Project Number **260041**

SUPPORTING ACTION

EnRiMa
Energy Efficiency and Risk Management in Public Buildings

D4.1 Requirement Analysis

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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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List of acronyms

API	Application program interface
BEMS	Building energy management systems
CHP	Combined heat and power
CPI	Customer price index
CVaR	Conditional value-at-risk
DB	Database
DBMS	Database management system
DER	Distributed energy resources
DER-CAM	DER customer adoption model
DG	Distributed generation
DHW	Domestic hot water
DM	Decision maker
DMP	Data-making process
DoW	Description of Work
DSM	Demand-side management
DSS	Decision-support system
DW	Data warehouse
Dx.y	Deliverable y of WPx
EeB	Energy-efficient buildings
EnRiMa	Energy Efficiency and Risk Management in Public Buildings
ESC	Energy supply contract
ESCO	Energy service company
EVPI	Expected value of perfect information
FiT	Feed-in tariffs
GUI	Graphical user interface
HVAC	Heating, ventilation, and air conditioning
ICT	Information and communication technologies
IPMVP	International Performance Measurement and Verification Protocol
JBI	Java Business Integration
JEE	Java Enterprise Edition
MCEEM	Microgrid customer engineering and economics model
PCL	Programmable logic controller
PV	Photovoltaic
RA	Requirements' analysis
RES	Renewable energy sources
SCADA	Supervisory control and acquisition system
SMS	Short message service
TOU	Time of use
VaR	Value-at-risk
VSS	Value of stochastic solution
WPx	Work package (x stands for its number)
ZNEB	Zero-net-energy building

Executive summary

In order to design and implement a Decision Support System (DSS) that actually meets the needs of the building operators, it is necessary to understand and document the decision-making environment, actors and processes that the DSS shall support, and then use it as a basis for analysis of requirements the DSS should meet. First, we provide extensive characteristics of the public space buildings that implicitly define a class of building for which the DSS will be developed, and that will serve as test sites for the DSS. Next, we characterize the diverse types of future users of the DSS, and follow with description of their objectives and the decisions they make for reaching them, as well as with explanation of the corresponding decision-making processes. Subsequently, we characterize the requirements for data and integration with the existing information infrastructure of the sites, as well summarize the general functional and non-functional requirements for the DSS. Finally, we present a complementary view on the DSS requirements through a representative set of use-cases and scenarios of their usage.

1. Introduction

This report contains the Requirement Analysis (RA) for the EnRiMa[1] Decision Support System (DSS). According to good modelling practice, an RA shall define a problem without attempting to define solutions for it. Therefore, this report defines a class of decision-making problems faced by managers and operators of energy-efficient public buildings to be supported by the EnRiMa DSS. This class of problems corresponds to the scope of the EnRiMa project, and in particular to its test sites. However, the EnRiMa DSS will be a modular, open system designed for future adaptations and extensions to other energy-efficient buildings.

The RA is composed of the following elements:

- Problem description, including characteristics of the EnRiMa test sites, and requirements for improving support for the decision-making
- Users and stakeholders
- Users' decisions and objectives
- Decision-making workflows
- Data requirements
- Integration requirements
- General requirements
- Use-cases and use-case scenarios

In this structured way, the report:

- Describes the major types of the DSS users, and organizational context of the decision-making processes
- Contains a comprehensive list of functionality and features the users expect from the DSS (including those elements that the EnRiMa team knows some users will need or desire, and are currently not available)
- Includes the requirements on the key elements needed for designing a DSS, in particular:
    - Characteristics of the buildings
    - Specification of the decisions to be supported
    - Specification of objectives (criteria, outcomes, indicators) that the decision-makers use for evaluation of consequences of implementation of the decisions, including those used as optimization objectives

[1] Energy Efficiency and Risk Management in Public Buildings.

- Characteristics of uncertainties and risks

The set of the developed use-cases[2] represents in a structured way the DSS functionality required by different types of its users, each having a particular goal for using the DSS. In this way the report provides also user-centered guidelines for designing the DSS that will fit well the actual requirements of the users. The RA is written in a way the actual DMs (future users of the DSS) can understand; therefore, it contributes to building understanding between the users and the DSS developers.

This is an initial version of the RA, which specifies the wish list for the DSS functionality. It defines an initial aspiration level for the DSS that will be adjusted to attainable goals during forthcoming EnRiMa activities, in particular development of symbolic model specifications, generation and testing of the corresponding computational tasks, verification of the actual data availability, testing the DSS prototype on the test sites, and learning from the hands-on experience of the practitioners.

This deliverable is complementary to D1.1 (Requirement Assessment, being developed in WP1), which will document the RA of the EnRiMa test sites. In order to make this report self-contained, we have included extensive summaries of those elements of the forthcoming D1.1, which are necessary for the characteristics of the decision-making processes to be supported by the EnRiMa DSS. The relations of this deliverable to other EnRiMa project activities are summarized in Section 10 of this report.

The report results from close collaboration of all EnRiMa partners. According to good practice, the partners who are experts in the field of operational and strategic planning of energy in public buildings have taken the leading role in finalizing these elements of the RA that are key for designing functionality of the DSS. Section 10 of this deliverable contains the details about the lead-authors of each section of this report.

[2] Please see Section 9 for explanations of the use-cases background and role, as well as for scenarios illustrating their use.

2. Problem description

2.1. Background

The overall objective of EnRiMa is to develop a decision-support system (DSS) for operators of energy-efficient buildings and spaces of public use. By providing integrated management of conflicting goals such as cost minimisation, meeting energy, efficiency, and emission-reduction requirements as well as risk management, the DSS should enable operators to improve building energy efficiency in the most cost-effective manner based on their tolerances for comfort and risk. The DSS will facilitate the operators' on-site generation dispatch, and off-site energy purchases from diverse sources. The DSS should also enable long-term planning aimed at increasing energy efficiency, specifically analysis of retrofits and/or expansion of on-site energy sub-systems, in order to meet forthcoming EU targets for reducing CO_2 emissions.

2.2. Description of sites

Here we provide an executive summary of corresponding elements of the Deliverable D1.1.

2.2.1. FASAD

The FASAD building was constructed in 1975 in Meres, Siero in a rural area in the north of Spain. The owner of the building is the Asturian Foundation for Attending Handicapped People (Fundación Asturiana de Atención y Protección a Personas con Discapacidades y/o Dependencias - FASAD).

It is located on a plot of approximately 31,363 m^2, and the ground area of the building is approximately 10,300 m^2. The building was designed as volumes in the shape of prisms located around interior patios, and it has a cellar, a ground floor, and a first floor. In some of the different zones, these volumes have only the ground floor, and, in another zones, the volumes do not have cellar. Inside the building, there are accommodation zones for boarders, classroom and workshop zones, indoor sports facilities, meeting rooms, and office zones.

The existing technologies used for building heating are:

- Gas boilers
- Gas micro-CHP
- Solar heat

This heating system provides heating, domestic hot water (DHW), and heats the swimming pool of the building.

The building does not have any ventilation system for assuring the air quality as required by the norm RITE (Reglamento de Instalaciónes Térmicas de Edificios – Norm for Thermal Installations in Buildings) 2007 (IT 1.1.4.2), because it was built before the entry into force of this norm. The electric installation of the building has a maximum permissible power of 276.8 kW. The most relevant electric consumption takes place in the kitchen and the laundry. The lighting of the building is done by fluorescent lamps, with a total installed lighting power of 60 kW. In most of the rooms, there are linear fluorescent lamps of different powers.

2.2.2. Market and regulations in Spain

In Spain, buildings with installed DER devices, like in this case the FASAD building in Meres, are generally subject to three different tariffs: one for the consumed gas, another one for the consumed electricity, and a third one for the produced electricity.

The first two mentioned tariffs, since gas and electricity retailing are non-regulated activities, are agreed by contract between customer and retailer for a period of normally 1-2 years. These tariffs usually consist of a power component and an energy component, depending on the maximum demanded power and the consumed energy, respectively. For example, FASAD's current tariff for its consumed electricity is 2,962.80 €/year (power) + 121.53 €/MWh (energy). This means that cost savings can be achieved by not only reducing the consume of energy but also taking measures for reducing the contracted maximum power, like for example load shifting or energy storage.

The tariff that the building owner receives for generating electricity is regulated in Spain by the "Royal Decree 661/2007, 25th of May, special scheme for electricity generation with renewable energy sources"[3]. This RD sets different renewable energy sources subject to the special scheme. The main sources that could be used in public buildings are cogeneration using natural gas, photovoltaic, wind, and biomass.

The remuneration mechanisms of the electricity produced under the special scheme are two:

a) Regulated tariff: same tariff in every time period.

b) To sell the produced electricity in the electricity market: the selling price of the electricity will be the price resulting from the electricity market plus a feed-in tariff.

[3] http://www.boe.es/aeboe/consultas/bases_datos/doc.php?id=BOE-A-2007-10556

The cogeneration and biomass installations that have chosen option a) can make use of the time-of-use rate scheme with the two following periods:

Winter		Summer	
Peak	Off-peak	Peak	Off-peak
11 – 21 h	21 -24 h & 0 – 11 h	12 – 22 h	22 -24 h & 0 – 12 h

In this case, the regulated tariff will be the corresponding tariff multiplied by 1.0462 for the peak period and by 0.9670 for the off-peak period. The producer can choose one of these remuneration options for a period not shorter than one year, after which he has the possibility of switching to another option.

The feed-in tariff referred to in option b) is an additional quantity to the resulting price in the electricity market. For some of the technologies like photovoltaic, wind, and biomass, the feed-in tariff is variable depending on the resulting market price. For these installations, a reference feed-in tariff and upper and lower limits are established.

The tariffs and feed-in tariffs for micro-CHP using natural gas will be updated quarterly depending on fluctuations of defined indexes, which are related to the fuel prices and to the consumer price index (CPI). These micro-CHP installations, after 10 years of operation, will get also a long service benefit in the following updates.

The tariffs, feed-in tariffs, complements and upper and lower limits defined in this RD for photovoltaic, on-shore wind and biomass will be updated yearly depending on the CPI variations minus a value that will be 25 basis points until the 31st of December 2012 and 50 basis points afterwards. The formulas used for calculating and updating all the above mentioned tariffs and feed-in tariffs are explained in detail in the referred RD.

The current prices for electricity generation with renewable energy sources under special scheme in Spain are:

Group	**Subgroup**	**Fuel**	**Power**	**Regulated Tariff c€/kWh**	**Reference Feed-in tariff c€/kWh**
a.1	a.1.1 CHP	Natural Gas	P≤0.5 MW	16.3436	-
			0.5<P≤1 MW	13.4113	-
			1<P≤10 MW	10.8303	4.5348
			…	…	…

Table 1: Tariffs and Feed-in tariffs for cogeneration with natural gas (updated quarterly: last update October 2011).

Group	**Subgroup**	**Power**	**Period**	**Regulated Tariff c€/kWh**	**Reference Feed-in tariff**	**Upper Limit c€/kWh**	**Lower Limit c€/kWh**

					c€/kWh		
b.1	b.1.1 Photo-voltaic	P ≤100 kW	1st 28 years	47.5597	-	-	-
		100 kW<P≤10 MW	1st 28 years	45.0886	-	-	-
		…	…	…	…	…	…
b.2	b.2.1 Onshore Wind	-	1st 20 years	7.9084	2.0142	9.1737	7.6975
			after	6.6094	-	-	-
b.6 Bio-mass	b.6.1 Biomass from energy crops	P≤2 MW	1st 15 years	17.1596	12.9361	17.9599	16.6423
			after	12.7362	-	-	-
		…	…	…	…	…	…
	b.6.2 Biomass from agri-culture	P≤2 MW	1st 15 years	13.5763	9.3528	14.3744	13.0568
			after	9.1530	-	-	-
		…	…	…	…	…	…
	b.6.3 Biomass from forest residues	P≤2 MW	1st 15 years	13.5763	9.3528	14.3744	13.0568
			after	9.1530	-	-	-
		…	…	…	…	…	…

Table 2: Tariffs and Feed-in tariffs for photovoltaic, onshore wind, and biomass (updated yearly: last update January 2011).

2.2.3. Pinkafeld campus

The University for Applied Science of Burgenland (UAS) is composed of two campuses, and EnRiMa focuses on just one campus situated roughly 120 km south of Vienna. UAS hosts roughly 1600 students where approximately 600 are based at the Fachhochschule campus Pinkafeld (fh-Pinkafeld). At the Pinkafeld campus, there are approximately 35 employees working part and full time. The heated gross area of the new building is about 2000 m². The heated gross are of the old building is about 2100 m².

The building was renovated in 2002, and therefore, the building shell and window quality is good, i. e. U-value (heat transfer coefficient) for windows are around 1.34 W/m^2K and for walls around 0.31 W/m^2K. A building quality upgrade is not very likely.

The rated peak heat capacity of the heat exchanger and, therefore, of the district heating system is 162.8 kWh_{th}. About 70.7 kWh_{th} is used to heat the air in the air-conditioning system.

The air conditioning system is able to transport ~13 000 m³/h. Within the air ventilation cooling, dehumidification, and pre-heating is done. The required cooling load is provided by a cold water aggregate with a 1.1 kW_{el} motor for the auxiliary fans on the roof of the office building. Two compressors with an electrical consumption of 23 kWh_{el} can deliver a cooling capacity of 47.9 kW_{th}. The district heating provides also some heat for the preheating of the ventilation air during winter months. The average heat recovery by the air ventilation system is given by 71%.

There is a 1.28 kWp PV system installed close to the old building of fh-Pinkafeld. The generated electricity is sold to the BEWAG with €0.0759/kWh, and no special FiT is applied. On average, the system supplies between 700 and 800 kWh/a. For each generated and sold kWh, the fh-Pinkafeld gets €0.0759/kWh compared to €0.15/kWh (electricity price in 2009) for purchased electricity.

2.2.4. ENERGYbase

ENERGYbase is the showcase project of a new generation of office properties. With the construction of this trend-setting Competence Center for Renewable Energy, the Vienna Business Agency sets new standards in the development of energy optimized office properties.

The building was constructed in 2008 and has five floors for renting and a basement for the building equipment and a garage. The total usable floor space is about 7500 m^2 and the gross floor area within the thermal/building shell is about 7800 m^2. With an average room height of 3 meters, the gross volume is 23 400 m^3.

The building was built in 2008, and therefore, the building shell and window quality is very good, i. e. U-value (heat transfer coefficient) for windows is around 0.75 W/m^2K and for walls around 0.16 W/m^2K. The U-value for basements and ceiling is given by 0.18 respectively 0.12 W/m^2K.

For building heating, two heat pumps in combination with the 285 m^2 solar collectors are used. The water/water heat pumps use the ground water as source and have a capacity of 170 kW_{th} each. For the proper separation of the different sources and the heat emission systems, a hydraulic switch with 2000 liters is installed.

The distribution of the cold or hot water is done by concrete core activation, which is divided into four independent zones (west-north, west-south, east-north, and east-west). In the corner offices, an additional floor heating system is installed. For the heating of the laboratory, an air circulation system is used. To cover a part of the electrical consumption, a PV-system with 48 kWp is installed at the southern facade.

There is no detailed information on the tariffs available due to confidentiality issues and this also includes information about feed-in tariffs (FiT). However, ENERGYbase uses a flat tariff typical for Austria.

