assess a methodology and guidelines for a renovation of historic buildings with internal insulation, based on the methodologies developed in WP4 and WP5. The purpose of these guidelines is to help decision making regarding e.g. whether internal insulation is relevant at all or not, and whether it is affordable to make a detailed calculation and which parameters or part of the construction that should be paid special attention to in the specific case. Due to the complexity and many potential risks and uncertainties of applying internal insulation there is a need for practical guidelines that are simple in relation to what to do when internal insulation is to be considered in a specific situation. Some manufactures of insulation materials and systems do have some simple guidelines but there is a need for neutral, non-product-specific and comprehensive guidelines.

The applicability of the methodology and the guidelines is evaluated and validated on demonstration projects, where the methodology is used as a basis for decision making to optimise the design and implementation of internal insulation to increase the energy efficiency of and comfort in historic buildings in an economical and environmental friendly way.

Description of work and role of partners

WP6 - Application and evaluation of assessment tools [Months: 25-58]
DTU, AAU, RTU, TUD, KU Leuven, UNIVPM, SP, HES-SO, IFLEX, EMA
This WP6 will involve all partners as the findings and results of previous WP's are in WP6 condensed to the applicable guidelines for improving energy efficiency and comfort in historic buildings. DTU is the leading partner together with EMA, an architectural design office specialized in retrofitting historic and cultural heritage buildings. Main partners from WP4 and WP5 give the essential input in form of the use of the probabilistic methods in WP6.1. All partners are involved in the demonstration activity and evaluating the methodology to ensure the comprehensive feedback and evaluation.

Task 6.1 Development of assessment methodology and guidelines for internal insulation based on probabilistic models.
Lead: DTU
Participants: All, except INTRA FLEX

One of the main challenges of any holistic approach for a building renovation is how to simultaneous assess widely different (physical, environmental, social, economical, cultural, aesthetical, etc.) parameters. The main scope of this task is to combine the probabilistic methods developed in WP4 and WP5 and end up with comprehensive decision making guidelines which take into account the complexity of the parameters. An important part of the scope is the implementation of the risk assessment; The guidelines will therefore be based on the different risks if and when implementing internal insulation; it can go wrong both at the internalside (dampness, mould growth), inside the wall (interstitial condensation and decay of wooden constructions, reduction of thermal insulation) and at the outside (algae growth, frost damages).

The focus in the probabilistic methods developed in WP4 and WP5 is on setting up the methodology for assessment of the thermal envelope of historic buildings and the improvement og it in the context of hygrothermal performance (WP4) and in the context of environmental impact and life cycle economy (WP5). WP6 takes the next step in this assessment and has the aim of combining these contexts to a common methodology and a set of guidelines usable for building designers, owners etc. The impact of various possibilities for improved energy-efficiency and comfort by adding internal thermal insulation without adversely affecting their architectural and historic value, the risk for degradation of the building envelope and the indoor environment will be assessed, including the overall environmental impact and life cycle economy. The work in Task 6.1 builds on the state-of-art approaches for holistic assessment methods and guideline design.The goal is achieved by creating comprehensive guidelines for comparative assessment of internal insulation solutions based on life cycle cost, combining the probabilistic assessment of hygrothermal performance developed in WP4 with the quantification of life cycle costs of internal insulation's benefits and damages formulated in WP5.

The resulting methodology will be formed as guidelines to be used in the decision making in the pre-renovation phase and practical guidelines about how to do it: #
- Guideline for determining whether a building is suitable for internal insulation or not
- Guideline for standardised simulation and testing methodology

- Guideline with a catalogue of possible internal insulation renovation measures; different solutions depending on the construction type, climate etc.
- Guideline for evaluating the energy saving potential and the environmental impact
- Guidelines will also include evaluation criteria.

The resulting guidelines will be demonstrated and validated in Task 6.2 and T6.3.

Task 6.2 Demonstration of the methodology and the guidelines
Lead: EMA
Participants: All

The applicability of the guidelines developed in previous subtask (T6.1) will be demonstrated in this subtask. The methodology will be applied to real cases, i.e. selected historic buildings to be subject for a refurbishment. This demonstration will be conducted in close collaboration with consulting engineers, architects, building owners and users. The purpose is to illustrate the challenges throughout a typical project course for improving an existing building, in addition to the focus in previous WP's: how to - include users in decision making, - minimise genes for users, - prove future maintenance, - etc.

