Fine-tuned DREEAM approach for the multiple building energy renovation

D1.5

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no 680511. This document does not represent the opinion of the European Union, and the European Union is not responsible for any use that might be made of its content.

Deliverable number

PROJECT INFORMATION	
Project acronym	DREEAM
Grant agreement number	680511
Project title	Demonstration of an integrated Renovation approach for Energy Efficiency At the Multi building scale

DOCUMENT INFORMATION	
Title	Fine-tuned DREEAM approach for the multiple building energy renovation
Version	2.0
Release date	
Work package	WP1
Dissemination level	P

DOCUMENT AUTHORS AND AUTHORISATION	
Lead	Chalmers (Claudio Nägeli, York Ostermeyer, Izabela Kurkowska, Jana Dahmen, Mohamad Kharseh)
Contributor(s)	Exeleria, 3C-Precon
Reviewed by	Exeleria, RISE
Authorised by	Coordinator (Holger Wallbaum)

DOCUMENT HISTORY			
Version	Date	Modified contents	Implemented by
1.0	22.10.2017	First draft – overview of DREEAM tool development status	Chalmers
2.0	29.06.2018	Second draft – tool validation results summarised	Chalmers
3.0	20.09.2018	Ready for submission to period 2	Chalmers

Executive summary

The DREEAM tool developed by Chalmers is the core of the approach to refurbishment concept design taken within the DREEAM-project, which takes a larger renovation scale (multiple buildings or even portfolio level) as starting point for renovation planning and design. This report outlines the implementation of the process into the tool and gives a step by step manual of how to use it. The tool combines an energy calculation model for the building with economic and environmental assessments in order to assess and optimize refurbishment concepts, both with respect to economic and environmental criteria. The optimization is done by multidimensional optimization approach, based on an evolutionary algorithm that can automatically find the Pareto-boarder for multiple criteria selected by the user. Thereby, the DREEAM-Tool enables the development of an optimized design of renovation concepts that best meet multiple objectives (e.g. energetic, environmental or economic indicators). By doing so, the tool can support building owners in making strategic refurbishment decisions for their portfolio and help them translate those decisions in corresponding refurbishment concepts and select between different refurbishment approaches in line with overarching targets.

The first functional version of the DREEAM-Tool is already being tested with DREEAM project partners and potential users.

Table of contents

1 Introduction

1.1 DREEAM Approach

Within the DREEAM-project an approach to refurbishment concept design was developed, which takes a larger renovation scale (multiple buildings or even portfolio level) as starting point for renovation planning and design. By taking a multi-building approach to refurbishing their residential building stock, building owners can act more strategically than it is the case when renovating one building at a time and aim to achieve better energy efficiency results.

The overall process can be divided into 4 steps:

1. **Baseline Analysis:** The aim here is to give an overview of the status quo of the buildings and to identify the most important hotspots to be addressed in refurbishment concepts.
2. **Indicator Definition:** At this stage indicators for the assessment of renovation concepts are identified in exchanges with the housing company. These can be energetic (i.e. 75% net-energy demand reduction), economic (i.e. return on investment) or environmental (i.e. greenhouse gas emissions) indicators.
3. **Tentative Concepts:** Tentative concepts are generated. The solutions which are theoretically possible, but unfeasible in a given case, due to technical or acceptance reasons, are excluded at this stage through a feedback loop with a building owner.
4. **Optimized Concepts:** The energy demand reduction of the concepts is calculated and optimized, based on the indicators selected in step 2. The results visualized on a Pareto-curve allow a building owner to select the most optimal refurbishment concept in an informed way.

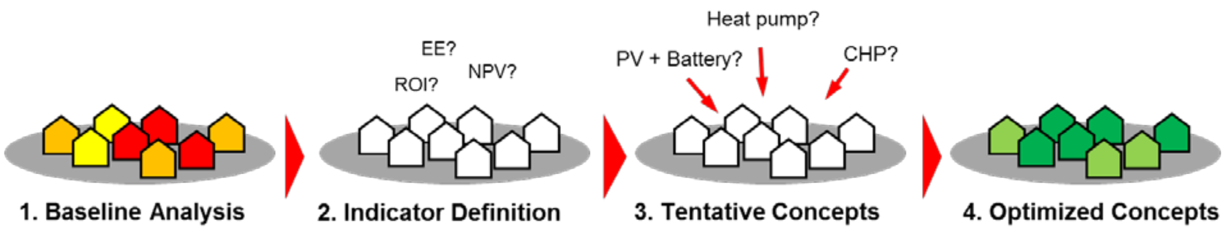

Figure 1: 4 step approach to refurbishment concept development

1.2 Assessment Tool Concept

At the core of this approach is the DREEAM-Tool, which is designed to support the process in step 4. The tool makes use of the ongoing research in building design optimization, life cycle assessment (LCA) and life cycle costing (LCC). It adds value to typical renovation design approaches in the following aspects:

• It includes both energy demand and supply side in the renovation concept development

• It applies an optimisation routine for building(s) to be renovated (from single building to a building portfolio scope)

• The optimization routine applied by the tool is a multidimensional one – i.e. optimal refurbishment concepts fulfil both environmental and economic indicators identified by building owners.

Therefore, the DREEAM-Tool generates a set of different refurbishment concepts, by selecting the optimal combination of refurbishment solutions against the indicators identified in step 2, as well as balancing the application of renewable energy generation and energy efficiency measures on a multi-building and portfolio scale (see Figure 2).

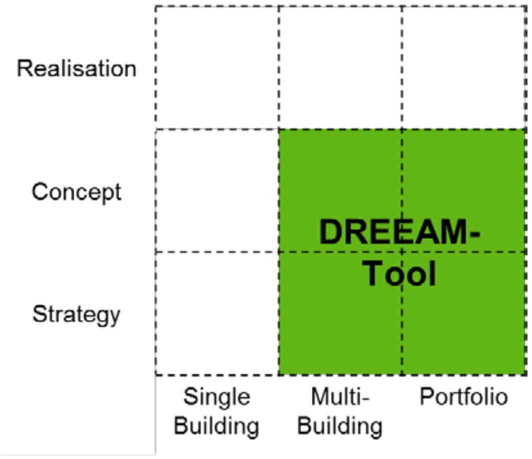

Figure 2: The DREEAM-Tool's strategic approach to building portfolio assessment and strategic refurbishment concept development

The resulting Pareto-curve of possible solutions highlights the trade-offs between the different indicators (e.g. environmental vs. economic benefits) and allows the building owners to select the concept that is most suited to their preference.

At the end of step 4, the final renovation concept can be chosen from the Pareto-curve which visually demonstrates how these potential renovation concepts correspond to the decision indicators identified by a building owner in step 2.

A first functional Minimal Viable Product (MVP) version of the tool is already available and being tested with DREEAM project partners and potential users. This deliverable describes the different parts of the web tool and gives detailed instructions on how to use it. More importantly, the deliverable describes the tool validation steps where the calculation results performed by the tool have been compared with the calculation results from HAP (marked-ready calculation tool used within WP2 for IT and UK pilot sites).

2 Implementation of the DREEAM Approach – The DREEAM-Tool

2.1 Introduction

This section describes the implementation of the DREEAM approach into the web tool and gives a comprehensive guide of the current version. Furthermore, it details what is given and what parameters are required in each step.

The functioning of the tool can be broken down into three key parts (see Figure 3). First the building portfolio and refurbishment database has to be added. In the second part the energy performance of the building is calculated according to multiple target criteria (e.g. max. energy demand reduction vs. ROI) and then matched with suitable renovation solutions. As a result a selection of optimal renovation scenarios are presented on a pareto-curve.

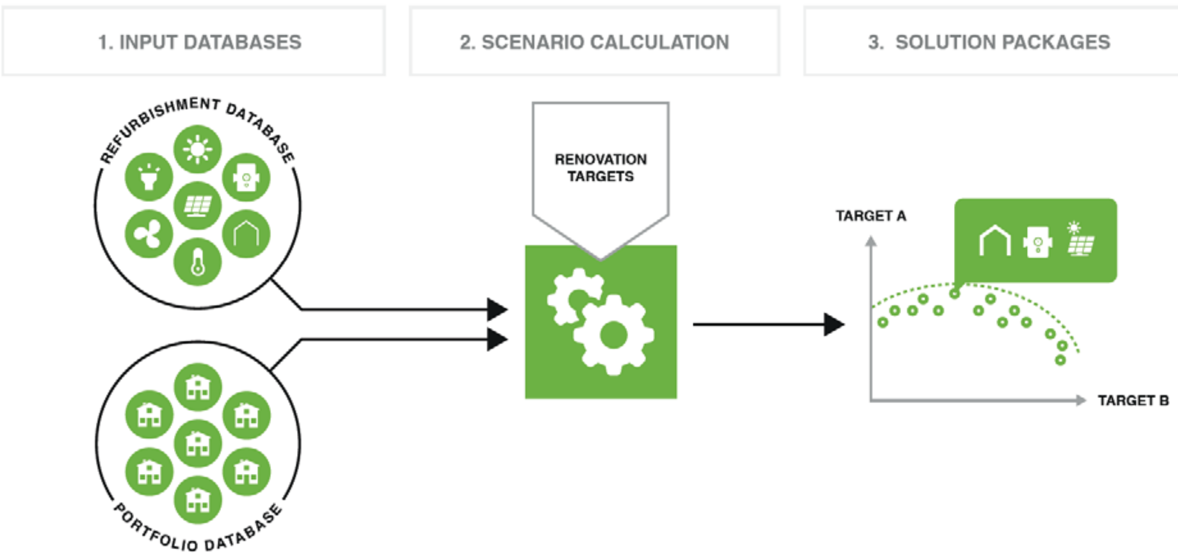

Figure 3: Functions of the DDREAM-Tool

2.2 Structure

The user interface of the DREEAM-Tool is divided into three parts:

- Building Portfolio
- Refurbishment Database
- Explore Scenarios

In the section Building Portfolio the user describes, adds and manages existing building data like locations, building groups and individual buildings with their properties. In the Refurbishment Database the user adds and edits location-specific renovation solutions and renewable energy technologies, described in terms of technical properties and price. The last section, Explore Scenarios, gives the opportunity to start new scenario calculations that meet the target criteria for the individual user building portfolio and to explore the optimal strategies when the calculations are done.

2.3 Building Portfolio

Here the user can add and manage the existing building data with an easy-to-use editor. This includes the location, building groups and individual buildings with their properties. The properties include all the technical and geometrical data of the different buildings.