2.2.5. Austria's regulatory environment

Also the knowledge of the recent tariff structure has to be known. In Austria, the situation is as follows (eControl, 2011):

- PV system on buildings: for systems between 5 and 20 kWp €0.38/kWh are given; for systems above 20 kWp €0.33/kWh are given;
- PV system not on buildings: for systems between 5 and 20 kWp €0.35/kWh are given; for systems above 20 kWp €0.25/kWh are given;
- Wind systems: €0.097/kWh;
- Biomass systems: up to 500 kW: €0.1498/kWh; between 500 and 1,000 kW: €0.1354/kWh;
- Biogas: up to 250 kW: €0.1850/kWh; between 250 and 500 kW: €0.165/kWh;
- Geothermal systems: €0.075/kWh;
- CHP systems: investment grant of maximum 10% of the investment for systems between 2 to 100 MW: €100/kW;

2.2.6. Comfort level regulations

In Spain, there are two Laws establishing these limits for comfort levels:

- Real Decreto 1027/2007, de 20 de Julio, por el que se aprueba el Reglamento de Instalaciones Térmicas (Royal Decree 1027/2007, of 20th of July, which approves the Norm for Thermal Installation in Buildings)[4]. It states that:
    - Internal hygienic and comfort levels in buildings for people with sedentary metabolic activity of 1.2 met, with a clothing degree of 0.5 clo in summer and 1 clo in winter and a PPD (Predicted Percentage of Dissatisfied) between 10% and 15%, are:

Season	Operative temperature (ºC)	Relative humidity (%)
Summer	23…25	45…60
Winter	21…23	40…60

For different metabolic activity values, clothes, and PPD, it is valid the calculation of the operative temperature and relative humidity given by the procedure UNE-EN ISO 7730.

[4] http://www.boe.es/aeboe/consultas/bases_datos/doc.php?id=BOE-A-2007-15820

- Air average speed. It should be calculated and maintained within the following limits. For air dry temperature values within the limits 20ºC and 27ºC:

  - with mixed air diffusion, 40% turbulence intensity and PPD due to air currents of the 15%:

$$v = \frac{t}{100} - 0.07 m/s$$

  - with mixed air diffusion, 15% turbulence intensity and PPD due to air currents lower than 10%:

$$v = \frac{t}{100} - 0.1 m/s$$

- The PPD value should be calculated following the method of the standards UNE-EN ISO 7730 and UNE-EN 13779, as well as CR 1752.
- Inside air quality requirements: Different values of the following parameters are given depending on the type of building under consideration:

  - External air flow per person (dm3/s), perceived air quality in decipols, direct method for CO_2 concentration, indirect method for air flow by surface unit.
  - The types of buildings considered are: IDA1 buildings that require optimum quality air (hospitals, clinics, laboratories, kindergardens), IDA2 buildings that require air of good quality (offices, residences, museums, educational buildings, swimming pools), IDA3 buildings with a medium air quality (commercial buildings, cinema, theatres, hotels, restaurants, coffee shops), IDA4 buildings with a low air quality.

- Real Decreto 1826/2009, de 27 de noviembre, por el que se modifica el Reglamento de Instalaciones Térmicas en los edificios, aprobado por el Real Decreto 1027/2007, de 20 de Julio (Royal Decree 1826/2009, of 27th of November, which modifies the Norm for Thermal Installation in Buildings analysed above)[5]. For energy efficiency reasons, restrictions on the internal temperature of the buildings destined to the following uses were set:
  - Administrative use, commercial use (shops, supermarkets, commercial centers), cultural use (theatres, cinemas, auditorium, congress centers, expositions).

[5] http://www.boe.es/aeboe/consultas/bases_datos/doc.php?id=BOE-A-2009-19915

  - The temperature of the heated rooms will not be greater than 21ºC, when for that purpose conventional energy consumption by the heating system is required.
  - The temperature of the cooled rooms will not be lower than 26ºC, when for that purpose conventional energy consumption by the cooling system is required.
  - The above mentioned temperature limits are referred to a relative humidity between 30 and 70%.

These comfort requirements, defined in the Spanish regulation, could apply for Austria as well.

2.3. Overview of the current operational planning

2.3.1. Operation of the supply/storage resources, and the loads

The following subchapters will identify the steps considered by the building managers to operate the energy systems of the building and analyse the investments. It also provides an overview of what the needs could be concerning the operational planning and strategic planning in the currently available building sites.

The most important energy consumptions in a public use building come from:

- Internal lighting
- Heating and cooling for the:
  - Heating, Ventilating and Air Conditioning (HVAC) system
  - Sanitary hot water
- Others (external lighting)

In some cases, these loads are operated by means of a Supervisory Control And Data Acquisition (SCADA) system centralizing monitoring and control purposes. This advanced control can be centralized or distributed in the building with local / room level light switching and / or thermostats.

In most cases, the control is almost manual and local over each component of the system: the HVAC comes into operation with a simple clock on pre-defined time schedules and manual changes on the set points of thermostats. Usually, the person in charge operates it following some comfort criteria, but there are also targets from reducing maintenance, wearing equally equipment (so the available devices are cycled periodically), preferring partial loading on several units over heavy duties on one (implying worse performance), etc.

The SCADA functions could include monitoring and control of:

- on/off positions of lights,
- light intensities (dimming),
- outside air temperature,
- air temperature and humidity within the controlled space,
- air handling units temperature air diffusion,
- air mix (fresh and internal) at the air handling units,
- position of valves allowing the heating or cooling interchange water/air in the air handling units,
- temperature of water being heated or cooled by chillers, boilers, heat pumps, and pumped into the system,
- on/off of fan-coils,
- maximum and minimum temperatures of the air diffusion by fan-coils

Some control actions could be:

- The consumed electricity can be bought from the utility or self consumed from the available generation equipment (e.g., photovoltaic, cogeneration, batteries).
- In the case of lighting, the control actions, e. g. the use of presence sensors, are easy and have direct relation to the lighting load pattern.
- In the case of HVAC and sanitary hot water, the generation and storage devices are operated following the load pattern and giving output power or temperature set-points.
- The thermal solar units, geothermal units, boilers, chillers, heat pumps, cogeneration units and water storage tanks are controlled by software and hardware solutions; the values set by the operator through the interface provided in SCADA are fed to the local control. The control program runs the generation and storage devices automatically to adjust the physical magnitudes to the set-points.
- It is possible to give priority to certain heat generation devices such as renewables by dispatch orders.

There are not standards, and in most cases, the control program is closed and usually employs some proprietary communication protocol or specific device drivers. Some engineering and reverse engineering work could be needed to interface with other software solutions and algorithms, trying to run the system with more sophisticated criteria (i.e. energy efficiency).

2.3.2. FASAD

The main operational objective is to meet the required user comfort at the minimum cost; CO_2 emissions are not considered at this moment. Therefore, it is necessary to integrate the different heating devices that over the years were installed at several renovation works by different companies. The following improvement opportunities were identified:

- The solar heat system is not well integrated into the rest of the heating system, and its efficiency is unknown.
- The return water temperature of heating and DHW circuit is too high for the micro-CHP unit. For this reason, this device can only operate for heating the pool.

2.3.3. Pinkafeld campus

The management of Pinkafeld campus is thinking about further improvements in user comforts by reducing the energy costs. Therefore, options based on renewable energy resources are very welcome, but, this is the management's view, and on the operational level, the person responsible for running the building expressed some interest in the operations goal. However, these goals are very vague. Overall, the major objective seems to be cost minimization.

During the site visit, two principal approaches could be identified:

- Long-term planning and an investment DSS system that identifies the best DER investment options.
- Operational planning on an hourly basis to minimize day-to-day operation.

The main objectives for the operational optimization are:

- Minimize the energy demand by considering weather forecasts and uncertainty.
- Minimize the energy cost with equal comfort by considering weather forecasting and uncertainty.

2.3.4. ENERGYbase

The owner of the building is the Vienna Business Agency (Wiener Wirtschaftsförderungsfonds – WWFF). The energy costs per student are already very low. For confidentiality issues, no detailed numbers are available.

The main objectives for the operational DSS are:

- Check if a changed shutter (reduction of the perforation below 10%) will satisfy all renters and check the impact to the increase of artificial lighting and, therefore, a higher electric consumption is estimated. The main goal of the used shutters is to utilize day lighting as much as possible.
- Check if a ventilation system with a demand-related flow rate requires a CO_2 emissions measurement and would reduce the electric consumption for the ventilation. The recent system is not designed for part-load behavior.

2.4. Overview of the current strategic planning

2.4.1. Planning different supply/storage resources in the building

In order to decide the best supply or storage device, the building designer, architect, decision-maker, one third party being outsourced, or even the purveyor commercial should:

- Estimate the building baseline. It can be done either by simulations, by past experience, e.g., in the case of a new building, or either by analysis of energy bills and measurements in case of existing buildings.
- Estimate the available primary energy resources in place: sun irradiance, wind speed, land composition, biomass or biogas availability in the surroundings, etc.
- Estimate the electricity, gas, biomass, and/or biogas price evolution.
- Analysis of technology conditions: primary energy resources to be used, efficiency, number of running hours, operational constraints (power modulation, power, current, temperature set-points), maintenance actions, investment price, maintenance and operation costs.
- Analysis of the temporal horizons for the calculations/simulations: the simulations can be performed on typical summer, winter days, in a 24-hour time horizon, or if storage devices are available or considered, wider time horizons. For example, if seasonal geothermal storage is considered, then the whole year should be simulated, since the exceeded heat in summer time is stored and consumed in winter time.
- Analysis of other considerations related to the building: spaces, noises, electric or gas connection points, freight load, discharge, etc.

The decision-maker in the building would be interested in a study/analysis of the best option for the investment to be done. Others like CO_2 emissions or external risks (normative changes, price evolution, etc.) are hardly considered in most cases.

2.4.2. FASAD

The main objectives for the strategic planning are:

- Check if a replacement of the existing gas boilers by new ones or by a different technology can lead to an increase of the efficiency.
- Check if a different tariff for the generated electricity can bring more returns.

2.4.3. Pinkafeld campus

The main objectives for the strategic planning are:

- A long-term goal is to check and optimize possible investments scenarios. It will be analyzed which possible option or combination of options can achieve minimum costs or CO_2 emissions and maximize the energy efficiency.
  - Which investment should be considered to minimize energy costs?
  - Which investment should be done to minimize CO_2 emissions?
  - How does the investment change if a flexible electricity tariff is announced by the utility?

Based on an analysis of the recent situation, the introduction of one or more of the following DER technologies could be beneficial:

- PV,
- Solar thermal,
- Biogas or natural gas fired CHP,
- Electric and heat storage systems, and
- Demand side measures.

2.4.4. ENERGYbase

The main objectives for the strategic planning are:

- Check if a replacement of one well water pump of the heat pump system by a smaller one can reduce the current energy consumption for heating and cooling. At present, there are two identical well pumps installed. These pumps are designed for full load, but in most cases the delivered quantity is too high. Thus, a pump with a lower flow rate could reduce the current consumption of the well water system.

- Check if a direct connection of the solar storage to the heat distributor can reduce the current consumption and increase the efficiency of the solar system because of a lower inlet temperature and therefore reducing the mean collector temperature.
- Check if the secondary pump would be upgraded, the inlet temperature for the solar collector would be lower because of the lower temperature difference at the heat exchanger and this would result in a higher efficiency of the solar collector.

According to the EnRiMa Validation Test Site Questionnaire for ENERGYbase, the following options are interesting for the management:

- installation of a puffer storage for the heat pump
- smaller well water pump
- larger pump for the secondary solar circle
- change in integration of the solar thermal system

2.5. Key uncertainties

First, safe and efficient energy provision to public buildings is becoming increasingly dependent on external energy sources. Also, due to the deregulation of energy sectors and such targets as the 20/20/20 in the EU, building operators are becoming more subject to uncertain prices and EU legislative requirements. Building managers can have little influence on energy supply but can substantially influence energy demand and hedge against diverse risk. A solution to the above problems is to reduce energy consumption by improving energy efficiency of technologies in place and by investing in new, higher-efficiency technologies. In face of diverse uncertainties about the climate change, energy demands, and prices, and the reliability and efficiency of technologies, the choice of a portfolio of technologies optimal against all scenarios of these uncertainties has to reflect optimal deployment of existing energy resources and loads as well as provide guidance on adoption of new equipment and retrofits. Not all uncertainties are known at the time decisions are taken. Therefore, the DSS has to be flexible for advising about strategic long-term decisions taken under uncertainties and be able to adjust these decisions as soon as new information about uncertainties arrives.

The DSS should support planning safe and cost-efficient energy provision, while taking into account the diverse character of inherent uncertainties and their potential dramatic interaction with decisions. The DSS should assist in finding robust decisions, optimal in a sense against all foreseen scenarios of uncertainties. Therefore, it should support using proper risk measures (applicable for heavy-tailed distributions) in combination with ideas of flexible decisions adjustable to new information. In what follows, we summarise few uncertainties specific to test cites of EnRiMa project.

2.5.1. FASAD

The main identified sources of uncertainty are:

- Volatility of discount rates: The owner (or the Energy Service Company if it is involved in the project finance) needs to consider the discount rate when deciding whether to spend money on buying a new piece of equipment or on refurbishing. This is a common problem of every investment decision, so nothing else could be specifically said regarding this issue.
- Weather conditions: Studies conducted in Asturias to assess the effects of Climate change have shown a pattern of increasing temperatures (up to 2 degrees Celsius) with the 2040-2060 scope but not significant changes need to be taken into account for a short-term (next 15 years) analysis.
- Energy prices: electricity and natural gas: Some studies[6] conducted to describe, analyse, and model the dynamic of daily price series and its volatility in the Spanish Wholesale Electricity Market have shown evidence of asymmetric conditional volatility as well as a weekly seasonal non-stationary stochastic pattern in price. The later implies instability and, therefore, the absence of mean reversion in price, which could be due to the continuous changes in electricity market rules and the poor competitive performance of the electricity pool in Spain. To cope with this volatility, energy companies use hedging strategies in order to offer their customers the most stable contracts with flat rates or indexed prices. In spite of their hedging strategies, contracts for periods longer than four years are almost non-existent in the Spanish energy market.
- Feed-in tariffs: Current Spanish feed-in legislation is based on Royal Decree 661/2007. Originally under 661/2007, photovoltaic feed-in tariffs have been developed afterwards under a separate specific law framed due to the rapid growth experienced by this technology since release of the original scheme. All these figures are subjected to:
  - Quarterly or yearly updates (Article 44 of Royal Decree 661/2007).
  - Changes under political will to foster renewable electricity production.
- Occupancy of the building: The occupancy degree of the building influences directly the energy demand. Although some periods of lower occupancy are easily predictable, like for instance holidays, summer vacations, etc., is not possible to know accurately the number of persons inside the building at any time.

[6] "Comportamiento del precio y volatilidad en el pool electric español (Price behaviour and volatility in the Spanish Wholesale Electricity Market)"; Ángel León y Antonio Rubia, Universidad de Alicante, March 2001.

2.5.2. Pinkafeld campus

Pinkafeld's most important recent uncertainties:

- Internal loads/occupancy: While the occupancy of the building is unsure, also the amount of other internal loads and heat gains (through e. g., people, computer or other machines) are difficult to estimate.
- Failure of machines like pumps if they are not redundant.
- As the district heating system runs on a biomass CHP power plant based on maize, the availability of maize is crucial. If the distance of the delivery chain is increasing, then the estimated CO_2 emissions will increase as well.
- The changes of existing laws and implementation of new laws according to energy efficiency and/or CO_2 emissions could change the situation.
- Change in tariffs will lead to changed prices. Both FiT and TOU tariffs could vary by law, inflation, or other economic effects.
- Cold water temperature: In the long run, it is uncertain if the cold water will deliver always the same temperature levels for cooling. If more surrounding buildings will use the ground water as a source, then it will affect the ground water temperature, which will influence the efficiency of the systems.
- Weather (e. g. solar gain, external temperature): Heating and cooling demand directly depends on the weather. The solar gain and external temperature have a large influence on the efficiency of the systems.

