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List of abbreviations / Nomenclature

Abbreviation	Definition
A_f	Surface of the facade (m^2)
A_k	Surface (m^2)
A_r	Surface of the roof (m^2)
A_w	Surface of the window (m^2)
$CDH_{i,j}$	Cooling degree hour
DMM	District Mapping Module
ECI_f	Economic impact of the facade refurbishment measure (€/m^2)
ECI_k	Economic impact of the refurbished building (€)
ECI_r	Economic impact of the roof refurbishment measure (€/m^2)
ECI_w	Economic impact of the new window (€/m^2)
ENI_f	Environmental impact of the facade refurbishment measure ($kgCO_2/m^2$)
ENI_k	Environmental impact of the refurbished building ($kgCO_2$)
ENI_r	Environmental impact of the roof refurbishment measure ($kgCO_2/m^2$)
ENI_w	Environmental impact of the new window ($kgCO_2/m^2$)
$FACD_k$	Future annual cooling useful energy demand (kWh $year^{-1}$)
$FAHD_k$	Future annual heating useful energy demand (kWh $year^{-1}$)
GWP	Global Warming Potential
H&C	Heating and Cooling
$HDH_{i,j}$	Heating degree hour
i	Hour of the day
j	Day of the year
LCA	Life Cycle Assessment
LCI	Life Cycle Inventories
n_{HR}	Heat recovery system efficiency (%)
U_k	Thermal transmittance (W m^{-2} K^{-1})

1 Introduction

Energy security and climate change are driving a future that must show a dramatic improvement in the energy performance in Europe's buildings. The 27 Member States have set an energy savings target of 20% by 2020, mainly through energy efficiency measures, which is one of the fastest, most efficient and cost-effective means to reduce the environmental impact, improve the indoor air quality and increase the quality of life of each inhabitant.

By applying different strategies, the main objective of an energy refurbishment of a building is based on improving their energy performance. In this manner, an energy refurbishment project generates benefits directly and indirectly to the different pillars of the concept of sustainability.

Energy Refurbishment Benefits

⇩	⇩	⇩	⇩
Environmental	*Energetic*	*Social*	*Economic*

Environmental Benefits	
Reduced air pollution	By reducing the need for energy production from fossil fuels, there is a reduction in the amount of pollutants such as SO2, NOx and particulates that are damaging to health, to buildings and the environment
Reduce emissions	Europe's roadmap towards a low carbon economy 2050 [1], sets a target for reducing emissions in the European Union's buildings by between 88 and 91% by 2050
Energy Benefits	
Energy security	The reduction of the energy demand could increase the European energy security [2]
Reduced peak loads	Energy demand reduction measures save a disproportionate amount at times of high demand
Social Benefits	
Reduced fuel poverty	Improving the energy efficiency of homes could be vital to achieving affordable warmth for families on low incomes. Between 50 million and 125 million people in Europe (10-25% of the total EU population) are estimated to be fuel poor [3]
Health	Health benefits from warmer homes with less condensation and improved indoor air quality.
Increased comfort and productivity	Improvement in terms of increased comfort. It is well established that a better working environment leads to increased productivity.
Architecture-society relationship	The demolition of these urban areas by substituting new ones, influence directly in the social life of a high percentage of occupants. Therefore, refurbishment projects benefit directly in maintaining air quality and occupant architectural-social relationship.
Economic Benefits	
Energy cost saving	Renovation potential for net energy costs savings as much as €1300 billion (2012 value), arising to end users [4]
Economic stimulus	The employment generated could be on average as much as 1.1 million net additional jobs throughout the period to 2050 [5].
Impact on Gross Domestic Product.	Energy Efficiency Directive impact assessment identified that achieving the targeted savings would result in an increase in the EU's GDP of €33.8 bn in 2020 [6].

Property values	Buildings with high energy performance could be more valuable than their less efficient counterparts
R&D	By creating the drive towards ever more efficient ways to reduce energy consumption in buildings, a major programme of building renovation will spur research & development
Impact on public finances	According to a Copenhagen Economics report [7], investment in building retrofits will have a positive impact on public budgets, equivalent to 0.5-1.0% of GDP.

The concept of how energy refurbish a building to meet the guidelines set by the various European and global directives, is totally related to the theory of "Trias Energetica" (see Figure 1), which is a simple and logical concept that helps to achieve energy savings, reduce our dependence on fossil fuels, and save the environment.

