Concept of the DREEAM approach for the multiple building energy renovation

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Executive summary

This report outlines 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. 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 visualised on a pareto-curve allow a building owner to select the most optimal refurbishment concept in an informed way.

At the core of this approach is the DREEAM-Tool, which is designed to support this process. 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 optimised design of renovation concepts that best meet multiple objectives (e.g. energetic, environmental or economical 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.

A first functional prototype of the tool is already available, but the development continues in order to generate a minimum viable product which can be tested with DREEAM project partners and potential users.

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1 Introduction

1.1 Background

Buildings account for around 40% of the energy used in European countries. In order to improve their energy efficiency, increase the use of renewables for energy generation, and so decrease the greenhouse gas emissions from building use, European countries need to foster the retrofit of their building stock. This is a challenge, considering the structure of the European building stock - over 35% of the buildings are more than 50 years old and often do not adhere to current energy standards. The European Union has addressed this issue through the two key directives: the Energy Performance of Buildings Directive [1] and the Energy Efficiency Directive [2]. Through these directives the EU aims to introduce nearly Zero-Energy Building (nZEB) standards across all member states by 2020 and 2018 for all public buildings and to put in place frameworks, fostering the refurbishment of the existing building stock. However, the current refurbishment rate is still stagnating at around 1% per year (opposed to the targeted 3% annually) and the majority of refurbishments being performed so far do not meet the high energy demand reduction standard the EU aims for (i.e. nZEB standards). Therefore, new approaches to refurbishment are needed, in order to increase the refurbishment and energy demand reduction rate.

1.2 Aim

The objective of DREEAM is to demonstrate that 75% reduction of net-energy demand can be achieved in a cost-efficient way for residential buildings in the social housing sector. Towards this aim DREEAM takes a large-scale approach, by increasing the renovation scope from a typical single building to multiple buildings, or even a building portfolio level. This approach will be complemented through the development of a renovation design and optimisation tool (referred in the report as the DREEAM tool). The DREEAM tool will enable building portfolio owners to plan and conceptualise the renovation of their buildings at a multi-building or portfolio scale, and by doing so, to take a more strategic and long-term approach to refurbishment. This will open the opportunity for a better integration of renewables in renovation concept design and an optimized interaction between energy supply and demand, which will in turn make nZEB-refurbishment more cost effective.

2 Refurbishment Concept Development

2.1 Overview

The DREEAM approach to a refurbishment conceptualisation on a multi-building scale is implemented in four steps, described shortly below and outlined in Figure 1:

5. **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.
6. **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.
7. **Tentative Concepts:** Tentative concepts are generated by selecting solutions which are feasible both from a technical standpoint as well as for acceptance reasons. These concepts are evaluated at this stage through a feedback loop with a building owner.
8. **Optimized Concepts:** The energy demand reduction of the concepts is calculated and optimized, based on the indicators selected in step 2. The results visualised on a pareto-curve allow a building owner to select the most optimal refurbishment concept in an informed way.

The four-step approach is supported by the DREEAM-Tool (see chapter 3 for more detailed description), applied in step 4 for the identification of the most suitable concepts that meet multiple indicators identified in step 2.

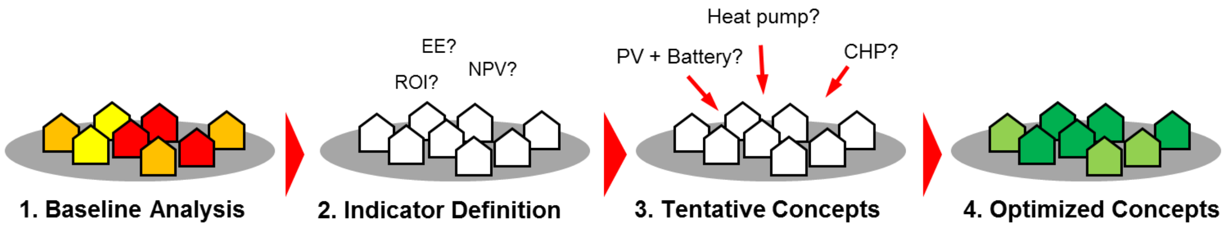

Figure 1 4 step approach to refurbishment concept development

The four steps of the DREEAM approach are described in more detail in the following sections.