2.5.3. ENERGYbase

ENERGYbase most important recent uncertainties:

- Well water temperature: In the long run, it is uncertain if the well will deliver always the same temperature levels for cooling and heating. If more surrounding buildings will use the ground water as a source, then it will affect the ground water temperature, which will influence the efficiency of the systems.
- Occupancy: Each of the upper floors is divided into four individual rent areas. Thus, there are sixteen independent office areas and three rent areas on the ground floor. Depending on how many areas are rented, the heating and cooling loads will change. At present fourteen renting areas are occupied, and it is uncertain whether the remaining areas will be rented out in the future.
- Weather (e. g. solar gain, external temperature): The heating and cooling demands directly depend on the weather. The solar gain and external temperature have a large influence on the efficiency of the systems. In the long run, it will be

uncertain if the solar gains can be maintained due to possible building constructions on surrounding lots.
- Humidification by plant buffer: The plant puffer humidifies the supply air of the ventilation system, and therefore, reduces the artificial humidification demand. But the humidifying capacity depends on the sunshine and the size of the plants. Thus, it is uncertain how much the plants can contribute to the humidification at this point.
- Internal loads: The size of the rent areas are given and cannot be changed, and the usage of the space depend on the renter. Thus, the internal loads can vary a lot. In particular, the number of computer and other electrical devices can vary.
- Failure of a pump: Another uncertainty is the time between failures and the time of repair. Some pumps in the system are redundantly implemented; thus, a failure would have only a small influence. It has to be checked which pumps are redundantly implemented and which are single pumps that would lead to a failure of the whole system.
- Supply by solar thermal system (solar cooling): The heating unit for the regeneration of the desiccant wheel is supplied by the solar system. As the solar storage cannot be fed by the heat pumps, the solar system has to provide sufficient energy to operate the solar cooling at the ventilation system. During the transition time, it is uncertain whether the solar plant produces sufficient energy since this depends on the weather and especially on the solar radiation.

2.6. Current risk management

Currently, there is no active strategy for risk management at any of the EnRiMa test sites. Therefore, no decisions are made for hedging against risks of, e.g., increasing energy prices or changes in regulations, in particular related to the environmental impact of energy use. The reasons for this situation are:

- FASAD is connected to the electricity and the gas grids. Although the building has a micro-CHP unit, it does not have enough power to satisfy the building needs in case of a power cut.
- Pinkafeld is connected to the district heating system of the city, which is very reliable. In 2009, the average energy cost per person was about €79.
- In ENERGYbase, no risk management is considered since the energy costs per student are very low compared to those of other universities. For confidentiality issues, no detailed numbers are available for ENERGYbase.

However, building managers are aware of possible changes to current energy provisions, and show increasing interest in investigating alternative options.

3. Users and stakeholders

The DSS should serve the needs of diverse users involved in the energy management of the building as well as those who contribute to decision-making processes. In this section, we identify, describe and link the different roles of such users of the DSS. We do not include here the building users, i.e., the persons making use of the building; although they are stakeholders, they will not use the DSS because their interests are represented by the building managers.

The DSS shall provide decision-making support to the following organizations and persons:

- **Building owner. Financial manager.** Person in charge of the financial accounts of the building. Usually this person has an economic background. He/she is aimed to provide good service to the building users while controlling the costs. It is the person manager of the investment decision on new infrastructures within the building.
- **Building owner. Operations manager.** Person manager of the operation of the infrastructures within building. This means: to establish the comfort levels, to make the infrastructures operate for obtaining the established comfort levels, to make the daily supervision of the infrastructures and to be manager of the maintenance of the infrastructures. This person is used to solve technical problems of the installations. Some of its commitments can be outsourced to a maintenance company, and he/she manages the progress of the tasks.
- **Outsourced maintenance manager.** Company/person manager for the maintenance of the infrastructures within the building. The type of contract could vary from a contract based on hourly tariffs per activity to an annual fixed quantity. The person or group of people in charge of the maintenance can be physically in the building or they can periodically attend the maintenance works. These people have a medium technical skill, but very specialized in electricity and thermal domains. Their manager is currently an electrical or thermal engineer in contact with both, the operations manager and financial managers.
- **Energy Service Company (ESCO).** It is a commercial business providing a broad range of comprehensive energy solutions including designs and implementation of energy savings projects, energy conservation, energy infrastructure outsourcing, power generation and energy supply, and risk management.
    - The ESCO performs an in-depth analysis of the property, designs an energy-efficient solution, and installs the required elements for running either an Energy Supply Contract (ESC) or an Energy Performance Contract (EPC). The Energy Service Company is also often a maintenance company with a

contract for the building. It offers this kind of contract in order not to lose the customer and/or because it is a business opportunity in the building, and to gain a new customer.

- EPC. The savings in energy costs is often used to pay back the capital investment of the project over a five- to twenty-year period or reinvested into the building to allow for capital upgrades that may otherwise be infeasible. If the project does not provide returns on the investment, then the ESCO is often responsible for paying the difference. In this business model it is important to 1) define a simple baseline of the energy consumption of the building (dependent on the outside temperature for example) before the energy efficient measure is implemented, 2) define a type of contract where this baseline is explicit, 3) implement the energy-efficiency measures, 4) measure the new energy consumption, 5) verify and compare with the calculated baseline. There is an International Performance Measurement and Verification Protocol, IPMVP[7] [1], where this process is outlined.
- ESC. The ESCO supplies useful energy. This company normally has made the investment of a set of primary energy conversion equipment into electricity or thermal energy (photovoltaic panels, batteries, micro-CHP units, chillers, heat pumps, boilers, geothermal pipes, solar thermal panels and others). It looks for correct operation and maintenance of this equipment and supply and are paid for the useful energy it provides. Normally, the investments undertaken for acquiring this equipment is greater than in an EPC. Thus, the amortization of the investment requires longer ESC (about 10 years) than the EPC ones (about 5 years, although some could take 20 years, mainly in the case of building envelope upgrades).

- **Utility.** Company with an energy supply contract with the building. These are big companies, traditional electricity generators, distributors and retailers, who are evolving and diversifying to other markets: gas energy provision, thermal energy supply, ESCO markets. So, in practice apart from selling electricity, they could also become an Energy Service Company providing ESC contracts for useful thermal energy supply.
- **Energy consultants.** A variety of companies whose business is oriented to energy audits performance and engineering studies development for analyzing specific needs manifested by the building owners.

[7] The International Performance Measurement and Verification Protocol (IPMVP) provides an overview of current best practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects in commercial and industrial facilities. It may also be used by facility operators to assess and improve facility performance.
IPMVP® is registered trademark of Efficiency Valuation Organization (EVO®).

- **Policy makers.** These are public, regional or national organizations promoting policies, financial programmes, funded projects and solutions focused on sustainability and energy efficiency measures.
- **Energy auditors.** These are experts who make an inspection and analysis of energy flows, energy saving and energy optimizing options in a building. Auditors are required to identify the most efficient and cost-effective Energy Conservation Opportunities (ECOs) or Measures (ECMs). Energy conservation opportunities (or measures) can consist in more efficient use or of partial or global replacement of the existing installation.

Other (than those who use the DSS for decision-making support) users of the DSS include:

- **Data providers**: companies and individuals who provide data for the underlying models

- **Technology providers.** Companies manufacturing a technological solution in the field of the distributed energy supply/generation/storage or building energy loads control and regulation. They could be interested in the use of the DSS or analyse the results provided by it, to improve their technologies, or study how to integrate them, or under which conditions, in a certain building.

- **Researchers and students** who may get access to the DSS versions customized for research and education
- **DSS developers** who will either enhance the DSS or adapt it for use at other buildings

In every case the simpler the tool is presented the better, independently of the personal skill levels. The tool is a way to consider scenarios and to take decisions. In reality, difficult to understand/use tools are never used. Always the final decision suggested by the DSS should be accepted by the facility operator, facility manager or maintenance manager.

References

[1]International Performance Measurement and Verification Protocol (IPMVP),

IPMVP® , EVO®, www.**evo**-world.org

4. Decisions and objectives

4.1. General considerations

The key function of the DSS shall be to support the Decision-Maker (DM, a person who actually makes the decisions) to find such decisions that best fits her/his preferences, expressed (usually implicitly) in terms of objectives (often called also outcomes, goals, criteria, indicators) used for evaluation of consequences resulting from implementation of a given set of decisions. In particular, the DSS should respect the sovereignty of the DM. Therefore, the DSS should:

- adequately model the relations between the decisions and objectives, and
- support integrated model analysis.

In order to achieve the first requirement, we specify below pairs of sets of decisions and objectives, for the operational and strategic planning. For each problem, we also specify the corresponding sets of parameters (which are often aspects beyond the control of the supported DM). These sets of model variables should drive the specification of models to be used by the corresponding DSSs, i.e. operational and strategic.

Here, we summarize the key requirements for the integrated model analysis that should be supported by the EnRiMa DSS. Such analysis should integrate two types of approaches:

- Goal oriented, for which the user specifies objectives and the DSS computes values of decisions for reaching them. The corresponding methods analysis methods should include:
    - Traditional (single-criterion) optimization and its extensions including parametric optimization and various types of regularized optimization.
    - Multiple-criteria analysis supporting exploration of trade-offs between conflicting objectives.
- Alternative focused, for which the user specifies values of decisions, and the DSS computes the corresponding values of objectives (including diverse indicators characterizing the consequences of implementing the given decisions). The corresponding methods should include diverse simulation approaches (e.g., traditional, soft, inverse).

4.2. Operational planning

The operational DSS shall assist decisions on how to operate an existing centralized HVAC system of a building.

4.2.1. Decisions

The set of the supported decisions is specific at each site; it typically includes:

- The temperature set-points of a room. The rooms under control should be supplied by the same air-air heat-pump, air-handling unit or fan-coil.
- These set-points are constrained to a band with an upper and lower temperature and humidity thresholds, which limit the comfort region.
- Amount of free-cooling, that is, to calculate the percentage of external air mixed with internal air of the building. This free-cooling is regulated by the air-handling units or air-air heat pumps.
- The switch on/off of the air-air heat pumps, air handling units or fan-coils.
- Selection of energy carrier sources

The active control over other parameters that affect the efficiency of the primary generating units like outlet temperature, on-off of units depending on the external temperatures of chillers, heat-pumps, boilers or CHP units are out of the scope of the operational module.

4.2.2. Objectives and indicators

The set of objectives typically includes:

- Minimization of operational costs
- Minimization of environmental impact, in particular the CO_2 emissions
- Diverse indicators of the user comfort
- Analysis of the HVAC performance
- Economic dispatch of the dispatchable primary generating units (CHP units)

4.2.3. Input parameters

The following parameters are typically treated as inputs to the operational DSS:

- Building facades, materials, and their thermal behaviour.
- Air leakages.
- External temperature.
- External humidity.
- Occupancy.
- Internal temperature set-points.
- Energy prices.
- Energy efficiency of installed equipment.

The DSS should assist in analysis of impact of such parameters on the proposed solution.

4.3. Strategic planning

The strategic DSS should support making long-term decisions to secure energy supply, minimize energy consumption costs and environmental impacts, and hedge against risks while improving existing energy infrastructure. This module enables integration with elements of the operational module, which evaluates building's energy system performance in real time and triggers long-term decisions of strategic model on instalment of new and decommissioning of obsolete technologies, retrofitting, credits and options for financing new technologies, etc. The strategic module takes into account at least the following:

- Long-term evolution of equipment and activities;
- The long-term evolution of the load curves;
- Availability of new technologies;
- Depreciation of available equipment.

Since uncertainties (weather, prices, tariffs, equipment lifetime, discounting) seriously affect long-term decisions, the DSS should support analysis of exploiting a rolling time horizon planning approach, which permits revision of decisions when new information on uncertainties become available. Such analysis shall explore the so-called two-stage dynamic stochastic optimisation framework, where some decisions (anticipative strategic investments) have to be taken before uncertainties are resolved and some others, adaptive, decisions will be taken once values for uncertain parameters are known, thereby providing a trade-off between long- and short-term decisions. Therefore, the strategic DSS should include flexibility to adjust strategic decisions if additional information about new technologies, prices, and tariffs becomes available.

4.3.1. Decisions

The set of the supported decisions is specific at each site; it typically includes:

- Selection of new devices;
- Decommissioning of devices;
- Selection of energy sources for electricity and heat generations, as well as for cooling;
- Financial instruments for coping with uncertainties and risks, such as rates and inflation rates.

4.3.2. Objectives and indicators

The set of objectives typically includes:

- Minimization of operational and maintenance costs;
- Minimization of investment costs;
- Diverse indicators related to evaluation of investments;
- Minimization of environmental impact, in particular the CO_2 emissions;
- Indicators of the service quality;
- Indicators of safety and risks.

4.3.3. Input parameters

The following parameters are typically treated as inputs to the strategic DSS:

- Existing building facades, materials and their thermal behaviour;
- Options for the building retrofitting;
- Long-term climate parameters;
- Long-term forecasts of prices and availability of energy carriers;
- Long-term forecasts of energy loads/demand at the building;
- Scenarios for changes of regulations affecting building operations;
- Scenarios for changes in the energy markets.

The DSS should assist in analysis of impact of such parameters on the proposed solution.

4.4. Specific objectives of diverse users

Here, we briefly describe specific objectives of two kinds of users that should be supported by the DSS.

4.4.1. Objectives of energy managers

The main task of the energy building manager is to plan and take the required investment decisions on retrofits and/or expansion of on-site energy sub-systems and operate the energy systems in place, aiming at providing comfort to the building users by satisfying their energy needs in the most efficient way.

In the development of this task, the manager should be supported in finding a compromise among five possibly conflicting goals:

- User comfort;

- Ensuring safe energy provision;
- Cost minimisation;
- Management of energy loads;
- Environmental targets, like for instance CO_2 emissions reduction.

Therefore, the DSS should support:

- Analysis of possible combinations of refurbishing and retrofitting measures that optimize the cost and abatement of CO_2 for the analysed time horizon in the most probable scenario of prices and weather conditions;
- Operation of the energy systems in the building.

4.4.2. Objectives of policymakers

One of objectives of the policymaker may be to promote RES (Renewable Energy Sources) and energy efficiency measures in buildings.

The DSS should support analysis of possible combinations of refurbishing and retrofitting measures that optimize the cost and abatement of CO_2 for the analysed time horizon in the most probable scenario of prices and weather conditions. However, the performance of the on-site energy system is not so much affected by gradual changes and frequent scenarios, but rather by rare extreme scenarios and high variability, e.g. variability of weather or market distortions. Thus, the objective of the energy managers is to install equipment capable of hedging in cases of highly uncertain and rare (possibly, extreme) scenarios.

The goals of the policymaker are:

- Set CO_2 emission targets
- Define the remuneration scheme for the energy produced by RES installed in buildings.

For achieving these goals, the user shall be support in evaluating the costs and the associated CO_2 emissions of various technological scenarios.

5. Decision-making workflows

The decision-making processes the EnRiMa DSS should support are summarized here in the form of mutually related workflows organized into two sets, each corresponding to one of the models supporting:

- Operational planning, i.e., support decisions on how to operate an existing centralized HVAC system of a building.
- Strategic planning, i.e., support long-term robust decisions on the building retrofits, and/or changes of the on-site energy systems, including sources of the energy carriers, and possible financial instruments in face of diverse future uncertainties about the climate change, energy demands, and prices, and the reliability and efficiency of technologies

The specification of, and the data used by, the strategic and operational DSSs should be consistent. Moreover, the operational DSS should provide indicators suitable for evaluation of the performance of the existing system, and its comparison with results of possible strategic decisions.