The needed input for the holistic assessment method will be collected for the demonstration cases based on WP2 and WP3 (e.g. building typology, material data including environmental impact and cost, etc)Even though the focus in this approach is on internal insulation, it is important to emphasize that a "real holistic" approach includes also involves other measures, like improving windows, HVAC installations, energy supply etc. However, the focus is on the specific challenges related to historic buildings: They can be listed or have very special appearance including non-standard details and materials. The validation of the methodology is performed in subtask T6.3 on the basis of this demonstration approach.

Task 6.3 Validation and assessment of the methodology and the guidelines
Lead: DTU
Participants: All

The effectiveness and suitability of the methodology and guidelines developed in T6.1 as decision making tools will be validated in this subtask. The focus is on the assessment of the impact on reduction of the energy use, life cycle cost and the environmental impact, while increasing values like indoor climate, architectural aesthetics etc. The methodology and the means of the internal insulation will be evaluated in the whole building performance context and other measures for improving it. The final validation criteria of the method is defined and applied in this subtask. As the guidelines should reflect and describe the risks and the benefits of internal insulation across different building typologies, local building contexts, geographical locations and climatic conditions, the methodology will be validated and tested for its replicability. The importance of including project delivery and continuous commissioning strategies and user impact in the guidelines is evaluated, as well. The overall scope of this task is to prove that the developed methodology will provide important – but still today missing – support for building retrofitting strategies and ensure an improvement in the prediction of energy performance, environmental impact, costs benefits, etc. in a consistent, applicable, user friendly and replicabale way – and that it facilitates a deep impact.

Participation per Partner

Partner number and short name	WP6 effort
1 - AAU	6.00
2 - RTU	6.00
3 - TUD	10.00
4 - KU Leuven	20.00
5 - UNIVPM	10.00
6 - DTU	19.00
7 - SP	6.00
8 - HES-SO	12.00
9 - IFLEX	10.00

Partner number and short name	WP6 effort
10 - EMA	12.00
Total	111.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D6.1	Assessment Methodology	6 - DTU	Report	Public	56
D6.2	Risk assessment guidelines for insulation of historic buildings	6 - DTU	Report	Public	58
D6.3	Evaluation of methodology	6 - DTU	Report	Public	58

Description of deliverables

D6.1 : Assessment Methodology [56]

Methodology of assessment of the performance of internal insulation of historic buildings

D6.2 : Risk assessment guidelines for insulation of historic buildings [58]

Guidelines for determining whether a building is suitable for internal insulation or not, with a catalogue of possible renovation measures, and for evaluating the energy saving potential and the environmental impact

D6.3 : Evaluation of methodology [58]

includes guidelines and their impact on performanceof historic buildings.

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS22	Methodology for assessment of the performance of internal insulation of historic buildings	6 - DTU	56	D6.1
MS23	Risk assessment guidelines for insulation of historic buildings	6 - DTU	58	D6.2
MS24	Evaluation of the methodology and guidelines and their impact on performance of historic buildings	6 - DTU	58	D6.3

Work package number [9]	WP7	Lead beneficiary [10]	1 - AAU
Work package title	Communication and dissemination		
Start month	1	**End month**	60

Objectives

The objective of WP7 is, first to communicate those results of the project that are relevant to public authorities, building owners, consulting engineers and other professional practitioners within the construction industry in the Member States, secondly to spread the results among international academics. The ultimate goals are to improve knowledge among practitioners about when internal post-insulation is an adequate measure in historic buildings and by which methods, and to further research in the field by pointing out yet uncovered issues of importance to society and business. Also, it is desirable if some of the research results can be used in industry's innovation of new products and methods.

Description of work and role of partners

WP7 - Communication and dissemination [Months: 1-60]
AAU, RTU, TUD, KU Leuven, UNIVPM, DTU, SP, HES-SO, IFLEX, EMA
WP7 holds track of and coordinates the overall communication of the RIBuild project. A project communication plan will be drafted and executed. Project communication activities will be monitored. Furthermore, WP7 will hold track of the dissemination activities of RIBuild. AAU will lead WP7. All the participants of RIBuild are involved to ensure a thorough communication of the findings of the project through their existing networks of professional practitioners and academics.