2.2 Step 1 – Baseline Analysis

In the baseline analysis the initial state of the buildings is assessed, based on data on the general building information (floor area, surface areas, building components, technical systems, etc.) and historical energy demand measurements, which was gathered in WP2 and WP4. The measurement data allows to 1) calibrate standard energy demand models of the buildings, 2) identify their main energetic hotspots, 3) and compare different buildings between each other. Based on that, buildings and intervention areas subject for renovation can then be prioritised. During baseline analysis additional data relevant to the buildings, such as the state of repair of individual components (i.e. are there any components that absolutely need to be refurbished as they are close to the end of their lifetime) and other aspects relevant to the refurbishment plans (i.e. problems in the buildings not-related to the energetic performance, occupancy levels, etc.) is also collected.

At the end of step 1 the building owner has an overview of the current state of the buildings, as well as the main issues and hotspots that need to be addressed in the renovation. This sets the ground for informed prioritisation and decision making later on in the process.

2.3 Step 2 – Indicator Definition

In step 2 the goals and targets of the refurbishment are developed by selecting indicators for the evaluation of the potential refurbishment concepts. This may include certain economic indicators that need to be fulfilled (e.g. a Return on Investment target), environmental goals (i.e. greenhouse gas emissions reduction target) or energetic targets (i.e. 75% net-energy demand reduction) that should be achieved through the renovation action. These quantifiable indicators are later used as benchmarks for different renovation concepts and enable the DREEAM-Tool to optimize refurbishment designs based on them.

At the end of step 2 the building owner has set the economic and environmental frame conditions for the conceptualisation of the refurbishment concepts, after which the renovation concept development can start.

2.4 Step 3 – Tentative Concepts

In step 3 tentative concepts are developed by pre-selecting certain building components and refurbishment options, as well as excluding others. Certain building components that need to be refurbished because they are at the end of their technical lifetime might be prioritized and others, e.g. components refurbished recently, might be left out for concept development. For each of the building components, different refurbishment solutions can be selected from the Technology Database developed in Deliverables D1.1 and D1.2 as well as additional ones can be added (e.g. based on local preferences of the building owner). In addition, solutions that should not be considered because they cannot be applied, due to technical conditions (e.g. limited space) or because of other reasons (e.g. reliability or tenant acceptance concerns) can be excluded from design conceptualisation at this stage. These tentative concepts are developed as part of WP2 through the technical partners. This is to make sure that the refurbishment concepts that will be developed in the next step are generally feasible for implementation.

At the end of step 3 the technical frame conditions for the development of the refurbishment concept are set and possible solutions as well as limitations for the refurbishment of each building component are defined.

2.5 Step 4 – Optimized Concepts

In step 4 the tentative concepts designed in step 3 are calculated and optimized by the DREEAM-Tool. The 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. 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.