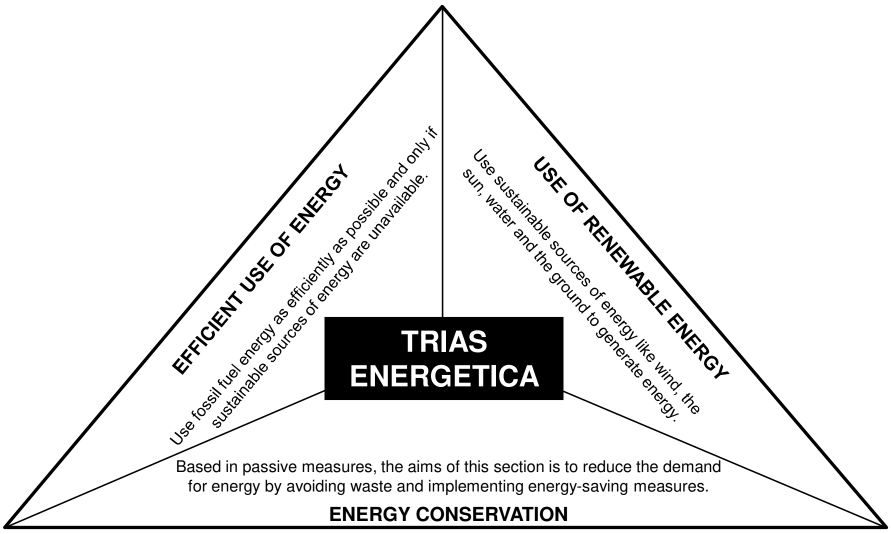

Figure 1: Trias Energetica scheme

By the District Mapping Module (DMM) and the City Mapping Module (CMM), Planheat insert two of the main concepts of the “trias energetica”:

- The DMM allows to improve the thermal properties of the buildings by energy conservation or passive measures.
- The CMM allows to improve the thermal properties of the buildings by energy conservation or passive measures.

2 Retrofitting or passive measures at district level

2.1 What is a passive measure

Passive strategies are designed to provide a significant reduction of the energy need for heating and cooling, independently of the energy and of the equipment’s that will be chosen to heat or cool the building. Many of the studies with a view to the evolution of architecture towards energy efficiency and sustainability [4], [8]–[10] are based on this “Trias Energetica” pillar (Energy Conservation), where these kind of passive refurbishment strategies improve the characteristics of different elements that directly affect in the building energy consumption and its influence is direct in three of the pillars of sustainability.

These strategies mainly based on the increment of the thermal resistance of the envelope, on the replacement of the current windows, on the reduction of air leakage or on the usage of bioclimatic strategies, are aimed at improving the life quality of inhabitants:

- Reducing the energy demand.
- Reducing the economic bill.
- Increasing the indoor air temperature in winter.
- Reducing the indoor air temperature in summer.
- Increasing the thermal comfort of the inhabitants.

Passive strategies for energy conservation try to minimize the heat losses of a building by its envelope retrofitting. Building's envelope consists of certain building elements' types, while certain passive strategies are applicable to each type. By the DMM-Planheat plug.in the following building elements' types are going to be refurbished:

- Facade
- Roof
- Openings

During this project it is not considered the possibility to apply any passive strategy to improve the ground floor thermal properties.

2.2 List of passive measures to be considered by Planheat

In order to improve the thermal requirements of the façade, roof and openings, the DMM-Planheat plug-in consider 3 types of refurbishment strategies:

- Façade → ventilated façade.
- Roof → add an insulation layer to the current roof.
- Window → replacement of the windows.

For each refurbishment strategy has been defined 3 different efficiency levels: low, medium and high. Due to these levels, DMM-Planheat plug-in considers:

- 3 ventilated façade systems with different insulation thicknesses.
- 3 different insulation thicknesses to add to the roof.
- 3 different combination of windows: double glazing + aluminium frame with thermal bridge break (1); low emissive double glazing + PVC 3 chambers (2), triple glazing + PVC 6 chambers (3).

2.2.1 Description

VENTILATED FACADE

This system is nowadays on the demands in architectural, because of enhancing the aesthetic image of buildings, but also, keeping energy consumption low. It provides a multilayer skin between the building and the external agents of the climate, with an internal air chamber. Normally, the ventilated façade is fastened to an auxiliary metal structure, which is fixed to the external walls of the existing building. The continue insulation layer is fixed on the external wall to improve the thermal conditions and to avoid heat losses from the inside of the building. There is a chamber of air between the external facade and the insulation layer to achieve the performance of the measure. The chamber removes the humidity and reduces the heat losses. The principal objective is to create a continuous insulation layer to avoid thermal bridges. Also in summer can reduce the energy gains due to solar radiation through the ventilation chamber.

ROOF INSULATION

It consists in an insulation layer in the internal face of the roof, in this case to make habitable normally the upper space in pitched roofs or as a protection for the house. It consisted in structural elements such as wood with insulation between it with a vapour control.

WINDOW REPLACEMENT

Replacement of the windows of the buildings improves thermal behaviour and also comfort. Its modification also gives a new and better aesthetical appearance to the building, increasing its value.

2.2.2 Relevant information to characterise measures

VENTILATED FACADE

Components

- Support: It is where the auxiliary structure is fixed. The support transfers the efforts to the building structure. If the wall is weak, the support should be the slabs or columns.
- Anchorage: It has to be adapted to the constraints of the support; the system should be design by modules and has to avoid the accumulation of humidity.
- Cladding: The external conditions and actions have to be resisted by this element, (Wind actions, Physical impacts, Resistance to external climate agents' Thermal changes…).
- Air chamber: Through the chamber humidity and water is dispersed. It also reduces noise and fire transmission, it ensures drainage and ventilation.
- Insulation: The continuous insulation removes the thermal bridges that normally are in the façade of old buildings, are removed. It has different thickness (7, 10, 15mm). Requirements: not hygroscopic, waterproof, unalterable, continuous application.

