Extension of DREEAM approach to district scale

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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	Extension of DREEAM approach to district scale
Version	1
Release date	
Work package	WP1
Dissemination level	

DOCUMENT AUTHORS AND AUTHORISATION	
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Authorised by	

DOCUMENT HISTORY			
Version	Date	Modified contents	Implemented by
1.0	2018-09-20	First version of the report completed	Chalmers

Executive summary

Renovating the existing building has a significant potential to achieve the goal of reducing GHG emissions in the European Union. However, the main challenges that face the designers and stockholders are the identification of the optimal renovation approach in which the GHG emission in maximized or the economic visibility of the project maximized. To achieve this goal a novel design DREEAM-too has been developed. DREEAM toll has been developing in the way that helps designers and stockholders to plan a renovation project on a single building or multi-building. The tool was built in the way to optimize the renovation project taking into consideration different criteria, such as economic or environmental criteria. In other words, the tool combines an energy calculation model for the building with economic and environmental assessments to assess and optimize refurbishment concepts.

The previous report outlines the implementation of the process into the tool and gives a step by step manual of how to use it the DREEAM too. The objective of the current report is to investigate the extension of the DREEAM approach to the district level in order to tailor the decision-supporting tool towards cities and their energy renovation plans within the broader scope and higher complexity of the city environment. The district level of the DREEAM approach means additional theoretical studies on the effect of scale when considering the application of energy systems to groups of buildings in a district. The main advantage of the district level renovation design is that the interaction between the different buildings in the district, which leads to increase the visibility of the renovation project. Besides, in such significant scale, the integration of renewable energy (RE) resource into the renovation project might, in most cases, increase the feasibility of implementing RE. On another side, implementing RE into the energy system can significantly help in achieving the desired reduction in GHG emissions reduction toward approaching the near-zero energy building.

Since the existing infrastructure can significantly influence the optimal set of the energy efficiency measures, planning refurbishment on the district level would dramatically change the decision-making process. However, planning the renovation project on district level means a massive amount of information needs to be prepared before the designing process. The required data can be classified into main three groups including buildings, energy system, and weather. These data might be sort of challenge to collect, but once they are ready, they can be inserted in the DREEAM tool so that any other project, with similar conditions, can use them. So far, the current version of the DREEAM tool considers only residential buildings, which means the current version of the tool is not ready to be used on a district level. However, upgrading the DREEAM tool to be able to consider other types of building is possible. It is worth to be mentioned that in the current report a district is defined as a group of multi buildings of different usage, i.e., residential, commercial, etc.

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1. Introduction

Urban areas stand for about 75% of global energy consumptions. Most of these energy consumptions occur in the buildings sector. Therefore, more sustainable urban, or smart city are needed. Recently, many studies have been concentrating on the smart city concept, in which the energy flows of the whole city are kept stable. The integration of renewable energy and the implementation of different energy saving measurements are forming the initial approach to fulfill the smart city concept. In this regard, smart grid seems to be an essential role in meeting the near-zero emission buildings. In such case, diversity from residential to industrial buildings, within the district or the city, are incredibly diverse in term of their energy needs.

Consequently, the smart grid will be as energy carrier from building to another according to the energy generation and demand. Collecting the energy consumption profile of the buildings and the energy generation profile of the different renewable energy technologies that are integrated into the system is a central challenge to achieve the goal of energy efficiency in the district, and consequently, more energy efficient city. It is also essential to know the conditions on the boundaries of the considered district in the term of integration with the district neighborhood. It is worth mentioning that in the current report a city was defined as a group of different districts.

It is worth mentioning that in district planning, not all building causes the poor state of conservation. These mean that the implementing energy-saving measures must concentrate on the stocks of the worst performance in terms of energy efficiency. In another word, district energy analysis, in the case of implementing energy generation technologies, aims at classifying the building, in the considered area, into:

- The positive unit, buildings with energy generation higher than its demand.
- The negative unit, buildings with energy generation lower than its demand.
- The neutral unit, buildings with energy generation equals its demand.

Moreover, afterword, the sustainable development of the district means creating synergy between different buildings units in which the global energy consumption of the district from the utility grid is minimized. While in the case of the refurbishment of the existing building the analysis of the district aims to define the units to be renovated in which the energy saving target is maximized

As compared to a single building, refurbishment on multi buildings level or district level has higher economic potential because of scale price of the materials, as well as the impact of better labors-management and tools utilization on site. These parameters have a direct influence on the cost of the process, planning, and construction. Consequently, the total cost of renovation on multi buildings level has been reported to be 5-15% lower as compared to the single building renovation. However, optimizing a more significant renovation project always aligns with challenges due to the complexity of synchronization of generation and consumptions. An initial problem that might be faced when renovating district is the grid ability to manage both supplying and production.

