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2nd Newsletter

Energy consumption prediction with building usage measurements to support decision making in building retrofitting

Introduction

The EnPROVE project has developed a platform to support building renovation by directing the available investment to the most appropriate technologies. The aim of this project is to maximise energy efficiency. The solution offered includes a wireless sensor network that is used to perform a building audit to analyse the real usage of various areas in the building. The Energy Prediction and Decision Support System (EPDSS) provides suggestions for potential renovation scenarios for the building taking into account the current situation, i.e. baseline scenario, and the real use of the infrastructure. The alternative scenarios are analysed and compared from both technical and financial perspectives. A technical consultant is in charge of comparing energy consumption of each scenario, taking on board installation and maintenance costs. An investor then reviews the scenarios from a financial perspective, comparing initial investment, payback period, return on investment (RoI) and net present value for each. The combination of these two perspectives enables the investor to make an informed decision and direct the available investment to the solution that will also maximise energy efficiency.

Rui Neves-Silva
Project Coordinator

The project has successfully completed a test case in the University College Dublin in Ireland, where the CLARITY Centre building was analysed to renovate its lighting system. The infrastructure was monitored by the wireless sensor network for six months. Energy consumption for this building was analysed by the platform. EnPROVE suggested a set of twelve possible renovation scenarios, offering possible energy savings ranging from 12% to 82%, with initial investment from €70 to over €7000.

The EnPROVE Platform supports the building owner, technical and audit consultants in going through the complete planning of a building renovation. This process comprehends 13 steps represented in a clockwise direction as shown in Figure 1. starting on the right side, with "Create new project".

The objective of this newsletter is to demonstrate the functionality offered by the EnPROVE platform and the results achieved in the Irish test case.

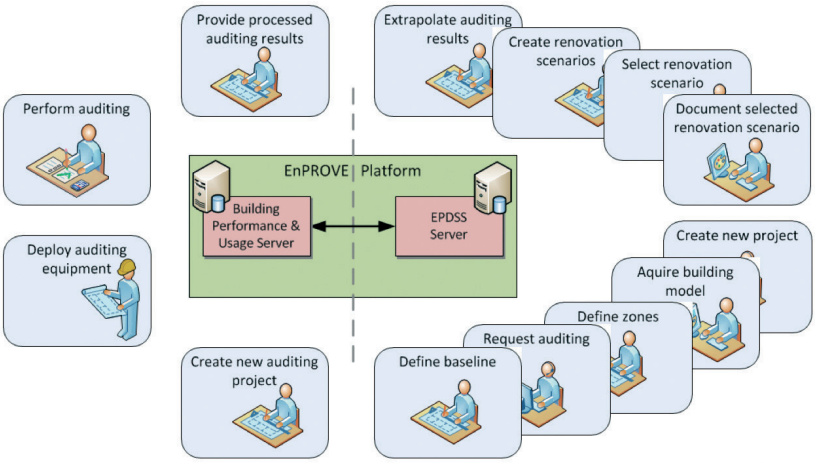

Figure 1. EnPROVE process steps.

Building Model

A building to be audited in the EnPROVE system is described by its model. The model consists of walls, openings (doors, windows), spaces and also the relations between those building elements. Figure 2 demonstrates an example of a building model.

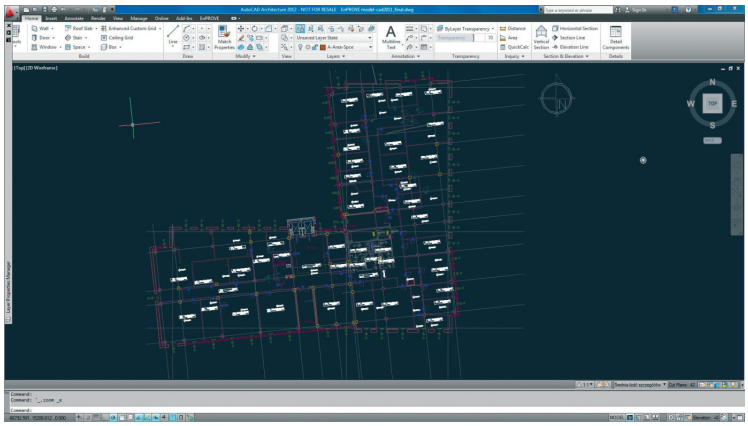

Figure 2. 2D building model in CAD system.