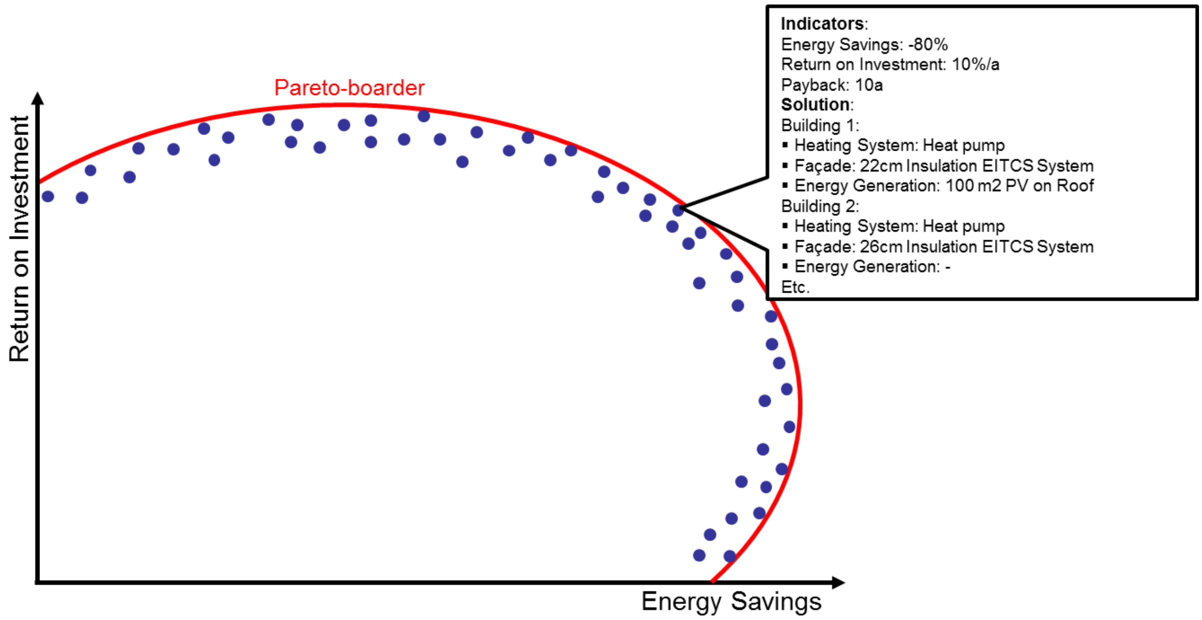

Figure 2 Example visualization of pareto-optimal results of a multi-dimensional optimization of refurbishment concepts

3 DREEAM Assessment Tool Concept

3.1 Overview

The DREEAM-Tool is a key aspect of the optimised renovation concept development for multi-building renovation projects presented above. This section describes the methodological approach behind the functioning of the tool.

The DREEAM-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 that:

- 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.

The tool is aimed to be used for strategic renovation decisions and the development of optimized concepts on a multi-building and portfolio scale (see Figure 3).

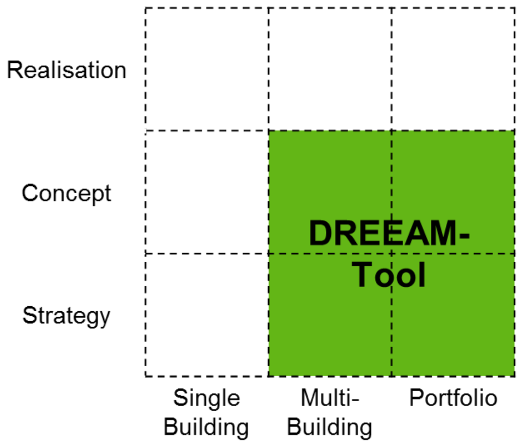

Figure 3 The DREEAM-Tool's strategic approach to building portfolio assessment and strategic refurbishment concept development

3.2 Structure

The DREEAM-Tool is based on a modular structure. The main modules are: the energy module, and indicator assessment module, the optimization module, and different databases that serve as a basis for the performed calculation (see Figure 4). The tool uses the modules in a sequential manner.

Firstly, the energy module calculates the energetic performance of the buildings through the application of established norm-based calculation methods (see below for details).

Secondly, the calculated energetic performance serves as input for the assessment module, where renovation concepts are assessed based on different economic and environmental indicators.

Lastly, generated renovation concepts are evaluated and optimised against the decision indicators defined by the building owner. Here, the tool makes use of a multidimensional evolutionary optimization algorithm, which automatically generates the Pareto-boarder for a given set of indicators. The output of the optimization module is a set of overarching refurbishment concepts for all assessed buildings which make up the Pareto-boarder. Each concept is a combination of refurbishment solutions (on a building and building component level) which can be further evaluated by the user and from which the most suitable refurbishment options can be selected.

In the following sections, the different tool modules are described in more detail.