Several tools are developed to simulate the renovation on district level to evaluate the saving potential and assist designers and stakeholders. However, to our knowledge, no tool can generate the optimal combination of the energy-saving measures and the implementation of renewable energy sources for energy generation of heating/cooling purposes. Therefore, developing the current version of DREEAM tool, which is used on multi-residential buildings level, to enables evaluation of different retrofitting choices on the district level, will be of significant benefits for designers and stakeholders. The tool must be developed taking into account different indicators, e.g., economic and environmental aspects so that the profitability of the renovation project is maximized.

2. Literature Review

When it comes to energy renovation planning processes, the integration of the space variable is of great importance. Ongoing trends in urbanization require urban energy systems that emit less carbon and use less energy. Around 75% of global energy use occurs in urban areas, with more than 40% of the final energy demand is consumed in the building sector[1]. Therefore, more sustainable systems are needed. In another word, improving the thermal performance of the building plays a crucial role in reducing the net energy consumptions and consequently, fulfill the target toward reducing the greenhouse gases emissions to mitigate the climate change [2]. Based on current levels of the thermal quality level of a considerable number of the existing building in the European Union, there is a significant potential to improve the energy performance of the buildings.

However, based on the quality of existing residential building in EU, convectional renovation measures cannot achieve higher than 40-50% of energy consumptions. Never less, to produce a higher reduction in the energy consumption, integrating new energy system beside the energy saving measures tend to increase. As results near-net-zero energy building (NZEB), in which the total amount of energy used by the building on an annual basis is roughly equal to the amount of renewable energy generated on the site, has been suggesting. Thus, the renovation project is becoming a more complicating process that requires a computational tool for evaluating many different design options and obtain the optimal or near optimal [3].

Because its current relatively high investment cost, utilizing renewable energy resource on a single building level seems not very feasible and might not very attractive. On the other side, a remarkable number of a study recently have been conducted to show the advantage of carrying out a renovation project on multi-building or district level.

On the other hand, the selection of the best energy saving measures to be implemented in which the benefit of the refurbishment is maximized is subject to a single or multi-objective optimization criterion [4].

Several tools are developed to simulate the renovation on district level to assist designers and stakeholders before deciding on buildings refurbishment. The District ECA that is formed by EU MODER project, for instance, is available for free as the international version. The D-ECA tool can perform energy efficient strategies and technologies for the energy efficient renovation of districts. However, the calculation is based on the use of pre-defined archetype buildings. This means the geometry and user profile of the archetype buildings specific for the individual country is fixed, which reduce the freedom of the user.

Recently, Fan et al. presented an optimized mathematical model to help decision makers to identify the best combination of retrofit options for buildings to ensure policy compliance in the most cost-effective way in the office sector [5]. The model determines optimal retrofit plans for a whole building in a systematic manner, considering both the envelope components and the indoor facilities. The model also considers the rooftop PV system to reduce the usage of electricity produced from fossil fuels. The model was built based on the dynamic method of calculating heating and cooling load of the building. However, the model can be used for a single building and cannot be used at the district level.

Also, the optimization method is a genetic algorithm meaning, taking into consideration a large number of variable, a long computational time.

Wu et al. (REF) developed a model using EnergyPlus for the simulation of the energy demands and CPLEX for optimizing [6]. The aim of the model is optimizing both annual costs and GHG emissions. The model considers both retrofits in the building envelope as well as local production of energy with boilers, heat pumps, solar thermal and PV modules. The optimization is posed as an epsilon-constrained mixed integer linear program and takes into consideration a set of previously simulated retrofit scenarios, along with the rest of the local energy production measures. It does not detail how much insulation should be put; it just targets U-values that come from the Swiss regulation. The space heating simulations are thorough, but just a few scenarios are explored.

FASUDIR is another European project [7], which was conducted by industrial and academic parents, has developed FELICITY web-based decision support tool, termed FELICITY, for assessing the condition and energetic performance of large building stocks as well as setting up and comparing retrofitting concepts based on key performance indicators [8].

Finally, designPH EDU was developed specifically with students and universities in mind [9]. The model was developed to help designer and building owner to pan a refurbishment in order to achieve a passive house level. Therefore, the model cannot be used to optimize the retrofitting. Also, it cannot be used at the district level.

3. Motivation

Around 75% of global energy use occurs in urban areas, especially in the building sector. Therefore, more sustainable systems are needed. The common European renovation project focuses on improving the thermal performance of the building shell using adding insulation to the opaque surfaces and improve the thermal quality of the windows and does not consider the integration of renewable energy resource. Consequently, the reduction in total net energy demand can be 40-45% in the buildings sector. This is way far from the target of near-net-zero energy building (NZEB) standards. Thus, in order to achieve the goal of NZEB the share of renewable energy in the energy supply system needs to be increased. However, in most cases utilizing renewable energy in single building level might not be visible nor attractive to the building owner.