Application

- Where external walls are poorly insulated.
- Where external walls are deteriorating or are insufficiently weather-tight, causing damp, draughts and heat loss.
- Where external walls are in good structural conditions.
- Where it is intended to change the image of the building.
- Where the building is not in a conservation area.

Installation

It has some complication in installation because the secondary structure. But its modulation makes it affordable in a medium period of time.

- Installation of the auxiliary structure on the support constructive element. If the wall is weak, the support should be the slabs or columns.
- The module anchorage is adapted to the constraints of the support.

- There should be place enough for the air chamber.
- The insulation layer is fixed over the external layer of the wall. It is necessary to have some distance between the vertical structures.

Advantages

- Energy saving: Noise insulation, low heat dispersion in cold periods and low heat absorption in hot months. The average of energy efficiency is among the 30%.
- Healthier environment: It prevents thermal bridges, and avoids the humidity present in the building due to its air chamber.
- Static technical and aesthetic performances: The materials maintain all the characteristics from its installation because the large lifecycle.
- Protection from water: Ventilated facade stops rainwater from entering the walls, reducing decay and relevant maintenance costs at both faces of the wall.
- Ideal for renovation work: The system can be applied over existing plaster without the need for restoration work, it change dramatically the image of the building.
- Maintenance: It doesn't need much maintenance and most of the solutions are self-cleaning. It doesn´t need maintenance and service for at least 30 years after installation
- Durability: A copper structure has the lifetime of up to 100 or more years.

Disadvantages

- Time: The time of application is larger due to the structure and complexity.
- Costs: Costs are higher also because of the different materials needed and its quality.
- Complication: The measure in fact is not so complicate when it is spoken about technical issues, but the fact is that a secondary structure (scaffold) is needed.
- Not applied in protected areas: Because of the change of façade and image this measure cannot be applied in many historical neighbourhood.

Costs

This cost depends on the preparation of the support layer, the installation of the anchorages, installation of the sub-structure, placement of the insulating layer, cladding material and the type of elements and the placement with the regulation system.

ROOF INSULATION

Components

The main component of this strategy is the insulation layer, which improve the thermal properties of the roof element, reducing the U-value of the roof and reducing the thermal losses of the building.

Application

- Where external roof insulation is not possible or too costly.
- Where external roof is protected and cannot be modified.
- Installing external insulation would adversely affect the appearance of the building.
- Where the pitched roof is renovated for making it habitable.
- Where there is internal or cavity wall insulation in the facade (optional).

Installation

- Check conditions of the roof and undertake remedial work.
- Decide how to deal with reveals, roof voids and other potential cold bridges.
- Remove everything fixed to the roof.
- Carry out any preparation work to the roof.
- Build the new stud structure (if required) and/or fix insulation.
- Seal joints and skim plasterboard to finish.
- Install light switches, plug sockets, etc.

Advantages

- Energy saving: Low heat losses in cold periods and low heat gains in hot months
- Healthier environment, Comfort: It avoids the humidity present in the building due to its air chamber.
- Time: Application is shorter than external roof renovation.
- Costs: Costs are less than external renovation.

Disadvantages

- Thermal bridges may appear if the layer is not continuous
- Difficult to ensure entire water tightness and zero moisture because of the conditions of the roof.

Costs

This cost depends on the material of the insulation and on the placement of the insulating layer.

WINDOW REPLACEMENT

Components

The main components of this strategy are the glazing and the frame. Glazing allows one chamber with air or gas and one possible layers of coating in order to achieve better U values. Triple glazing allows two chambers with air or gas and two possible layers of coating in order to achieve lower U values. Regarding the frame, the aluminum frame is used commonly in the retrofitting of windows. Its characteristics make its moldable but also, as with the metallic properties, may appear thermal bridges along the entire frame. Due to that nowadays it is needed a thermal break point. In addition, the PVC frame with 3 or more chambers, has a reinforcement in its interior and the 3 chambers allows to increase the thermal performance to its maximum level for an actual frame.

Application

- Where the windows are deteriorated.
- Where the windows have not enough thermal performance.
- Where it is renovated the external façade.

Installation

- Take measures of the replaced windows.
- Remove old windows.
- Repaired all edges problems.
- Insert the new window with the specifications of the manufacturer.
- Use the fill insulation materials to recover holes.

- Use the attaching materials to attach definitely the window to the wall.
- Clean and make testing.

Advantages

- Energy saving: Low heat losses in cold periods and low heat gains in hot months.
- No thermal bridges if combined with exterior insulation.
- Low cost and easy installation.
- Aesthetic appeal: It has an important role in improving the external image.
- Increase value of the building.
- Increase comfort of the building.

Disadvantages

- Costs: Costs of retrofitting windows in buildings are higher.
- Complication: Colocation and alignment with insulation (insulation the edges).
- Not applied in protected windows areas (specific windows).

Costs

This cost depends on the frame and glazing properties and frame material.

2.2.3 Impacts per Declared Unit

Each retrofitting or passive measure will contain environmental and economic impact information (see Table 1).