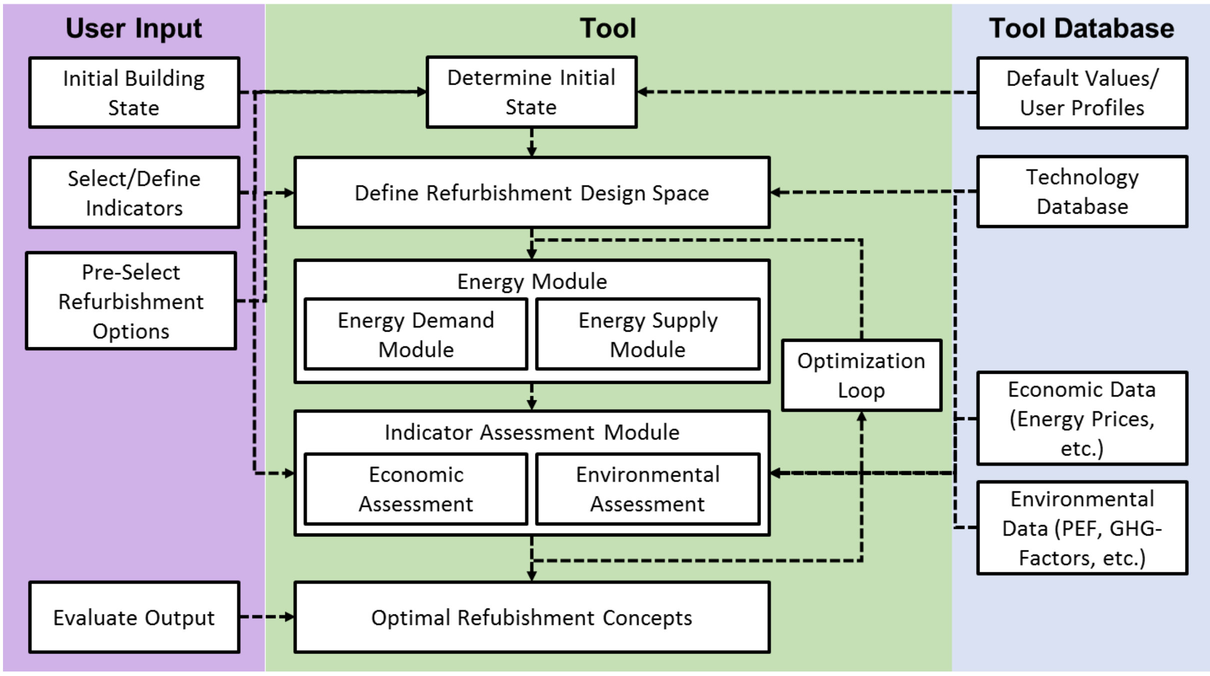

Figure 4   Overview of DREEAM-Tool structure

3.3 Energy Module

The energy module of the DREEAM-Tool consists of two main sub-modules, the energy demand module and an energy supply module. The energy demand module calculates the energy demand for heating, cooling, ventilation, domestic hot water, lighting and appliance use of the buildings based on current norms and standards (see Figure 5). The heating and cooling demand is calculated, based on the simple hourly method of the EN 13790 [6]. The choice of this standard calculation method instead of a more detailed dynamic model (e.g. EnergyPlus) was taken in order to keep the computational time demand low as the optimization module will have to run many iterations of the model. The energy demand module is complemented with a module that calculates the on-site energy production through photovoltaic modules or combined heat and power. Through the combination of these modules, the energy module calculates the energetic performance of the buildings in its current state or for potential refurbishment alternatives. The output is used by the indicator assessment module, in order to calculate the running energy costs and the environmental impact (e.g. GHG-Emissions) of the use phase of the buildings both before and after refurbishment.

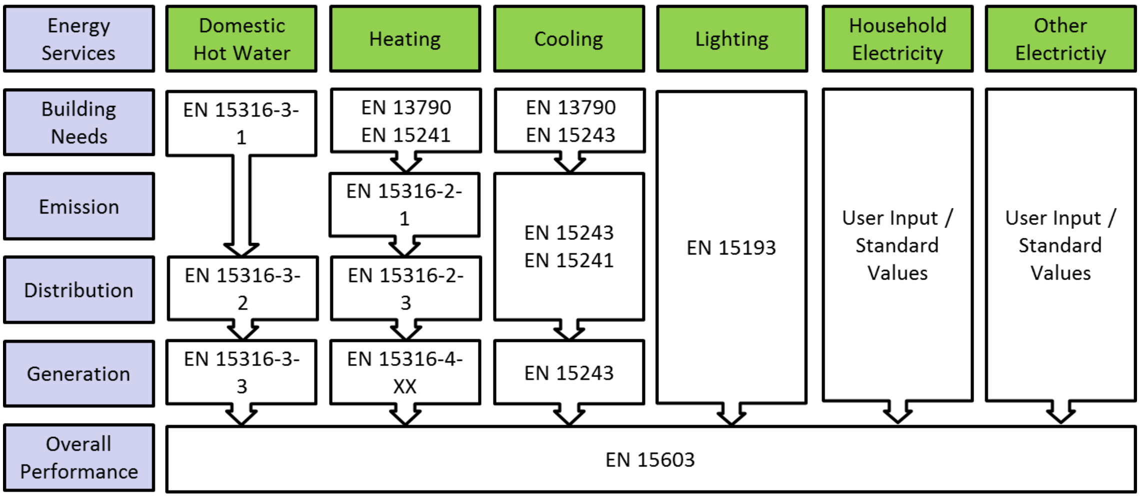

Figure 5 Overview of the building energy demand module and the European standards used for calculation