The building model can be imported from an external Computer Aided Design (CAD) system into the EnPROVE system. To accomplish this, EnPROVE has importer plug-ins for different CAD systems (such as AutoCAD Architecture, Autodesk Revit) that do a full-automatic import of the relevant building model data into the EnPROVE system.

The CAD drawing is required to include building elements (walls, openings, spaces, …). Alternatively, a simple 2 dimensional (2D) CAD drawing geometry must be replaced by the corresponding building elements. The result of this process is a 3 dimensional (3D) model of the building as shown in Figure 3.

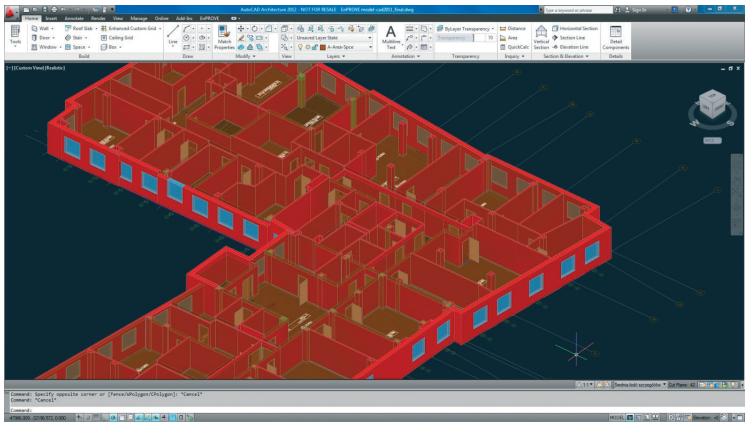

Figure 3. 3D building model in CAD system.

The working unit for the EPDSS system is the zone. So once the building model has been imported into EnPROVE, it needs to be partitioned into zones. A powerful, easy to use zone browser and editor with a graphical user interface is included in the EnPROVE system to assist in defining zones.

The part of the building to be renovated is completely subdivided into an arrangement of zones which are categorized as HVAC, lighting or combined zones. Figures 4 and 5 show the CLARITY Centre building model imported to the EnPROVE system and its zone definition, respectively.

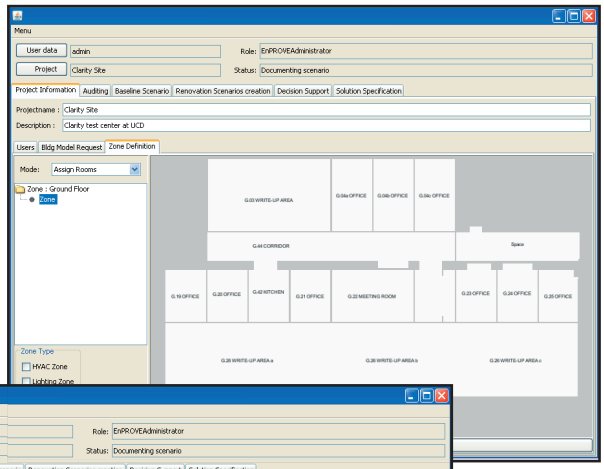

Figure 4. Building model imported into EnPROVE system

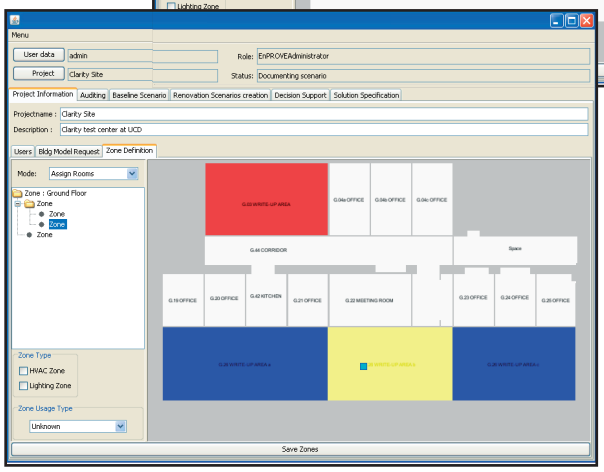

Figure 5. Defining zones for the building model for the CLARITY Centre case.