Task 7.1 Communicating with professional practitioners Lead: AAU
Participants: All

Some of the project's results will be relevant to public authorities, building owners, consulting engineers etc., and others will not. The first job is to select which results should be given priority and to decide how to communicate these effectively, as this is expected to vary considerably depending on the nature of the specific results. The lead of this subtask will set up procedures to ensure that all results are properly handled in this respect. The procedure will include the use of internal communication professionals who are experienced in building research communication (D7.1). It is expected that the most effective method to communicate the project's research results goes through networks that the target audience are already used to use when searching for new knowledge on energy upgrading and building renovation. These networks are constituted by national organisations, trade media and public authorities. Thus, it is an important job to map these networks (D7.2) and to engage in partnerships with institutions with well-established relations to the different groups of professional practitioners (D7.3). The project will deliver knowledge to these networks of communication partners, who – on their side – will benefit from communicating useful results to their audiences. One of the measures for this is the production and distribution of information kits including text, illustrations, fact sheets and instructive videos (D7.4). Another measure is to offer the partners relevant lectures at their seminars and conferences. Rather than developing and promoting new media and events dedicated for the project, the project aims to connect with existing media and events arranged by local partners.

There will be three phases in Task 7.1: #
1) The first phase will consist of establishing working procedures and organisation, mapping potential national partners, forming the partner network and warming up for the research results. This phase will end up with a common seminar (D7.5) where the project is presented and the expected implications are discussed.
2) The second phase will consist of a gradually intensifying screening and communication of the research results in collaboration with the national communication partners.
3) The third phase will consist of final communication of the more conclusive results. This phase will end up with a common conference (D7.5) where the conclusive results are presented and discussed.

Task 7.2 Spreading results among international academics Lead: AAU
Participants: RTU, TUD, KUL, UNIVPM, DTU, SP, HES-SO

The project is expected to result in a large amount of new knowledge of interest to at least three different groups of the international academic community: #
- those who do research on building physics (heat, moisture, air tightness and thermal insulation)
- those who do research on energy efficiency of buildings
- those who do research on refurbishment and maintenance of buildings worth of preservation.

Results of the project will be spread among all three groups by publishing in scientific journals such as 'Journal of Building Physics', 'Energy and Buildings' and 'Journal of Architecture'. Moreover, results of the project will be presented at international scientific conferences, such as 'Nordic Symposium of Building Physics', 'Durability of Building Materials and Components', CIB W086 Building Pathology (D7.6).

Task 7.3 General project communication
Lead: AAU
Participants: All

For the purpose of external as well as internal communication of the progression of the total project, there will be a project website, continuously updated with actual status of the ongoing research projects and their communication (D7.8). The website will be used for both internal communication among the researchers of the project and for external communication with the network of communication partners. At the website there will also be templates for reporting etc., project descriptions, press material etc. As part of the general project communication at least two press releases will be issued: One about the start of the research project and another about the conclusive results (D7.9 and D7.10). The press releases will be possible to adjust for national distribution.

Participation per Partner

Partner number and short name	WP7 effort
1 - AAU	19.00
2 - RTU	3.00
3 - TUD	3.00
4 - KU Leuven	4.00
5 - UNIVPM	3.00
6 - DTU	3.00
7 - SP	3.00
8 - HES-SO	3.00
9 - IFLEX	3.00
10 - EMA	3.00
Total	47.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D7.1	Procedure for evaluating research results	1 - AAU	Report	Public	6
D7.2	Mapping of networks	1 - AAU	Report	Public	6
D7.3	Formation of network partnerships	1 - AAU	Report	Public	6
D7.4	Information kit on project results	1 - AAU	Report	Public	60
D7.5	Report on first workshop/ seminar	1 - AAU	Report	Public	12

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D7.6	Report on final conference	1 - AAU	Report	Public	60
D7.7	Report on jounal and papers	1 - AAU	Report	Public	60
D7.8	Project website	1 - AAU	Websites, patents filling, etc.	Public	3
D7.9	First press release on the project	1 - AAU	Report	Public	6
D7.10	Final press release on the project	1 - AAU	Report	Public	60

Description of deliverables

D7.1 : Procedure for evaluating research results [6]

in terms of relevance to practice

D7.2 : Mapping of networks [6]

Maps of Member States' relevant professional networks

D7.3 : Formation of network partnerships [6]

Engagement in partnerships with institutions with well-established relations to the different groups of professional practitioners

D7.4 : Information kit on project results [60]

Production and distribution of a number (>5) of information kits on basis of the project's results

D7.5 : Report on first workshop/seminar [12]

The consortium will arrange at least one workshop/seminar at the beginning and one conference at the end of the project

D7.6 : Report on final conference [60]

The consortium will arrange at least one workshop/seminar at the beginning and one conference at the end of the project

D7.7 : Report on jounal and papers [60]

The consortium aims at producing a number (>20) of journal and conference papers throughout the project lifetime.