5.1. Operational planning

An existing centralized HVAC system in the building means that boilers, microCHP units, heat pumps, chillers, air-handling units, fan-coils, air diffusers, vents, radiators and other equipment are controlled from a central intelligent unit, either a PC or a PLC (Programmable Logic Controller). The system usually also includes/could include energy flows measurement probes, electric meters, temperature and humidity sensors.

The control of the HVAC system is provided by an engineering company, specialized in the HVAC system design and control, programming on the top of hardware controllers (market solutions provided by multinationals). The programming of the controllers is currently based on proprietary protocols, although gateways to open standard protocols are also available.

In some cases, the HVAC system schematic, set-points and measurement results could easily be modified/followed thanks to a SCADA system (Supervisory Control and Acquisition) system.

The operational DSS should support the operator in making decisions on how to operate the given HVAC system of a building. This means that its outputs should be implemented in the existing HVAC control. Requirements for the implementation of the interface between the operator and the existing HVAC control of the building are not a part of this report; this issue will be dealt with by Deliverable 5.1.

5.1.1. Activities

The ideal DSS should be able to support the following routine activities in the operational planning module. This is an intensive list giving an idea of the activities that could be performed, based on the discussions and analysis made by the Consortium in the frame of work packages 1, 2 and 4. It is a list of intentions. It could happen that not all the activities will be finally needed or developed depending on the final solution adopted, needed input data and provided output data.

1. Weather forecast

   - Receive the weather forecast from any regional weather forecast agency: at least (temperature, humidity) for the next 24 hours. Solar irradiation also should be recommendable. If the solar irradiation is not available a value for cloud coverage should be available. A value of one represents a full covered sky; a value of zero represents a totally uncovered sky.
   - Store the weather forecast data being provided.
   - Adapt the weather forecast data for the DSS.
   - Store the weather forecast data adapted.
   - Read the real weather data from HVAC system sensors.
   - Store the real weather data from HVAC system sensors.
   - Process the data of the weather forecast to make them compatible with the timing of the DSS.
   - Update the calculations of the weather forecast uncertainty with the historical data.
2. Building occupation
   - Check/estimate the building occupancy in each thermal area of the building. It is considered thermal area the room or set of rooms whose temperature is controlled by the same air-air heat pump or air handling unit.
   - Store the occupancy data estimation.
   - Adapt the occupation data estimation in order to transfer them like input parameter to the DSS.
   - Read the real occupancy data from HVAC system sensors.
   - Store the real occupancy data from HVAC system sensors. This could be expressed as indoor humidity and indoor CO_2 content. Both are parameters for users comfort.

- Update the calculations of the building occupancy uncertainty with the historical data.

3. Energy price data
   - Receive energy prices from utility companies or system operators, including natural gas price, electricity purchased price, price of electricity generated for sale, heat purchased price, and CO_2 emissions cost. The frequency of the energy prices variation depends on the countries specific regulation, on the utility being contracted, and even on the type of contracts: they could vary even once in a year, or daily in the most advanced case.
   - Store the energy prices being provided.
   - Adapt the energy prices in order to be used in the DSS.
4. Building envelope
   - Collect all the required data of the thermal area of building from the building manager, including heat transfer area, thickness, thermal conductivity, thermal resistance, etc. of each component. These data are changed rarely, maybe if some construction or envelope improvement is given (double skin, windows changes, and thermal areas changes).
   - Store the thermal envelope's data provided and adopt them in a way to be useable in the DSS.
5. Electricity demands
   - Receive the electricity demands for different end uses from the building manager.
   - Store the electricity demands and adopt them to be used in the operational DSS.
6. Calculations, implementation and verification
   - Run the operational DSS, and calculate the outputs.
   - Transfer/adapt the outputs, in order to implement in the HVAC system, after building operators acceptance. Also prepare the result for the building operators to check it visually.
   - Read the real temperature values in the thermal areas from the HVAC system sensors.
   - Read the parameters regulating the free-cooling from the HVAC system sensors.

The DSS should also support the following extra activities, with the purpose of checking the benefits of the outcomes:

- Compute the difference of the former day set-points calculated by the DSS, and the real measurements.
- Store the difference between set-points and measurements.
- Estimate the savings (in terms of costs and/or CO_2 emissions) being achieved by the DSS in the former day against the previously computed baseline.

- Store the savings estimation.
- Analyse different performance parameters:
    - output thermal, electrical power, efficiencies of generating primary energy conversion devices (boilers, CHP, PVs, solar thermal panels, etc in place),
    - stored energy, remaining energy, output energy of storage devices (batteries, water tanks, etc. in place).

5.1.2. Timing

The operational DSS should be run daily. The inputs should be adapted to and the outputs should be calculated/given in configurable time intervals. Time interval is the result of dividing the observation/control period by the number of data. This time interval should be modified by the user. Common integration periods should be 15 minutes, 1 hour or three hours. For example, in a day ahead control, or subsequent day observation, if the observation/control period is 24 hours, and the configured time interval is 15 minutes, then, input and output parameters should be provided in 96 data points' collection.

5.1.3. Possible triggers

- Apart from the automatically programmed daily activities of the operational DSS, three different set of triggers could make restart its activities. The error of the weather forecast magnitudes with respect to the measured ones is greater than a certain acceptable value.
- The error of the occupancy data with respect to the real ones is greater than a certain acceptable value.
- The error of the calculated set-points data with respect to the measured values is greater than a certain acceptable value.

5.2. Strategic planning

The strategic DSS supports long-term planning of public building, and/or changes of the on-site energy systems, including sources of the energy carriers, and possible financial instruments for integrated risk management. It should assist the users in finding optimal and robust combination of technologies ensuring secure energy provision, cost minimization, CO_2 emissions reduction under investments constraints and environmental targets in view of future uncertainties and risks related to changing climate, appearance of new technologies, new environmental legislations and targets. The DSS should support analysis of the long-term evolution of equipment, services, and load curves, as well as applicability of new technologies, and obsolesce of the installed equipment.

5.2.1. Activities

The strategic DSS should support the following three mutually dependent sets of activities:

1. Data storage and preparation:

- Store information on the installed equipment: nominal capacity, availability, expected lifetime, hours of operation, efficiency, costs, prices.
- Store data on energy demand/consumption by different users/services
- Store data on water demand/consumption by different users/services
- Store data on variability of energy/water consumption: peak consumption; mean, median, percentiles (by days, weeks, months, seasons)
- Store information on the constraints of the on-site energy system (derived from operational DSS)
- Adapt the data on demand/consumption to resolutions of the strategic DSS
- Store energy reduction/efficiency goals (e.g. per sq meter building)
- Store information on CO_2 targets and other relevant legislations
- Receive information on new installations/technologies: nominal capacity, availability, expected lifetime, efficiency, costs, prices, etc.
- Store information on new technologies
- Adapt the data on technologies to resolutions of the strategic DSS
- Adapt the data on targets and constraints to resolutions of the strategic DSS
- Store data on building envelop
- Store data characterising weather/climate variability: precipitation, sunshine, etc.
- Adapt the data on weather variability to resolutions for being read by the strategic DSS.
- Store the data adapted.
- Store information on past energy prices
- Store scenarios of future energy prices
- Adapt information/scenarios on energy prices to the strategic DSS
- Store information on current and future tariffs
- Store financial data: market returns, depreciation, credits, funds

2. Prepare background for the model analysis:

- Select the model and data versions
- Specification of user preferences (goals, objectives)
- Generate computational (optimization and/or simulation) tasks
- Solve computational tasks

- Store the results
- Prepare the results for visualization
- Visualize the results in a form suitable for the model users negotiating approval of the decisions by energy auditors, executive committee, building managers, investors

The strategic DSS should perform the following solution analysis with the purpose of checking the benefits of the outcomes:

3. Solution analysis:

- Visualize stochastic constraints: risk measures; expected violation; expected shortfall; penalties
- Visualize stochastic scenarios of loads/prices
- Derive optimal robust combination of technologies with a given payback period
- Derive optimal robust combination of technologies with minimal discounted levelized costs
- Compare solutions
- Estimate required investments
- Quantify the benefits of robust solutions (VSS) with respect to solutions of deterministic problem (e.g. certainty equivalent solution).
- Illustrate these benefits to energy auditors, executive committee, building managers, investors
- Estimate the savings (in terms of costs and/or CO_2 emissions) being achieved by the strategic DSS
- Visualize the savings

5.2.2. Timing

Strategic planning horizon involving investments is typically 10 – 30 years; other strategic decisions may be taken for much shorter horizon. Strategic DSS therefore may take much longer than the operational DSS to provide results.

5.2.3. Possible triggers

The following events are examples of triggers for using the strategic DSS:

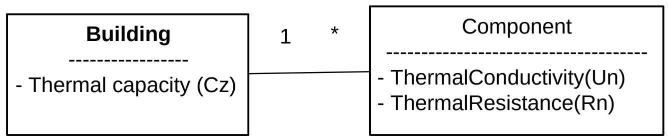
- Equipment failure
- Obsolesce of equipment
- Bad performance of the on-site energy system
- Increased energy bills

- Weather/climate outliers (extremely hot summer of cold winter)
- Market distortions
- Appearance of new technologies
- New legislation or environmental targets
- Energy saving programs

6. Data requirements

6.1. Data overview

To have an overview of the required information structures that the EnRiMa DSS need to handle we use Unified Modeling Langue (UML) Class Diagrams. To explain the syntax a short example class diagram is provided below:

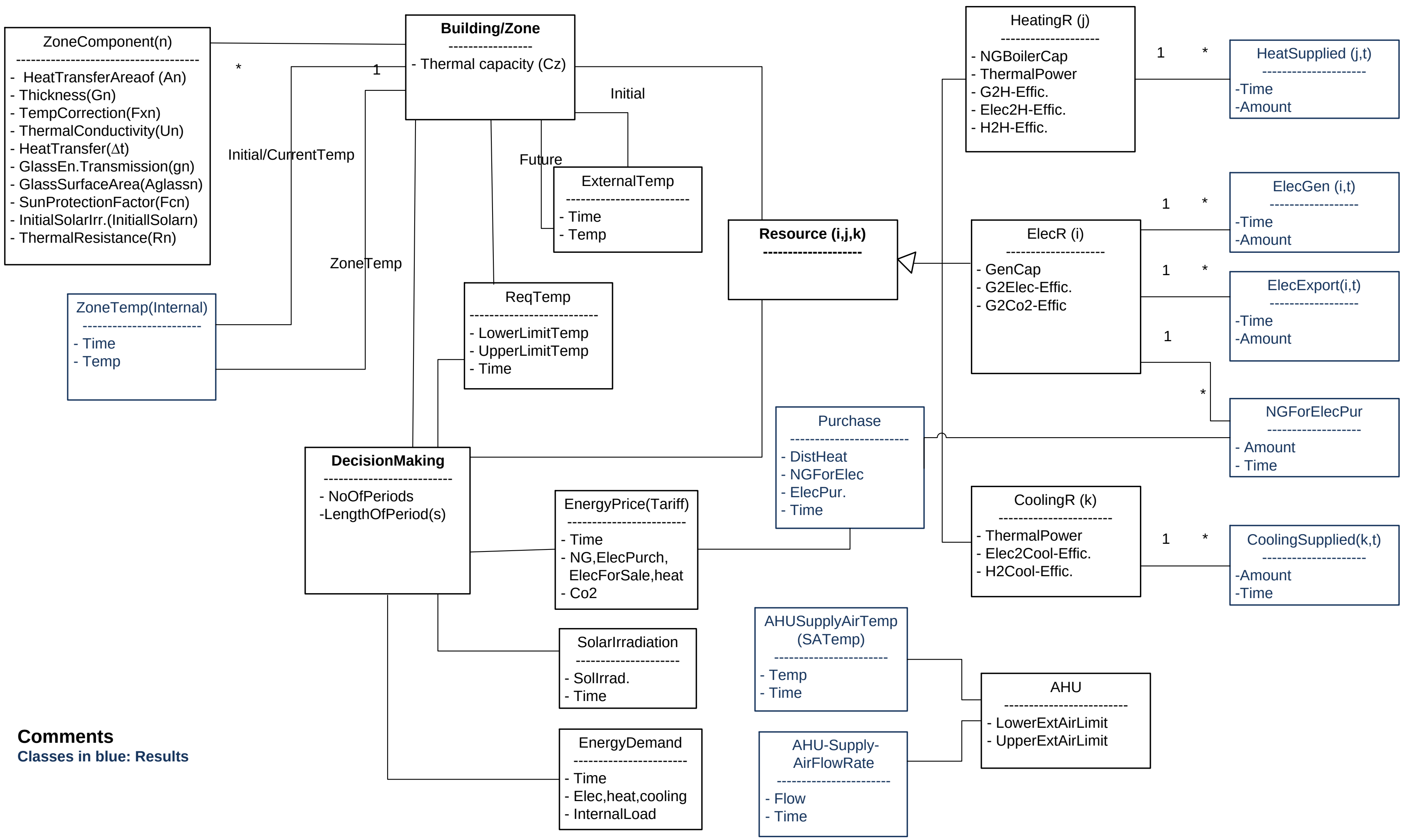


This class diagrams shows that the system needs to handle two classes (depicted by the boxes); Buildings and Components. Furthermore for each class there is a list of attributes/properties that the class can have, for example the system need to be able to handle the thermal capacity of buildings. Associations between classes (depicted as lines) show that the classes are related. In this case Building consists of a set of Components.

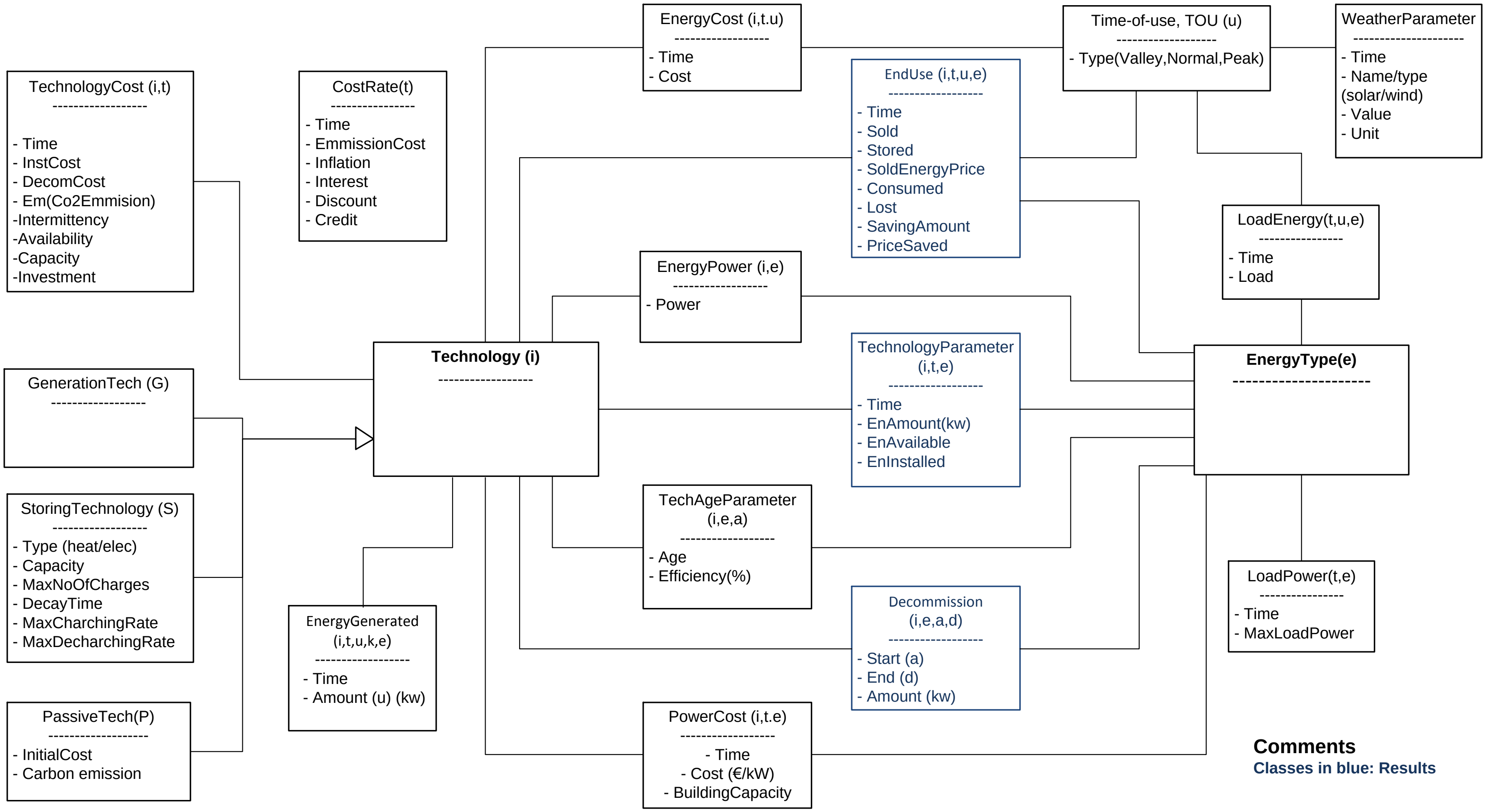
The data requirements are divided into operational and strategic. In the next section an overview is given, using UML class diagrams, subsequent sections contain a detailed list of the data required.