3.4 Technology Database

The technology database is a key part of the tool. It provides a list of potential solutions, incl. a detailed description of relevant parameters, used by the assessment module for the development of renovation concepts. The database is structured according to the different building components and systems (see Figure 6). For each building component the database lists different refurbishment solutions and for each of these solutions it contains a detailed list of the materials and work needed to install this technology, as well as technical performance data (e.g. thermal conductivity of the materials). This data for the technology database is collected from national construction cost catalogues such as [7] for Sweden, [8] for Germany or [9] for Spain and France (see deliverable report D 1.2 for more detail) and organised according to a structure developed in deliverable D1.1 (see deliverable report D1.1. for further details). The material information can then be linked to the data from the database ecoinvent [10], so that the embodied environmental impact of the materials can also be assessed. The cost and environmental data included in the database is then used by the assessment module to benchmark the refurbishment solutions against the economic and environmental indicators identified in step 2 of the DREEAM approach.

Building Components

Passive Components	Reference Unit
1. Outer walls against air	m^2 surface area
2. Outer walls against earth	m^2 surface area
3. Basement floor	m^2 surface area
4. Floors against unheated	m^2 surface area
5. Ceiling against unheated	m^2 surface area
6. Flat roof	m^2 surface area
7. Tilted roof	m^2 surface area
8. Windows in Wall	m^2 surface area
9. Windows in Tilted Roof	m^2 surface area
10. Windows in Flat Roof	m^2 surface area

Active Components	Reference unit
11. Heating System	$kW_{Thermal}$
12. Heat Distribution	$kW_{Thermal}$ or m^2
13. Ventilation	m^3/h
14. Cooling System	$kW_{Cooling}$
15. Lighting	m^2 floor area
16. Shading	m^2 window
17. Solarthermal	m^2 collector
18. Storage Tank	m^3 tank volume
19. PV	kW_{peak}
20. Control Systems	
21. Battery Systems	$kWh_{Capacity}$

Refurbishment Solutions

ID	Solution	Insulation
1.1.	External insulation	
1.1.1.	Brickwall	50 mm
1.1.1.	Brickwall	80 mm
1.1.1.	Brickwall	100 mm
1.1.1.	Brickwall	120 mm
1.1.1.	Brickwall	150 mm
1.1.1.	Brickwall	170 mm
1.1.2.	Sandwich	50 mm
1.1.2.	Sandwich	80 mm
1.1.2.	Sandwich	120 mm
1.1.2.	Sandwich	150 mm
1.1.2.	Sandwich	200 mm
1.1.3.	Wooden Facade	45mm
1.1.3.	Wooden Facade	70 mm
1.1.3.	Wooden Facade	120 mm
1.1.3.	Wooden Facade	170 mm
1.1.3.	Wooden Facade	220 mm
1.2.	Internal insulation	
1.2.1.	Wooden Substructure	45 mm
1.2.1.	Wooden Substructure	70 mm
1.2.1.	Wooden Substructure	120 mm
1.2.2.	Steel Substructure	45 mm
1.2.2.	Steel Substructure	70 mm
1.2.2.	Steel Substructure	120 mm

Material and Labour Breakdown

ID	Materials	Reference Unit	Material Cost [SEK]	Labour [h]	Labour Costs [SEK]
1.	Scaffolding	1.15m²	33	0.18	35.1
2.	Façade plaster	1m²	0	0.4	78
3.	Cardboard, demolished	1m²	0	0.02	3.9
4.	Lock panel	1m²	105.4	0.78	152.1
5.	Lath	3m	8.45	0.03	5.85
6.	Gypsum board, windshield	1m²	40.95	0.14	27.3
7.	Mineral wool board	1m²	41.6	0.09	17.55
8.	45x70 Bars	3.5m	8.9	0.08	15.6
9.	Plank wall, retained	1m²	0	0	0
10.	Plastic foil incl. Tape	1m²	7.55	0.09	17.55
11.	Gypsum board	1m²	40.7	0.16	31.2

Figure 6   Structure of the component specific Technology database listing labour and material cost

3.5 Assessment Module

The assessment module generates the indicators that can be used to evaluate different refurbishment options during the optimization routine as well as evaluate the generated output of the optimization module. The assessment module is divided into two submodules, an economic assessment module and an environmental assessment module.