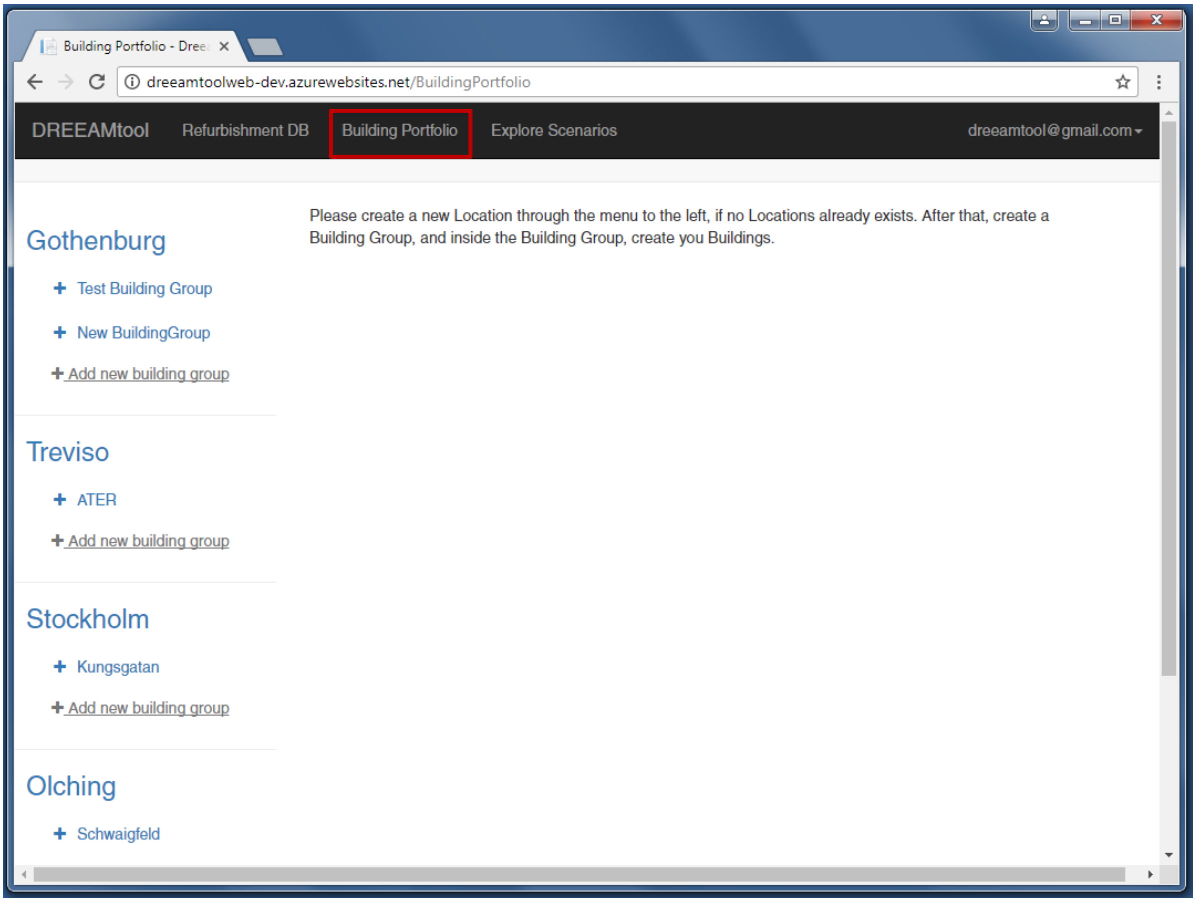

Figure 4: Building Portfolio in the DREEAMtool

<u>Add new locations</u>

The user can create a new location through the menu on the left (Figure 5), if no location already exists or if the user wants to add a new one. In this section data which is important for the energy module is inserted:

1. Location Name
2. Choose a Weather File
3. Information about Energy Carriers

Table 1: Parameters for Energy Carriers

Name	Unit	Input	Description
Energy Price	currency/KWh		Price for the different energy carriers
GHG-Emission Factor	$kg_{CO2\text{-}eq}/kWh$		Average amount of greenhouse gas (GHG) emission equivalents per kWh of energy
PEF total	$kWh_{primary}/kWh_{final}$		Primary Energy Factor = Expresses the connection between a produced amount of heat or electricity and the amount of fuel that were needed to produce that heat or electricity
PEF Non-Renewable	$kWh_{primary}/kWh_{final}$		PEF only for the non-renewable energy part
PEF Renewable	$kWh_{primary}/kWh_{final}$		PEF only for the renewable energy part

If needed there is also the possibility to add more energy carriers at the end of the list.

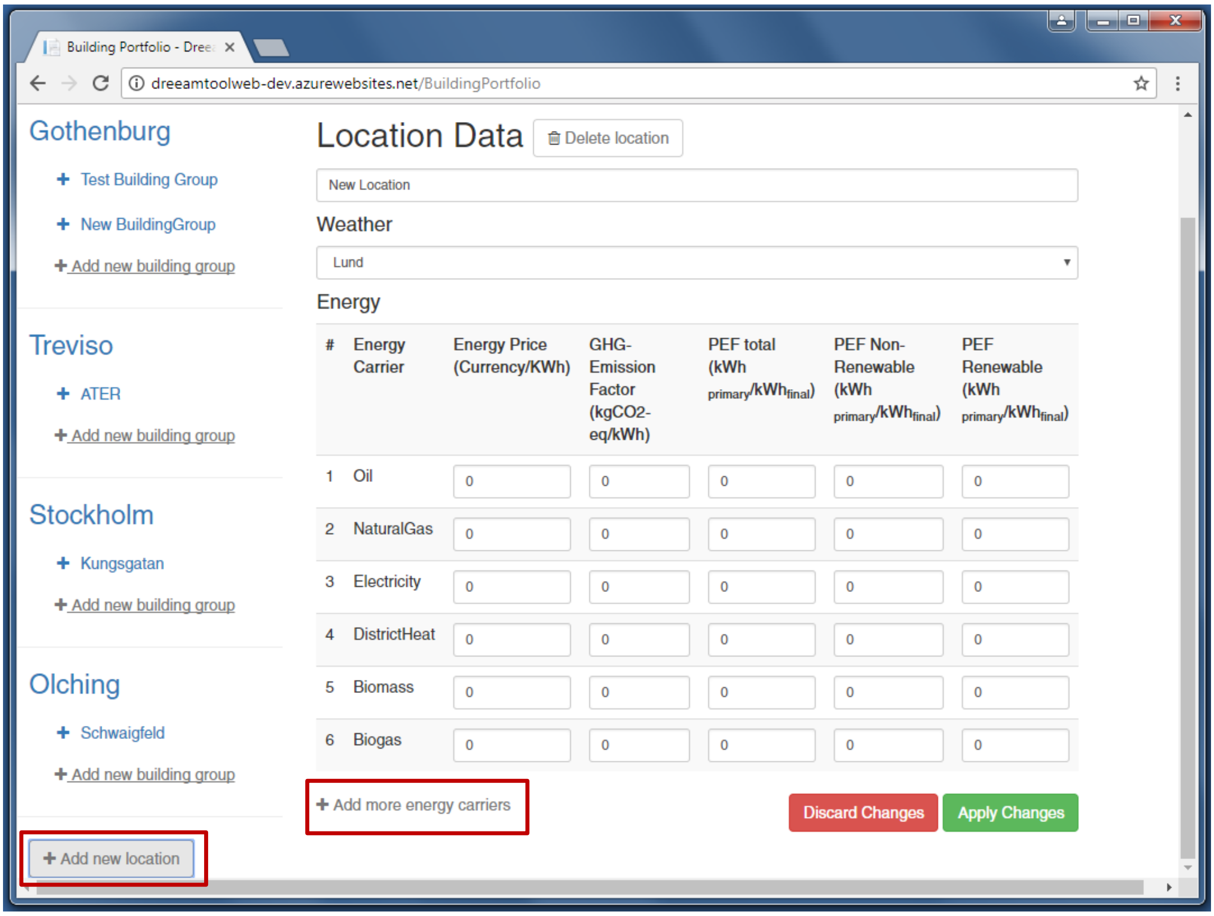

Figure 5: Adding new locations and location data

Add new building groups and buildings

After creating a location, the user can add building groups, and inside the building groups, create different building types. The overview of the status quo of the buildings serves as the foundation for the calculations.

When entering a new building different sections have to be considered, the summary and the building components.

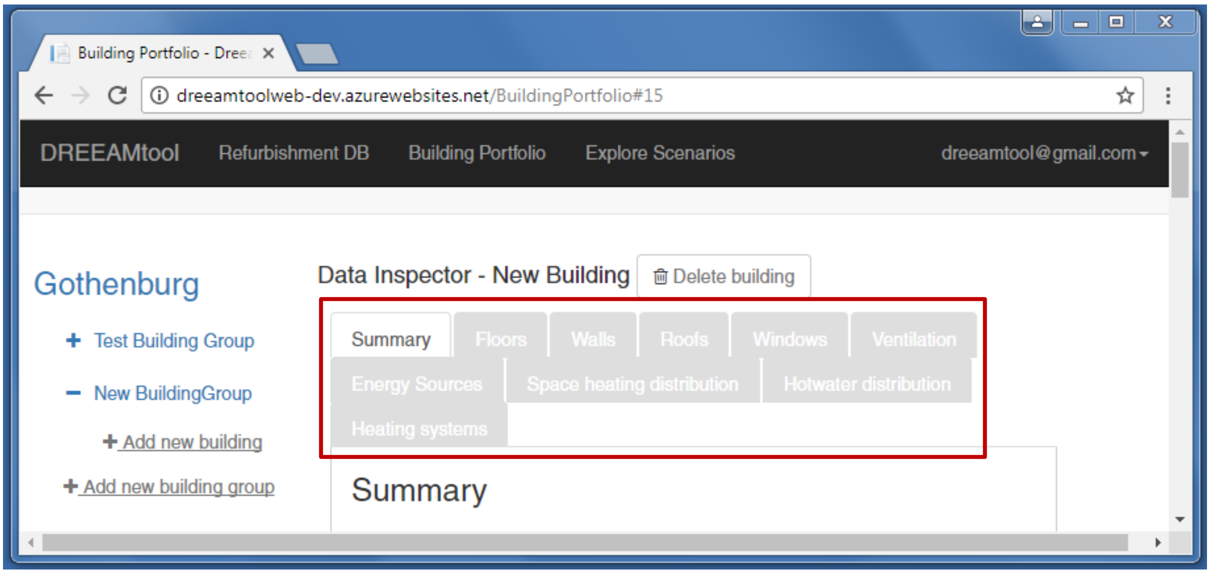

Figure 6: Editing information of the existing building

The first page shows the summary section. Here the user has to add the following basic information about the properties on the right end of the page (see Figure 7):

- Overview (Name, Street, etc.)
- Indoor set temperatures for heating and cooling
- Water temperatures and consumption
- Electricity use
- Thermal mass of the building
- Building dimensions
- Information about occupancy