Once all the zones are defined, the auditing of the building can be requested.

Zones that are not going to be audited can be represented with a placeholder (proxy-zone), defining the usage and consumption behaviour of that zone.

Extrapolation

The audit process consists of installing a wireless sensor network in the selected zones to collect information on how the building is actually used. This information will be used to calculate the energy consumption in the building.

One of the key aspects for the investor is to be able to gather the most possible information about the building minimizing the investment costs. This implies reducing the number of sensors installed and also the auditing period length, without compromising the validity of the results for the whole building.

An intelligent post-processing of audited data makes it possible to get information of variables that are not directly measured, or can complement these measurements, e.g., a window actuation event also gives the information of presence detection. Also, using the concept of proxy-zones drastically reduces the number of sensors needed to characterize a whole building.

In parallel, the system also implements intelligent extrapolation strategies which permit to obtain usage and ambient values for the whole year. Although the audit provides only information of short period of time (2-3 months), it makes possible to reuse the sensors during the year, as it is shown in Figure 6 in several buildings. The key issue is to find the correlations between different measurements during audited period and apply them to the rest of the year. For example the software of the platform analyzes the collected data for external daylight, internal daylight and on/off patterns of luminaires and deduces how the luminaires will be operated in different daylight conditions. Knowing what external daylight conditions are anticipated in any moment of the year (using historical or climate files), these luminaire actuation patterns can be deduced for the rest of the year.

An equivalent situation for HVAC would be to detect if there is any correspondence between when the users switch on or off the terminal units regarding perceived temperature and if the windows are opened in such situations or not, obtaining some probabilistic factor for different events, depending on the measured variables. Then, those probabilistic functions are applied to the rest of the year. This process is demonstrated in Figure 6.