In the light of the fact that most renovation projects take place in a multi-building scale accounts for 36% of all EU's residential buildings, innovative approach in which the balances between energy saving measure and implementing of renewable energy on multi buildings scope seems to be the method to increase the saving in energy demand cost-effectively. However, many of the technologies to be considered for cost-effective solutions are available on the market or having been piloted in real-life environments, the integrated approach for the targeted market segment does not exist.

DREEAM tool considers the possibility of integrating the available renewable energy resource as well as the interaction between the different buildings in order to achieve 75% in the net demand an integrated renovation approach. In another word, the developed tool aims at achieving high energy reduction demands by cost-optimally balancing between energy efficiency (EE) and renewable energy supply measures (RES) to deliver 75% NED reduction.

Extending the DREEAM tool to be Used to plan the refurbishment of the district, four major groups of measures need to be studied:

- Improving the thermal resistance of the exterior walls
- Increasing the thermal quality of the window.
- Improving the performance of the HVAC system.
- Increasing the share of green energy in the global energy consumption of the district

4. DREEAM on District Level

4.1 Introduction

Extending DREEAM approach to the district level for the energy renovation aims to demonstrate different cost-effective scenarios of refurbishment so that the most optimal renovation strategy maximizing the energy optimization potential between multiple buildings. Although implementation of energy saving measures on single building level can achieve a reduction in the energy demand of the district; but paying attention to the interaction between the buildings and the system components can significantly increase the benefit of the renovation project. Thus, the main advantage of the DREEAM approach is taking into consideration the interaction between different buildings, and between the system components and the buildings, seeking to maximize the viability of the renovation project. The framework will not only recommend innovative technologies which have been proved at the small scale in similar projects but also will indicate an optimal balance between the energy efficiency measures and the energy supply systems.

The definition of the DREEAM approach will result in a process manual to guide the project promoters in the energy renovation of multiple buildings. Application of the DREEAM approach results in an optimal balance between energy supply (conventional centralized options as well as decentralized self-supply via PV for example) and energy efficiency measures (façade refurbishment or exchange/ upgrading of housing services/ HVAC). This will include management strategies of the energy supply, energy storage as well as the load management and shifting.

The DREEAM approach will be extended to the district scale in order to tailor the decision-supporting tool towards cities and their energy renovation plans within the broader scope and higher complexity of the city environment. The extension of the DREEAM approach will include additional theoretical studies on the effect of scale when considering the application of energy systems to groups of buildings in a district. Also considering smart optimization potential concerning other cities´ infrastructure and assets like the proximity of water for cooling or additional heating sources. This will be seen in the results of the DREEAM tool when different prices of renovation measures (based on the scale price) will be considered in the calculations. This way, the results will demonstrate the effect of the scale on the potential of the renovation project. The extension of the approach will also include the incorporation of additional stakeholders in the decision-making process.

Chalmers will be responsible for creating an online tool, which incorporates the DREEAM framework for choices of the technology scenarios. In particular, Chalmers will identify the condition change in the multiple buildings and infrastructural settings and how it influences an optimal set of the energy efficiency measures.

As it has been shown in the previous report, simulation renovation project at a single building level requires many data to be used as input for the DREEAM tool, such as building dimension, construction materials, etc. Nevertheless, in order to simulate the renovation project on the district level, lots of additional data are needed such as grid specification, and district heating/cooling network, etc. Table 1 shows a comparison between the required data on single building and district levels. It is worth mentioning that the current version of DREEAM tool does not have the possibility to enter these data, which means additional work is required the interface of the tool as well.

Table 1: Required input data for city district simulations

Multifamily-building level	City district level
Construction dimensions	Electric grid and transformer specifications
Construction materials	Data on gas and district heating networks
Distribution of façade surfaces	Information on geological properties and groundwater levels
Energy conversion units	
Energy delivery systems	
Local renewable energy generation	

4.2 DREEAM tool user interface

The user interface of the DREEAM tool has been built to be user-friendly and composed of three sections as follows:

1. Building Portfolio: 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.
2. Refurbishment Database: 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.
3. Explore Scenarios: 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.

4.3 Preparation Guide

It is worth mentioning that the "Building Portfolio" and "Refurbishment Database" are inserted in the tool as has been explained in the previous report. However, the tricky part when using DREEAM tool on the district level is the "Explore Scenarios" as follows. 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 1.