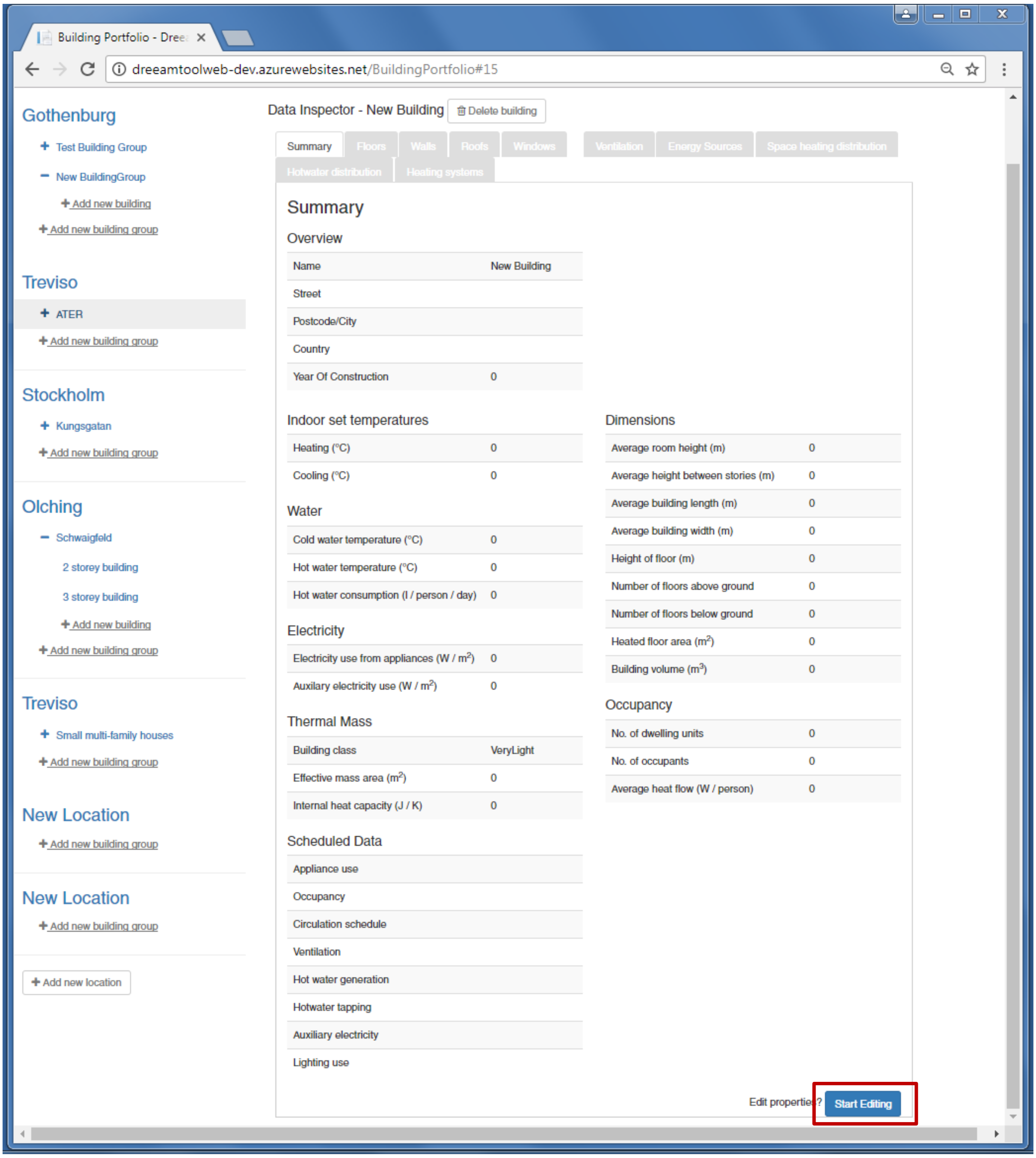

Figure 7: Editing of basic information of the building

As shown in Figure 6 also further information about the building components (floors, roofs, etc.) have to be added. Detailed information as well as all the parameters that are needed for the different sections are listed in Appendix 1 and 2.

2.4 Refurbishment Database

In the Refurbishment Database sector, the user adds own custom refurbishment options and can edit properties of all the refurbishment options that were added. Those refurbishment packages will be stored in the database and the user can select later on which are chosen for the calculations.

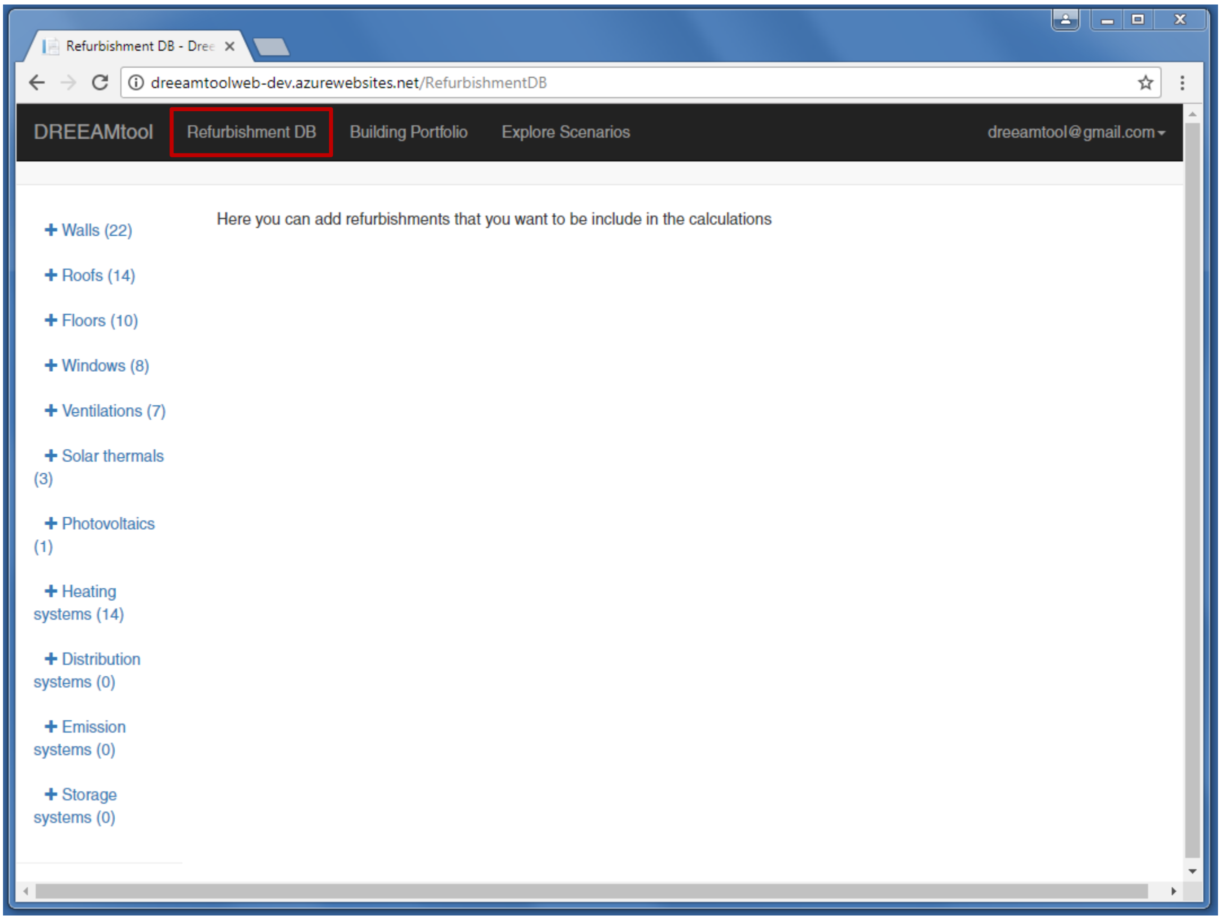

Figure 8: Refurbishment Database Section in the DREEAM-Tool

Add new refurbishment options

By clicking on "Add new …" for each component (see Figure 9) and system one can add and remove refurbishments that should be stored in the database. The database is structured according to the following different building components and systems:

Table 2: Components and systems considered in the refurbishment database

Components & Systems	
Walls	Photovoltaics
Roofs	Heating systems
Floor	Distribution systems
Windows	Emission systems
Ventilations	Storage systems
Solar thermals	

For each building component and system, the database will list the refurbishment solutions that were added and each solution contains a list of parameters needed for the calculations.

For example, Figure 9 shows which parameters are needed for a new floor. Detailed information as well as all the parameters that are needed for the different components and systems are listed in Appendix 3.

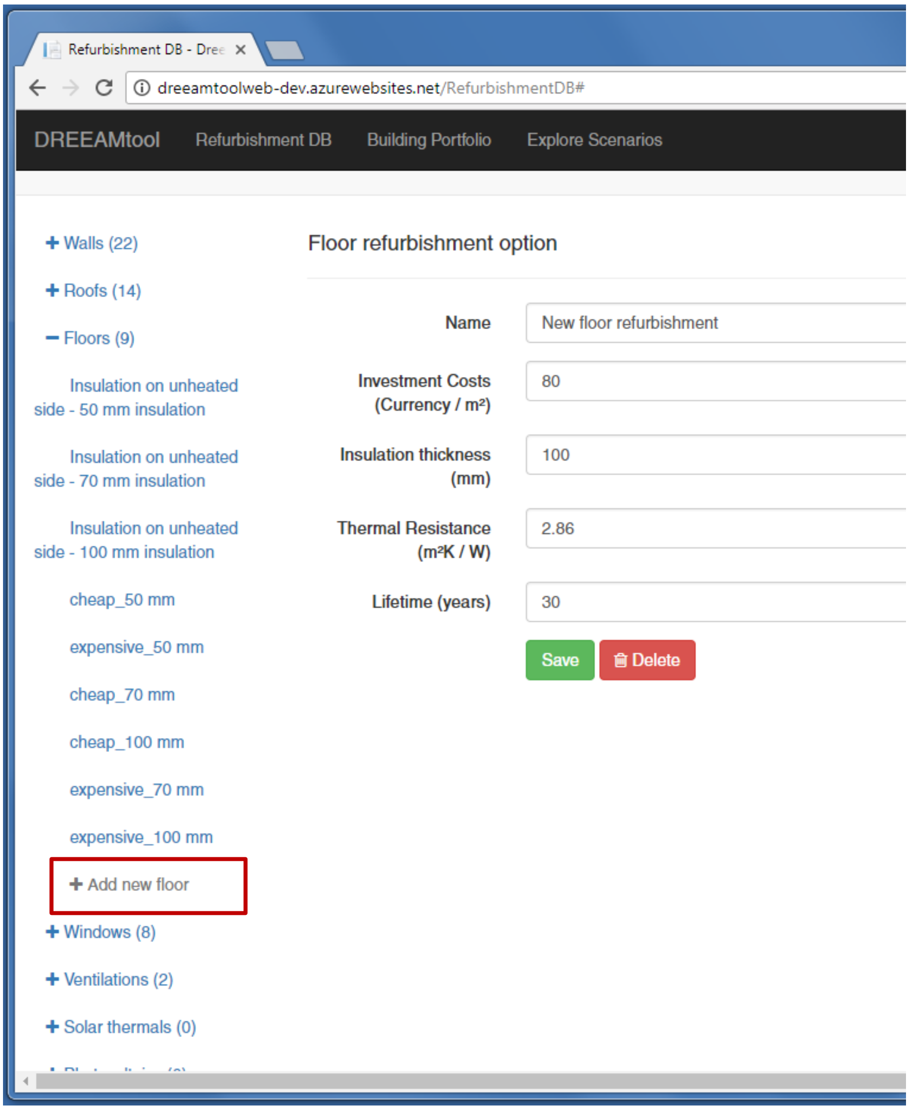

Figure 9: Adding a new floor refurbishment option

2.5 Explore Scenarios

The Explore Scenarios section presents the core of the tool. Here new scenario calculations for the building portfolio can be started, and the optimal strategies can be explored when the calculations are done. The different strategies can be selected and exported for external use.

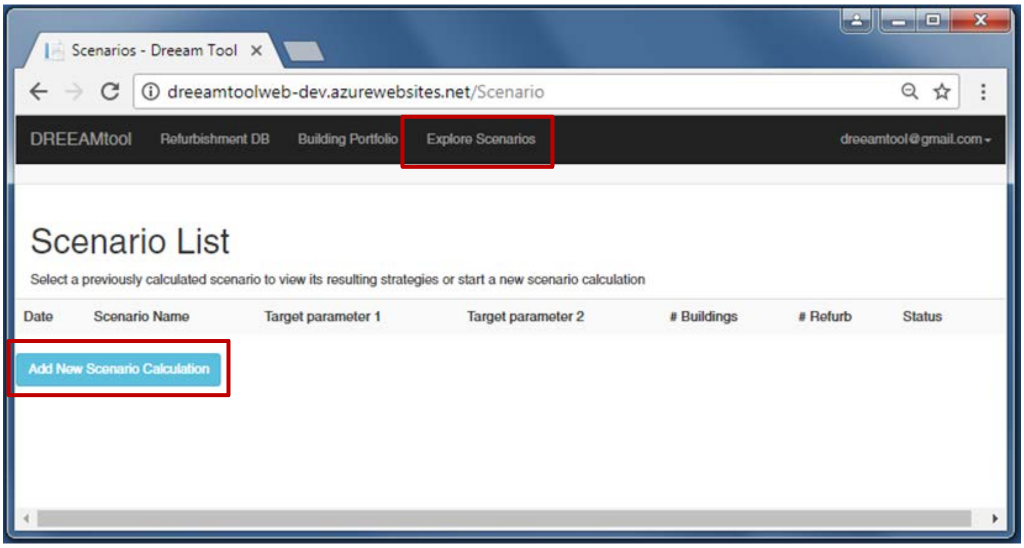

Figure 10: Explore Scenarios in the DREEAM tool

2.5.1 Add new Scenarios

In order to start a new calculation, the tool provides a button "Add new Scenario calculation" at the end of the scenario list as shown in Figure 10.