Table 1 Environmental and economic impact of each passive measure

	Efficiency level	**Environmental impact ($kgCO_2/m^2$)**	**Economic impact (€/m^2)**
Facade	Low	14	106
	Medium	17	113
	High	24	126
Roof	Low	48	54
	Medium	52	55
	High	57	55
Window	Low	76	256
	Medium	136	281
	High	256	292

The environmental impact will be quantified in terms of Global Warming Potential - GWP ($kgCO_2/m^2$). This impact considers the impact of the production phase of each passive measure. That is, this stage covers the 'cradle to gate' processes for the materials used in the manufacturing process of each measure.

In order to estimate the environmental impacts associated with the production of the different refurbishment strategies, the formula recommended by EN 15804 [11] has been used. This choice has been made because this standard is the reference for the elaboration of environmental data for building materials, and thus of passive measures. In terms of data sources, used Life Cycle Inventories (LCI) have been taken from the Ecoinvent database v3.2 [12]. This database is the most acknowledged database within the LCA community. When needed, the LCIs have been adapted to the European context by adjusting the specific energy (electricity and heat) production.

The economic impact will be quantified in terms of Euros (€/m^2). This impact considers sale price of each passive measure. The economic information of these passive measures is obtained by different information sources [9], [13], [14].

2.3 Integration of passive measures into the DMM

Passive measures are integrated into the DMM Planheat plug-in by the "retrofitted scenarios" option (1) of the initial interface.

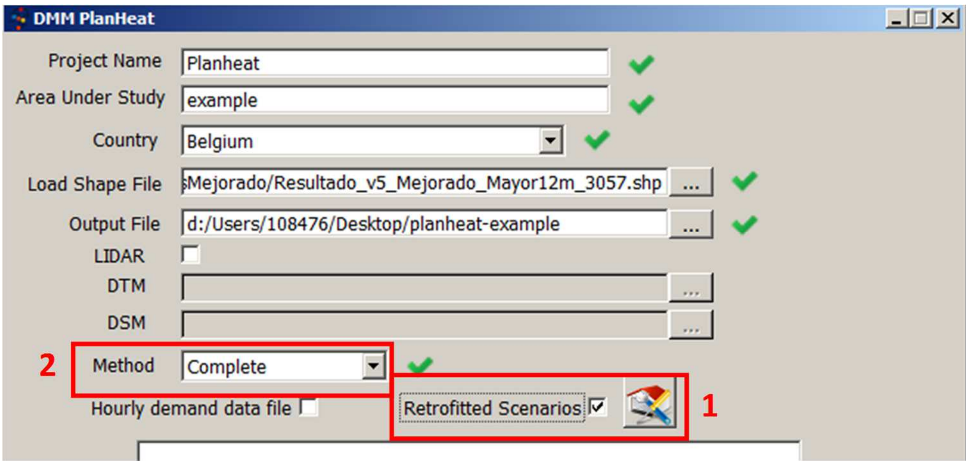

Figure 2 Initiation of the future scenario definition into the DMM PlanHeat plug-in

Highlight that according to the assessment method (complete or simplified) selected in the baseline scenario analysis (2), the integration of passive measures into the DMM is going to be different.

2.4 Generation of refurbishment scenarios and future demand calculation

This issue is described by the section 2.2.4 of the D2.1 (Models for mapping and quantifying current and future H&C demand in cities).

By this section a specific example is described. For example, the end-user wants to assess what is the influence if the municipality defines to refurbish a determinate area by the following characteristics:

- Only residential buildings will be refurbished.
- Only building built between 1945-1989 will be refurbished.
- The refurbishment efficiency level will be medium.
- 0% of the façade surface will be refurbished.
- 100% of the roof surface will be refurbished.
- 100% of the windows will be replaced.

By the "Retrofitting Scenario Generator" GUI, the end-user inserts this previous scenario.

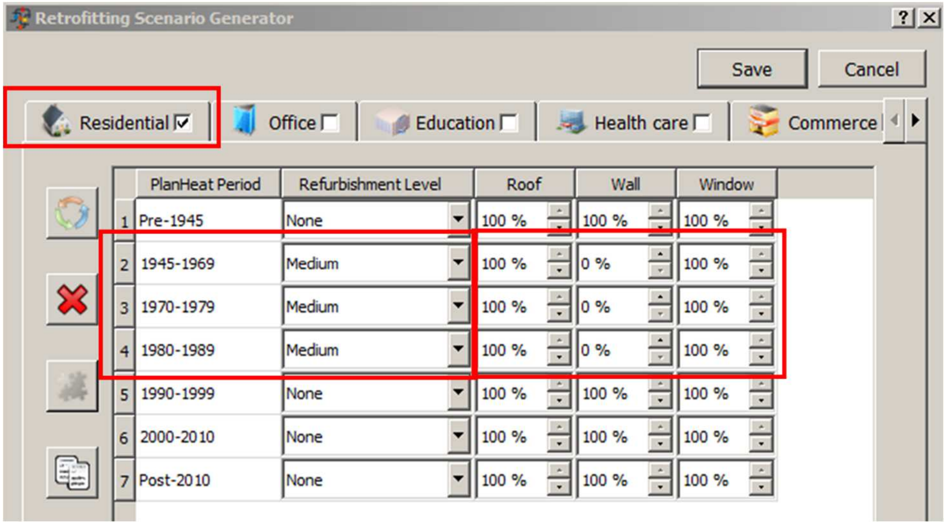

Figure 3 Example of a retrofitting scenario defined by the DMM-PlanHeat plug-in

The future demand calculation is an internal assessment and it is going to base on the following equations:

$$\boldsymbol{FAHD_k} = \sum_{i,j=1}^{8760} \left(HDH_{i,j} \times \boldsymbol{A_k} \times \boldsymbol{U_k} - Gains_{i,j} + \boldsymbol{hventilation\ losses_{i,j}} \times (1 - n_{HR}) \right) \cdot heating\ schedule_{i,j}$$

$$\boldsymbol{FACD_k} = \sum_{i,j=1}^{8760} \left(CDH_{i,j} \times \boldsymbol{A_k} \times \boldsymbol{U_k} + Gains_{i,j} + \boldsymbol{cventilation\ losses_{i,j}} \times (1 - n_{HR}) \right) \cdot cooling\ schedule_{i,j}$$

When the municipality want to assess the future energy demand of a specific area of the district, they should base on the working-process defined by the D2.1 (see section 2.2.4.4).

2.5 Examples of application and impacts calculation

This issue is described by the section 2.2.4 of the D2.1 (Models for mapping and quantifying current and future H&C demand in cities).

The environmental impact (ENI) and economic impact (ECI) of the refurbishment strategies are assessed based on the following equations

$$ENI_k = (ENI_f \times A_f) + (ENI_r \times A_r) + (ENI_w \times A_w)$$

$$ECI_k = (ECI_f \times A_f) + (ECI_r \times A_r) + (ECI_w \times A_w)$$

The following table shows the information about a specific building of the area under study:

- External façade opaque area: 800 m^2
- Roof area: 150 m^2
- Window area: 120 m^2

Based on the retrofitting scenario defined by the end user, the DMM-Planheat assesses the amount of the retrofitted area:

- Refurbished external façade opaque area → 800 m^2 x 0% = 0 m^2
- Refurbished roof area → 150 m^2 x 100% = 150 m^2
- Refurbished window area → 120 m^2 x 100% = 120 m^2

After defining the refurbished area, the DMM PlanHeat plug-in select the environmental and economic impact of each passive measure according its efficiency level:

- Façade refurbishment efficiency level → MEDIUM level → 17 $kgCO_2/m^2$ and 113 €/m^2
- Roof refurbishment efficiency level → MEDIUM level → 52 $kgCO_2/m^2$ and 55 €/m^2
- Window refurbishment efficiency level → MEDIUM level → 136 $kgCO_2/m^2$ and 281 €/m^2

Finally, this information allows to calculate the environmental and economic impact related to the refurbishment of each building:

$$ENI_k = (17 \times 0) + (52 \times 150) + (136 \times 120) \ = 24120 \ kgCO_2$$

$$ECI_k = (113 \times 0) + (55 \times 150) + (281 \times 120) = 41970 \ €$$

3 Retrofitting or passive measures at city level

Retrofitting or passive measures at city level will be included in the Planheat platform and specifically within the City Planning Module. Further information will be provided in the framework of deliverable D3.9 First release of the planning and simulator module (RINA-C, M24).

Within the City Planning Module, users will have the possibility to estimate useful energy demand related to future H&C scenarios starting from the assessment of the useful energy demand in the baseline scenario. The general procedure to estimate future H, C and DHW demand has been already defined and it's based on the application of scaling and corrective factors to the baseline useful energy demand. These factors correspond to:

(For assessing H, DHW, C future useful demand)

- Future share of useful energy demand covered by each energy source;
- Demographic correction factor to take into account future increase/decrease of population;
- Envelope conversion factor to take into account possible future energy efficiency measures on buildings envelopes.

(For assessing H and DHW future useful demand only)

- DHN penetration factor

(For assessing Cooling future useful demand only)

- DCH penetration factor
- Increase of cooling demand

The aforementioned "Envelope conversion factor" corresponds to the corrective factor by means of which users have the possibility to take into account passive energy efficiency measures within the City Planning Module. This corrective factor will correspond to a percentage to apply to heating demand to reduce it as a consequence of possible refurbishment measures applied on the buildings/part of the buildings of the area of interest. Refurbishment measures are meant as enhancements to the envelope components, namely: façade, windows and roofs.

The users will have the possibility either to provide a value or to use default figures stored in the Planheat database. Default values will be provided according to the Heating Degree Days of the city under analysis according to the building typology (considering two main categories: single family house and apartment buildings). This information has been extrapolated from guidelines provided by ENEA with reference to energy savings in buildings [15] and it is presented in Table 2 and Table 3: Expected Energy Savings [%] in different climatic areas according to adopted refurbishment measures – Apartment buildingsTable 3.