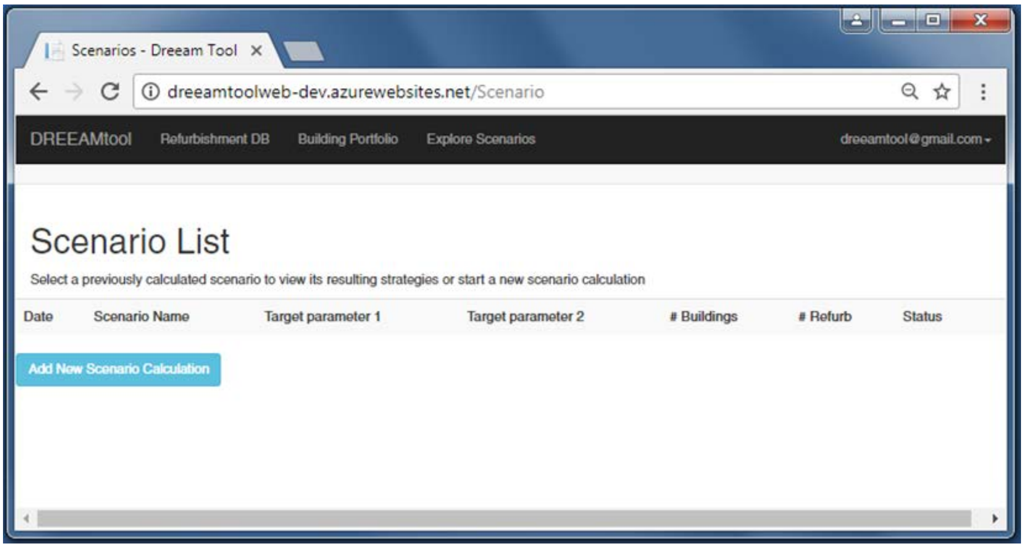


Figure 1: Explore Scenarios in the DREEAM tool

After choosing the right location, on the left side of the interface, the user must select the buildings to be included in the new scenario (see Figure 2). Additionally, there appear two more sections: Allowed Refurbishment Measures and Scenario Settings.

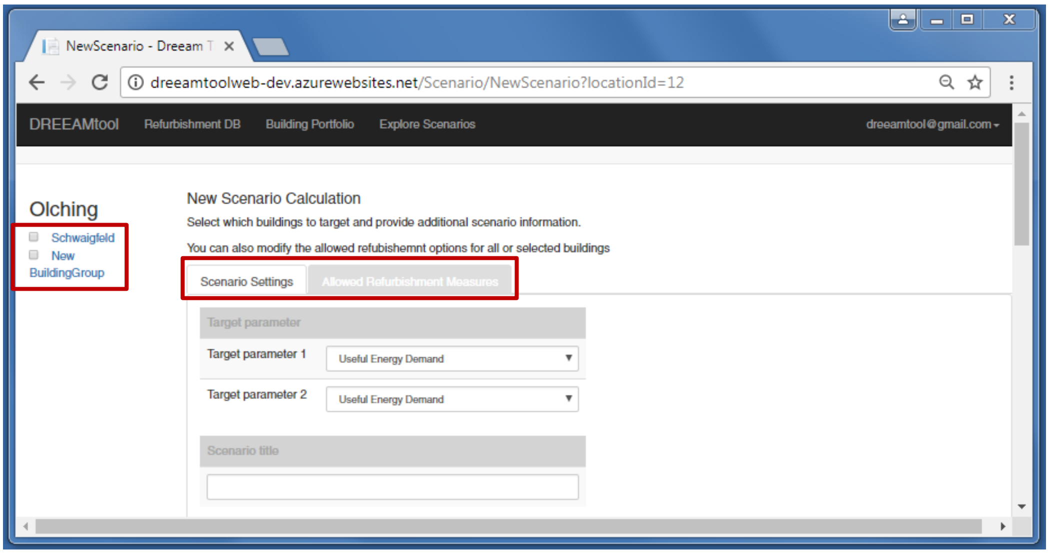


Figure 2: Adding a new scenario

In the scenario, settings must identify two target parameters that are going to be used to optimize the refurbishment scenario. As listed in Table 2 DREEAM tool provides a long list of different target parameters. The selection of the indicators of the target parameters depending on the concern of the designer or the decisionmakers.