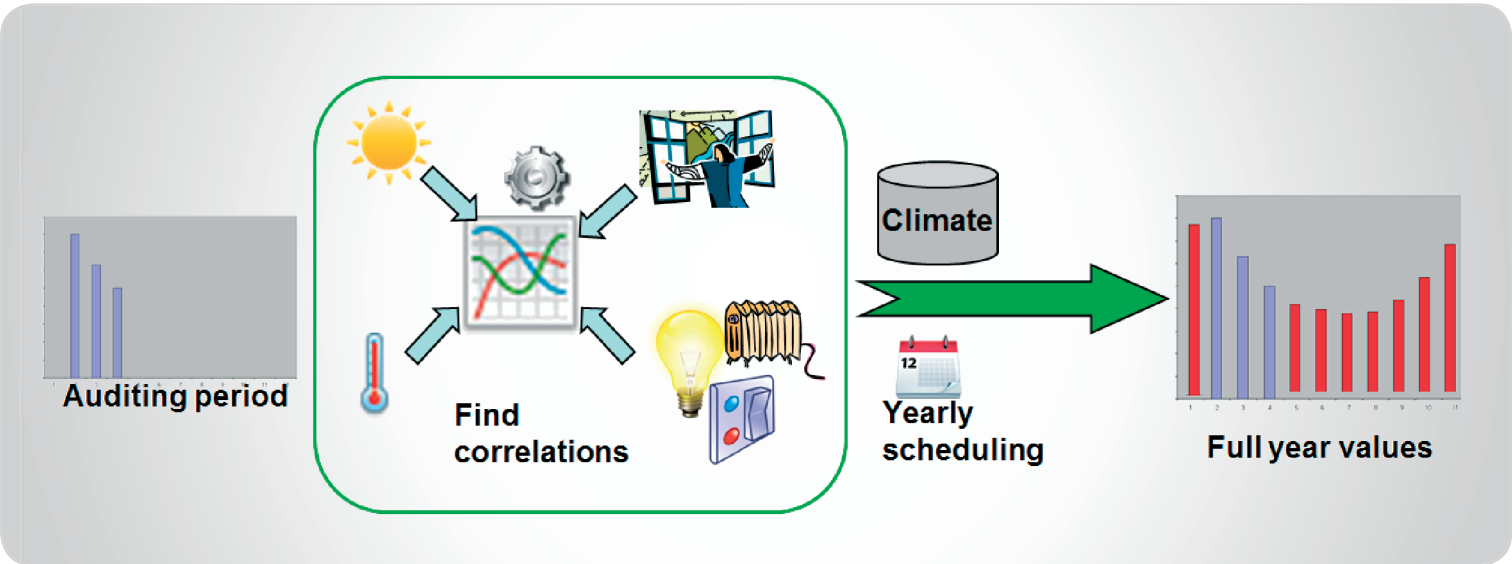

Figure 6. Procedure for extrapolating auditing period values to the whole year

Concept Creation – Lighting Use Case

Proxy zones act as reference for zones with similar usage and energy performance characteristics. The concept of proxy zones does not only reduce the amount of auditing equipment to be deployed during data collection phase, but does also greatly limit the complexity for renovation scenario creation. Figure 7 outlines the chosen setup for the CLARITY Centre demonstration case. In total, reference zones for 3 different single person offices, 2 open space offices, the corridor and a conference room were chosen.

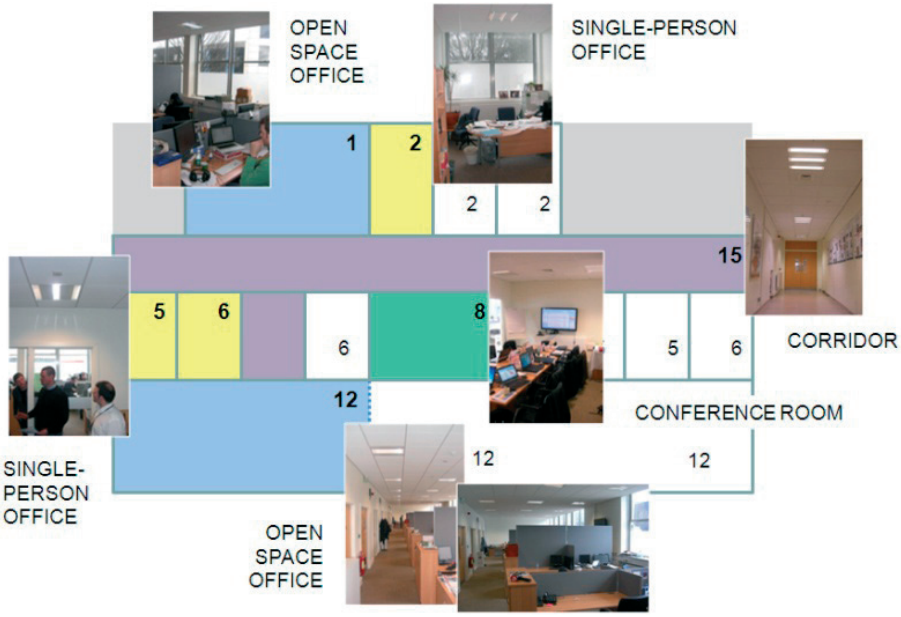

Figure 7. Proxy zone definition for CLARITY Centre; reference zones indicated with colored boxes

Selected renovation strategies and solutions for the proxy zones are applied to all zones that refer to a particular proxy in the same way in order to determine a full site renovation scenario.

Scenario creation of EnPROVE generates, evaluates and characterizes a set of renovation scenarios for the lighting domain and the HVAC domain (Figure 8) In addition, combined scenarios can be created that comprise strategies for both, lighting and HVAC. A scenario creation control dashboard allows the user to steer the combined scenario generation according to their preferences, e.g. based on renovation budget or envisioned energy savings.

The system demonstration at CLARITY Centre focused mainly at appropriate lighting strategies measures. The scenario creation application uses 3 key performance indicators (KPI) to generate meaningful scenarios and to provide assessment information at the same time.

The following KPIs have been defined for EnPROVE lighting scenario creation:

LENI: Lighting Energy Numeric Indicator [kWh/(m2*year)]

LINI: Lighting initial INvestment Indicator [€/m2]

LIMI: LIghting Maintenance Indicator [€/(m2*year)]

While the LENI is initially used to select the most attractive strategies in terms of energy saving potential, i.e. the scenario creation engine determines ‚what to implement' (Figure 9), the cost indicators for required investments and future maintenance efforts help the user to steer the selection of attractive renovation scenarios at solution- and product-level in a second step ('how to implement').