The economic module applies a lifecycle costing (LCC) assessment methodology based on the regulation of the European Commission 244/2012 [11] which can calculate the overall life cycle costs, as well as other economic indicators such as the Return on Investment (ROI) or the Net-Present Value (NPV). The different cost components are structured according to [11] (see Figure 7). Investment costs are calculated, based on the information from the technology database which includes labour, material and additional costs. Other costs, such as professional fees (planning costs), taxes and profit margins depend on the optimization scenario and can be adapted by the user. The annual costs are calculated with reference to replacement and running costs. The running costs are based on operational, maintenance and energy costs. The energy costs are calculated based on energy prices included in the tool database and the output of the energy module.

The environmental assessment module applies a simplified lifecycle assessment (LCA) to calculatethe environmental impact of the refurbishment approach. Currently only the primary energy demand and the greenhouse gas emission are assessed. Adding further impact categories might be considered at a later stage of the tool development. The assessment is carried out by evaluating both the impact of the building use phase through the output of the energy module, as well as the embodied impact in the materials. The impact of the use phase is assessed by multiplying the energy consumption with GHG-Emission and primary energy factors of the energy carrier used in the building. The embodied impact is calculated by multiplying the materials used in the refurbishment with factors from the ecoinvent database [10].

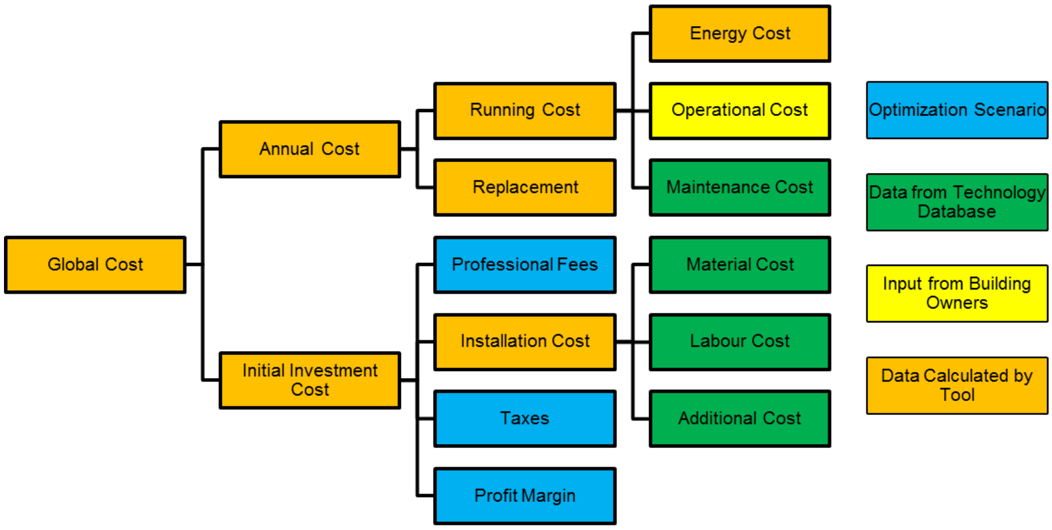

Figure 7 Cost Structure applied in the DREEAM-Tool (adapted from [11])

Table 1 shows a list of economic, environmental and technical indicators, as well as combined indicators the user can choose from in the current version of the tool. It is possible to add further indicators related to energy module outputs and currently implemented assessment indicators. For example, an indicator that constitutes a combination of both environmental and economic indicators might be of interest to some users (e.g. GHG-Emission savings per Investment Cost). It would allow the optimisation of refurbishment concepts beyond the best economic solutions and evaluate, for example, on how to achieve further GHG-Emission savings through additional investment. This would enable building owners to evaluate how much additional investment is needed from subsidies or other funding sources, in order to reach the nZEB standard for their buildings.