Single-family house - Expected Energy Savings [%]					
HDD range	Facade outer insulation	Facade inner insulation	Roof insulation	Windows replacement	Basement insulation
0-600	20-25	15-20	30-40	5-10	5-10
601-900	20-25	15-20	30-40	5-10	5-10
901-1400	20-25	15-20	30-40	5-10	5-10
1401-2100	20-25	15-20	35-40	5-10	10-15
2101-3000	15-20	15-20	40-45	3-5	10-15
>3001	25-30	25-30	30-35	3-5	15-20

Table 2: Expected Energy Savings [%] in different climatic areas according to adopted refurbishment measures – Single family house

Apartment buildings - Expected Energy Savings [%]				
HDD range	Facade outer insulation	Roof insulation	Windows replacement	Basement insulation
0-600	30-35	10-15	10-15	10-15
601-900	30-35	10-15	10-15	10-15
901-1400	30-35	10-15	10-15	10-15
1401-2100	30-35	10-15	10-15	10-15
2101-3000	30-35	10-15	8-10	10-15
>3001	30-35	10-15	8-10	10-15

Table 3: Expected Energy Savings [%] in different climatic areas according to adopted refurbishment measures – Apartment buildings

In addition, the users will have the possibility to select multiple refurbishment measures. The tool will weigh the selected measures providing a combined reduction percentage.

4 Active Energy efficiency measures

4.1 What is an energy efficiency measure

Active energy efficiency measures correspond to measures that have a direct impact on energy consumptions by reducing them.

The equipment for ventilation and air conditioning (HVAC) is the largest contributor to the total EU energy consumption.

According to Kemna [16], the trend for future total EU space heating load will be stable. The load will be decreasing due to improvement of insulation, more efficient conversion technologies, increased urbanization (heat island) and global warming. On the contrary, aspects like growth of population, dwelling size and comfort level will lead to an increase of space heating load. Moreover, internal heat gains from lighting and appliances will decrease due to efficiency improvement which will bring to an increase of the heating load.

In some of trends taken into account for the period 2010-2020 are related to active energy efficiency measures [17]. In particular in the document is reported that the heat load per heating system will decrease by 1.2-1.5% per year because of better insulation and less ventilation heat losses. A best estimate is that improvement of insulation and ventilation efficiency can yield an improvement of 1.2% per year.

Space cooling demand is expected to continue to rise. According to the EIA projections space cooling demand is expected to rise to 305 TWh (+38%) in 2020 and 379 TWh in 2030. Residential (room) air conditioners are expected to represent the largest growth in space cooling.

4.2 List of energy efficiency measures to be considered by Planheat

Within the PLANHEAT platform and specifically, using the PLANHEAT Planning Module, users will have the possibility to take into account active energy efficiency measures. According to the approach followed for the Mapping Module, the planning module will enable two types of analysis at city level (City Planning Module) using a top-down approach and at district level (District Planning Module) using a bottom up approach. Within both modules, users will have the possibility to define future H&C scenarios adopting active energy efficiency measures related to:

- Energy systems and sources: Selecting more efficient technologies for energy production integrating RES and waste heat coming from unconventional urban sources and industrial activities
- Distribution networks: optimizing the number of connections and the routes to district heating and cooling networks (DHCNs).

4.2.1 Description

The decarbonization of the European heating and cooling sector is an urgent need taking into account that this sector is currently representing 50% of total final energy consumption in Europe. In this framework the exploitation of renewables and unconventional sources and their integration within new and existing energy systems is of fundamental importance. Specifically there is a big unexploited potential in recovering waste heat available at low temperature from urban sources.

Within both CPM and DPM, users will be able to create future energy efficient H&C scenarios by selecting energy sources among the ones available at local level and related technologies considering both single building solutions and centralized systems, i.e. DHC networks.

Information about availability of local energy sources will come from the Planheat Mapping Module and specifically from the Supply Mapping Module provided with algorithms to estimate potential H&C supply coming from renewables (solar, thermal and geothermal) and urban waste heat from unconventional sources (water bodies, sewage, underground network and datacentres) and industrial activities (industry, waste incinerators, power plants)

Relevant technologies for the PLANHEAT purposes have been already identified, as presented in the following list.

	Simulation module technology library
1	**Solar thermal**
1.1	Flat plate solar thermal collectors (FPC)
1.2	Evacuated tube solar thermal collectors (ETC)
2	**Thermal storage**
2.1	Daily/hourly thermal energy storage
2.2	Seasonal thermal energy storage
3	**Boiler**

3.1	Biomass boiler
3.2	Gas boiler
3.3	Oil boiler
4	**Heat pump**
4.1	**Compression heat pump**
4.1.1	Air source heat pump
4.1.2	Water source heat pump
4.1.3	Ground source heat pump
4.2	**Absorption heat pump**
5	**Electrical heaters**
6	**CHP**
6.1	**Internal combustion engine (ICE)**
6.1.1	Natural gas ICE
6.1.2	Diesel ICE
6.2	**Rankine steam cycle**
6.2.1	Biomass fired
6.2.2	Gas fired
6.2.3	Oil fired
6.3	**Organic Rankine cycle (ORC)**
6.3.1	Biomass fired
6.3.2	Gas fired
6.3.3	Waste heat
7	**Heat exchangers for waste heat utilization**

Table 4: Simulation module - Technologies

For each technology, specific input will be required to the end-users and in case of missing information a specific database will provide default values. This database will contain information about technologies, efficiencies and costs (D3.6 Database of technology efficiencies, costs and energy tariffs for the EU countries, M21).

In future scenarios, alternative technologies will gradually substitute fossil-fuel based boilers that currently cover the majority of buildings thermal loads. For temperature below 50°C shallow geothermal represent the best solution while CSP for temperature up to 100°C.