Table 2. The available target pampers in DREEAM tool

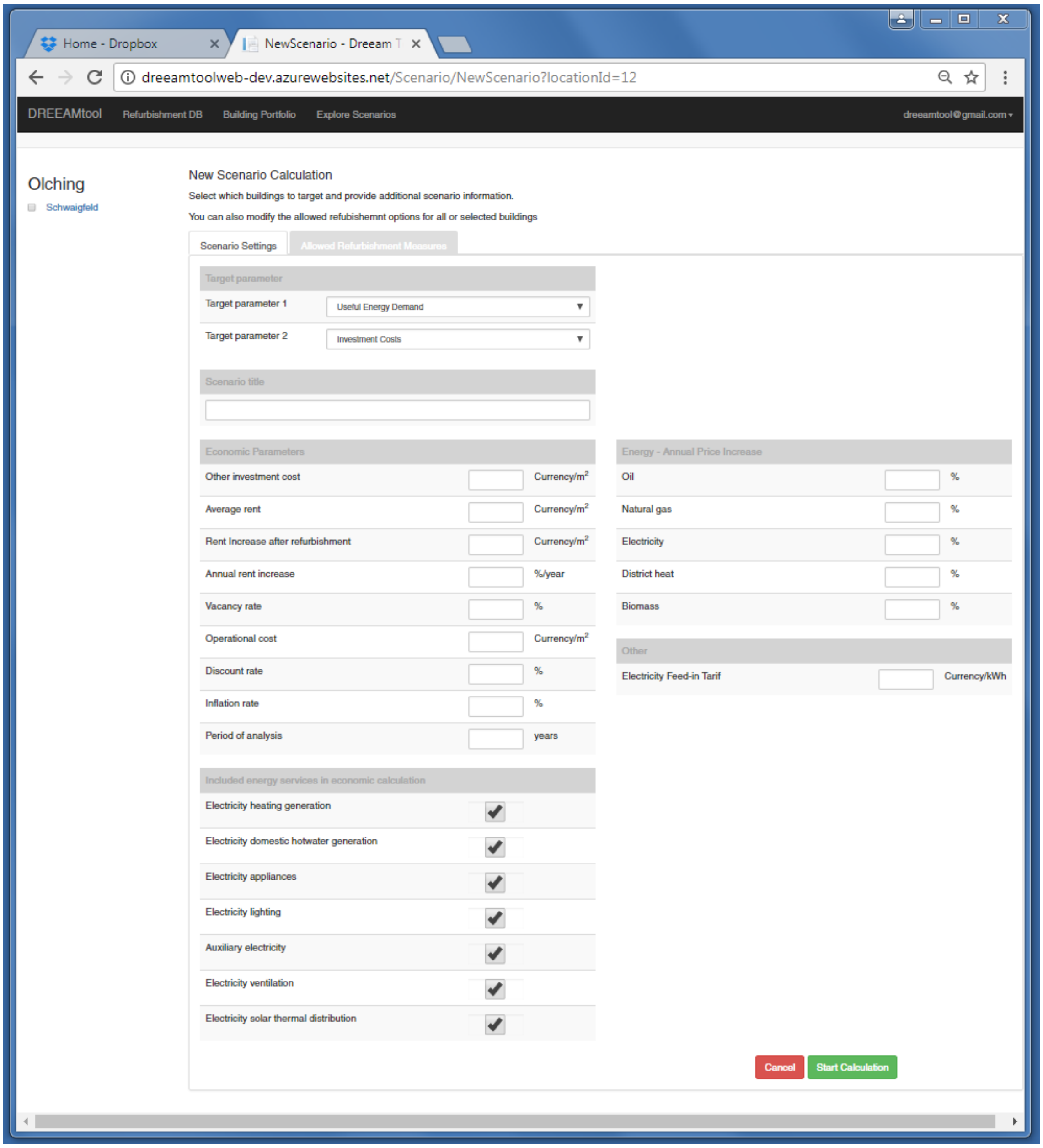
Indicators	
Environmental Indicators	**Economic Indicators**
Final Energy Demand	Investment Costs
Final Energy Savings	Running Costs
Electricity Production	Total Life Cycle Cost
GHG Emissions	Net Present Value
Primary Energy	Internal Rate Of Return
GHG Emission Savings	Return On Investment
Primary Energy 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	

Also in the scenario sitting the user needs to specify, see Figure 3:

a. Included energy services in the economic calculation: If not given otherwise, all options are selected.

b. Energy - Annual Price Increase: Oil, Natural gas, Electricity, District heat, Biomass

c. Other: Electricity Feed-in Tarif (only when PV is used)

d. 

e. Figure 3: Scenario setting interface

In the section “Allowed refurbishment measures” the user must choose all the refurbishment measures planned to be included in the scenario calculation for each building individually (Figure 4).