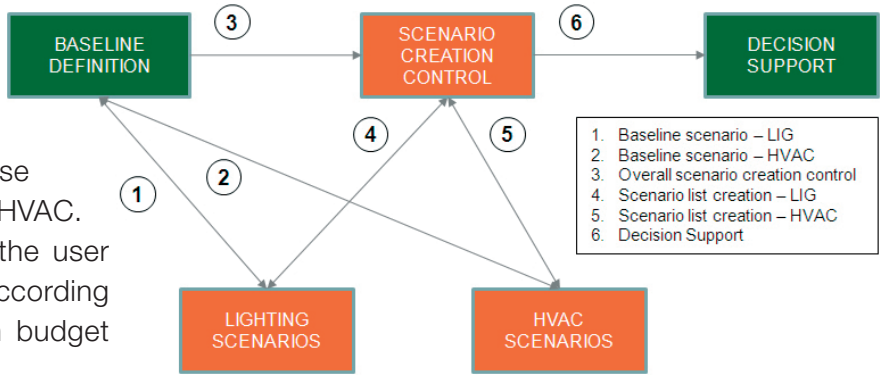

Figure 8. Lighting and HVAC scenario creation

A User Interface (UI) has been developed for the EPDSS prototype application software such that the user is guided through lighting scenario creation and refinement. Several dialogs and sub-menus allow to properly pre-configure the solution space explored by the scenario creation engine. In addition, the user has means to freely modify, combine or skip proposed scenarios and to proceed with the desired scenario list for each refinement step. Figure 10. depicts 2 user dialog screens, one at strategy-level scenario selection and one at product-level scenario definition.

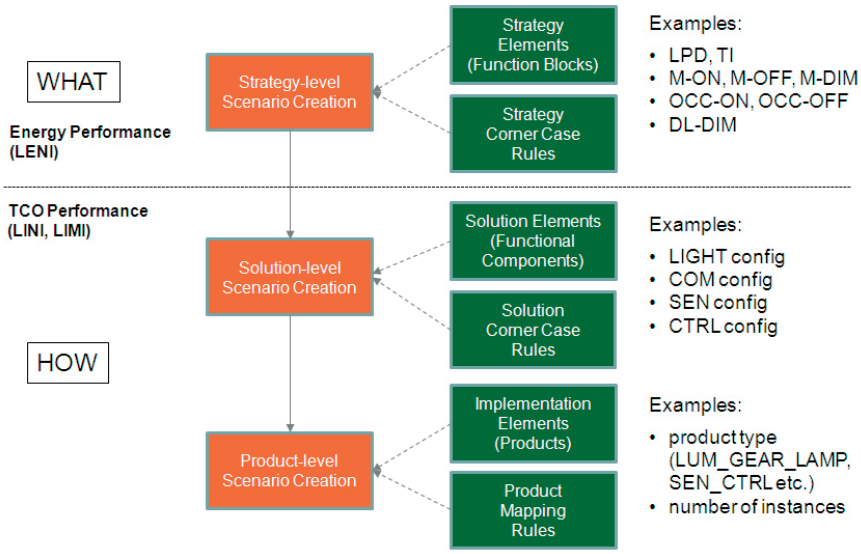

Figure 9. Refinement of lighting scenarios via strategy-, solution- and product level

The EPDSS software demonstration for the CLARITY Centre case confirmed several high-level findings. For instance, no sensible light point upgrade opportunities exist due to the relatively new TL5HE luminaire installation. However, several scenarios for the introduction of controls were identified, which would enhance overall energy performance of CLARITY Centre site.

For CLARITY Centre case, a list of 12 lighting scenarios were created. The proposed scenarios greatly vary based on the involved control measures and corresponding set of affected zones. In order to get guiding insights to the financial consequences and to the holistic performance of the individual scenario, the user is referred to the decision support application following the EPDSS workflow.