Table 1 Selection of the main Indicators currently implemented in the Tool from which the user can choose from

Indicators	Unit	Calculation
Environmental Indicators		
Final Energy Demand	$\frac{kWh}{a}$	$E_{final} = \left(\sum_{es\,=\,energy\ service} E_{final,es}\right) - E_{production}$
Final Energy Savings	%	$E_{final,saving} = \frac{E_{final,SQ} - E_{final,RC}}{E_{final,SQ}}$
Electricity Production	$\frac{kWh}{a}$	$E_{production} = \sum_{p\,=\,production\ system} E_p$
GHG Emissions	$\frac{kg\ CO_2eq}{a}$	$GHG = \sum_{ec\,=\,energy\ carrier} E_{ec} \cdot GHGF_{ec} + GHG_{embodied}$
Primary Energy	$\frac{kWh}{a}$	$PE_{tot} = \sum_{ec\,=\,energy\ carrier} E_{ec} \cdot PEF_{ec,tot} + PE_{embodied,tot}$ $PE_{nonrenew} = \sum_{ec\,=\,energy\ carrier} E_{ec} \cdot PEF_{ec,nonrenew} + PE_{embodied,nonrenew}$
GHG Emission Savings	%	$GHG_{saving} = \frac{GHG_{SQ} - GHG_{RC}}{GHG_{SQ}}$

Primary Energy Savings	%	$PE_{tot,saving} = \frac{PE_{tot,SQ} - PE_{tot,refurbished}}{PE_{tot,SQ}}$ $PE_{nonrenew,saving} = \frac{PE_{nonrenew,SQ} - PE_{nonrenew,RC}}{PE_{nonrenew,SQ}}$
Economic Indicators		
Investment Costs	€	$C_{Investment} = C_{Material} + C_{Labour} + C_{Additional} + C_{Fees} + C_{Taxes} + C_{Margin}$
Running Costs	$\frac{€}{a}$	$C_{Running} = C_{Maintenance} + C_{Operational} + C_{Energy}$
Total Life Cycle Cost	€	$LCC = C_{Investment} + \sum_{t=1}^{calculation\ period} \frac{C_{Running} + C_{Replacement}}{(1+r)^t}$
Net Present Value	€	$NPV = \sum_{t=1}^{calculation\ period} \left(\frac{C_{Earnings} - C_{Running} - C_{Replacement}}{(1+r)^t}\right) - C_{Investment}$
Internal Rate Of Return	%	$NPV = 0 = \sum_{t=1}^{calculation\ period} \left(\frac{C_{Earnings} - C_{Running} - C_{Replacement}}{(1+IRR)^t}\right) - C_{Investment}$
Return On Investment	$\frac{\%}{a}$	$ROI = \frac{(C_{Earnings,SQ} - C_{Running,SQ}) - (C_{Earnings,RC} - C_{Running,RC})}{C_{Investment}}$
Running Cost Savings	%	$C_{savings} = \frac{C_{Running,SQ} - C_{Running,RC}}{C_{Running,SQ}}$
Technical Indicators		
Self-Consumption Of Produced Electricity	%	$E_{self-consumption} = \frac{1}{E_{production}} \cdot \sum_{h=1}^{8760} \begin{cases} E_{production,h}\ if\ E_{production,h} < E_{final,electricity,h} \\ E_{final,electricity,h} if\ E_{production,h} > E_{final,electricity,h} \end{cases}$
Self-Production Of Consumed Electricity	%	$E_{self-production} = \frac{1}{E_{final,electricity}} \cdot \sum_{h=1}^{8760} \begin{cases} E_{production,h}\ if\ E_{production,h} < E_{final,electricity,h} \\ E_{final,electricity,h} if\ E_{production,h} > E_{final,electricity,h} \end{cases}$
Combined Indicators		
Final Energy Savings per Investment	$\frac{kWh}{€}$	$E_{final,Investment} = \frac{E_{final,SQ} - E_{final,RC}}{C_{Investment}}$
Primary Energy Savings per Investment	$\frac{kWh}{€}$	$PE_{tot,Investment} = \frac{E_{tot,SQ} - PE_{tot,refurbished}}{C_{Investment}}$ $PE_{nonrenew,Investment} = \frac{PE_{nonrenew,SQ} - PE_{nonrenew,RC}}{C_{Investment}}$
GHG-Emission Savings per Investment	$\frac{kg\ CO_2eq}{€}$	$GHG_{Investment} = \frac{GHG_{SQ} - GHG_{RC}}{C_{Investment}}$