Heat from deep geothermal is suitable for temperature from 50 to 150 °C and biomass can supply heat at temperature below its combustion temperature (900 – 1000°C); the technology is nowadays competitive with the traditional boiler fuelled by fossil fuels.

CHP can produce simultaneously heat and electricity with overall efficiencies up to 90%.

Solar heating and cooling comprises different technologies in a wide range of efficiencies and prices from mature domestic hot water heaters to systems providing cool from solar panels. Solar cooling is a promising technology that is gaining favours due to its very low GHG emissions combining solar panels with heat pumps.

Also District Heating could benefit of solar systems and are usually used to provide low temperature heat on daily basis. Coupled with high efficiency absorption chiller DHC enables the use of surplus of heat from electricity production of CHP units, industry, waste heat and renewable sources; moreover, district cooling networks can use lakes, sea, river water and other local sources to provide the energy instead of outside air: the cooling potential of these sources can be increased by the use of heat pumps.

In buildings with high demand for cooling and heating and air conditioning high efficiency absorption chillers which use mixtures of water and ammonia fed by natural gas or waste heat sources can be used instead of traditional electrical air conditioners and chillers based on vapour compression refrigeration cycles.

4.2.2 Relevant information to characterise measures

Energy systems

The following input data will be required to characterize the different technologies models. In case of missing information as aforementioned, default values will be available on the Planheat database.

Technology library inputs	Unit of measurement
Solar thermal	
optical efficiency	-
1st order heat loss coefficients	$W/(m^2K)$
2nd order heat loss coefficients	$W/(m^2K^2)$
Mean temperature of the working fluid	°C
Ambient temperature, hourly distribution	°C
Collector inclination angle and azimuth orientation	°
Global solar irradiation	W/m^2
Solar thermal collector surface	m^2
Specific cost	€/m^2
Specific O&M costs	€/kWh
Technical lifetime	y
Thermal storage	
Thermal storage size	m^3
Specific thermal storage capacity	kWh/ m^3
Thermal storage losses	kWh/h
Specific price of a thermal storage	€/m^3 €/kWh
Specific O&M costs	€/kWh
Technical lifetime	y
Boiler	
Peak capacity	kW
Boiler efficiency	%
Ramp up/down speed	kW/h
Min.power - technical minimum	kW
Fuel heating value	kJ/kg kJ/m^3
Specific boiler cost	€/kW
Specific O&M costs	€/kWh
Technical lifetime	y
Specific emissions	t_{CO2e}/kWh
Heat pump	
Heat pump capacity	kW
Coefficient of performance, COP	
Specific price	€/kW
Specific O&M costs	€/kWh
Technical lifetime	y
Electrical heater	
Peak capacity	kW
Heater efficiency	%
Ramp up/down speed	kW/h
Min.power - technical minimum	kW
Specific heater cost	€/kW
Specific O&M costs	€/kWh
Technical lifetime	y
CHP	
Peak capacity	kW
Power-to-heat ratio	-

Thermal and electrical efficiency	%
Ramp up/down speed	kW/h
Min.power - technical minimum	kW
Fuel heating value	kJ/kg kJ/m^3
Specific CHP cost	€/kW
Specific O&M costs	€/kWh
Specific emissions	t_{CO2e}/kWh
Technical lifetime	y
Additional data for waste heat ORC	
Heat source type/temperature	°C
Heat supply distribution potential - hourly level	kWh/h
Heat exchanger	
Peak capacity	kW
Efficiency	%
Waste heat supply distribution - hourly level	kWh/h
Specific heat exchanger cost	€/kW
Specific O&M costs	€/kWh
Technical lifetime	y

Table 5: Simulation module: Input data for calculation models of technologies

Energy sources

Regarding the energy sources, the Planheat end-user has the possibility in the assessment process of different energy scenarios to determine a desired mix. Starting from the baseline scenario mix of sources, in the future scenarios assessment the mix can be changed in order to reshape the current rates of energy consumption.

In the following list the energy sources/carriers included by default in Planheat platform are reported:

- gas (from fossils fuels)
- electricity
- heating oil
- biomass
- solar thermal
- other fossil fuels

The end user can also input different sources/carriers not included in the list.

Particular attention is given to waste heat and heat from the ground sources that are not directly included in the list but that are crucial in the definition of future scenarios since they are two of the local sources that are mapped in the Mapping Module plug-in. In fact they are considered as a consequence of the use of HPs and related through efficiency to the electricity consumption.

The reshape of the source mix is done on the heat and cool produced by each source/carrier thanks to a particular technology; when considering the useful demand covered by HPs technology also the heat recovered by external sources is calculated in order to take it into account when defining future scenarios and the rate of local sources available to be used.

Distribution networks

Distribution networks can be also assessed in the definition of future scenarios within Planheat tool. Fourth generation DHNs providing heat at lower temperatures in association with more efficient conversion technologies can be used to cover the demand of future low demand buildings connected.

A specific submodule of the Planning Module called District Heating and Cooling Route Optimizer allows starting from the current picture of previous existent networks if any to determine the best configuration of future networks in terms of buildings connected and piping routes development given some constraints and optimization criteria.

D3.5 will go into the details of the submodule explaining all features and characteristics.