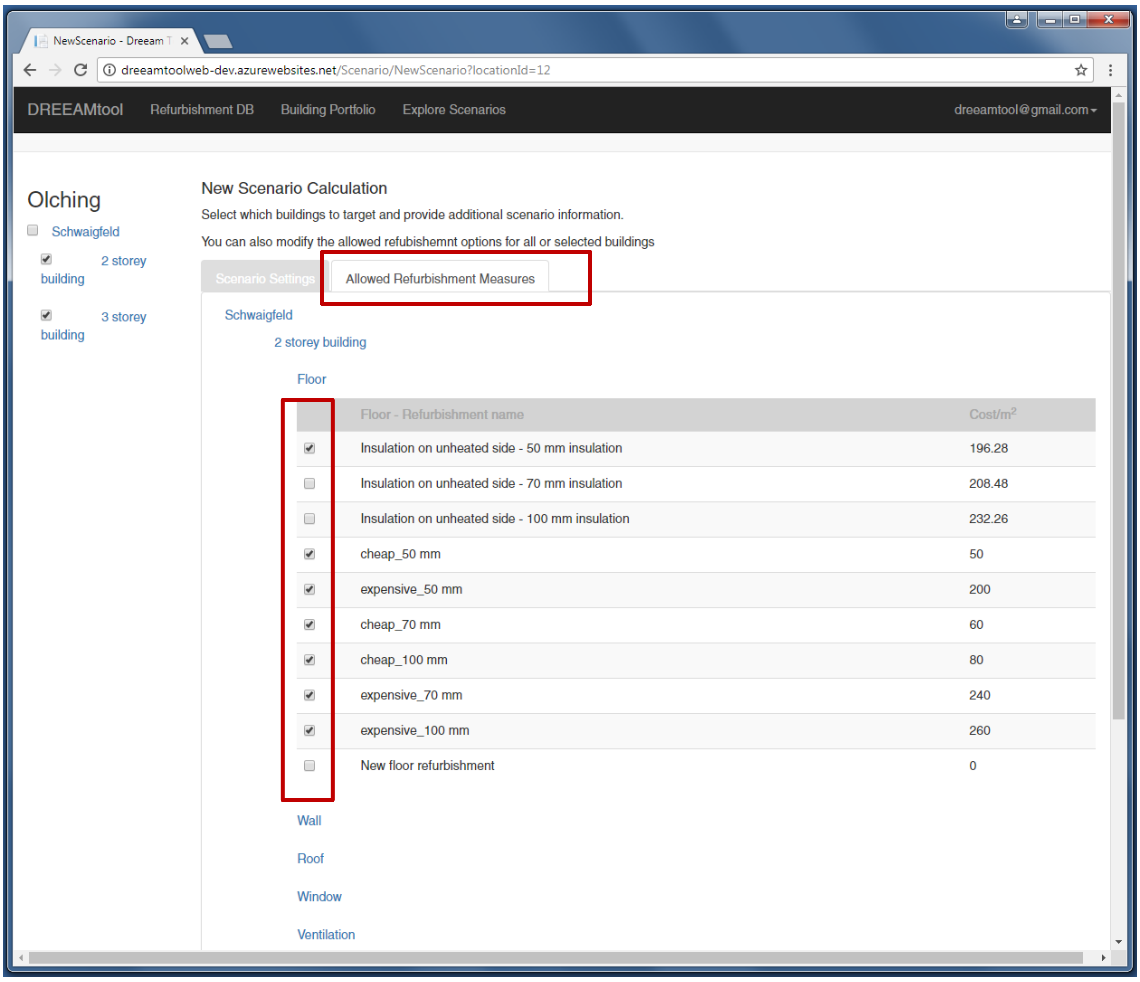


Figure 4: Selection of refurbishment measures for the scenarios

Finally, the user returns to the Scenario sitting page and click "Start calculation" bouton at the right bottom corner of the screen, see Figure 3. The calculation takes 20-25 minutes, but the user does not need to keep the computer on meanwhile. The calculation will be carried out online, and once it is ready the user can see a sing of 100% as shown in Figure 5