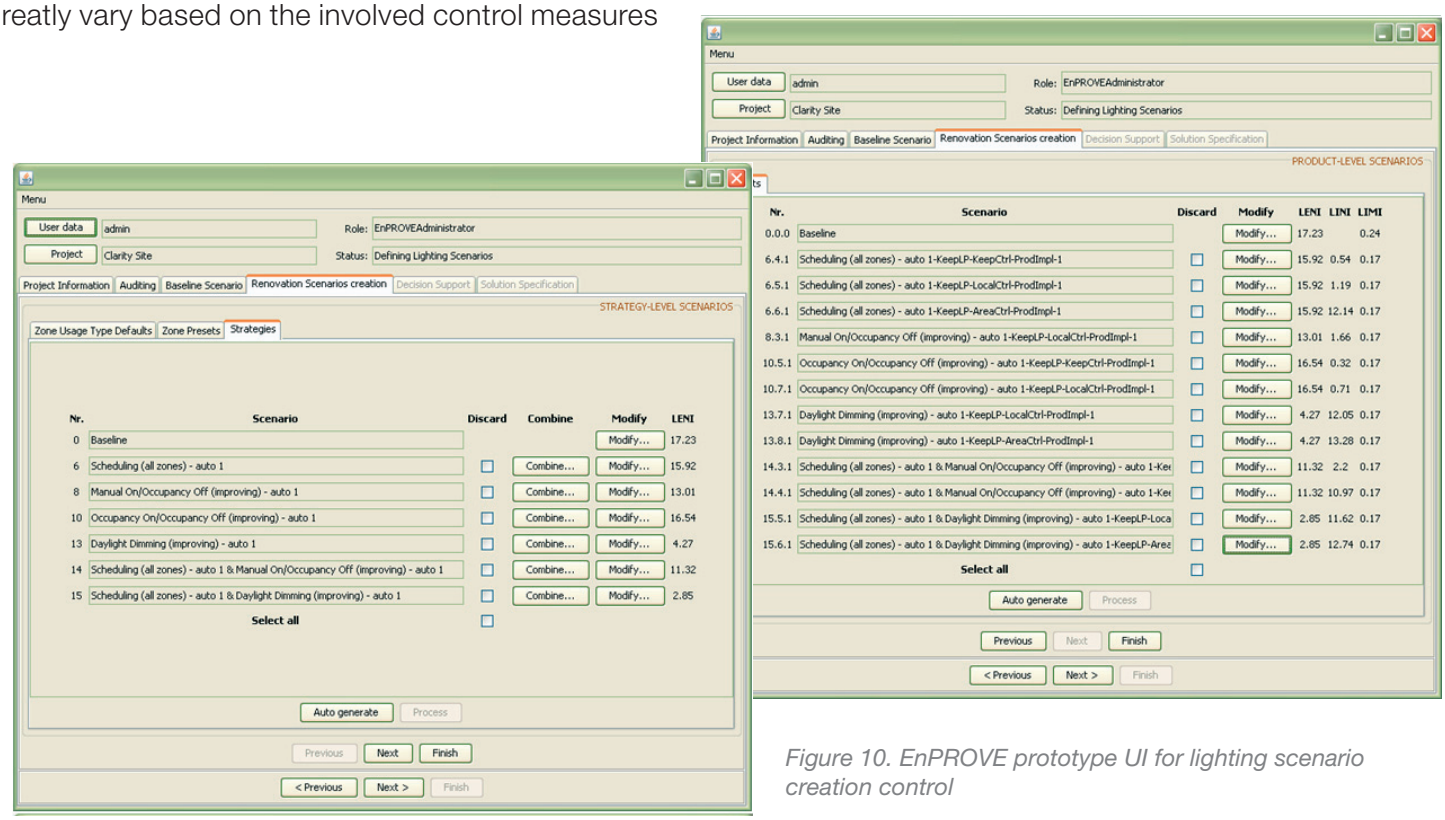

Figure 10. EnPROVE prototype UI for lighting scenario creation control

Decision Support

The backbone of the EnPROVE system is its decision support system i.e. EPDSS. Once the complete set of renovation scenarios has been generated and the technical consultant has selected the desired ones to be analysed in more detail, the decision support module assists the investor in comparing and ranking the selected scenarios against different criteria.

Demonstrating EnPROVE system at the CLARITY Centre led to the comparison of twelve renovation scenarios in the decision support module.