D7.8 : Project website [3]

The website will include templates for reporting, project descriptions, press material etc.

D7.9 : First press release on the project [6]

The consortium aims at producing at least two press releases on the project - one at the beginning of the project and one at the end.

D7.10 : Final press release on the project [60]

The consortium aims at producing at least two press releases on the project - one at the beginning of the project and one at the end.

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS25	Procedure for evaluating research results in terms of relevance to practice	1 - AAU	6	Appendix to D0.3 and D0.4
MS26	Map of Member States' relevant professional networks	1 - AAU	6	Appendix to D0.3 and D0.4
MS27	Formation of network partnerships	1 - AAU	6	On website
MS28	Production and distribution of a number (>5) of information kits on basis of the project's results	1 - AAU	60	D7.1
MS29	At least one workshop/ seminar at the beginning and one conference at the end of the project	1 - AAU	60	D7.2
MS30	A project website with templates for reporting, project descriptions, press material etc.	1 - AAU	3	Hyperlink
MS31	At least two press releases on the project	1 - AAU	60	Copies

Work package number [9]	WP8	Lead beneficiary [10]	1 - AAU
Work package title	Project management		
Start month	1	**End month**	60

Objectives

WP8 will form the basic management framework and has the following objectives:
-# Scientific, financial, contractual, ethical and legal coordination through all project phases, including monitoring of progress, risks and reporting.
-# Establish and maintain an effective project administration for RIBuild throughout all project phases.
-# Establish and maintain an effective communication and knowledge sharing infrastructure.
-# Ensure co-ordination with cluster activities and related projects.

Description of work and role of partners

WP8 - Project management [Months: 1-60]
AAU
The Project Coordinator has the overall responsibility of managing the project. He will be supported by a professional Administrative Manager to form the External Expert Advisory Board (EEAB). The Project Coordinator and the Administrative Manager will, when relevant, draw on the expertise of an administrative support team. The work includes managing the meeting-, event-, progress-, reporting- and financial framework in the project and recruiting of the EEAB.

Task 8.1 Administrative coordination Lead: AAU

The Coordinator is responsible for the overall administrative coordination of the project, but will be supported by the Administrative Manager. This includes the accomplishment of project reports in strict accordance with the guidelines for reporting by the EC as well as the organisation of project meetings in the EB, GA and the EEAB. The financial administration is another important part of the management work package.

Subtask 8.1.1 Organisation of project meetings
Lead: AAU
WP8 will be responsible for arranging and coordinating the projects non-technical meetings and the provision of minutes and agendas:
- Consortium meetings:
-# Kick-off meeting (month 1).
- Review or amendment of the project with regard to time schedule and deliverables.
-# Progress meetings (EB) (Month 6, 12, 18, 24, 30, 36, 42, 48 and 54) Evaluation of results from the last six months, critical review of implementation plan, decision about further work-plan and adjustments (if necessary), planning of the next 6-12 months, suggestions for update of the implementation plan
-# Final Meeting (month 60): Evaluation of all gained results, critical review of the project and its outputs, comprehensive presentation of project results to EU-Commission and End-Users, decision about publication and dissemination activities beyond the lifetime of the project, if any
-# Support to the organisation of additional work package meetings
-# Review meetings will be scheduled according to the requirements.

Web-based teleconferences will be held on an ‘ad hoc’ basis between the progress meetings to address any specific issues that may arise and to ensure the common focus and direction of the project research and innovation activities and to minimize travel costs.

General Assembly meetings (GA) and External Expert Advisory Board (EEAB) meetings: GA meetings will be held once a year (plus the kick-off meeting) and will be held in order to steer the project. Advice and support to the decisions of the Project Coordinator on project operational and management issues will be provided, as well as on general managerial issues, contractual issues, and financial issues. GA meetings will be held in conjunction with EB meetings. EEAB meetings will be held once a year and will be held in order to check the technical viability and evolution of RIBuild. EEAB meetings will be held in conjunction with EB meetings.

Subtask 8.1.2 Administration of contractual documents
Lead: AAU

The aim of this task is to prepare, collect and maintain contractual documents (consortium agreement (signed before project start), EC grant agreement, etc.) and assume the logistics for report duplication, distribution, archiving as well as logistics for travel and meetings.