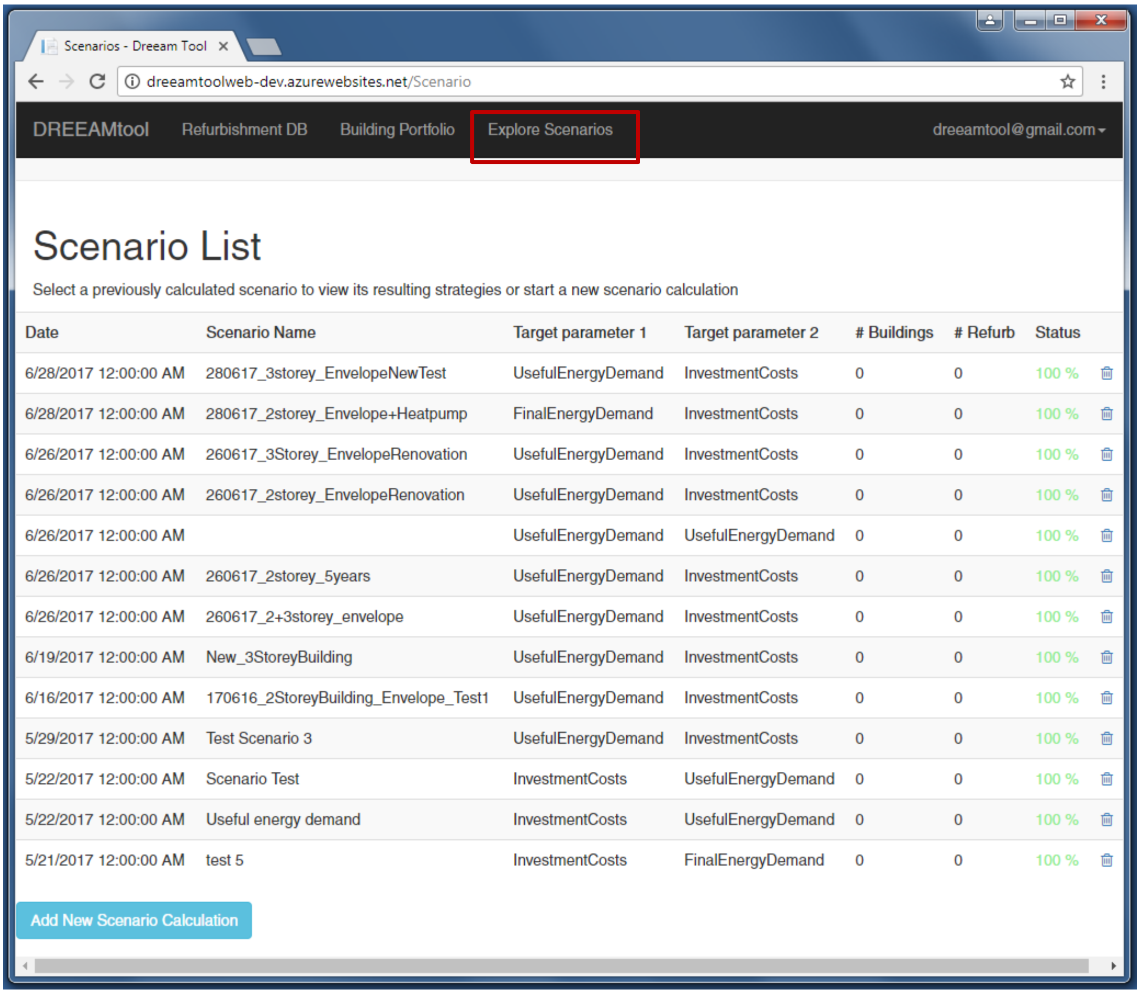


Figure 5: Calculation of the scenario

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.

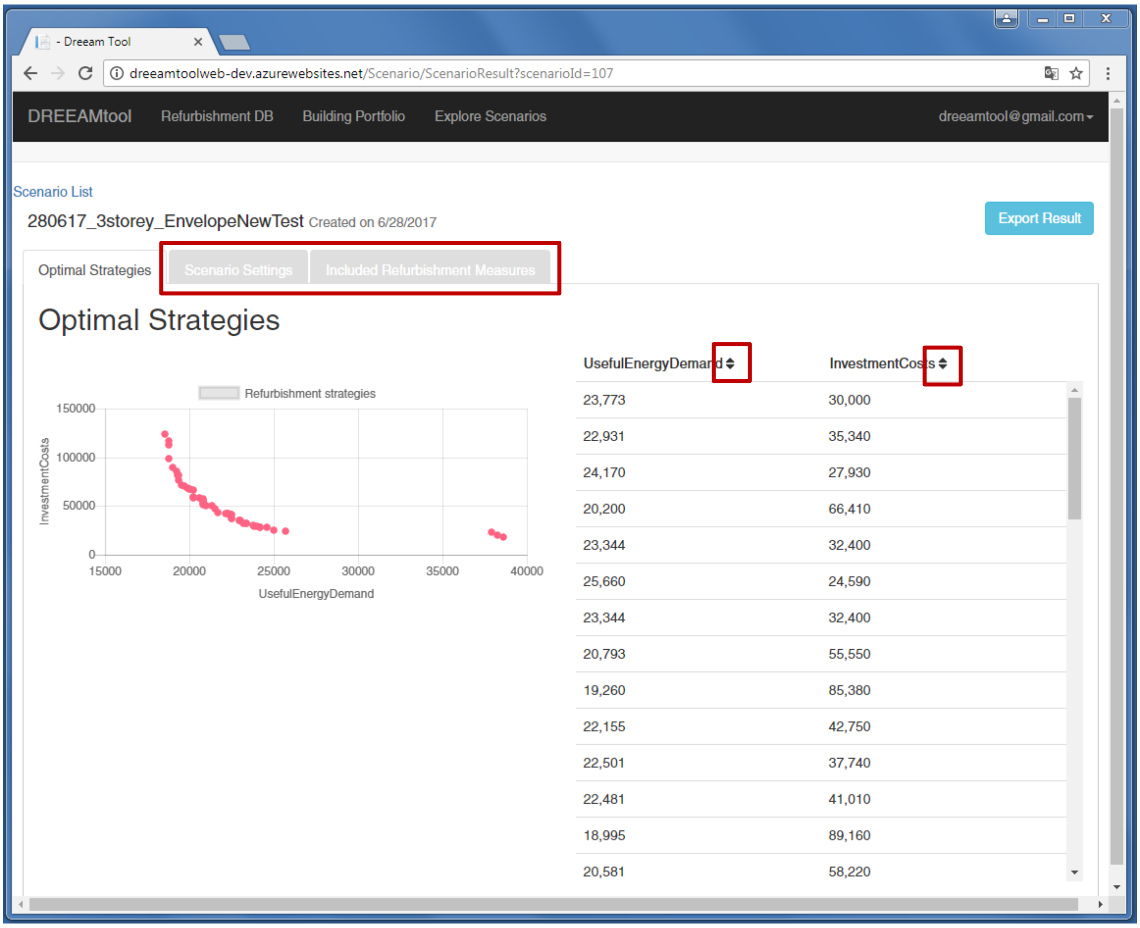


Figure 6: Scenario results

As also shown in Figure 6 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 details (Figure 7):