The first step was the calculation of the cash flows and the financial indicators. The objective of this step is to provide sufficient information that the investor can use to reduce the number of scenarios, if needed. For example, it can be difficult to do a full comparison or sensitivity analysis of 12 scenarios. It is more efficient to consider less than seven scenarios to compare. The decision support module starts by creating standard, discounted and accumulated cash flows for all renovation scenarios and calculated the payback period (PP), net present value (NPV) and internal rate of return (IRR). The investor gets a screen with all the scenarios, as presented in Figure 11, and can use any of the indicators to order the scenarios.

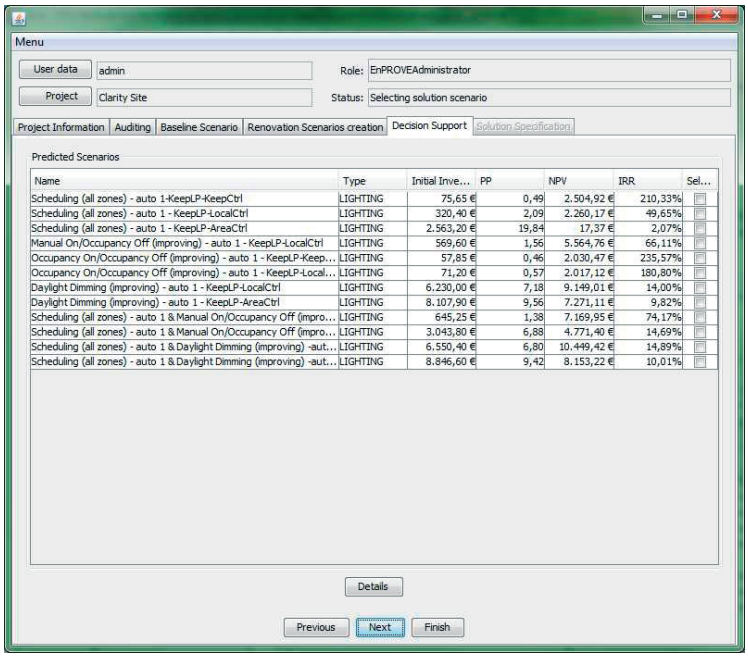

Figure 11. List of renovation scenarios in decision support for the CLARITY Centre case.

The investor has the opportunity of reviewing the details and calculations of any renovation scenario, obtaining the discounted cash flow represented in a table and graphic (see Figure 12).

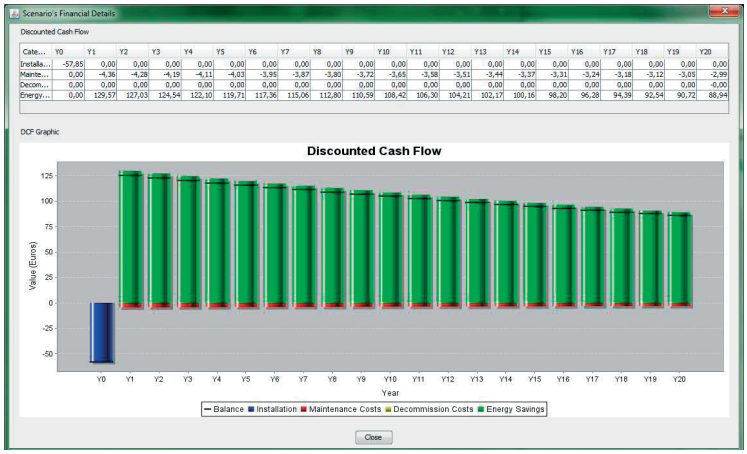

Figure 12. Financial details of one renovation scenario for the CLARITY Centre case.

The selected renovation scenarios are then compared against each other. The decision support module identifies the best scenario regarding each of the three financial indicators, i.e.:

- The scenario with the shortest payback period,
- The scenario with the highest net present value, and
- The scenario with highest internal rate of return.

The best scenarios are ranked first in the respective indicator, and all other scenarios are then proportionally evaluated. This comparison is then represented in a radar chart, as displayed in Figure 13.