Subtask 8.1.3 Reporting procedures
Lead: AAU
This task aims at managing the technical periodic progress reports and financial reports during the whole project (Month 12, 24, 36, 48 and 60). Interim activity reports will also be prepared in between progress reports (Month 6, 18, 30, 42 and 54) in order to monitor project progress. The project progress reports will be submitted to the EC after month 12, 24, 36, 48 and the final report in month 60. The periodic reports will also include, as stated by the EU Commission, an updated plan for dissemination and exploitation. The final report will include the final confirmed plan. Furthermore, the partners will be informed about EC requirements. The Project Coordinator will be supported by the Administrative Manager at AAU which will be responsible for requesting and collating the reports and deliverables and sending them to the EC.

Task 8.2 Internal Quality control
Lead: AAU

Quality assurance processes for all project deliverables and published materials will be defined during the first three months of the project to achieve a common standard for the whole project.

Task 8.3 Progress and Risk Management
Lead: AAU

In this task the overall progress management and risk contingency planning for the project will be implemented. Any minor deviations from the plan will be reported to the Administrative Manager at AAU who will consider the problems and, where appropriate, make recommendations for implementing the contingency plan(s) associated with the work package(s) in question. In the event of more serious problems, the Project Coordinator will convene the GA to determine the best route forward and will advise the EC's Project Officer of the problem and seek their approval for the proposed solution. As shown WT5, the main sources of risks have already been identified during the project preparation phase and contingency plans have already been established. However, unexpected risks can arise during the project lifetime. The Coordinator will be in-charge of the overall risk management plan and the GA will be responsible for proactively managing the risks. The risk management related tasks will be put in the agenda of every consortium meeting in order to identify potential risks as soon as possible.

Task 8.4 Gender and Ethical Issues
Lead: AAU

The Project Coordinator will ensure that the project and its partners comply with the EC's activities on gender equality in Horizon 2020 thereby ensuring that they are in line with the RTD strategy on gender as well as with the ones set in the ERA Communication of July 2012. The only ethical issue to be handled in RIBuild is the import and export of data material from/to a non-EU country. The Project Coordinator has handled this issue in line with the RIBuild strategy for knowledge management, i.e. the partner for Switzerland has, as all other partners, receive/conclude a mutual non-disclosure agreementl.

Task 8.5 Financial management
Lead: AAU

Task 8.5 comprises the financial controlling of the project and all associated issues. The task is taken on by the Project Coordinator, but all partners are obliged to contribute to the controlling of the project costs by providing detailed information about the resources spent on project activities. Financial records will be established and maintained. Furthermore, this task's aim is the coordination and control of annual cost claims and certificates on the financial statements (if necessary) submitted by all project partners, the follow-up of EC payments, the distribution of partner shares and the monitoring of payments.
-# Monitor costs against budget
-# Report on financial issues as stated in the reporting guidelines
-# Distribution of financial forms
-# Collection of certificates on the financial statements (if applicable)
-# Coordination and monitoring of payments to the project partners

Task 8.6 Knowledge protection and commercialization
Lead: AAU

The Project Coordinator will ensure these issues to be handled in line with the RIBuild strategy for knowledge management and protection as outlined in Part B, Section 2.2. Whenever relevant, the Project Coordinator will draw on the expertise of the members of the support team dealing with Intellectual Property Rights and patents. The role of the project Coordinator and the Administrative Manager is presented in Part B.

Participation per Partner

Partner number and short name	WP8 effort
1 - AAU	28.00
Total	28.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D8.1	Data Management Plan	1 - AAU	ORDP: Open Research Data Pilot	Confidential, only for members of the consortium (including the Commission Services)	6

Description of deliverables

D8.1 : Data Management Plan [6]
Data Mangement Plan deliverable to be prepared by AAU.

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS32	Kick-off meeting	1 - AAU	1	Minutes of Meeting
MS33	Consolidated Detailed Work Plans	1 - AAU	3	Minutes of Meeting
MS34	Executive Board and External Expert Advisory Board meeting (M6)	1 - AAU	6	Minutes of Meeting
MS35	Executive Board and General Assembly meeting (M12)	1 - AAU	12	Minutes of Meeting
MS36	Executive Board and External Expert Advisory Board meeting (M18)	1 - AAU	18	Minutes of Meeting
MS37	Executive Board and General Assembly Meeting (M24)	1 - AAU	24	Minutes of Meeting
MS38	Executive Board and External Expert Advisory Board meeting (M30)	1 - AAU	30	Minutes of Meeting