The detailed data requirements in this Section are an initial attempt to operationalize decisions and objectives of section 4 in terms of relevant data objects. Thus, as the project evolves we expect data requirements to evolve as well.

6.1.1. Data overview of the operational model



6.1.2. Data overview of the strategic model



6.2. Data required for models

6.2.1. Model for operational DSS

In the following table, C denotes Constants, D Deterministic parameters, and S Stochastic parameters.

Table 6.1 - Data requirements for each decision-making period, *t=2, …, T*

Parameters - Input (Symbolic representation)	Unit	Prop.	Source
Decision-making period			
Total number of periods (T)	-	C^*	Building Manager
Length of each period (Δt)	s	C	Building Manager
Resources			
Electricity resources (i)	-	C	Building Manager
Heating resources (j)	-	C	Building Manager
Cooling resources (k)	-	C	Building Manager
Temperature			
Initial zone temperature ($InitialZoneTemp$)	K	C	Building Manager
Initial external temperature ($InitialExtTemp$)	K	C	Building Manager
Future external temperature ($ExtTemp_t$)	K	D^*/S^*	Met. Stations
Lower limit for the required temperature ($LowerTempLimit_t$)	K	C	Building Manager
Upper limit for the required temperature ($UpperTempLimit_t$)	K	C	Building Manager
Air-Handling Unit (AHU)			
Lower limit for the proportion of air taken externally ($LowerExtAirLimit$)	-	C	Equipment Manufacturer
Upper limit for the proportion of air taken externally ($UpperExtAirLimit$)	-	C	Equipment Manufacturer
Supply air temperature ($SATemp_t$)	K	C/D	Equipment Manufacturer

Supply-air flow rate (f_t)	m^3/s	C/D	Equipment Manufacturer
Energy Prices			
Natural gas ($NGPrice_t$)	€/kWh	C/D/S	Utility Comp./ Sys. Operator
Electricity purchased ($ElecPurPrice_t$)	€/kWh_e	C/D/S	Utility Comp./ Sys. Operator
Electricity generated for sale ($ElecExpPrice_t$)	€/kWh_e	C/D/S	Utility Comp./ Sys. Operator
Heat purchased ($DistHeatingPrice_t$)	€/kWh_{th}	C/D/S	Utility Comp./ Sys. Operator
CO_2 emission ($EmissionCost_t$)	€/tCO_2	C/D/S	Regulator
Thermal envelope of building:			
Overall thermal capacity of the zone (C_z)	kJ/kgK	C	Building Manager
Components of the thermal envelope of building (n)	-	C	Building Manager
Heat transfer area of each component (A_n)	m^2	C	Building Manager
Thickness of each component (G_n)	m	C	Building Manager
Temperature correction coefficient of each component (Fx_n)	kW/mK	C	Building Manager
Thermal conductivity of each component (U_n)	kW/mK	C	Building Manager
Thermal bridge heat transfer coefficient of each component (ΔU_n)		C	Building Manager
Energy transmission coefficient of glass (g_n)		C	Building Manager
Surface area of glass for each component ($Aglass_n$)	m^2	C	Building Manager
Sun protection factor of each component (Fc_n)		C	Building Manager
Current solar irradiation for each direction ($InitialISolar_n$)	kW/m^2	C	Building Manager

Future solar irradiation for each direction ($ISolar_{t,n}$)	kW/m^2	D/S	Met. Stations
Thermal resistance of each component (R_n)	K/kW	C	Can be calculated
Capacity			
Natural gas boiler capacity ($NGBoilerCap$)	kW	C	Equipment Manufacturer
Generation capacity of resource *i* ($GenCap_i$)	kW$_e$	C	Equipment Manufacturer
Thermal/cooling power of resources *j* and *k* ($ThermalPower_{j/k}$)	kW$_{th}$	C	Equipment Manufacturer
Conversion efficiency of each resource (partial/ full-load)			
Gas-to-heat conversion efficiency of boiler (β)	kWh$_{th}$/kWh	C/S	Equipment Manufacturer
Gas-to-electricity conversion efficiency of resource *i* (ε_i)	kWh$_e$/kWh	C/S	Equipment Manufacturer
Electricity-to-heat conversion efficiency of resource *j* (γ_j)	kWh$_{th}$/kWh$_e$	C/S	Equipment Manufacturer
Electricity-to-cooling conversion efficiency of resource *k* (γ_k)	kWh$_{th}$/kWh$_e$	C/S	Equipment Manufacturer
Heating-to-cooling conversion efficiency of resource *k* (λ_k)	kWh$_{th}$/kWh$_{th}$	C/S	Equipment Manufacturer
Heating-to-heating conversion efficiency of resource *j* (δ_j)	kWh$_{th}$/kWh$_{th}$	C/S	Equipment Manufacturer
Gas-to-CO_2 conversion coefficient of resource *i* (α_i)	tCO_2/kWh	C/S	Equipment Manufacturer
Gas-to-CO_2 conversion coefficient of boiler (α_{boiler})	tCO_2/kWh	C/S	Equipment Manufacturer
Energy Demand			
Electricity demand ($ElecDemand_t$)	kWh$_e$	D/S	Building Manager
Heat demand ($HeatDemand_t$)	kWh$_{th}$	D/S	Model Developer
Cooling demand ($CoolingDemand_t$)	kWh$_{th}$	D/S	Model Developer
Internal load (people, lighting, working machines, etc.) ($IntLoad_t$)	kWh	S	Building Manager

Decision variables

Table 6.2 – Decision variables for each decision-making period, t = 2, …, T

Decision variables	Unit
Temperature	
Required zone temperature ($ZoneTemp_t$)	K
Air-Handling Unit (AHU)	
Proportion of air taken externally ($ExtAir_t$)	-
Supply	
Heat supplied by resource *j* ($HeatSupp_{j,t}$)	kWh_{th}
Cooling supplied by resource *k* ($CoolingSupp_{k,t}$)	kWh_{th}
Electricity generated by resource *i* for local consumption ($ElecGen_{i,t}$)	kWh_e
Electricity generated by resource *i* for sale ($ElecExp_{i,t}$)	kWh_e
Purchase	
Heat purchased ($DistrictHeating_t$)	kWh_{th}
Natural gas purchased for use in resource *i* ($NGforElec_{i,t}$)	kWh
Natural gas purchased for use in the boiler ($NGforHeat_t$)	kWh
Electricity purchased ($ElecPur_t$)	kWh_e

6.2.2. Model for strategic DSS

Table 6.3 – Data requirements for each decision period

Parameters -economic	Unit
Cost of the energy (power) of technology *i* in period *t* (€/kW). For non-fueled technologies ($i \notin F$) this corresponds to the investment cost annualized. **Stochastic** (for $i \in F$). **(** $PowerCost_{ite}$ **)**	€/kW
Cost of the energy (flow) of technology *i* in period *t* and TOU *u* (€/kWh). **Stochastic** (for $i \in F$). ($EnerCost_{itu}$)	€/kW
Price of the energy type *e* sold by technology *i* in period *t* and TOU *u* (€/kWh). **Stochastic** (for $i \notin F$). ($EnerPrice_{itue}$)	€/kW
Cost of installing technology *i* in period *t* (€/kW). **Stochastic** (for $i \in F$) ($InstCost_{it}$)	€/kW

Cost of decommissioning technology *i* in period *t* (€/*kW*). ($DecomCost_{it}$)	€/kW
Cost of emissions in period *t* (€/*Kg*) ($EmCost_t$)	€/tCO_2
Inflation rate (inf_t)	%
Market interest rate (r_t)	%
Discount rate (d_t)	%

Table 6.4 – Data requirements, technology

Parameters -technology	Unit
Nominal energy power type *e* of technology *i* (*kW*). ($EnerPower_{ie}$)	*kW*
Efficiency of technology *i* at age *a* for energy type *e* production (ratio). ($EnerEff_{iae}$)	ratio
Carbon emissions of technology *i* in the period *t* (*kg/kWh*). (Em_{it})	*kg/kWh*
Savings of energy type *e* during the period *t* and TOU *u* (hours). (Sav_{itue})	*h*
Capacity of the building for technology *i* in period *t* (*kW*). (Cap_{ite})	*kW*
Price of the energy type *e* saved with technology *i* during period *t* and ToU *u*. ($PriceSav_{itue}$)	€
Intermittency or variability factor (VarFac_{it})	%
Availability factor ($AvFac_{it}$)	%
Capacity factor of technology ($CapFac_{it}$)	%

Table 6.5 – Data requirements, weather

Parameters –weather	Unit
Average wind speed in period *t* and TOU *u* (*m/s*). **Stochastic** ($WindSpeed_{tu}$)	*m/s*
Average solar irradiation in period t and TOU u (kWh/m2). Stochastic. ($SolarIrr_{tu}$)	kWh/m2

Table 6.6 – Data requirements, loads

Parameters – loads	Unit
Maximum power of energy type *e* needed in the period *t* (*kW*). **Stochastic**. ($LoadPower_{te}$)	*kW*
Energy Load of energy type e in the period t and TOU u (kWh). Stochastic. (LoadEnergytue)	kWh

Decision variables

Table 6.7 – Decision variables

Decision variables	Unit
Energy type *e* to be installed of technology *i* in the period *t* . ($EnInst_{ite}$)	*kW*
Energy type *e* of technology *i* installed in period $a < d$ to be decommissioned in the period *d*. ($EnDecom_{iade}$)	*kW*
Energy type *e* available from technology *i* in the period *t* (*kW*). These variables are calculated. ($EnAvailable_{ite}$)	*kW*
Energy of type *e* to be generated by technology $i \in I$ with technology $k \in F$ in the period *t* and TOU *u* (*kWh*). ($EnGen_{ituke}$)	*kWh*
Energy of type *e* to be sold from technology $i \in I$ in the period *t* and TOU *u* (*kWh*). ($EnSold_{itue}$)	*kWh*
Energy of type *e* to be stored from technology *i* in the period *t* and TOU *u* (*kWh*). ($EnStored_{itue}$)	*kWh*
Energy of type *e* to be consumed from technology *i* in the period *t* and TOU *u* (*kWh*). These variables are calculated within the constraints. ($EnConsumed_{itue}$)	*kWh*
Energy of type *e* lost from technology *i* in the period *t* and TOU *u* (*kWh*). These variables are calculated within the constraints. ($EnLost_{itue}$)	*kWh*
Payback period (*Pb*)	Years
Credits ($Cred_t$)	€
Investments (Inv_{it})	€

6.2.3. Data requirements and sources for uncertain model parameters

From the data overview above, some parameters/classes may be stochastic or affected by uncertainties. In order to describe all parameters in these classes, an additional index is necessary, denoting the respective scenario. The potentially stochastic parameters are listed below, together with possible sources to gain data from.

Operational model:

- *Energy and CO_2 prices, data availability:*
    - Current electricity and natural gas prices are available, e.g., from Europe's Energy Portal , for Spain also from IBERDROLA S.A.
    - Historical prices are also downloadable from Europe's Energy Portal (for a charge), but are aggregated as monthly prices, from January 2005 on.
    - Daily prices for electricity and CO_2 for Germany can be obtained from the European Energy Exchange EEX; historically, German and Austrian prices were approximately identical.
    - Historical electricity and CO_2 prices for Austria (and Germany) are also obtainable from Energy Exchange Austria as daily spot prices from 2002 on.
- *Feed-in-tariffs for generated electricity*: Typically, such tariffs are subject to regulation, but may also be tied to market conditions. In both cases, however, they do not vary over the time span envisioned for the operational model and can therefore be considered deterministic for this model.
- *Weather conditions*: data can be obtained directly from local weather forecasts, possibly with a few scenarios and probabilities to take into account uncertainty about these forecasts (most good weather forecasts include such a spread nowadays).
  Historical observations are also available from the test sites.
    - FH Pinkafeld observations of all possible weather data (wind, temperature, humidity etc.) are obtainable, measured in 5 min intervals since 2004 although some data are erroneous or missing. Assuming the availability of historical weather forecasts it may, therefore, be possible to adapt the forecasts to local observations.
    - For Spain, it is possible to obtain observations for outside temperature, humidity or irradiance from a nearby weather station
- *Building occupancy*: It is difficult to record daily occupancy numbers as they are highly variable and affected by a number of external factors. A suitable approach can be to construct a few scenarios based on rules of thumb for different occupancy patterns (morning/noon/afternoon/evening on a typical day, week-end, holidays, or exam period).

- *Energy load curves and load profiles*: Scenarios can be generated based on a sufficient amount of historical data.
  - FH Pinkafeld: historical yearly data for water and energy consumption are available from 2005 to 2009. No full information is available on an hourly basis.
  - For Spain, historical data can be provided on aggregated electricity consumption (lights, computers, laboratory equipment and HVAC) with 15min granularity. Also monthly (aggregated) electricity and gas consumption data are available for the years 2007 to 2010.
  - Deliverable D1.1 will outline approaches to calculate hourly energy load profiles, and a load forecasting model is being developed by CET together with UCL within WP2 of the EnRiMa project. This model can be used to generate hourly load profiles and, consequently, scenarios based on (scenarios for) weather and building occupancy data where such profiles are missing or incomplete.

Strategic model:

- *Energy purchase prices* (e.g., for evaluating operational costs of installed equipment): either use selected operational data or indices with a larger granularity:
  - The Energy Price Index gives yearly price indices for all energy sources relevant for our model for Austria, from 1986 on.
  - "Europe's Energy Portal" (www.energy.eu/#industrial) provides historical monthly data from January 2005 on (for a charge).
  - Half yearly energy data are available from the European Commission's statistical handbook "EU Energy and Transport in figures".
  - Half yearly historical prices also are obtainable from Eurostat .
  - Yearly gas prices may also be obtained from BP's annual report, which states average values for Europe.
- *Feed-in-tariffs for generated electricity*: Typically, such tariffs are subject to regulation, but may additionally be tied to market conditions.
  - For Spain, the tariffs are regulated by “Royal Decree 661/2007”, and two choices are described. Depending on the fuel source, the tariffs are updated quarterly or yearly and according to different formulae, based on the consumer price index and, for natural gas, fuel prices.
  - Austrian regulation is described in earlier sections of this document, specifying prices according to the source of the generated electricity.
  - No specific feed-in-tariff is used at FH Pinkafeld; electricity generated by PV is sold at a flat rate, similar to purchased energy.