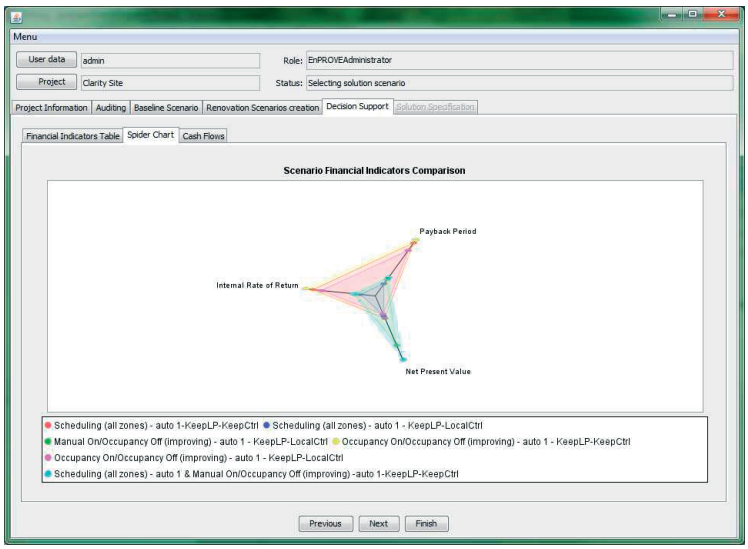

Figure 13. Comparison of selected renovation scenarios (radar chart) for the CLARITY Centre case.

Figure 14. Comparison of accumulated cash flows of selected renovation scenarios for the CLARITY Centre case.

The investor can also compare the accumulated cash flows of the selected scenarios, to easily identify the payback period and the net present value, as presented in Figure 14.

The investor defines the importance of each of the three financial indicators, as a percentage. The decision support module ranks the scenarios using the investor's preferences and the indicators calculated. The result is an ordered list of scenarios.

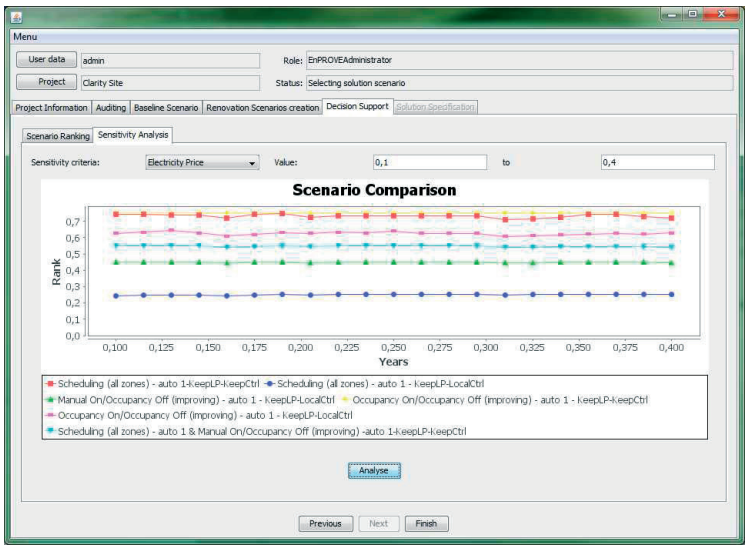

Figure 15. Sensitivity analysis for the CLARITY Centre case.

After comparing and ranking the renovation scenarios, the investor has once again the possibility of reducing further the list, before proceeding to the sensitivity analysis. This analysis considers variations of either the discount rate or the electricity price. The investor defines a range for the selected parameter and obtains a graph of the resulting ranking of the scenarios, as presented in Figure 15.

The investor can finally select the renovation scenario that best fulfils his plan for the building and indicate this section to be saved in the EPDSS supporting database. The assessment of the project's status is modified to reflect the decision made. The investor can still go back and start a completely new decision process, by selecting a different sub-set of scenarios or different decision criteria.

Events

EnPROVE sponsored the IT4ENERGY, an international workshop held in Lisbon, on September 6th and 7th. During these two days, UNINOVA maintained a stand at the event, showing the project's results.

The project was presented with the support of two posters, explaining the concept of the project and the support offered by the EnPROVE platform developed. In addition, a video was displayed showing the sensor deployment at CLARITY, the first test case.

The IT4ENERGY counted attendants from research institutions and industry, particularly in the area of energy monitoring and auditing. EnPROVE had the possibility of establishing contacts with several companies, who showed significant interest in EnPROVE's results.

IT4energy 2012 WORKSHOP

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