4.2.3 Impacts per Declared Unit

The impact of the active energy efficiency measures adopted will be assessed in terms of Key Performance Indicators covering different domains:

- Energy
- Environmental
- Social
- Economic

The Planheat KPI panel that will be integrated within the PLANHEAT Simulation module has been preliminarily presented in D1.5 Report and presentation on PLANHEAT integrated tool functionalities (RINA-C, M12) and additional information will be included within the deliverable D3.6 KPIs calculation models (RINA-C, M21).

4.3 Generation of future scenarios – Selection of H&C energy systems and sources

The procedure for generating future H&C scenarios within the PLANHEAT planning module has been described within D1.5 Report and presentation on PLANHEAT integrated tool functionalities (RINA-C, M12). A brief summary is presented in table below.

City Planning Module	District Planning Module
Technology assignment at city/area level using technology from Planheat library (with specific efficiency, CAPEX, OPEX, etc.)	1st step: shape file acquisition from Mapping Module 2nd step DHCNs assessment (DHC route opt. by Artelys) • Routes definitions • Buildings connections • Technology assignment 3rd step Technology assignment at building level Depending on district size: • For each single building • For group of buildings applying the same technology • For group of buildings of same destination of use • To cover the peak power demand of the building/group of buildings selected • Using technology from Planheat library (with specific efficiency, CAPEX, OPEX, etc.)

Table 6: Procedure for selection of H&C energy systems and sources within the Planheat Planning Module

4.4 Figure Examples of application and impacts calculation

As the PLANHEAT planning module is still under development, no applications are available so far. Further information will be provided in the framework of deliverable D3.9 First release of the planning and simulator module (RINA-C, M24).

5 Conclusions

The work presented in this document furnishes a vision of the application and properties of retrofitting measures into both approaches of the mapping module: the City Mapping Module (CMM) and the District Mapping Module (DMM). The work described in this document is part of the task T2.1.1 “Report detailing the models for estimating heating and cooling demand and results from models validation”.

The content of this document is structured in 3 main sections. After an introduction about the energetic retrofitting, the first section describes the main characteristics of the retrofitting measures integrated by the DMM. The second section describes the characteristics of the retrofitting measures integrated by the CMM. Finally, the fourth section describes the list of energy efficiency measures to be considered by Planheat and defines the generation of future scenarios by the application of these measures.

The work described in this document is complement with two other deliverables. On the one hand there is the deliverable D2.1 “Models for mapping and quantifying current and future H&C demand in cities”, which describes the definition of the future demand into CMM and DMM. On the other hand, the D3.9 “first release of planning and simulator modules” defines the properties of each active energy efficiency measure.

REFERENCES

[1] European Commission, "COMMUNICATION FROM THE COMMISION: A Roadmap for moving to a competitive low carbon economy in 2050," *COM(2011) 112 Final*, vol. 34, no. March, pp. 1–34, 2011.

[2] European Commission, "Energy 2020," 2010.

[3] European fuel poverty and energy efficiency, "European Fuel Poverty and Energy. Tackling Fuel Poverty in Europe," 2009.

[4] BPIE, "The BPIE data hub for the energy performance of buildings," *BPIE data hub*, 2015. [Online]. Available: http://www.buildingsdata.eu/.

[5] S. B. Anders, "World Business Council for Sustainable Development (WBCSD)," *CPA J.*, no. June, pp. 80–82, 2016.

[6] European Commission, "Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC," *Off. J. Eur. Union*, vol. 55, no. L315, pp. 1–97, 2012.

[7] Copenhagen economics, "Multiple Benefits of Investing in Energy Efficient Renovation of Buildings," 2012.

[8] Intelligent Energy Europe programme, "ENTRANZE interactive online data tool." .

[9] C. Petersdorff, T. Boermans, and J. Harnisch, "Mitigation of CO2 emissions from the EU-15 building stock: beyond the EU Directive on the Energy Performance of Buildings.," *Environ. Sci. Pollut. Res. Int.*, vol. 13, no. 5, pp. 350–358, 2006.

[10] F. Nemry *et al.*, *Environmental Improvement Potentials of Residential Buildings (IMPRO-Building)*. 2008.

[11] BSI EN 15804, "BS EN 15804:2012 - Standards Publication Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products," *Int. Stand.*, no. February, p. 70, 2014.

[12] Ecoinvent, "Swiss Centre for Life Cycle Inventories. Ecoinvent Centre," *Ecoinvent Centre, Dübendorf, Switzerland*, 2014. .

[13] G. T. del C. O. de A. A. T. e I. de E. de G. COAATGU, "Precio Centro Guadalajara," 2016. [Online]. Available: http://preciocentro.com/. [Accessed: 26-Jun-2017].

[14] X. Oregi, P. Hernandez, and R. Hernandez, "Analysis of life-cycle boundaries for environmental and economic assessment of building energy refurbishment projects," *Energy Build.*, vol. 136, 2017.

[15] ENEA, "RISPARMIO ENERGETICO NELLA CASA."

[16] R. KEMNA and J. Moreno, "Average EU building heat load for HVAC equipment. Final Report," *Delft Van Holsteijn en Kemna BV (VHK). Retrieved Sept.*, vol. 24, p. 2015, 2014.

[17] European Commission, "Ecodesign Impact Accounting, status report 2017," 2017.