- *Energy tariffs:* changes in the tariff structures may be estimated using expert knowledge (modelling a handful of conceivable tariffs, for example different forms of time-of-use tariffs, two-part tariffs or flat tariffs).
  - For FH Pinkafeld, it may be possible to obtain data on historical tariffs.
- Uncertainty about the *regulatory framework* (subsidies etc.) may be modelled similarly to the uncertainty about tariff changes.
- *Energy loads (selection for critical and typical operational periods)*: as mentioned for the operational model, scenarios can be calculated from (stochastic) data for weather and occupancy using the load simulation/prediction model by CET and are, hence, not truly stochastic.
- *Technological progress (future technology costs and performance/efficiency):* This can be described in some detail using S-curves or similar. For example, cost decrease can be estimated dependent on accumulative installed capacity and R&D expenditures. This, however, is far beyond the scope of the EnRiMa project, it would also be necessary to model these explaining parameters, in turn. It appears possible to use cost improvement forecasts done, e.g., by Noord, Beurskens, and Vries (2004) or the U.S. Energy Information Agency's annual energy outlook.
- *Weather:* Relevant data for the strategic model are selected weather conditions for critical / "extreme" and typical operational periods which may be obtained from the same sources as for the operational model or from observations at the corresponding test sites.
- *Climate change:* Scenarios are available from relevant publications, but may not be required even for the strategic optimization horizon. For example, for the FASAD test site, a pattern of increasing temperatures (up to 2 degrees Celsius) has been identified for the Asturias region within the years 2040 – 2060 but no significant changes need to be taken into account for a short term (next 15 years) analysis (see Section 2.5.1).
- *Discount rates*: historical data or rules of thumb may be used to create a few scenarios
- *Interest rates, inflation rates: For projecting future rates, it is possible to adopt stochastic models traditionally used in actuarial and financial practices generating scenarios based on historical observations of the interest rates and using calibration criteria for the 2-year, 10-year, and 30-year horizons projection.*

Handling uncertain model parameters - general considerations

To handle the energy price parameters scenario generation techniques can be applied. For the remaining parameters, scenarios can be constructed using given scenarios (e.g., general data from a weather forecast or climate change scenarios) or through careful selection by an educated user (e.g., discount rates or a selection of parameter values for critical / "extreme" and typical operational scenarios). Often, the number of such constructed scenarios is rather low, however the scenarios are stochastic, i.e. characterised by the likelihood of their occurrence. This needs to be properly treated in the operational as well as the strategic planning models. Tariffs for both purchase and sale of energy may be subject to regulation and also tied to market conditions. Note, therefore, that, in order to generate scenarios for energy prices, it may be necessary to estimate both the market development and the relation of the energy prices to the according market prices/indices.

Further parameters may be considered uncertain such as well water and cold water temperatures, humidification by plant buffer or solar cooling. However, lack of sufficient accessible data and/or difficulties in modelling and presenting the inherent uncertainty – as well as likely rather negligible effects of treating these parameters as uncertain – suggest to assume the mentioned parameters as deterministic for the current model development. Uncertainty about equipment reliability (for both the operational and the strategic models) may require additional investigations and modelling work. Observations from one / a few test sites may not be reliable enough to generate scenarios or other forecasts. In this case, the data may be derived from experts' opinions.

Accounting for stochastic parameters, it is essential to indicate, for both short-term operational optimisation as well as for long-term strategic planning models, how these parameters will be represented in the data base and in the models, e.g., efficiency parameters (energy-transfer coefficients), energy flows (left-hand sides of Sankey diagrams), or demands (right-hand sides of Sankey diagrams). The representation of uncertainties in the energy system is, thus, one of the main challenges for operational and strategic optimization, which needs to be addressed by the DSS.

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7. Integration requirements

The EnRiMa DSS should support the integration of both external data sources, such as data coming from building controls systems, and software modules, such as software for running optimizations and presenting results. In this section the requirements put on these integrations are described. Each test site got their own requirements and context of integrations, thus each site's integration requirements are described separately in subsequent sections. In order to be adaptable for future extension, the EnRiMa DSS should also consider general integration principles; these are described in the next section.

7.1. General integration considerations

From the requirements put forward from each site and our overall vision of how the EnRiMa DSS should be used in the future, it is clear that the EnRiMa DSS needs to be able to import data from different building control systems. As the EnRiMa system evolves, it is likely that the data formats that need to be handled needs to be extended, and that the number of systems that would like to make use of the EnRiMa DSS outputs will rise. In order to be easily extended the design of the EnRiMa DSS system should consider the following integration requirements:

- Protocols. The EnRiMa DSS should make use of well documented and standardized protocols for communication between software modules. For example, for integration purposes the use of WebService protocols such as SOAP and interface description such as WSDL should be used.
- Data import. As stated in the sections describing each site, there are requirements for the EnRiMa DSS to import data from the Honeywell MCR system (FASAD site), and the Siemens Desigo™ system (Pinkafeld Campus & ENERGYbase) and the ADM system (ENERGYbase). Thus, a requirement on the EnRiMa DSS is that it should be built to be easily extended to allow for the import of different data formats.
- Data export. The EnRiMa DSS will have built-in data representations, for example various forms of diagrams. However, there might be a need to further analyze the results from the DSS. In these cases it is important that the system supports export of the resulting data in easily accessible format. Currently both the systems at Pinkafeld Campus and FASAD supports export of data in the form of Microsoft EXCEL files. Similar functionality should exist in the EnRiMa DSS.
- External software modules. There are existing software modules that need to be a part of the EnRiMa DSS. For example the DSS will use solvers and data presentation software. These software modules should be integrated in such a way

that a) they do not dictate the internal structure of the EnRiMa DSS, or limit its functionality, and b) that the software modules can be exchanged, for example when the use of a new solver arises.

The following sections describe the more specific integration needs for each site.

7.2. Integration at the FASAD site

The control of the heating system of the building is based on software from Honeywell (Honeywell MCR-WEB). This software can be controlled via the Web from any computer and allows the monitoring of the water temperature in different parts of the heating system, the gas consumption of the micro-CHP unit (not the consumption of the whole building) and the generated electricity by the micro-CHP unit.

The main heating system controller is a Honeywell MCR50-PFL and operates the gas boilers, the micro-CHP unit, the pumps, etc. The communication between the sensors and the main controller (Honeywell MCR50-PFL) happens over local operation Network (LonWorks) and the communication between this controller and the central unit happens over C-Bus, Honeywells proprietary protocol on RS485. There is currently no way to integrate with the Honeywell system

7.2.1. Data points at FASAD

The installed sensors of the heating system are able to detect:

- temperature
- pressure
- water flow
- electrical consumption
- gas consumption
- heat quantity

This information can be exported in an Excel data sheet. The system is currently not storing historical data, however this is going to be amended.

At the moment the building managers at FASAD do not see the need to directly integrate the EnRiMa DSS with these systems.

The project will investigate further the possibilities of integration of the EnRiMa DSS with the Honeywell’s system.

7.3. Integration at the Pinkafeld campus & ENERGYbase sites

The building automation of the test sites ENERGYbase and Pinkafeld is based on the Desigo^{TM} Insight system from Siemens. At ENERGYbase Version 3.0.18.0 is used. The Pinkafeld Campus is using an older version.

The DesigoTM Insight system is a building automation system which is used for the control of the building equipment, especially the heating/cooling system and ventilation systems.

The data collection, as needed for EnRiMa, is not a core part of fh-Pinkafeld DesigoTM system. Nonetheless, basic data export features are available and can be used as a starting point for the EnRiMa DSS.

Contrary to Pinkafeld the data storage at the ENERGYbase is not provided by the Desigo^{TM} system. A second superordinate system (ADP – Advanced data processing) is used for data storage and processing.

For Pinkafeld’s and ENERGYbase’s management a fully integrated EnRiMa DSS system in their facility management system Desigo^{TM} is not desired. Both facility managers are against a fully automated integration of decision-making feedback into their Desigo^{TM} system due to legal considerations.

Data from Desigo^{TM} can be provided via FTP to the EnRiMa-DSS server in a predefined format which can then be imported by the EnRiMa DSS. The export can be done on a daily basis (respectively on a regular interval). After the file is available on the EnRiMa server, and the weather forecast is picked out of a negotiable weather data server the forecast for the next days can be done. The result could be presented to the facility manager in several formats, for example, as an iPhone APP or on an HTML-based web page.

The result of EnRiMa’s DSS could be that the DSS only gives proposals to the building management and the facility manager has to decide and to initiate the needed actions.

For all data which are provided a description of the data point is required.

7.3.1. Data points at Pinkafeld campus

About 300 measure points are available. All measure points are measured every 15 minutes.

The measure points are able to collect the following information:

- temperature
- pressure
- smoke detector
- switch setting
- operating states
- lux/light intensity
- window contact

They measure points are grouped in:

- office
- window
- heating
- illumination
- air conditioning
- presence

7.3.2. Data points at ENERGYbase

About 450 measure points are available. Temperature, operating states, lighting intensity and humidity is measured every minute. Operating hours and operating states of ventilation values are measured every 15 minutes. Electric meter, water flow meter and heat meter are measured every 3 hours.

The installed measure points are able to detect:

- temperature
- pressure
- humidity
- water flow
- electrical consumption
- smoke
- motion
- fire
- operation state
- door contact

- lux/light intensity
- heat quantity
- CO_2
- solar radiation
- wind speed
- operating hours

The most important groups of the measure points are:

- air handling units: 01, 02, and 03
- heat pump system
- solar thermal system
- weather station
- floor heating system
- well

8. General requirements

This Section presents the general (i.e., not covered by earlier sections) functional and non-functional requirements for the DSS. Some the requirements come from the future users while others from either the EnRiMa Project DoW or good modeling practice. All requirements will be discussed further with taking into account their importance for the users and the resources needed for their implementation, and then the final specification of the DSS functionality will be decided.

8.1. Requirements for the DSS operation and implementation

8.1.1. Modes of operations, and versions

The DSS shall have four modes of operations:

- Public (production), the basic DSS version available for authorized users; if required by diversified needs of groups of users, then more corresponding public subversions shall be deployed.
- Demonstration and tutorial, openly accessible version with limited functionality, operating on a sample of data and a mock-up of a site.
- Development, a version with extended functionality, available for the developers of the DSS. The additional functionality shall include modifications of model specifications, advanced methods of data analysis, experimental versions of algorithms, and other features suitable for development of next versions of the DSS.
- Test, various versions for testing purposes, available for the test team of the EnRiMa project.

Following the standard routine of software development, the DSS shall have, during the EnRiMa project duration, three, consecutively released, versions:

- Prototype,
- Prerelease, and
- Final.

Each version shall have sub-versions to be deployed whenever enhancements of the corresponding version will be implemented.

8.1.2. Execution, access, reusability

The DSS should conform to the following requirements on execution speed, response time, and throughput:

- Provide timely support, i.e., within the period between requesting a specific result and the time the corresponding decisions need to be made. In order to facilitate feasible solutions to this timing problem, extensive tests should be made to provide guidelines for preparing the necessary data and problem specification well ahead the time the advice is needed.
- The quality of decision-making support should not be compromised for reaching a quick response time; instead, either suitable computational power should be assured or pre-computation of decision-rules be arranged.
- The data types, sizes, and flows specified in Section 8.3 should be efficiently supported.

The DSS should fulfil the following access requirements:

- It should be accessible from any place the authorized users need to use it, i.e., it should be web-enabled.
- The user management (defining roles of users) should support access control according to the policy decided by each site.
- Data submitted by, and computed for each site should be protected according to the corresponding data privacy policy.

The DSS shall be possibly easily adaptable to the future needs of the test sites, and to other public buildings; therefore, in particular, it should:

- Have a modular structure allowing for upgrading software modules, and plugging-in new modules, and thus extending and/or improving the DSS functionality.
- Support possibly easy implementation for other buildings similar to the test sites, and adaptation for other public buildings.
- Support inter-operability of software components running at distant computational facilities.

8.1.3. Requirements for the interface

The user interface should support effective and efficient DSS use by diverse users (characterized in Section 3) who typically have rather limited ICT skills. The general guidelines, formulated by a practitioner, and to be conformed to by the DSS, read: *"In* *every case the simpler the tool is presented the better, independently of the personal skill levels. Difficult to understand/use tools are never used."*

The key DSS interface requirements are as follows:

- The interface should be multi-language: English and the official language of the site for which the DSS is deployed.
- The DSS should have well-designed tutorial mode and user manual; both verified by hands-on experiments with actual users, and augmented by either tutorial seminar or webinars.
- The DSS interface should provide context-sensitive help and API to an application supporting contact with either the DSS developers or a help-desk.

8.2. Functional requirements

The key, from the point of view of the effectiveness of the DSS use, functional requirements are as follows:

- The primary functionality of the DSS shall be to **support** decision-making. Therefore, the actual decision-maker sovereignty has to respected, i.e. the DSS should help to find decisions that fit best the user preferences; this shall be supported by generating and analysis of alternative decisions. Any decision suggested by the DSS should be either accepted or rejected by an actual decision-maker, i.e., the facility operator, facility manager or maintenance manager.
- The DSS should support the integrated model analysis that combines diverse methods of model-based problem analysis, in particular different methods of optimization, multiple-criteria analysis, and simulation. The DSS should also support the desired (by the decision-makers) analysis of the current site performance, and integration of operational and strategic planning support. The DSS should implement modern methods of reporting, including event notifications (also by email and SMS). All analyses, including the underlying data, should be properly documented.
- The DSS should use accurate measured building data, e.g., loads for validation of the model results. Furthermore, the DSS should collect historic data in an automated way whenever needed and possible; therefore, it should be linked with an existing building automation system. Moreover, the existing energy flows in the building, as well as the existing ICT infrastructure should be analysed. All these resources should be used for testing and verification of the underlying models and data.
- The DSS should provide advances towards most of the current approaches that rely on deterministic optimisation approach, which is unable to provide decisions

robust against scenarios of future inherent uncertainties. It shall support effective decision-making aimed at cost-efficient and safe energy supply to public buildings over a long time horizon, and thus cope with uncertainties and risks regarding energy markets, technological innovations, climate variability, weather conditions, etc., that substantially affect performance of currently installed systems.

- Although building managers currently have no risk perception, and therefore no incentives for considering risk hedging, the DSS shall deliver solutions robust against the uncertainties summarized above. Such solutions should assist the building managers in operational and strategic planning aimed at reaching long-term targets in a cost-effective way, taking into account that additional information about uncertainties will become available after the decisions are made.

8.3. Requirements for data management processes

8.3.1. Scope of data types

The DSS should handle in a consistent and efficient way all needed data, and support persistency and documentation of the data. The data space and services should support handling the following sets of data, some of them having possibly complex indexing structure:

- Data provided by the supported site, and needed by the DSS.
- Symbolic specification of models.
- Model parameters and results of analysis (data space to be generated automatically from the model specification).
- Specification of model instances (composed of a model specification and a given set of parameters).
- Model analysis tasks (specification of optimisation or simulation tasks).
- Data of authorised users (together with their roles as users of the EnRiMa environment).
- Modeling journal (automatically gathered information about modelling activities through the DSS Engine).

8.3.2. Characteristics of data size and flows

The initial estimations of the characteristics of the data size and flows is as follows:

- Maximum size of data for each site: 250MB/year.
- An average and maximum amounts of data that may be submitted and requested by one transaction handled by the DSS: 10KB, and 500KB, respectively.
- Average and maximum frequencies of data transactions: 20/24hrs and 2/sec, respectively.