First of all, one can choose the location that is needed for the new scenario. After choosing the right location one can select the building groups and buildings that should be included in the new scenario on the left side of the interface (see Figure 11). Furthermore there appear two more sections: Allowed Refurbishment Measures and Scenario Settings.

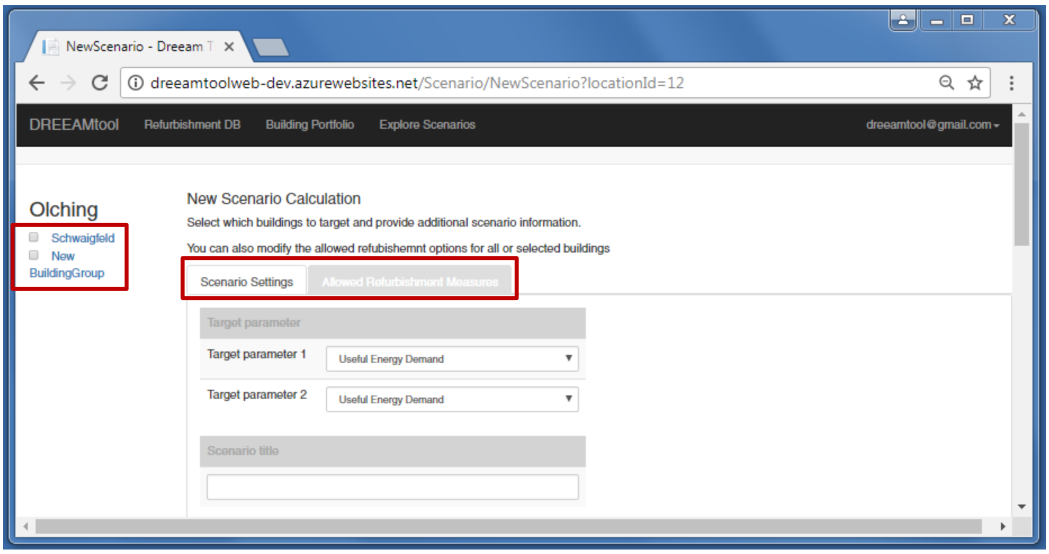

Figure 11: Adding a new scenario

Allowed refurbishment measures

In the section “Allowed refurbishment measures” one has to choose all the refurbishment measures that should be included in the scenario calculation for each building individually (Figure 12).

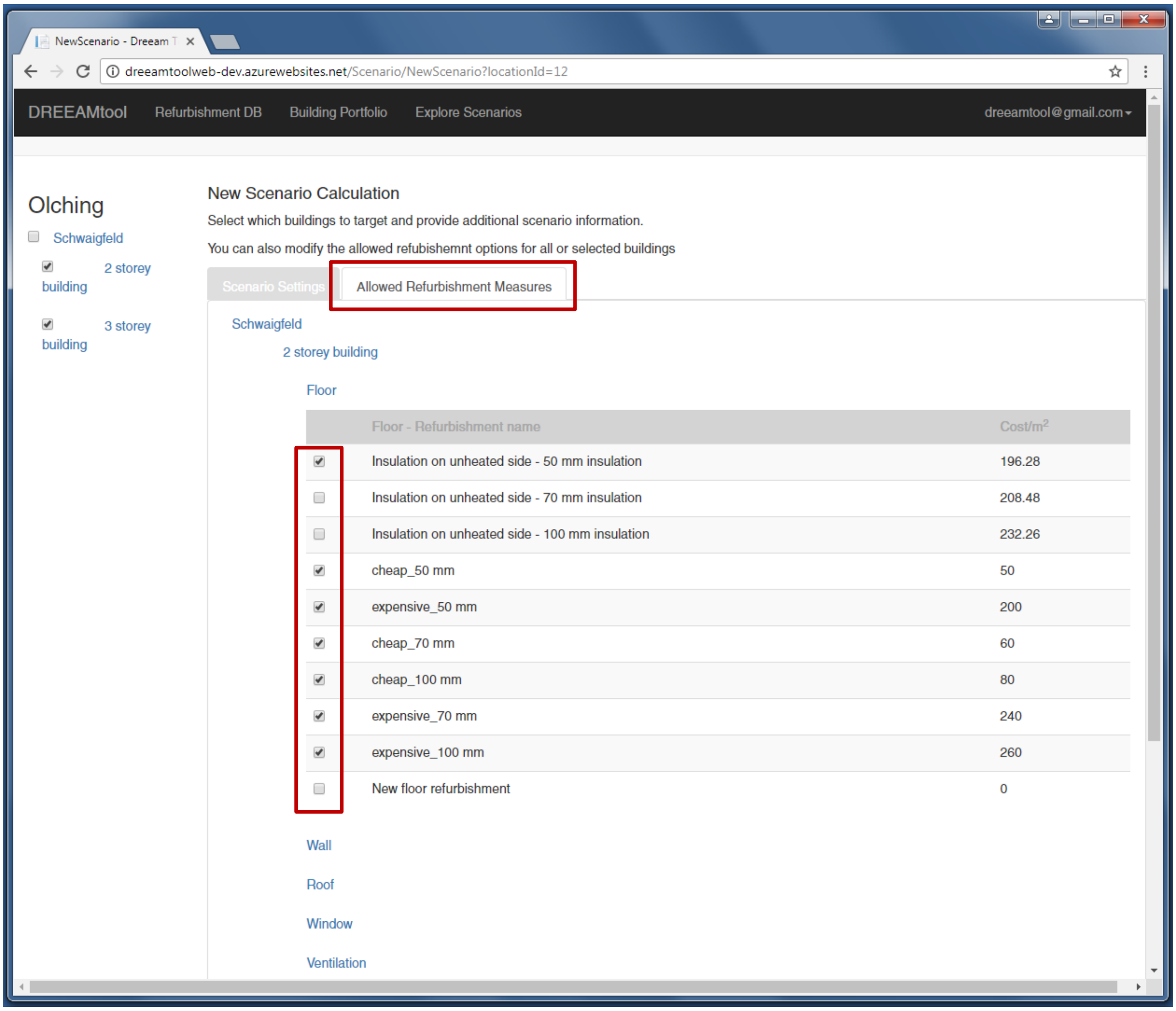

Figure 12: Selection of refurbishment measures for the scenarios

Section: Scenario Settings (see Figure 13)

Target parameters:

1. In the beginning of the scenario settings it is important to choose the two parameters that are going to be calculated and compared for the new scenario in order to evaluate the potential refurbishment concepts (for example: Useful Energy Demand & Investment Costs). According to Step 2 of the DREEAM approach (Indicator Definition) they are used as benchmarks for different renovation concepts and enable the DREEAM-Tool to optimize refurbishment designs based on them.

Indicators	
Environmental Indicators	**Economic Indicators**
Final Energy Demand	Investment Costs
Final Energy Savings	Running Costs
Electricity Production	Total Life Cycle Cost
GHG Emissions	Net Present Value
Primary Energy	Internal Rate Of Return
GHG Emission Savings	Return On Investment
Primary Energy Savings	Running Cost Savings
Combined Indicators	**Technical Indicators**
Final Energy Savings per Investment	Self-Consumption Of Produced Electricity
Primary Energy Savings per Investment	Self-Production Of Consumed Electricity
GHG-Emission Savings per Investment	

2. Scenario title
3. Economic parameters: They only need to be added when economic parameters such as Lifecycle costs, Net Present Value or Internal Rate of Return are used as target parameters, otherwise they can be left blank or set as 0.

Name	Unit	Description
Other investment cost	Currency/m²	
Average rent	Currency/m²	The average costs per m² living area
Rent Increase after refurbishment	Currency/m²	The cost increase per m² living area after the refurbishment
Annual rent increase	%/year	Percentage of annual cost increase for the living area
Vacancy rate	%	Percentage of the living area that is occupied by tenants
Operational cost	Currency/m²	Costs per m² living area to keep the place in operation
Discount rate	%	
Inflation rate	%	Rate at which prices increase over time, resulting in a fall in the purchasing value of money
Period of analysis	years	Amount of years that are being looked at in the calculation

4. Included energy services in the economic calculation: If not given otherwise, all options are selected.
5. Energy - Annual Price Increase: Oil, Natural gas, Electricity, District heat, Biomass
6. Other: Electricity Feed-in Tarif (only when PV is used)

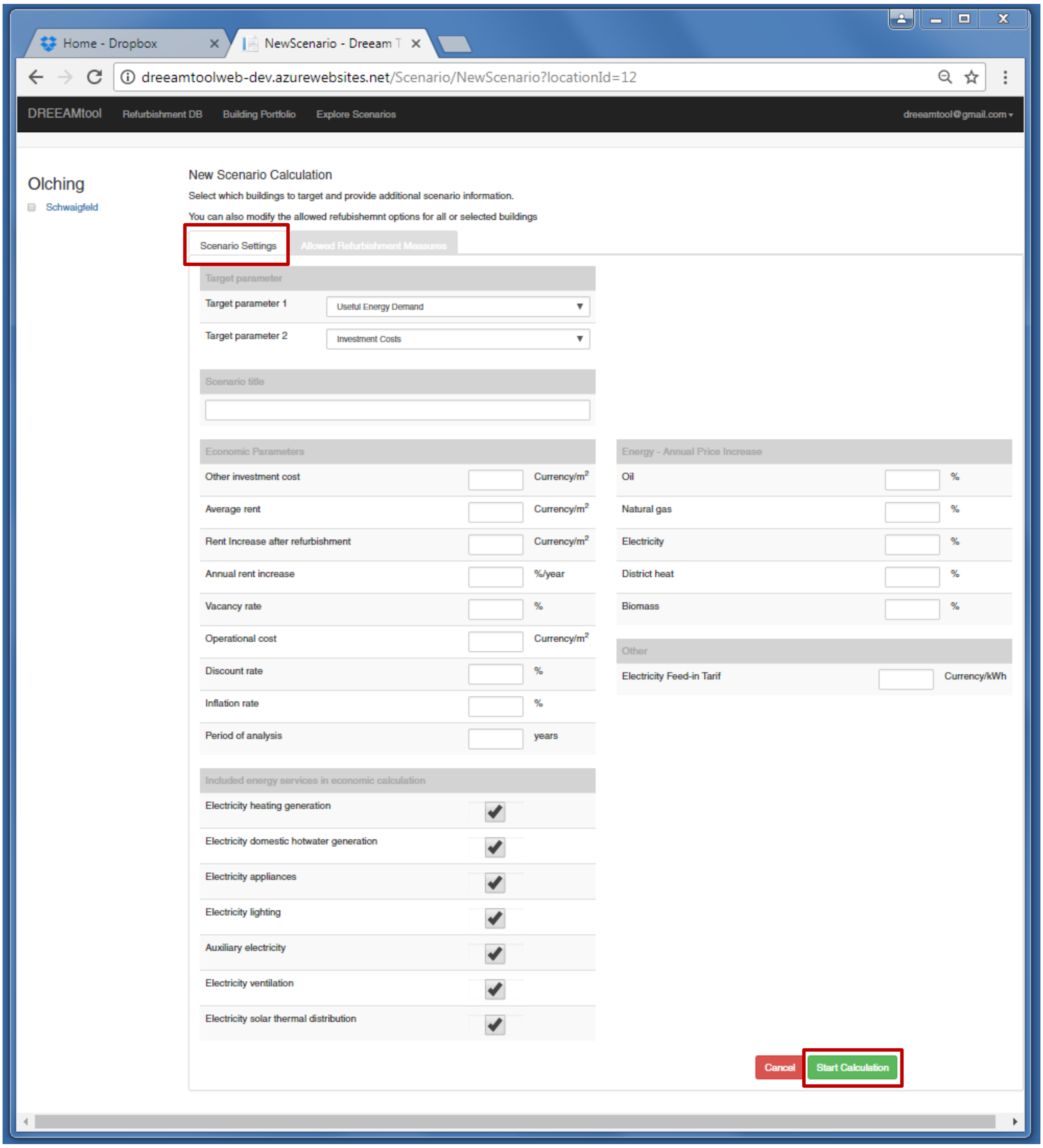

Figure 13: Start Scenario Calculation

After adding all information the calculation can be started with the “Start Calculation” button on the Scenario Settings page (Figure 13).