3.6 Optimization Module

The optimization module makes use of the evolutionary optimization algorithm NSGA2 (Non-dominated Sorting Genetic Algorithm) [11]. Evolutionary algorithms such as NSGAII are widely used in the field of energy efficient building design optimization [5]. The algorithm iteratively generates and evaluates different refurbishment options and thereby searches for the Pareto-boarder, i.e. those options that best meet the indicators selected by the user (see step 2 of the DREEAM approach). A more detailed description of evolutionary optimization algorithms and how they are used in building design is given in [5]. Next to optimization objectives, the user can also define boundary conditions which constrain the optimization routine for a component (e.g. by defining a maximum insulation thickness that can be applied to a certain component, due to space limitations), between components (e.g. choosing different insulation thicknesses for connected components such as neighbouring walls), or on a building level (e.g. by defining a minimum building standard that must be reached). While some of this logic can be included in the tool, a feasibility check and an informed output selection by an expert will still be necessary as not all aspects of the refurbishment design can be covered by the tool.

3.7 DREEEAM tool development

The current version of the DREEAM tool consists of a prototype using input data from Excel files and outputting results as tab-separated .txt-file which can easily be imported to Excel. The data input and output is currently done through a simple user interface which at this stage is built as a windows console application. The console application passes the parsed files on to the calculation core which is then used by the optimizer to compose output with a chosen algorithm and the fixed set of options provided as input.

The application is written in the C# programming language and built on the latest .Net Framework (currently 4.6.1). It is designed in a way to work on any system that supports this version of the .NET Framework and is easily run on any laptop. However, measures have been taken for increased performance when the CPU of the system got multiple cores, where more cores would provide better performance in terms of speed.

When designing the prototype some measures have also been made to facilitate a future deployment as a cloud based web application, aiming at the exploitation of the tool. Architecturally, the prototype consists of the three main parts:

- User interface
- Calculation core
- Optimizer

The user interface includes input parsing and output file creation where input parameters are accepted on the commandline when running the application and output files are created as simple tab-separated text files which can then be imported into Excel.

The calculation core holds all the computational logic for the entire application.

The last part, the optimizer, is the bridge between the calculation core and the multi-objective optimization algorithms and its main task is to provide solutions for the current optimization task. In order to easily include different multi-objective optimization algorithms the application uses the .NET based jMetal .NET library to run the actual algorithms.

Through empiric evaluation it has been observed that the current tool version demonstrates the best performance by using the NSGA2 algorithm [12]. However, the architecture is built in a way to easily include other multi-objective optimization algorithms, if it proves necessary.

The prototype version of the DREEAM tool described above is still under development. The Minimal Viable Product (MVP) version is planned to be finalized by the spring 2017 and the results will be described in the follow-up version of this deliverable. Once the MVP is ready, it will be tested with DREEAM partners and a number of potential end-users, as part of the product exploitation strategy.

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 starting point for renovation planning and design. Taking a multi-building approach to refurbishing their 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 of the larger renovation scale than common, the core of the DREEAM approach is also the DREEAM tool that allows an optimised design of renovation concepts that best meet multiple objectives (e.g. energetic, environmental or economical). 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. A first functional prototype of the tool is already available, but the development continues in order to generate a minimum viable product which can be tested with DREEAM project partners and potential users.

5 Abbreviations

Abbreviation	Description
E	Energy Use (either final energy or useful energy)
ec	Energy carrier
EE	Energy Efficiency
es	energy services (i.e space heating, space cooling, domestic hot water, ventilation, lighting, appliances etc.)
GHG	Greenhouse gas emissions
IRR	Internal Rate Of Return
LCA	Life Cycle Assessment
LCC	Total Life Cycle Cost
MVP	Minimum Viable Product
NPV	Net Present Value
NZEB	Near Zero Energy Building
p	(energy) production system (i.e. photovoltaic modules, combined heat and power plant)
PE	Primary Energy
RC	Refurbishment Concet
ROI	Return On Investment
SQ	Status Quo

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