These initial estimates will be improved during the forthcoming activities, in particular development of symbolic model specification and enterprise services requirement analysis.

8.3.3. Requirements for data services

The DSS should support the users in diverse activities related to data management. These include:

- Data sharing between both models and authorized users.
- Assuring consistency of model specification and data used for its parameters.
- Data versioning, i.e., assuring persistency and documentation of diverse versions of committed data modifications.
- Data harmonization, including: temporal downscaling and upscaling, as well as estimation of missing values.
- Basic support for data verification, e.g., through specification of data ranges, and basic statistics of data items.
- Data (original data, model parameters, model results) views and visualization.
- Data documentation, including meta-data, data source, time-stamps, and information about the users.

8.4. Beyond the state-of-the-art

The EnRiMa DSS should help, in a more effective way than the available methods and tools, the facility management and operators of public buildings to optimize the energy management under uncertainties with taking into account the CO_2 emissions. Therefore, the EnRiMa DSS is required to go beyond the state-of-the-art in both modelling technology and interfacing models with their users and the ICT infrastructure of the buildings. In particular, the DSS should have the following novel features necessary for effectively conforming to the requirements specified in this report:

- Incorporation of the impact of building retrofits on energy flows, and automation of procedure for calculating energy transfer efficiencies. The former innovation will be used in the subsequent DSS Engine in order to allow the consideration of changes to the building envelope, while the latter will enable generation of stochastic energy transfer matrices.

- Scenario generation should be performed jointly for both prices and loads in order account for their dependency. Both short- and long-term scenarios will be generated.
- The DSS should account for uncertainties in prices and loads, which is a novel feature at the building level. Furthermore, it should provide the user with the capability to manage risk, CO_2 emissions, and energy efficiency directly along with reducing costs via a multi-criteria objective function, the possibility of taking financial positions where available, and long-term and inter-period conditional value-at-risk (cVaR) constraints.
- The DSS shall be based on modern modeling technology of web-enabled applications; it should assure consistency of model symbolic specification and the corresponding data warehouse, where the latter handles all data (model parameters, results of analysis, documentation of the modelling process). The implementation should also provide flexibility needed for effective adaptation of the DSS for other sites that will likely require modifications of the model specification.

9. Use cases

This section provides a complementary view on the DSS requirements specified in earlier sections, namely the overview structured from the perspective of diverse types of users of the EnRiMa DSS. For this purpose a representative set of use cases is defined. Not all EnRiMa DSS users are familiar with the use-case approach and modeling methodology, therefore we start this section with an overview of the use-cases role and definition, as well as definitions of modeling terms used in the EnRiMa use-case specification.

9.1. General considerations

9.1.1. What is a use case?

Object Management Group defines[8] that *"a use case is the specification of a set of actions performed by a system, which yields an observable result that is, typically, of value for one or more actors or other stakeholders of the system."* We have followed this definition and documented the desired functionality for the EnRiMa DSS in the form of a set of use cases. As stated by the definition above each use case specifies a subset of the actions performed by the system. Thus, the use cases taken together provide a structured overview of the desired EnRiMa DSS functionality.

In the context of working with use cases the following concepts are of importance:

- **Actors** denote the roles that people, other systems or devices take when communicating with a particular use case or use cases. Actors are not the same as job titles or people. People with one job title may play the roles of several actors, e.g. an associated professor can play a role of teacher and supervisor depending on what he/she is doing.
- **Use case** describes a sequence of actions that the system performs to achieve an observable result of value to an actor. Use cases have names which usually is an active verb and a noun phrase.
- **Use case description** provides the documentation of how the system should work (i.e. requirements). There are several ways of describing use cases. In order to suite the purpose of specifying the functionality of the EnRiMa DSS we have elaborated the use-case template described below.
- **Use case diagram** illustrates connections of actors with use cases. A common misconception is that the use case diagram is sufficient for specifying

[8] OMG Unified Modeling Language (OMG UML), Superstructure, V2.1.2, p.594, OMG, 2007.

requirements. In fact use case diagram only gives an overview. Knowledge about how the system should work is provided by the use case descriptions. The use-case diagram is presented at the end of this Section.

9.1.2. Use-case template

The use-cases of the EnRiMa DSS are composed of the following elements:

- **Name:** concise label representing the use case content.
- **Actor/user:** a person (from those described in Section 3) involved in the interaction with the DSS
- **Goal/purpose:** goal(s) the actor aims at achieving through the use case
- **Trigger:** an event that initiates the use case
- **Input:** information the actor shall provide during the use case execution
- **Results:** expected outcome of the use case
- **Steps (workflow):** steps of the actor interaction with the DSS

The following standard initial steps are omitted in the workflows of use cases presented below:

- Login and access authorization
- Navigation through the GUI up-to the starting screen supporting the workflow of the use-case

9.1.3. Definitions of terms used in the use-cases

- **Symbolic model specification** defines formally components of a mathematical model. It is composed of generic model entities: variables, parameters, and relations between them, as well as indexing structure (indices and sets of indices) that is used for populating the generic entities into the corresponding sets of actual entities. In other words, symbolic model contains no actual data.
- **Population of a generic entity** is simply expanding an entity into a (typically multidimensional) matrix of the corresponding entities through applying all combinations of indices defined through the corresponding sets of indices.
- **Committed data** is a set of data that a user decided to be persistent, i.e., available for use. To assure replicability of results such data are kept unchanged. Typically, the data is verified before being committed.
- **Data versioning** is a mechanism that allows efficient reuse of data (i.e., minimize the need of data duplication) within sets of data in which some data elements are modified.

- **Base data** set is a committed data set that contains values of all parameters and sets of indices needed for the corresponding symbolic model specification.
- **Model instance** is a pair of a symbolic model specification and a corresponding base data set. In other words, a model instance (that contains values of all parameters) is a representation of reality, while symbolic model is a representation of types of relations between model variables and parameters. Symbolic model is used for analysis of analytical properties of such relations; quantitative analysis is done on model instances.
- **Analysis types** represent diverse methods of model instance analysis, e.g. goal oriented (traditional optimization, and its extensions, including multiple-criteria analysis) and alternative focused (diverse simulation methods).
- **Parameters of analysis** define a specific instance of an analysis method; e.g., for traditional optimization it is a selection of a variable representing optimized objective, and optionally also constraints on other objectives.
- **Computations** denote here all relevant computational tasks required for a selected analysis method
- **Notification** represents here a set of various mechanisms to be used for exchanging information between the DSS users, between users and the DSS software, and between the applications (software elements of the DSS)
- **Analysis of results** denotes not only the traditional way of considering the information provided computers, but also interactions between the DSS users, and between the users and the DSS components; such interaction shall be supported in diverse ways, e.g., different views on data and results of analysis, using selected results as inputs to another analysis or as actual values of controls of the system, attaching comments to results, and passing them for further analysis/consideration to other users.

9.2. Use cases specific for operational DSS

9.2.1. Data for operational planning

- **Name:** Data for operational planning
- **Actor/user:** Building owner operation manager
- **Goal/purpose:** Prepare data for operational planning.
- **Triggers:** periodical (daily) routine; comfort indicators outside the decided range
- **Input:** a base data set
- **Results:** a new data set
- **Steps (workflow):**
  1. Select a version of symbolic model specification
  2. Select a base data set

3. Receive all needed data updates from external sources (see Section 5.1.1)
4. Receive all needed data updates from local sources (see Section 5.1.1)
5. Process/adapt data (see Section 5.1.1)
6. Optionally, run the scenario generation (see the corresponding use-case)
7. Check data completeness
8. Commit data
9. Define the corresponding model instance

9.2.2. Operational planning

- **Name**: Operational planning
- **Actor/user**: Building owner operation manager
- **Goal/purpose**: Determine parameters for the HVAC system
- **Triggers**: periodical (daily) routine; comfort indicators outside the decided range
- **Input:** a model instance
- **Results**: control parameters for the HVAC system
- **Steps (workflow):**
  1. Select a model instance
  2. Select a type of analysis
  3. Select parameters of analysis
  4. Start the computations, and wait for notification of availability of results
  5. Analyze the results
  6. Get approval, if appropriate
  7. Implement the HVAC control parameters

9.2.3. Monitoring the HVAC system performance

- **Name**: Monitoring the HVAC system
- **Actor/user**: Building owner operation manager
- **Goal/purpose**: Monitor the performance of the HVAC system
- **Triggers**: periodical routine.
- **Input:** a set of measurements and the time period
- **Results**: values of measurements' results, and relevant indicators
- **Steps (workflow):**
  1. Select a predefined set of registered measurement results for monitoring.
  2. Select time period for monitoring
  3. Optionally, select indicators for the parameters (e.g., thresholds for alerts, performance measures)
  4. Start monitoring
  5. Optionally, forward information about the system state and/or performance

6. Optionally, store information about the system state and/or performance

9.3. Use cases specific for strategic DSS

9.3.1. Data for strategic planning

- **Name**: Data for strategic planning
- **Actor/user**: Building owner financial manager
- **Goal/purpose**: Prepare data for strategic planning
- **Triggers**: same as triggers for strategic
- **Input:** a base data set
- **Results**: an updated data set
- **Steps (workflow):**
  1. Select a version of symbolic model specification
  2. Receive all needed data updates from external sources
  3. Receive all needed data updates from local sources
  4. Process/adapt data
  5. Run the scenario generation (see the corresponding use-case)
  6. Check data completeness for strategic planning
  7. Commit data
  8. Define the corresponding model instance
  9. Send notification to the use case that requested the data

9.3.2. Strategic planning

- **Name**: Strategic planning
- **Actor/user**: Building owner financial manager
- **Goal/purpose**: Find a technological portfolio
- **Triggers**: increased energy bills; equipment failure; equipment aging; legislative requirements.
- **Input:** a selected model instance (prepared by the corresponding data use-case)
- **Results**: portfolio of technologies (devices), and values of objectives (criteria, indicators) that include:
  1. Investment costs
  2. Operational costs
  3. Financial instruments for risk management
  4. Measures of robustness with respect to all scenarios of uncertainties.
  5. Stochastic solution (VSS) measure which indicates economic gains of the robust technological portfolio in comparison to “scenario-by-scenario” solution.

- **Steps (workflow):**
  1. Select a model instance
  2. Select a type of analysis
  3. Select parameters of analysis
  4. Start the computations, and wait for notification of availability of results
  5. Analyze the results

9.3.3. Data provision for strategic planning

- **Name**: Data provision
- **Actor/user**: Data provider (either a person, or an application)
- **Goal/purpose**: Provide the requested sub-set of data
- **Triggers**: a request for data
- **Input:** specification of the requested data
- **Results**: a committed data set
- **Steps (workflow):**
  1. Upload data
  2. Check consistency
  3. Commit data
  4. Send notification

9.4. Use cases common for operational and strategic DSS

9.4.1. Data for scenario generation of operational planning

- **Name**: Operational planning
- **Actor/user**: Building owner operation manager
- **Goal/purpose**: Prepare data for scenario generator.
- **Triggers**: Once the operation manager wants to operate the HVAC system under different requirements or preconfigured scenarios.
- **Input:** a parent model instance (for which the scenarios are to be generated), a base scenario data set
- **Results**: a new data set
- **Steps (workflow):**
  1. Select a version of symbolic model specification (for the scenario generation)
  2. Select a base data set for scenario generator
  3. Receive all needed data updates from external sources
  4. Receive all needed data updates from local sources
  5. Process/adapt data
  6. Check data completeness for scenario generation

7. Commit data
8. Define the corresponding model instance
9. Send notification to the user who requested the data

9.4.2. Data for scenario generation of strategic planning

- **Name**: Operational planning
- **Actor/user**: Building owner financial manager
- **Goal/purpose**: Prepare data for scenario generator.
- **Triggers**: Once the financial manager wants to operate the HVAC system under different requirements or preconfigured scenarios.
- **Input:** a parent model instance (for which the scenarios are to be generated), a base scenario data set
- **Results**: a new data set
- **Steps (workflow):**
  1. Select a version of symbolic model specification (for the scenario generation)
  2. Select a base data set for scenario generator
  3. Receive all needed data updates from external sources
  4. Receive all needed data updates from local sources
  5. Process/adapt data
  6. Check data completeness for scenario generation
  7. Commit data
  8. Define the corresponding model instance
  9. Send notification to the user who requested the data

9.4.3. Scenario generation

- **Name**: Scenario generation
- **Actor/user**: The scenario generator or the developer supervising the scenario generation
- **Goal/purpose**: Generate the requested
- **Triggers**: a request for scenario generation
- **Input:** a parent model (model in which the scenarios will be used) instance, and data for scenario generation
- **Results**: a set of scenarios
- **Steps (workflow):**
  1. Run the scenario generator
  2. Analyse the diagnostics from the generator
  3. Upload the scenarios into the DSS data-warehouse

4. Send the notification on the availability of the scenarios

9.4.4. Energy audit

- **Name**: Energy audit
- **Actor/user**: Energy auditor
- **Goal/purpose**: Analyse the energy flows and possible energy savings, and provide input to the strategic planning
- **Triggers**: New EU or national legislation; change in utility bills; aging of equipment; equipment failure; availability of new technology; availability of funds for energy efficiency programs.
- **Input:** a selected model instance
- **Results**: Information about the analysis results, including:
  1. Indicators (metrics) of energy efficiency
  2. Instant energy-saving and conservation (ECO) opportunities
  3. Measures of robustness with respect to all scenarios of uncertainties.
- **Steps (workflow):**
  1. Select a model instance
  2. Select a type of analysis
  3. Select parameters of analysis
  4. Start the computations, and wait for notification of availability of results
  5. Analyze the results

9.4.5. Notifications

- **Name**: Notification
- **Actor/user**: any user or application
- **Goal/purpose**: provide specific information
- **Triggers**: a need for sharing information
- **Input:** recipient(s) and content of the notification
- **Results**: shared information
- **Steps (workflow):**
  1. Select notification type
  2. Select recipients
  3. Provide the content
  4. Send the notification

9.5. Use-cases for the DSS developers

9.5.1. Symbolic model specification

- **Name**: Symbolic model specification
- **Actor/user**: DSS developer
- **Goal/purpose**: Define or modify symbolic model specification
- **Triggers**: a request for model development
- **Input:** optional, a model specification to be modified
- **Results**: symbolic model specification
- **Steps (workflow):**
  1. Define model entities (indexing structure, parameters, variables, and relations)
  2. Develop initial data set (separate use-case)
  3. Validate the model
  4. Commit the model specification

9.5.2. Initial data set

- **Name**: Initial data set
- **Actor/user**: DSS developer
- **Goal/purpose**: Develop initial data set
- **Triggers**: a request from the symbolic model specification use-case
- **Input:** a symbolic model specification
- **Results**: a data set
- **Steps (workflow):**
  1. Run automatic generation of the data space for model parameters and results
  2. Import available data from the data warehouse
  3. Receive or develop the missing data
  4. Verify the data completeness
  5. Commit data
  6. Send notification about the data availability

9.5.3. Model validation

- **Name**: Model validation
- **Actor/user**: DSS developer
- **Goal/purpose**: Verify a model
- **Triggers**: request for model verification
- **Input:** a model instance, and a set of data for model verification

- **Results**: indicators of the model quality
- **Steps (workflow):**
  1. Run diverse model analysis methods
  2. Analyze the results
  3. Assess the model quality
  4. Store comments
  5. Send notifications