2.5.2 Explore Scenarios

Step 4 of the DREEAM approach is carried out through the calculations. After starting the scenario it will appear in the scenario list after clicking "Explore Scenarios". The status shows how far the calculation has gone. It might take up to 20 min until a calculation reaches 100%.

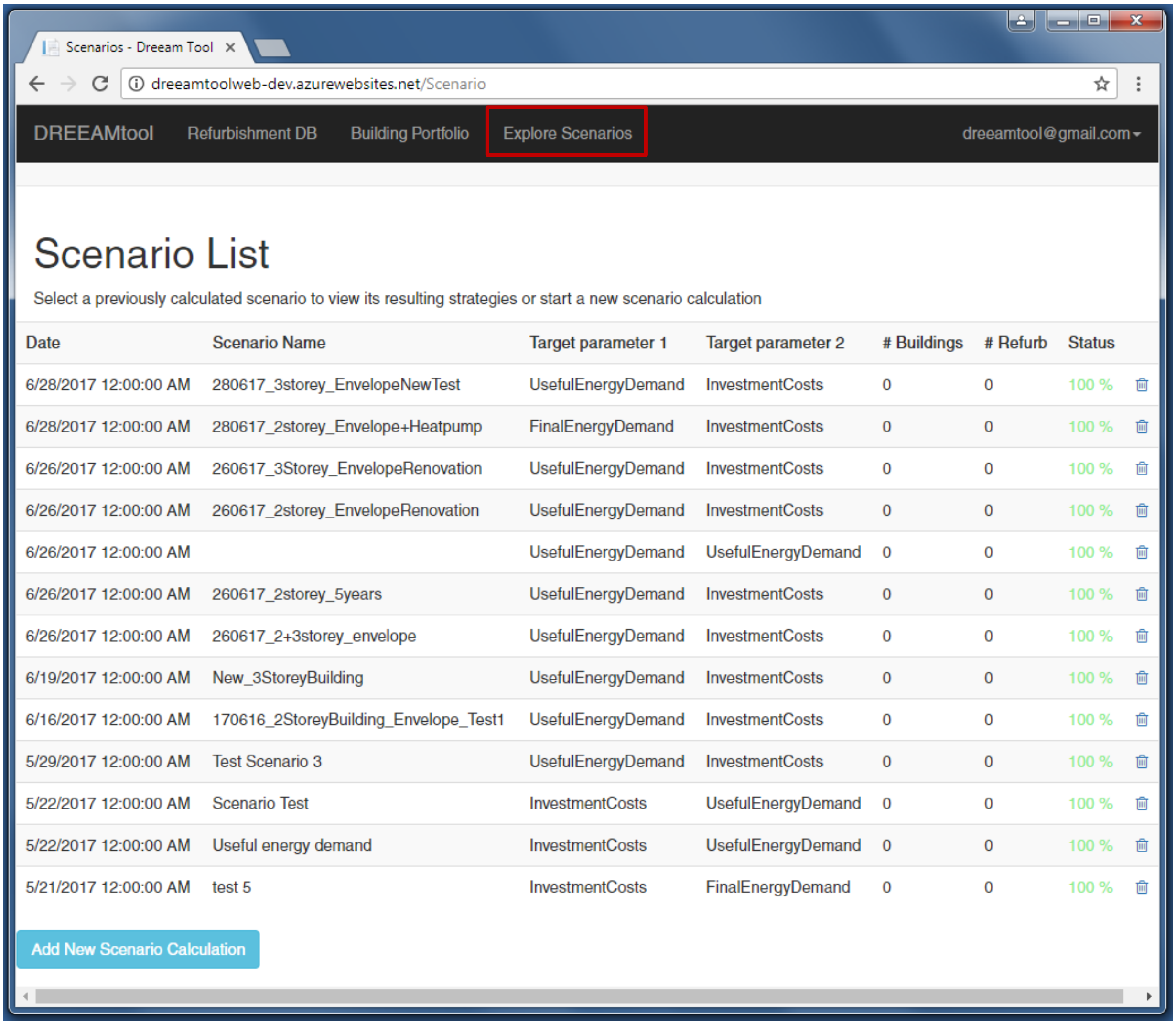

Figure 14: Calculation of the scenario

By clicking on the scenario a new window opens which shows the results of the calculation between the two chosen target parameters in a graph and table.

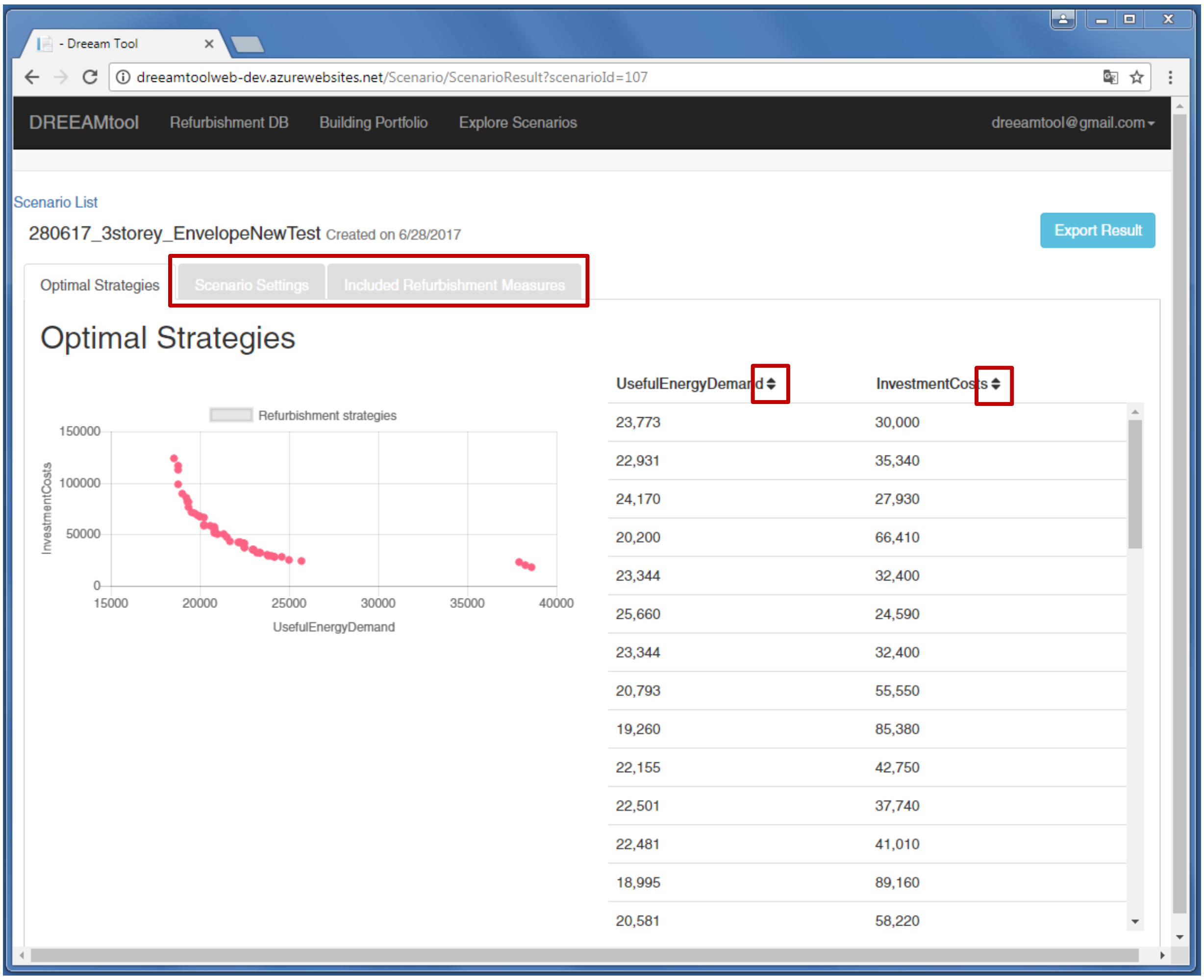

Figure 15: Scenario results

As also shown in Figure 15, one can recall the scenario settings and included refurbishment measures for the specific scenario. By clicking on a specific result in the table or graph, the strategy results are listed in more detail (Figure 16):

1. Target parameters
2. Costs
3. Energy use by energy carrier
4. Energy production
5. Energy use by type:
   - o Useful Energy
   - o Final Energy
   - o Primary Energy
   - o GHG Emissions
6. Economic indicators