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS39	Executive Board and General Assembly Meeting (M36)	1 - AAU	36	Minutes of Meeting
MS40	Executive Board and External Expert Advisory Board meeting (M42)	1 - AAU	42	Minutes of Meeting
MS41	Executive Board and General Assembly Meeting (M48)	1 - AAU	48	Minutes of Meeting
MS42	Executive Board and External Expert Advisory Board meeting (M54)	1 - AAU	54	Minutes of Meeting
MS43	Final meeting	1 - AAU	60	Minutes of Meeting
MS44	Final report	1 - AAU	60	Report

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	Report on historical building types and combinations of structural solutions	WP1	2 - RTU	9	D1.1
MS2	Report on main driving forces promoting renovation of historic buildings based on case studies	WP1	2 - RTU	9	D1.2
MS3	State-of-the-art on insulation materials for historic building retrofit projects	WP1	2 - RTU	12	D1.2
MS4	State-of-the-art on existing main strategies and methodologies used for retrofit of historic buildings	WP1	2 - RTU	12	D1.2
MS5	Standard laboratory procedure for determining material properties	WP2	1 - AAU	36	D2.1
MS6	Validated material characterisation models	WP2	1 - AAU	36	D2.1
MS7	Material properties of building materials used in historic buildings	WP2	1 - AAU	36	D2.1
MS8	Threshold values for failure, linked to types of building structure and failure modes	WP2	1 - AAU	48	D2.2
MS9	Design of tests at different scales in order to control hygrothermal processes under defined laboratory boundary conditions	WP3	3 - TUD	12	D3.1
MS10	Measurements of hygrothermal processes which lead to accumulation and redistribution of condensate, frost, durability loss, deterioration	WP3	3 - TUD	24	D3.1
MS11	Proper understanding of hygrothermal	WP3	3 - TUD	36	D3.1

Milestone number[18]	Milestone title	WP number[9]	Lead beneficiary	Due Date (in months)[17]	Means of verification
	behaviour of the material composites, building constructions and components				
MS12	Methodology for selection of case-buildings for full-scale tests	WP3	3 - TUD	12	D3.2
MS13	Documentation on materials and existing constructions, intervention needs, feasibility studies, and monitoring measures of test buildings	WP3	3 - TUD	12	D3.2
MS14	Development and installation of monitoring concepts for measurement of all relevant building parameters	WP3	3 - TUD	36	D3.2
MS15	Sound evaluation of the applied insulation systems and a certified quality assurance	WP3	3 - TUD	48	D3.2
MS16	A methodology for the efficient hygrothermal assessment of building components, based on direct three-dimensional simulations and indirect reduced-order-modelling approaches	WP4	4 - KU Leuven	36	D4.1
MS17	A methodology for the efficient probabilistic evaluation of building performances, based on direct sequential-sampling methods and indirect surrogate-modelling techniques	WP4	4 - KU Leuven	36	D4.2
MS18	Sets of data on the energy performance of the alternative insulation strategies, depending on buildings typologies, features, uses, climate conditions	WP5	5 - UNIVPM	30	D5.1

Milestone number[18]	Milestone title	WP number[9]	Lead beneficiary	Due Date (in months)[17]	Means of verification
MS19	Report on the energy saving potential of interior insulation solutions depending on building practice	WP5	5 - UNIVPM	30	D5.1
MS20	Report and tool: Probability based Life Cycle Assessment of the internal insulation solutions	WP5	5 - UNIVPM	36	D5.1
MS21	Report and tool: Probability based Life Cycle Cost and Cost-Optimal levels of the internal insulation solutions	WP5	5 - UNIVPM	42	D5.2
MS22	Methodology for assessment of the performance of internal insulation of historic buildings	WP6	6 - DTU	56	D6.1
MS23	Risk assessment guidelines for insulation of historic buildings	WP6	6 - DTU	58	D6.2
MS24	Evaluation of the methodology and guidelines and their impact on performance of historic buildings	WP6	6 - DTU	58	D6.3
MS25	Procedure for evaluating research results in terms of relevance to practice	WP7	1 - AAU	6	Appendix to D0.3 and D0.4
MS26	Map of Member States' relevant professional networks	WP7	1 - AAU	6	Appendix to D0.3 and D0.4
MS27	Formation of network partnerships	WP7	1 - AAU	6	On website
MS28	Production and distribution of a number (>5) of information kits on basis of the project's results	WP7	1 - AAU	60	D7.1
MS29	At least one workshop/ seminar at the beginning and one	WP7	1 - AAU	60	D7.2