9.6. Use-cases for the DSS administration

9.6.1. User administration

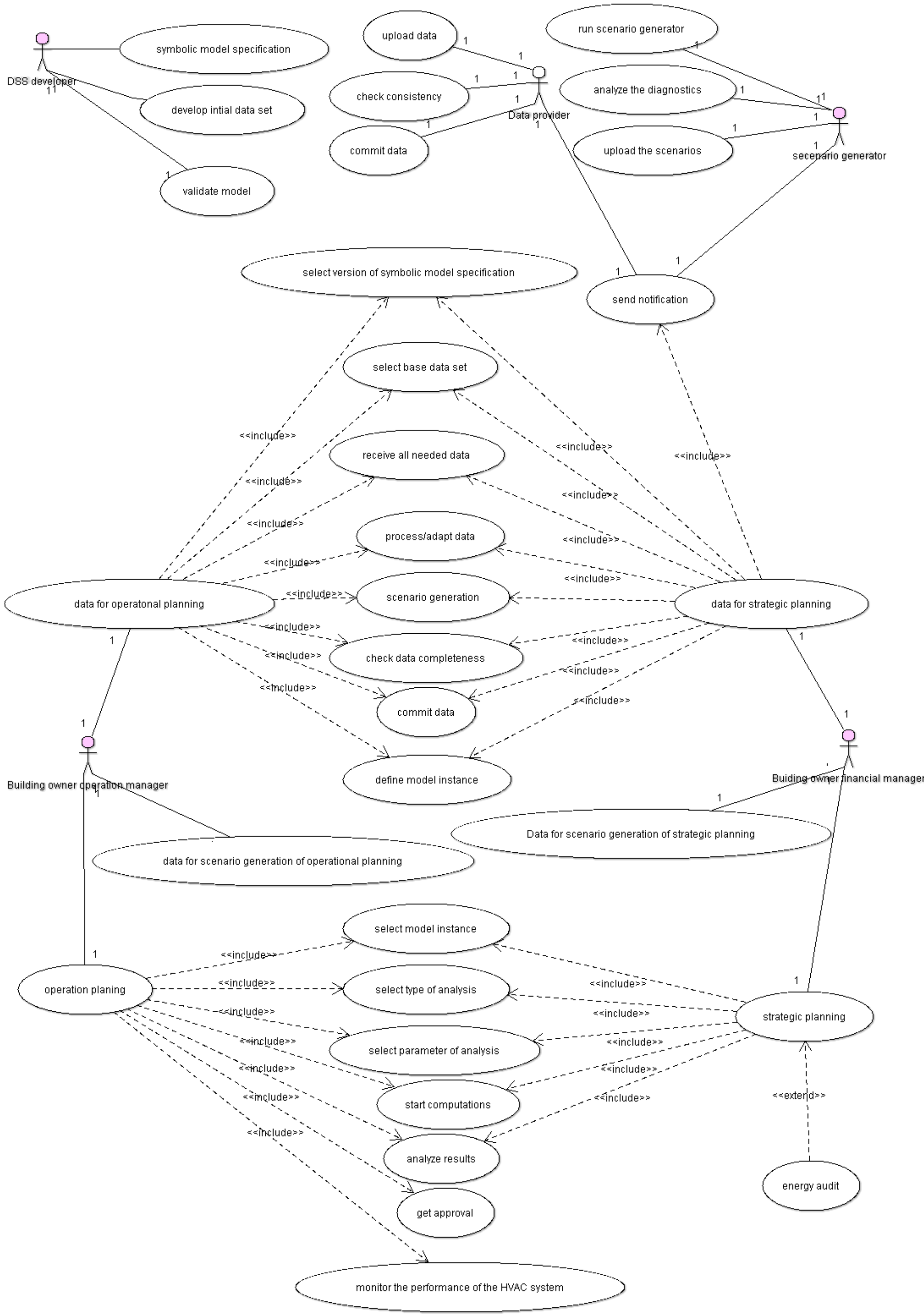
- **Name**: User administration
- **Actor/user**: DSS administrator
- **Goal/purpose**: Assign or modify roles for the DSS users, maintain access control.
- **Triggers**: a request for adding or modifying roles of a DSS user
- **Input:** data about the user, and her/his roles in the DSS
- **Results**: updated user data-base
- **Steps (workflow):**
  - Standard procedures for user administration

9.6.2. DSS administration

- **Name**: DSS administration
- **Actor/user**: DSS administrator
- **Goal/purpose**: Maintain the DSS
- **Triggers**: periodical routine; requests from users and/or supervisors
- **Input:** specification of administrator's task
- **Results**: properly maintained DSS
- **Steps (workflow):**
  - Diverse typical tasks of system administrator, including hardware and software maintenance, data back-ups, etc.

9.7. Use-cases diagram

The use-case diagram shown in the next page illustrates main relations between key actors and the use cases they directly use (therefore DSS administration use cases and the DSS administration are not included in the diagram). Each main actor employs different use-cases; many of them are composed of steps that include other use-cases.


DSS developer
symbolic model specification
develop intial data set
validate model
upload data
check consistency
commit data
Data provider
run scenario generator
analyze the diagnostics
upload the scenarios
secenario generator
select version of symbolic model specification
send notification
select base data set
receive all needed data
process/adapt data
scenario generation
check data completeness
commit data
define model instance
data for operatonal planning
data for strategic planning
Building owner operation manager
Buiding owner financial manager
data for scenario generation of operational planning
Data for scenario generation of strategic planning
select model instance
select type of analysis
select parameter of analysis
start computations
analyze results
get approval
monitor the performance of the HVAC system
operation planing
strategic planning
energy audit
<<include>>
<<extend>>

9.8. Illustrative use-case scenarios

In order to illustrate selected use-cases, we present here scenarios of their use. We stress that these are only illustrative examples. Actually, as shown by the examples, for each use case one can develop several scenarios of its use. In other words, each use-case defined above is a template for a family of parameterized scenarios.

9.8.1. Operation of the HVAC system, room temperature set-points

- **Name**: Operation of the HVAC system, room temperature set points
- **Actor/user**: Building owner operation manager
- **Goal/purpose**: To define and set the different temperature set-points of the building in the HVAC control and supervision system (SCADA)
- **Triggers**: periodical (daily) routine; a request for analysis.
- **Input:** weather, occupancy and energy price data.
- **Results**: Estimated temperature set-points evolution for the day, in the different building rooms, with the purpose of reducing energy bill and maintaining comfort.
- **Steps (workflow):**
  1. Select a predefined set of system performance indicators: in this example, cost reduction.
  2. Select time period for the analysis: : FROM: (year/month/day) – TO: one year later
  3. Run the computations, or get information on:
     a. Scenario generation for following 24 hours from the starting period of time of the weather forecast, occupancy, energy prices.
     b. Computation of temperature set-points
     c. Computation of the estimated cost.
  4. Analyse the results
  5. Accept the results and introduce them into the building's SCADA system
  6. Optionally, forward information about the system performance

9.8.2. Monitoring the HVAC system performance

- **Name:** Monitoring the HVAC system
- **Actor/user:** Building owner operation manager
- **Goal/purpose:** Monitor the state of the HVAC system. In this scenario one wants to periodically investigate the amount of electricity generated by the micro-CHP unit at FASAD in a given time period, just for visualising the generated electricity.

- **Triggers:** periodical routine.
- **Input:** a set of measurements and the time period
- **Results: values of measurements' trajectories, and relevant indicators**
- **Steps (workflow):**
  1. Select a predefined set of system parameters for monitoring: amount of electricity generated by the micro-CHP unit
  2. Select time period for monitoring: FROM: (year/month/day/hour) – TO: (year/month/day/hour)
  3. Optionally, select indicators for the parameters (e.g., thresholds for alerts, performance measures): no thresholds; performance indicators may include :
     a. Number of working hours of the micro-CHP unit in the given time interval.
     b. Curve "Power (kW)" (kWh generated/1 hour) vs. "Time".
     c. Curve "accumulated kWh" vs. "Time".
  4. Start monitoring
  5. Optionally, forward information about the system state and/or performance
  6. Optionally, store information about the system state and/or performance

9.8.3. Data for strategic planning

- **Name**: Data for strategic planning
- **Actor/user**: Building owner financial manager
- **Goal/purpose**: Prepare data for strategic planning (scenario described in the next subsection)
- **Triggers**: request from the strategic planning use case
- **Input:** a base data set
- **Results**: an updated data set
- **Steps (workflow):**
  1. Select a version of symbolic model specification
  2. Receive all needed (i.e., not available/current in the base data set) data updates:
     a. data on electric services and technologies including generation and storage capacities (e.g. CHPs, PVs, batteries); primal fuel consumption, availability, efficiency, losses, costs (installation, maintenance, decommissioning);
     b. data on heating and hot water technologies including generation and storage;
     c. data on buildings envelopes;
     d. data on laws/legislation constraints and energy standards;
     e. data on market transformations;

   f. data on regulations for safe energy provision – reliability of equipment (lifetime), maintenance requirements, etc.
3. Process/adapt data
4. Run the scenario generation for climate variability (weather), prices, tariffs, loads, equipment (e.g. wind/solar) availability scenarios; with a representation of other uncertainties.
5. Check data completeness for the requested strategic planning
6. Commit data
7. Define the corresponding model instance
8. Send notification to the use case that requested the data

9.8.4. HVAC performance analysis, plan the CHP or boiler operation

- **Name**: Plan the operation of CHP or boiler
- **Actor/user**: Building owner operation manager, or either building financial manager
- **Goal/purpose**: Evaluate the HVAC system performance: In particular, plan/analyse for a certain time period, the economical profitability of giving a prior operation to a device "i" (e. g. gas boiler) for meeting the heating and DHW of a building (f. e. FASAD), or to a device "j" (e.g. CHP unit)
- **Triggers**: periodical (monthly, annual) routine. Requested analysis. The manager would like to know the operation cost of a device and compare to the cost of operating other device, in a particular economical and regulatory scenario.
- **Input:** Time period, economical parameters like feed-in tariffs, costs of energy (electricity, gas), regulatory conditions (sell all the electricity produced by the CHP, possibility of self-consumption), weather and occupancy forecasts, technologies under analysis (e.g. boiler against CHP).
- **Results**: characteristics of the performance of each of the studied technologies, including values of the indicators (cost): Operation cost of running the device "i" for the given time period; Operation cost of running the device "j" for the given time period.
- **Steps (workflow):**
  1. Select a predefined set of system performance indicators: example cost. Other possible indicators could be CO2 emissions or efficiency of devices.
  2. Calculate the load of the building for this period of time:
     - Running the operational module, HVAC system load can be estimated.
     - By historical data other loads (lighting, other electrical appliances) can be estimated.
  3. Select time period for the analysis: FROM (year/month/day) – TO: (year/month/day)

4. Run the computations of the strategic planning
5. Analyse the results
6. Optionally, forward information about the system performance

9.8.5. HVAC performance analysis, choice of electricity selling tariff

- **Name**: Decision on the most suitable selling tariff for the electricity produced by the CHP
- **Actor/user**: Building financial manager
- **Goal/purpose**: Evaluate the HVAC system performance. Decision on the most suitable electricity produce by CHP selling tariff. Three scenarios should be compared: Compare savings from selling the electricity produced with the CHP unit at FASAD with the single period tariff, with the ToU tariff and with the market price plus the feed-in tariff for the next year
- **Triggers**: periodical (monthly, annual) routine. Requested analysis. In this scenario: the financial manager would like to analyse if there is a better energy price (tariff)
- **Input:** Time period, economical parameters: incentives for selling electricity (e.g. three tariffs scenarios: current single period tariff, ToU tariff and feed-in tariff), energy costs (electricity, gas), regulatory conditions (sell all the electricity produced by CHP, or possibility to self-consumption), weather and occupancy forecasts
- **Results**: Estimated savings for each of the scenarios
- **Steps (workflow):**
  1. Select a predefined set of system performance indicators: example savings.
  2. Select a predefined set of scenarios of selling electricity: produced by the CHP: current single period electricity tariff, ToU tariff and feed-in tariff
  3. Select time period for the analysis: : FROM: (year/month/day) – TO: one year later
  4. Estimate the loads for the time period:
     a. Running the operational module, HVAC system load can be estimated.
     b. By historical data other loads (lighting, other electrical appliances) can be estimated.
  5. Run the strategic planning computations, or get information on:
     a. Scenario generation for future tariffs
     b. Scenario generation for future energy demand
     c. Scenario generation for electricity market prices
     d. Weather forecasts

   e. Scenarios for working hours of the CHP unit, classified in peak and off-peak
   f. Computation of earnings
6. Analyse the results
7. Optionally, forward information about the system performance

10. Summary

10.1. Relations to subsequent activities

This report is based on the available results of WP1 (Work-Package 1, Requirement Analysis) that will be documented in D1.1 (Requirement Assessment) where, in particular, the following issues will be discussed in more detail than in this report:

- Sites' assessments, identification of key uncertainties, description of market environments. The former will study each site's existing energy resources and loads in order to identify stochastic components, whereas the latter will survey the market environment of each site, i.e., the extent to which prices are regulated and the need for managing risk exists.
- Each test site's existing ICT infrastructure will be assessed to determine how it can interface with the EnRiMa DSS. This will enable consistent data handling in the DSS integrated (to the extent justified by the site's needs) with the site's OCT infrastructure.
- Regulatory conditions faced at each site along with key uncertainties will be then summarized in form of use cases suitable for providing the basis for mathematical models developed in WP2, WP3, and WP4.

This report, together with D1.1, will provide the basis for:

- D3.1 (Model description, calibration, and validation) to be developed in WP3
- D3.2 (Scenario generation software tool) to be developed in WP3
- D4.2 (Symbolic model specification) to be developed in WP4
- Task 4.1 (Requirement analysis for the DSS Engine) of WP4
- Task 4.3 (The DSS architecture) of WP4
- Task 4.4 (Data warehouse and web-services) of WP4
- Task 4.5 (Stochastic optimization) of WP4
- Task 4.4 (The DSS Kernel) of WP4
- Task 5.1 (Enterprise services requirements analysis and design) of WP5
- Task 5.2 (Service integration in tools) of WP5
- Task 5.3 (Adaptive GUI for the DSS Engine) of WP5
- Task 6.1 (Requirement update at real-world sites) of WP6

The RA presented in this report will be adjusted to attainable goals during forthcoming EnRiMa activities, in particular development of symbolic model specifications, generation and testing of the corresponding computational tasks, verification of the actual data availability, testing the DSS prototype on the test sites, and learning from the hands-on experience of the practitioners during testing of the DSS prototype at real-world sites.

10.2. Acknowledgements

Requirement analysis for a DSS should be driven by actual needs of the DSS users. In order to achieve this, the leading role in formulating the key (from the user's perspective) elements of the DSS functionality should be played by domain experts, in our case, the partners who are experts in the field of operational and strategic planning of energy in public buildings; the other (rather technical) requirements are typically formulated by modeling experts. We have achieved this goal by the three-stage procedure:

1. Diversified contributions of all partners have been organized by IIASA into sections assuring overall consistency.
2. Each section has been taken over by a partner, who is the lead-author of the section, i.e., has developed its final version taking into account comments of other partners, deciding about the final content, and taking responsibility for it.
3. The consolidated version has been subject to the quality control done by CET and Tecnalia. The reviewers' recommendations have been used by the lead-authors for improving the corresponding sections.

The lead-authors of the sections are as follows:

1. Introduction: IIASA
2. Problem description: HCE (in consultation with CET)
3. Users and stakeholders: Tecnalia
4. Decisions and objectives: Tecnalia
5. Decision-making workflows: HCE
6. Data requirements: SU
7. Integration requirements: SU
8. General requirements: IIASA
9. Use-cases: HCE (in consultation with Tecnalia, based on the draft prepared by IIASA)
10. Summary: IIASA

The lead-authors, as well as CET, Sintef, UCL, and URJC have also contributed inputs and comments to all sections. In other words, the report is based on contributions of all EnRiMa partners; the lead-authors have made decisions in situations when the opinions about the content have differed amongst the partners, and prepared the final version of the corresponding sections.