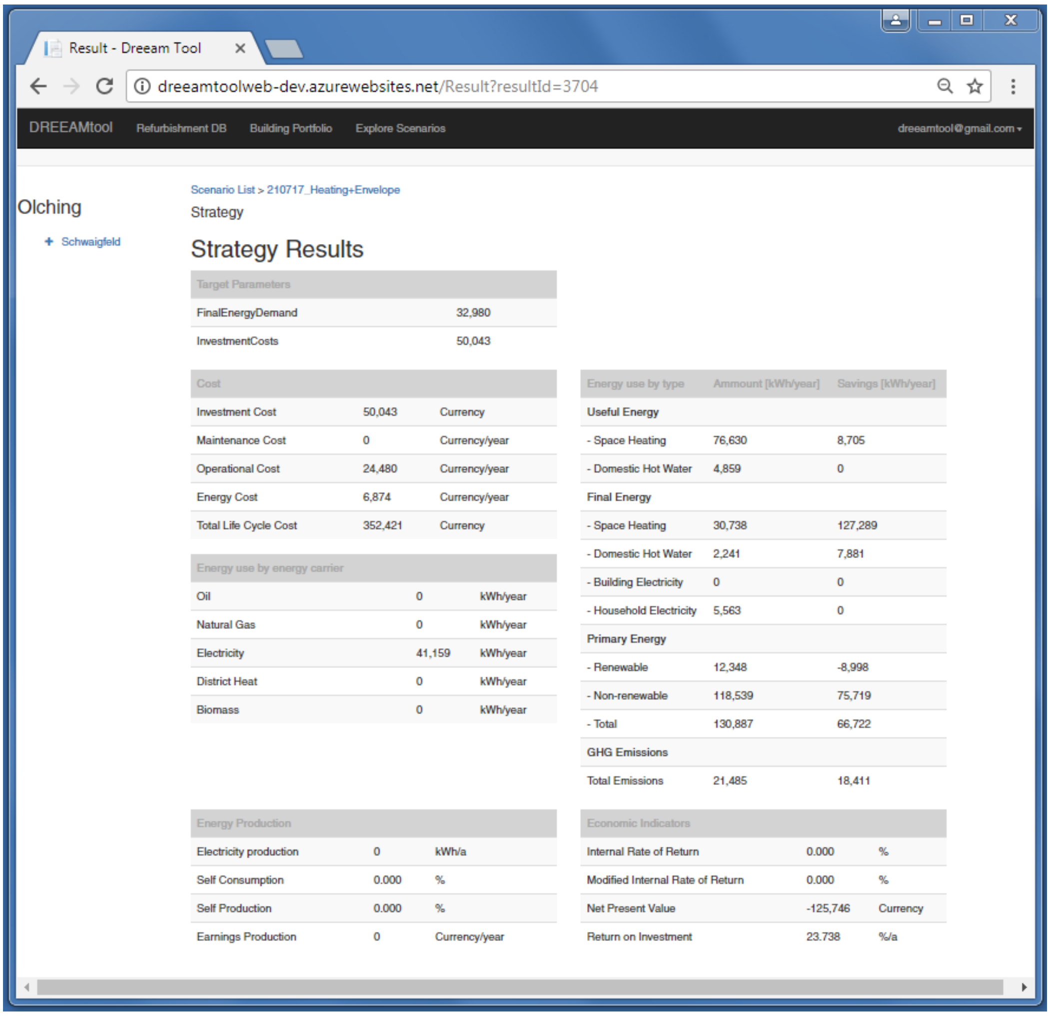

Figure 16: Detailed scenario results

When opening the building on the left side of the interface (here: Schwaigfeld) one can also see the selected refurbishment solutions for that specific strategy.

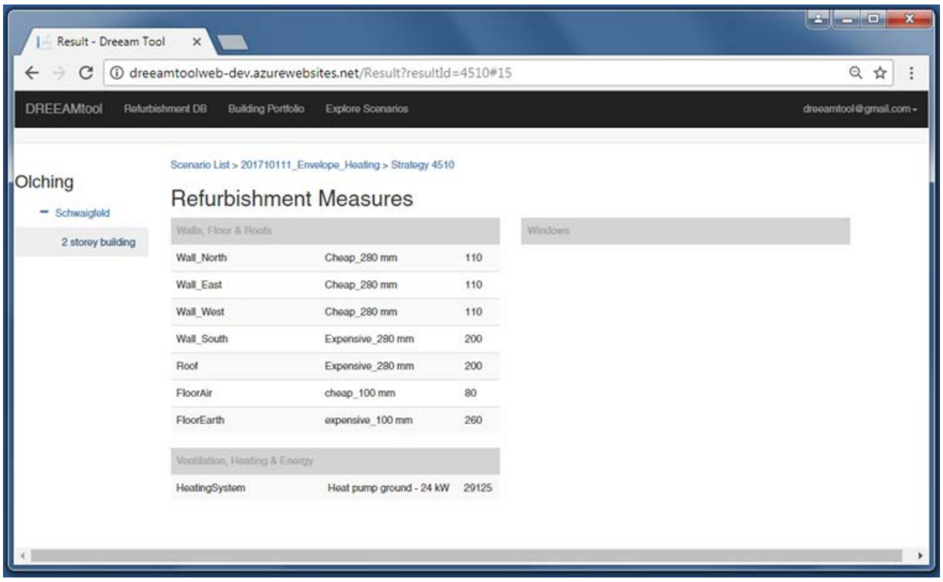

Figure 17: Selected refurbishment measures for a specific strategy

3 Validating the DREEAM Tool

In terms of its ability to calculate renovation scenarios according to multiple criteria, the DREEAM tool is an innovation that does not have an equivalent among tools available on the market. In order to validate the correctness of the calculations it generates, renovation design calculations with the use of a market-ready tool, HAP (also applied in WP2 work for IT and UK pilot sites) have been performed in parallel to the ones done by the DREEAM tool.

HAP uses the ASHRAE-endorsed transfer function method for the calculations and hour-by-hour energy simulation techniques for the energy analysis. It simplifies calculations and can provide the cooling loads arising from the all parts of the building, i.e., walls, windows, flat roofs, and floors. Hence, HAP tool is used to estimate the thermal load for the case study and the obtained results from HAP are used as a reference to be compared with DREEAM tool's results.

Renovation object

A stand-alone residential house was chosen as a case study. The house has a floor area of 150 m^2 and dimensions: 15m facing East and West, 10m facing North and South. Building height is 3 m. Total window opening area if 6 m^2 on each wall of U-value 1.5 W/m^2K and overall shade coefficient is 80%. The house is treated as one zone and was assumed to have a flat roof. Table 3 shows the specifications of the modeled house.

Table 3. Specifications of studied building

<table>
<tr><td>Throttling temp. range (°C)</td><td>1</td><td colspan="2">Outdoor ventilation air flow (l/s)</td><td>125</td></tr>
<tr><td>Building area (m^2)</td><td>150</td><td colspan="2">Designing outdoor temperature (°C)</td><td>46</td></tr>
<tr><td>Space volume (m^3)</td><td>450</td><td colspan="2">Number of people</td><td>3</td></tr>
<tr><td>Widows shade coefficient</td><td>0.8</td><td colspan="2">Unoccupied indoor temperature (°C)</td><td>27</td></tr>
<tr><td>Building weight (kg/m^2)</td><td>308</td><td colspan="2">Internal Equipment load (W/m^2)</td><td>6</td></tr>
<tr><td>Direction</td><td>Dimension</td><td>U-value</td><td>Absorptivity</td><td>Windows area</td></tr>
<tr><td>North</td><td>10x3</td><td>1.5</td><td>0.7</td><td rowspan="4">6</td></tr>
<tr><td>East</td><td>15x3</td><td>1.28</td><td>0.6</td></tr>
<tr><td>South</td><td>10x3</td><td>0.9</td><td>0.4</td></tr>
<tr><td>West</td><td>15x3</td><td>1.944</td><td>0.5</td></tr>
</table>

Validation approach

In order to verify the accuracy of the DREEAM tool, a comparison between the results obtained by HAP and the results obtained by DREEAM was carried out as follows.

Firstly, a stand-alone residential building was assumed as a case study. Table 3 the specifications of the case study, which were fed into DREEAM tool in order to create a building portfolio.

Table 3. Specifications of studied building

Throttling temp. range (°C)	1	Outdoor ventilation air flow (l/s)		125	
Building area (m^2)	150	Designing outdoor temperature (°C)		46	
Space volume (m^3)	450	Number of people		3	
Widows shade coefficient	0.8	Unoccupied indoor temperature (°C)		27	
Building weight (kg/m^2)	308	Internal Equipment load (W/m^2)		6	
Direction	Dimension	U-value	Absorptivity	Windows	
				area	U-value
North	10x3	1.5	0.7	6	1.5
East	15x3	1.28	0.6		
South	10x3	0.9	0.4		
West	15x3	1.944	0.5		

Secondly, different energy retrofitting measures, including wall, roof, floor, and windows, were chosen to generate refurbishment scenarios. Table 4 shows the specifications of the selected energy retrofitting measures used to validate the DREEAM tool.

Table 4. Specifications of considered energy retrofitting measures

Building element	Retrofitting measures	Thermal resistance m^2K/W
Floor	5 cm insulation	1.43
Wall	12 cm insulation	3.43
	24 cm insulation	6.86
Roof	10 cm insulation	2,86
Windows	Wood/aluminium	U-value=0.8 W/m^2K

Finally, the DREEAM tool was run to generate the optimal combination scenarios between the above-considered measures, and the results are listed in Table 5. It is worth mentioning that among the suggested optimal renovation scenarios, changing the current windows of the case study does not seem to be viable. This can be attributed to the facts:

- the thermal quality of the current windows is relatively good, and
- the price of the windows with U-value of 0.8 W/m^2K, at the current market price, is high.

Table 5. Specifications of studied building

Run	Wall N	Wall E	Wall S	Wall W	Roof	Floor	Window
1	Baseline						
2						Insulation 5 cm	
3	Brickwall 24 cm						
4	Brickwall 24 cm			Brickwall 240 cm			
5		Brickwall 12 cm		Brickwall 12 cm			
6				Brickwall 12 cm	External Insulation - 10 cm		
7				Brickwall 24 cm	External Insulation - 10 cm		
8				Brickwall 12 cm	External Insulation - 10 cm	Insulation 5 cm	
9				Brickwall 24 cm	External Insulation - 10 cm	Insulation 5 cm	
10	Brickwall 24 cm			Brickwall 24 cm	External Insulation - 10 cm		
11		Brickwall 12 cm		Brickwall 12 cm	External Insulation - 10 cm		
12	Brickwall 12 cm			Brickwall 12 cm	External Insulation - 10 cm	Insulation 5 cm	
13	Brickwall 12 cm	Brickwall 12 cm		Brickwall 12 cm	External Insulation - 10 cm	Insulation 5 cm	
14	Brickwall 24cm			Brickwall 12 cm	External Insulation - 10 cm	Insulation 5 cm	
15	Brickwall 12 cm			Brickwall 24 cm	External Insulation - 10 cm	Insulation 5 cm	
16		Brickwall 12 cm		Brickwall 24 cm	External Insulation - 10 cm	Insulation 5 cm	
17	Brickwall 12 cm	Brickwall 12 cm		Brickwall 24 cm	External Insulation - 10 cm	Insulation 5 cm	
18	Brickwall 12 cm	Brickwall 12 cm	Brickwall 12 cm	Brickwall 24 cm	External Insulation - 10 cm	Insulation 5 cm	

In order to calculate the thermal load of the case study using HAP, the refurbishment proposed by DREEAM tool, which is listed in Table 5, were manually inserted in HAP. Practically this means that 18 different buildings, one baseline building, and 17 different retrofitting scenarios, were created in HAP model and the thermal load of each one was simulated separately.

This way, the thermal load and, consequently, the savings due to implementing refurbishments for the case study and the all optimal combination of the selected energy retrofitting measures proposed in this study, Table 5, have been simulated using HAP software and DREEAM tool.

Accuracy Developments

In the first round, a massive difference between HAP and DREEAM tool was observed. Therefore, as a first step, the heating load of different building elements (walls, windows, roof, and floor) was tested element by element. The results obtained by DREEAM tool were compared with the corresponding results obtained by HAP. The compression leads to find a huge difference in the heating load of some building elements. Therefore, the coding was reviewed, and some mistyping errors were found. After code correction, the accuracy of dream results as compared with HAP was improved, but the difference was still huge, see Figure 18.