Milestone number[18]	Milestone title	WP number[9]	Lead beneficiary	Due Date (in months)[17]	Means of verification
	conference at the end of the project				
MS30	A project website with templates for reporting, project descriptions, press material etc.	WP7	1 - AAU	3	Hyperlink
MS31	At least two press releases on the project	WP7	1 - AAU	60	Copies
MS32	Kick-off meeting	WP8	1 - AAU	1	Minutes of Meeting
MS33	Consolidated Detailed Work Plans	WP8	1 - AAU	3	Minutes of Meeting
MS34	Executive Board and External Expert Advisory Board meeting (M6)	WP8	1 - AAU	6	Minutes of Meeting
MS35	Executive Board and General Assembly meeting (M12)	WP8	1 - AAU	12	Minutes of Meeting
MS36	Executive Board and External Expert Advisory Board meeting (M18)	WP8	1 - AAU	18	Minutes of Meeting
MS37	Executive Board and General Assembly Meeting (M24)	WP8	1 - AAU	24	Minutes of Meeting
MS38	Executive Board and External Expert Advisory Board meeting (M30)	WP8	1 - AAU	30	Minutes of Meeting
MS39	Executive Board and General Assembly Meeting (M36)	WP8	1 - AAU	36	Minutes of Meeting
MS40	Executive Board and External Expert Advisory Board meeting (M42)	WP8	1 - AAU	42	Minutes of Meeting
MS41	Executive Board and General Assembly Meeting (M48)	WP8	1 - AAU	48	Minutes of Meeting
MS42	Executive Board and External Expert Advisory Board meeting (M54)	WP8	1 - AAU	54	Minutes of Meeting
MS43	Final meeting	WP8	1 - AAU	60	Minutes of Meeting
MS44	Final report	WP8	1 - AAU	60	Report

1.3.5. WT5 Critical Implementation risks and mitigation actions

Risk number	Description of risk	WP Number	Proposed risk-mitigation measures
1	What if developed laboratory tests do not determine material characteristics of importance to the guidelines?	WP2, WP3	Tests determining material characteristics and material behaviour are often used determining performance-based descriptions of single materials and building components. The Consortium possesses the expertise to develop and run tests and run laboratories. However, should the Consortium fail in develop relevant tests contacts will be made to colleagues outside the Consortium or existing standard methods will be involved.
2	What if developed tests do not reflect action from real risk scenarios?	WP2, WP3, WP6	From field tests a broad knowledge has been provided describing characteristics of real risk scenarios. Parameters characterising real scenarios are used for developing PC models simulating heat, moisture and stress in a large number of building designs, with a large number of combinations of materials organic as well as inorganic. Cross-check of simulations are made using other field tests than those giving input to the simulations, eventually field tests from other projects. Eventually it is evaluated whether it is necessary to reduce the scope of application of the developed guidelines.
3	Is it a considerable risk that the project is not able to describe the correlation between developed tests characterising material properties and building design used for historic buildings, describing guidelines for suitable internal insulation measures?	WP1, WP6, WP7	No, it is not a considerable risk as the project contains WP1 to ensure that relevant building designs are involved. The consortium has large experience writing national and international guidelines for the built environment, e.g. about energy optimisation and consumption, and moisture balance in the building envelope. Guidelines are based on a scientific understanding of building physics combining theory and practice.
4	Is it possible to compile results describing guidelines that include all EU countries?	WP6	The consortium includes countries covering various climates in EU. Including climates described as hot summers, cold winters, high moisture levels, dry areas, coastal areas, forest, mountains and valleys. The individual partners are located in climates covering climates of the EU region.
5	Has the project the ability to carry out full-scale tests on real buildings in EU?	WP6	Individually the partners have carried out real-scale experiments. Experiments have covered indoor climate measurements, energy optimisation, use of new materials and implementation of energy refurbishment of buildings. The full-scale expertise includes residents' and tenants' association management, fundraising, consultancy as well as implementation and creating guidelines for implementation as well as for end users.