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

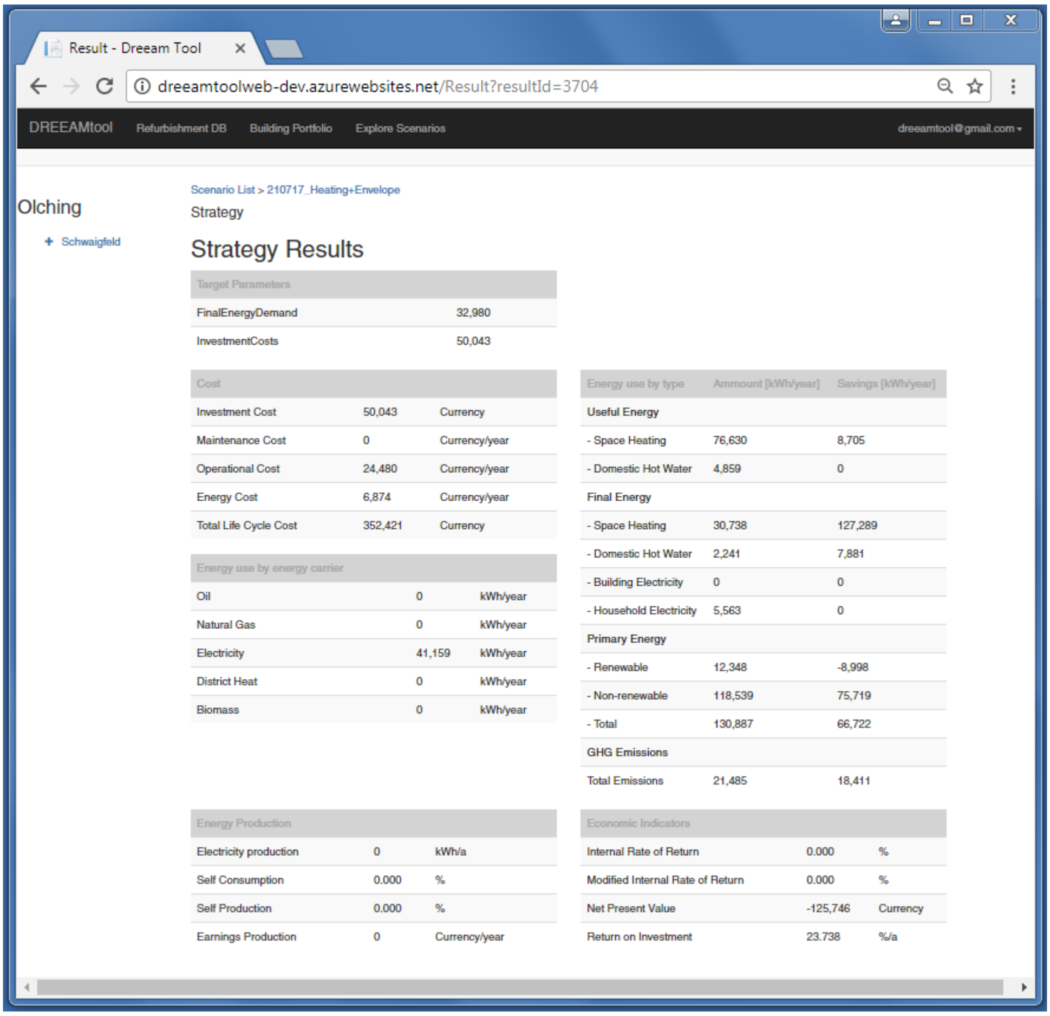


Figure 7: Detailed scenario results

5. DREEAM Tool Outlook

There are some things to be developed in DREEAM tool at this moment such as implementing the effect of the scale on the renovation cost, and the electricity night/day tariff, as well as the night/daytime zone temperature.

Similar to what has been done in the previous report, the tool needs to be validated at the district level. Namely multi buildings shall of different uses (residential, commercial, etc) be simulated using commercial software and the results to be compared with the results obtained from DREEAM tool.

The tool shall be developed to use 3D building database which can be used as an extendible basis for real-time thermal demand simulation. Also, the result illustrations shall be improved in the way that different retrofitting scenarios can be compared.

The main challenges that might face implementing the renovation scenario that is suggested by DREEAM tool are that the construction companies rejection since they have used to carry out a similar project in a different scenario using a conventional approach [10]. Therefore, high stakeholders engagement is needed. However, a significant benefit of the tool itself is to demonstrate the difference in project viability of a renovation project if it was implemented according to DREEAM tool suggestion as compared to the conventional approach.

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