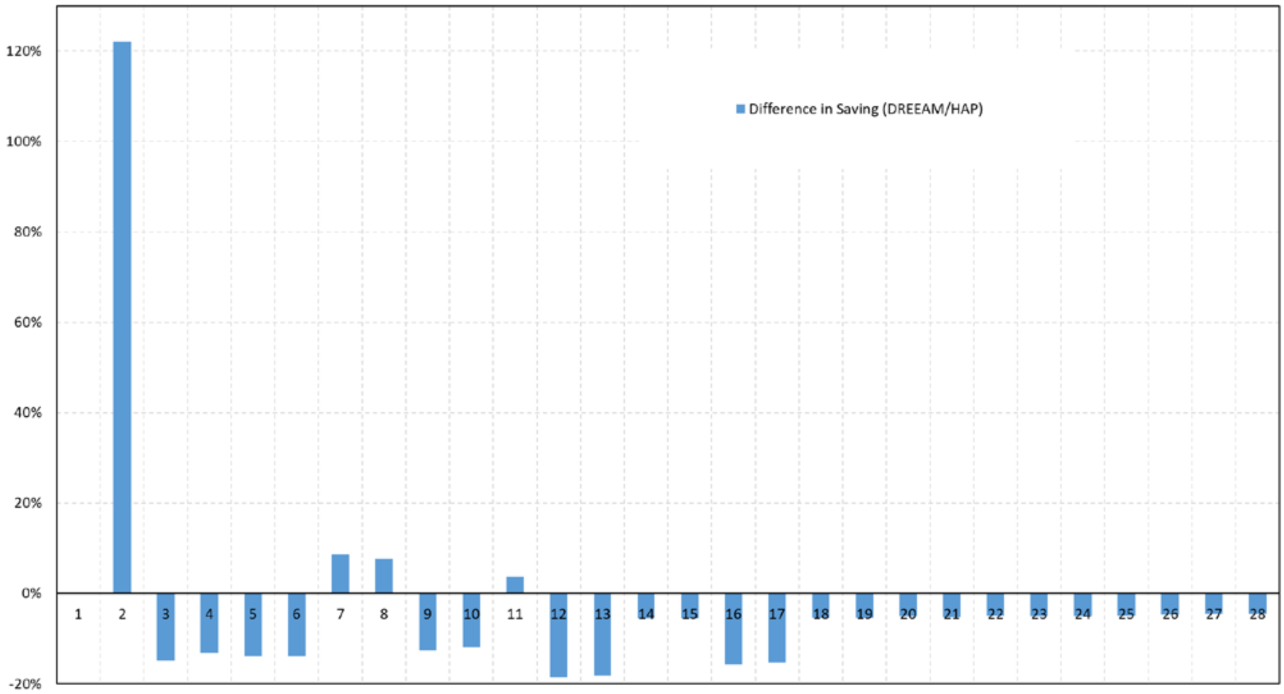

Figure 18: the results of the first compression between the saving in the heating demand obtained by DREEAM tool and HAP model

However, the most significant difference between the HAP and DREEAM tool results seems to be attributed to applying thermal insulation to the floor of the building. Therefore, different solutions, including testing the different value of b-factor and thermal conductivity of the ground, were tested in order to determine the source of the error, see Figure 19. As a result of different trials, it was concluded that reducing the heat losses from the ground in DREEAM tool will increase the accuracy of saving benefits due to implement energy-saving measures.

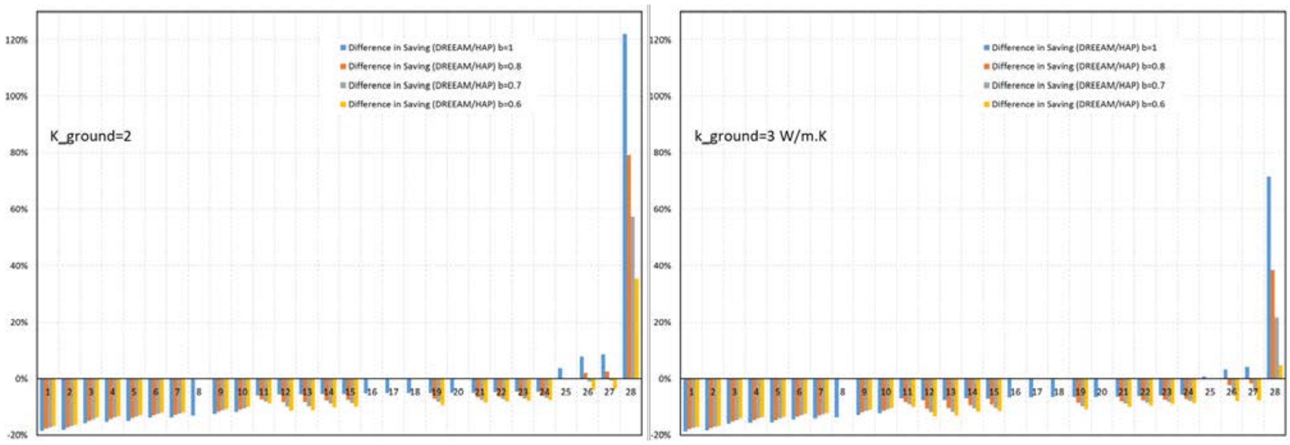

Figure 19: improvement of the accuracy due to reducing the heat loss from the ground calculated in DREEAM tool

Therefore, it was suggested to recalculating the U-value of the ground based on the EN ISO 13370: 2007 deals with U-value calculations for floors and basements, with three-dimensional heat flow in the ground below buildings. Thus, the code of DREEAM tool was modified, and the U-value of the floor of the building was calculated based on the new ISO standard. Table 6 shows the results of simulations. As it can be seen, the difference in thermal load of the case study obtained by DREEAM tool varies between 3% to 8% as compared to the HAP model; the difference in savings due to implementing different refurbishment scenarios is illustrated in Figure 18. As shown the difference in saving between DREEAM tool and HAP ranges between 0% to 3%. In other words, the calculation of the heating load and the reduction in it due to implementing different retrofitting measures in a residential building using DREEAM tool can be trusted. Consequently, the DREEAM tool can be safely used to calculate the refurbishment potential of a building.

Table 6. The results of simulation obtained by DREEAM tool and HAP model

	Thermal load (kWh)			Energy Savings (kWh)		Relative demand reduction	
Run	DREEAM	HAP	The difference in thermal load	DREEAM	HAP	DREEAM	HAP
1	48827	53167	-8,2%	-	-	-	-
2	47591	51871	-8,3%	1236	1296	2,5%	2,4%
3	45736	49616	-7,8%	3091	3551	6,3%	6,7%
4	38843	42001	-7,5%	9984	11166	20,4%	21,0%
5	38517	41734	-7,7%	10310	11433	21,1%	21,5%
6	36106	37889	-4,7%	12721	15278	26,1%	28,7%
7	35635	37409	-4,7%	13192	15758	27,0%	29,6%
8	34749	36658	-5,2%	14078	16509	28,8%	31,1%
9	34274	36160	-5,2%	14553	17007	29,8%	32,0%
10	32232	33915	-5,0%	16595	19252	34,0%	36,2%
11	31891	33642	-5,2%	16936	19525	34,7%	36,7%
12	31608	33385	-5,3%	17219	19782	35,3%	37,2%
13	27276	28987	-5,9%	21551	24180	44,1%	45,5%
14	31838	33112	-3,8%	16989	20055	34,8%	37,7%
15	31636	32902	-3,8%	17191	20265	35,2%	38,1%
16	30526	31802	-4,0%	18301	21365	37,5%	40,2%
17	26779	28451	-5,9%	22048	24716	45,2%	46,5%
18	25000	26683	-6,3%	23827	26484	48,8%	49,8%

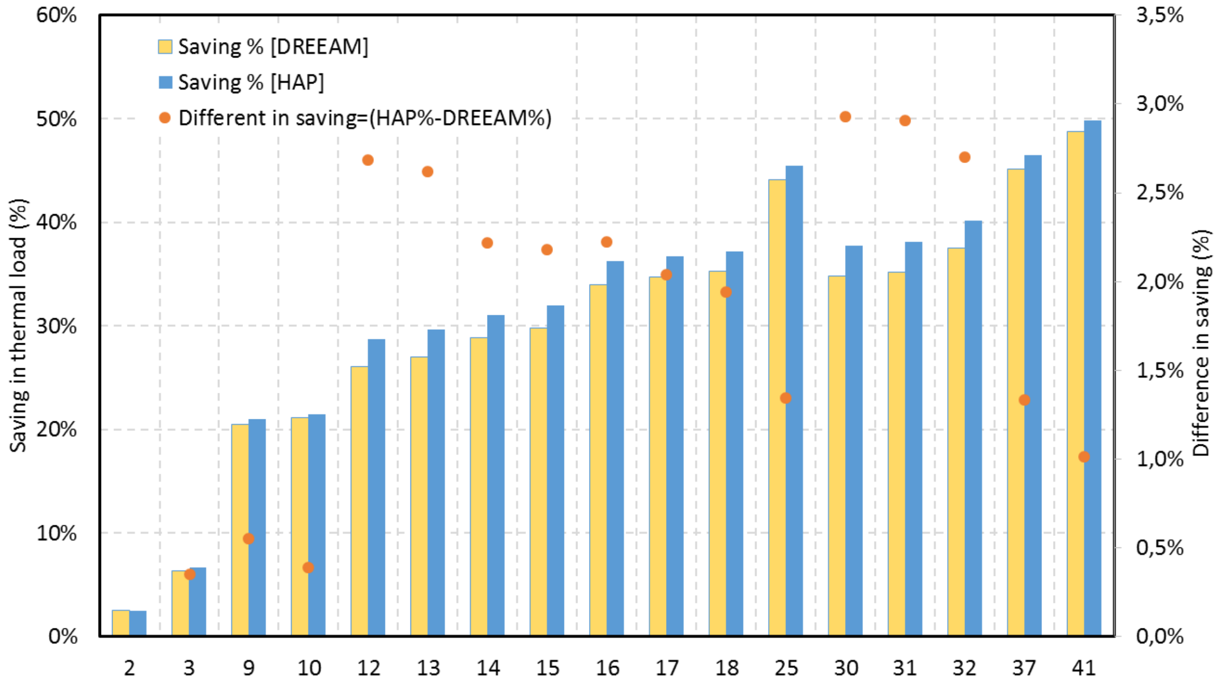

Figure 20: the compression between saving in heating demand, due to implementing different refurbishment scenario, obtained by DREEAM tool and HAP model

4 Conclusion

The aim of this deliverable was to describe the DREEAM approach to refurbishment which takes a larger renovation scale (multiple buildings or even portfolio level) as a starting point for renovation planning and design. Taking a multi-building approach to refurbishing the residential building stock, building owners can act more strategically than it is the case when renovating single buildings and aim to achieve better energy efficiency results. Apart from addressing a larger scale of renovation than the conventional one, the core of the DREEAM approach is also the DREEAM tool that allows an optimized design of renovation concepts that best meet multiple objectives (e.g., energetic, environmental or economic). By doing so, the tool can support building owners in making strategic refurbishment decisions for their portfolio and help them translate those decisions into corresponding refurbishment concepts. A first online version of the tool was developed and can now be tested with DREEAM project partners and potential users.

Finally, the verification analysis shows that the results obtained by DREEAM tool can be trusted and safely be used to calculate the refurbishment potential of a building.