Risk number	Description of risk	WP Number	Proposed risk-mitigation measures
6	Is it realistic within the time frame of the project to validate measurements from the on-site tests carried out in the project?	WP2, WP3, WP5, WP6	The Consortium is aware of the challenges carrying out full scale tests. The time line for the project, stretching over five years, has been outlined in full consideration with the challenges seen from other similar projects. The consortium has focus on the enterprise of full-scale testing.
7	Is the estimated increased efficiency in the development of PC models and the 3D simulations decreasing the calculation speed crucial to the project enterprise?	WP4	Yes it is, and this is why the project includes WP4 with the task to increase the calculation speed. Modelling and the development of PC-based tools developed to determine building physics characterisation within i.e. walls, materials and building components including, moisture, heat and stress distribution and balance are well known to the partners of the Consortium. Optimisation of the algorithm calculating is of importance to the project and lack of success will be time consuming, resulting in a reduced number of simulations (fewer materials, fewer details etc.).
8	Is it realistic that guidelines can be developed from laboratory tests and on-site tests and can it be done within the time frame of the project?	WP1, WP2, WP3, WP4, WP5, WP6, WP7	Partners of the Consortium have large expertise in transferring specific knowledge characterising material behaviour, i.e. stress resistance, heat distribution and moisture transport, gained through laboratory tests into performance-based descriptions and guidelines. Being aware of the challenges of carrying out full-scale tests within the timeframe of the project, the awareness also needs to be given to the collection of test data and development of guidelines.
9	How are uncertainties in parameters predicting LCA assessment analysed for their sensitivity?	WP5	A method will be used or developed to restrict the number of parameters predicting LCA assessment to the most influential for the specific case of deep renovation of historic buildings. Then, probability distribution functions for the most influential inputs for LCA will be defined and a propagation method for the uncertainties will be used based on available methods. In this way, parameter uncertainty is taken into account with a probabilistic approach, overcoming the limitations of current deterministic models. The methodology will be compliant with the state of the art approaches already existing for new buildings (cf. guidelines in recent LCA related EU projects such as LoRe-LCA and EeBGuide), but which need to be adapted for historical buildings renovation.
10	How are uncertainties in parameters predicting LCC assessment analysed for their sensitivity?	WP5	In Life Cycle Cost Analysis (LCC), data uncertainty is a well-recognized issue associated with deterministic calculation methods, which are not able to consider the numerous uncertainties on the input data that may have strong influence on the results. The LCC methodology developed in WP5 overcomes this limit, as will be based on probabilistic methods to account for data

Risk number	Description of risk	WP Number	Proposed risk-mitigation measures
			uncertainties through probability distribution functions. The main challenge is to manage the future scenarios in a probabilistic way e.g., initial costs, maintenance and replacement costs and energy (incl. electricity) rates variations and interest rate will be taken into account and represented through probability distribution functions. The final LCC result will be correlated to tolerance values in order to interpret the analysis in a right way.
11	Is it possible to incorporate the sensitivity on parameters predicting LCA and LCC into the guidelines?	WP5, WP7	Results from the probabilistic assessment methodology is brought into the guidelines pointing to the most cost-effective and sustainable insulation measures related to their functional performance, based on building practice and intended use. The results will be shown in terms of probability of occurrence in relation to different probability distributions of input parameters. The adopted approach and rules to set the tolerance values (see previous points) will be part of the guidelines.
12	It is difficult to go from building material to building.	WP2	We must prioritise; the guidelines will be limited to specific building types or the guidelines must be more on the safe side.
13	In Europe, there are too many different building materials, components and traditions.	WP2	We must prioritise; the guidelines will be limited to fewer building types.
14	Increased efficiency is targeted via multiple angles, what happens if many angles fail?	WP4	Some redundancy may be present. Probabilistic assessment is still possible, but will be time consuming. Monte Carlo is very easy in relation to parallel computing, so increase in computing power may be the solution.

1.3.6. WT6 Summary of project effort in person-months

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	Total Person/Months per Participant
1 - AAU	4	19	8	8	11	6	19	28	103
2 - RTU	21	9	20	0	4	6	3	0	63
3 - TUD	4	4	31	16	0	10	3	0	68
4 - KU Leuven	1	50	16	72	0	20	4	0	163
5 - UNIVPM	4	10	11	0	28	10	3	0	66
6 - DTU	4	10	18	0	15	19	3	0	69
7 - SP	4	16	8	0	0	6	3	0	37
8 - HES-SO	4	2	0	4	10	12	3	0	35
9 - IFLEX	0	4	10	0	0	10	3	0	27
10 - EMA	0	0	0	0	0	12	3	0	15
Total Person/Months	46	124	122	100	68	111	47	28	646

1.3.7. WT7 Tentative schedule of project reviews

Review number [19]	Tentative timing	Planned venue of review	Comments, if any
RV1	18	To be defined	This is tentative planning, to be confirmed.
RV2	36	To be defined	This is tentative planning, to be confirmed.
RV3	60	To be defined	This is tentative planning, to be confirmed.

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

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.