5 Appendix

Appendix 1: Building Portfolio - Basic information about the building properties

Name	Unit	Input	Description
Overview		Name Street Postcode City Country Year of Construction	
Indoor set temperatures Heating Cooling	 °C °C	 e.g. 21 e.g. 25	Set-temperature is the agreed temperature that the building will meet
Water Cold water temperature Hot water temperature Hot water consumption	 °C °C l/person/day	 e.g. 10 e.g. 60 e.g. 25	
Electricity Use from appliances Auxiliary electricity use	 W/m^2 W/m^2		Electricity use for appliances as well as auxiliary energy for building services
Thermal Mass Building class Effective mass area Internal heat capacity	 Choose from given options m^2 J/K	 Very light Light Medium Heavy Very heavy	
Dimensions Room height Height between stories Building length Building width Height of floor No. of floors above ground No. of floors below ground Heated floor area Building volume	 m m m m m m^2 m^3		
Occupancy No. of dwelling units No. of occupants Average heat flow	 W/person		

Appendix 2: Building Portfolio - Building parameters

Parameters for walls, roofs and floors:

Name	Unit	Input	Description
Name			
Area	m^2		
Orientation	°	0-360	0° = North 90° = East 180° = South 270° = West
Angle	°	0-90	0° = horizontal 90° = vertical
U-value	$W/(m^2K)$	The lower, the better -insulated the structure will be	Thermal transmittance= Rate of transfer of heat through a structure U = 1/R
b-Factor		0-1	adjustment factor, with value b unequal to 1 if the temperature at the other side of the component is not equal to the external air temperature
Against		Earth Unheated Outside Air Heated	Describes what is on the other side of the component

Parameters for windows:

Name	Unit	Input	Description
Name			
Window placed in			You can choose from the areas you have entered in the walls, roofs and floors sections
Surface	m^2		
U-value	$W/(m^2K)$	The lower, the better -insulated the structure will be	Thermal transmittance= Rate of transfer of heat through a structure
g-Value		0-1	Measure of solar energy transmittance of glass 0 = no transmittance 1 = max. of solar energy
Frame Ratio		0-1 e.g. 0.3 (= 30 %) e.g. 0 = no frame	Percentage of frame area looking at the whole window area
Shade Factor		0-1	Ratio of solar gain (due to direct sunlight) passing through a glass
Width	m		Width of the window
Height	m		Height of the window
Quantity			Amount of the windows

Parameters for ventilations:

Name	Unit	Input	Description
Name			
Design Air Flow Rate	m^3/h		Air volume added to or removed from a space per hours
Efficiency Heat Recovery	%	0-100	Efficiency of the Heat Recovery Unit- 0 = no heat recovery
Efficiency Sub-Soil Heat exchanger	%	0-100	Efficiency of a sub-soil heat exchanger unit 0 = no sub soil heat exchanger
Specific Fan Power	Wh/m^3	e.g. in high-performance housing 0.45 or less	Energy-efficiency of fan air movement systems
Maintenance Costs	currency/(m^3/h)		The annual costs incurred to keep the item in good condition
Additional Air Change Rate Infiltration	1/h		Additional air changes per hour from the ventilation
Type		Natural Exhaust Exhaust and Supply Exhaust and Supply with Heat Recovery Exhaust with Exhaust Air Heat Pump	

<u>Energy Sources</u>

Parameters for solar thermals:

Name	Unit	Input	Description
Name			
Installed On			You can choose from the areas you have entered in the walls, roofs and floors sections
Direction	°	0-360	0° = North 90° = East 180° = South 270° = West
Angle	°	0-90	0° = horizontal 90° = vertical
Area	m^2		Area that is covered by the thermal system
Thermal Efficiency	W/K		Heat losses from the collector
Optical Efficiency	%	0-100	The rate of optical (short wavelength) energy reaching the absorber
Power Circulation Pumps	W		Nominal power of circulation pumps

Parameters for photovoltaics:

Name	Unit	Input	Description
Name			
Installed On			You can choose from the areas you have entered in the walls, roofs and floors sections
Orientation	°	0-360	0° = North 90° = East 180° = South 270° = West
Angle	°	0-90	0° = horizontal 90° = vertical
Area	m^2		Area that is covered by the Photovoltaics
Peak Power	kWp		Peak power production of the PV-system
Collector Efficiency	%	0-100	The ratio of incident irradiation which is converted to electricity
Performance Ratio	%	0-100	Ratio of the actual and theoretically possible energy outputs (independent of location)

<u>Space Heating Distribution</u>

The user has the option to choose between default or an own system.

<u>Option 1:</u>

7. Use default efficiency: Default efficiency (% = 1-100)

<u>Option 2: Type in your own system</u>

8. *Parameters for Distribution System:*
    - Maintenance Costs (Currency/year)
    - Pipe between generator and vertical shafts, Pipe in shafts, Individual branching pipes:

Name	Unit	Input	Description
Name			
Length	m		Length of the distribution pipes
Share in heated space	%	0-100	Share of the pipes that are within the thermal zone
Temperature heated space	°C		Room temperature of the heated space

Temperature unheated space	°C		Room temperature of the unheated space
Linear transmittance	W/m K		Linear transmittance of the pipes insulation

9. *Parameters for Emission System:*

Name	Unit	Input	Description
Emission system type		Radiator Floor Wall Ceiling	
Control system		Unregulated Unregulated with Central Supply Temperature Regulation P-Controller PI-Controller PI-Controller with Optimization Function	See EN-15316-2-1 for details on the different types
Supply temperature	°C		
Return temperature	°C		
Maintenance costs	currency/year		The annual costs incurred to keep the item in good condition

Hotwater Distribution

The user has the option to choose between default or an own system.

Option 1:

10. Use default efficiency: Default efficiency (% = 1-100)

Option 2: Type in your own system

11. *Parameters for Distribution System:*

- Maintenance Costs (Currency/year)
- Pipe Diameter (m)
- Pipe between generator and vertical shafts, Pipe in shafts, Individual branching pipes:

Name	Unit	Input	Description
Name			
Length	m		
Share in heated space	%	0-100	
Temperature heated space	°C		Room temperature of the heated space
Temperature unheated space	°C		Room temperature of the unheated space
Linear transmittance	W/m K		Linear transmittance of the pipes insulation

12. Parameters for Storage System:

Name	Unit	Input	Description
Tank volume	l		
Heat loss coefficient	W/K		Heat losses from the storage tank
Temperature room storage tank	°C		Room temperature of the room the storage tank is placed in
Storage tank installed		Yes No	Select no if there is no hot water storage system installed
Maintenance costs	currency/year		The annual costs incurred to keep the item in good condition

Parameters for the heating system:

Name	Unit	Input	Description
Use for domestic hot water distribution		Yes No	Is the heating system used for hot water
Use for space heating distribution		Yes No	Is the heating system used for heating
Type		Boiler Heat pump* District heating Biomass Combined Heat and Power Direct Electricity	
Description			
Selected energy carrier		Oil Natural Gas Electricity District Heating Biomass Biogas	
Nominal power	kW		The value stating the power that the system can produce, when used in a given manner
Efficiency	%	0-100	Ratio of the energy developed by the system to the energy supplied to it. In case of a heat pump the efficiency refers to the Carnot efficiency of the heat pump
Maintenance costs	currency/year		The annual costs incurred to keep the item in good condition

*When choosing “Heat pump” additional information is needed: source, source temperature (see chapter 1.2 “Heating system”)

Appendix 3: Refurbishment DB - Parameters needed for the different options

Parameters for Walls, Roofs and Floors:

Name	Unit	Input	Description
Name			
Investment Costs	currency/m²		Costs for 1 m² of the new refurbishment measure
Insulation Thickness	mm	e.g. 100	
Thermal Resistance	(m²K)/W	The higher, the more a material prevents heat transfer	Ability of heat to transfer from hot to cold through materials R = 1/U
Lifetime	years	e.g. 30	Duration of use of the specific component

Parameters for Windows:

Name	Unit	Input	Description
Name			
Investment Costs	currency/m²		Costs for 1 m² of the new refurbishment measure
g-Value		0-1	Measure of solar energy transmittance of glass 0 = no transmittance 1 = max. of solar energy
U-Value	W/(m²K)	The lower, the better -insulated the structure will be	Thermal transmittance= Rate of transfer of heat through a structure U = 1/R
Lifetime	years	e.g. 30	Duration of use of the specific component
Frame Ratio		0-1 e.g. 0.3 (= 30 %)	Percentage of frame area looking at the whole window gap 0 = no frame

Parameters for Ventilations:

Name	Unit	Input	Description
Name			
Investment Costs	currency/(m³/h)		Costs for 1 m³/h airflow
Lifetime	years	e.g. 30	Duration of use of the specific component

Type		Natural Ventilation Exhaust Ventilation Exhaust and Supply Ventilation Exhaust and Supply Ventilation with Heat Recovery Exhaust Ventilation with Exhaust Air Heat Pump	
Specific fan power	Wh/m^3	e.g. in high-performance housing 0.45 or less	The energy-efficiency of fan air movement systems
Efficiency Heat Recovery	%	0-100	Efficiency of the Heat Recovery Unit- 0 = no heat recovery
Efficiency Sub-Soil Heat exchanger	%	0-100	Efficiency of a sub-soil heat exchanger unit 0 = no sub soil heat exchanger
Maintenance Costs	$currency/(m^3/h)$		The annual costs incurred to keep the item in good condition

Parameters for Solar thermals:

Name	Unit	Input	Description
Name			
Investment Costs	currency		Total costs of the solar thermal system
Lifetime	years	e.g. 30	Duration of use of the specific components
Area	m^2		Area that is covered by the thermal system
Thermal Efficiency	W/K		Heat losses from the collector
Optical Efficiency	%	0-100	The rate of optical (short wavelength) energy reaching the absorber
Power Circulation Pumps	W		Nominal power of circulation pumps

Parameters for Photovoltaics:

Name	Unit	Input	Description
Name			
Lifetime	years	e.g. 30	Duration of use of the specific components
Maintenance Costs	currency/year		The annual costs incurred to keep the item in good condition
Area	m^2		Area that is covered by Photovoltaics

Peak Power	kWp		Peak power production of the PV-system
Collector Efficiency	%	0-100	the ratio of incident irradiation which is converted to electricity
Performance ratio	%	0-100	Ratio of the actual and theoretically possible energy outputs (independent of location)

Parameters for Heating systems:

Name	Unit	Input	Description
Name			
Investment Costs	currency		Total costs of the heating system
Lifetime	years	e.g. 30	Duration of use of the specific components
Type		Boiler Heat pump* District Heating Biomass Combined Heat and Power Direct Electricity	
Energy Carrier		Oil Natural Gas Electricity District Heating Biomass Biogas	
Nominal Power	kW		The value stating the power that the system can produce, when used in a given manner
Efficiency	%	0-100	Ratio of the energy developed by the system to the energy supplied to it. In case of a heat pump the efficiency refers to the Carnot efficiency of the heat pump
Maintenance Costs	currency/year		The annual costs incurred to keep the item in good condition
***Heat Pump Source**		Air Brine Groundwater	

***Heat Pump Source Temperature**	°C		Temperature of the source medium. In case of air the temperature of the outside air from the weather data in the tool is used instead.

Parameters for Distribution systems:

Name	Unit	Input	Description
Name			
Investment Costs	currency/m		
Lifetime	years	e.g. 30	Duration of use of the specific components
Linear Transmittance	W/mK		
Maintenance Costs	currency/year		The annual costs incurred to keep the item in good condition

Parameters for Emission systems:

Name	Unit	Input	Description
Name			
Investment Costs	currency/(m³/h)		
Lifetime	years	e.g. 30	Duration of use of the specific components
Emission system type		Radiator Floor Wall Ceiling	
Control system		Unregulated Unregulated with Central Supply Temperature Regulation P-Controller PI-Controller PI-Controller with Optimization Function	
Supply temperature	°C		
Return temperature	°C		
Maintenance costs	currency/year		The annual costs incurred to keep the item in good condition

Parameters for Storage systems:

Name	Unit	Input	Description
Name			
Investment Costs	currency/(m³/h)		
Lifetime	years	e.g. 30	Duration of use of the specific components

Tank Volume	l	Inside dimensions of the tank
Heat Loss Coefficient	W/K	Heat losses from the storage tank
Maintenance Costs	currency/year	The annual costs incurred to keep the item in good condition