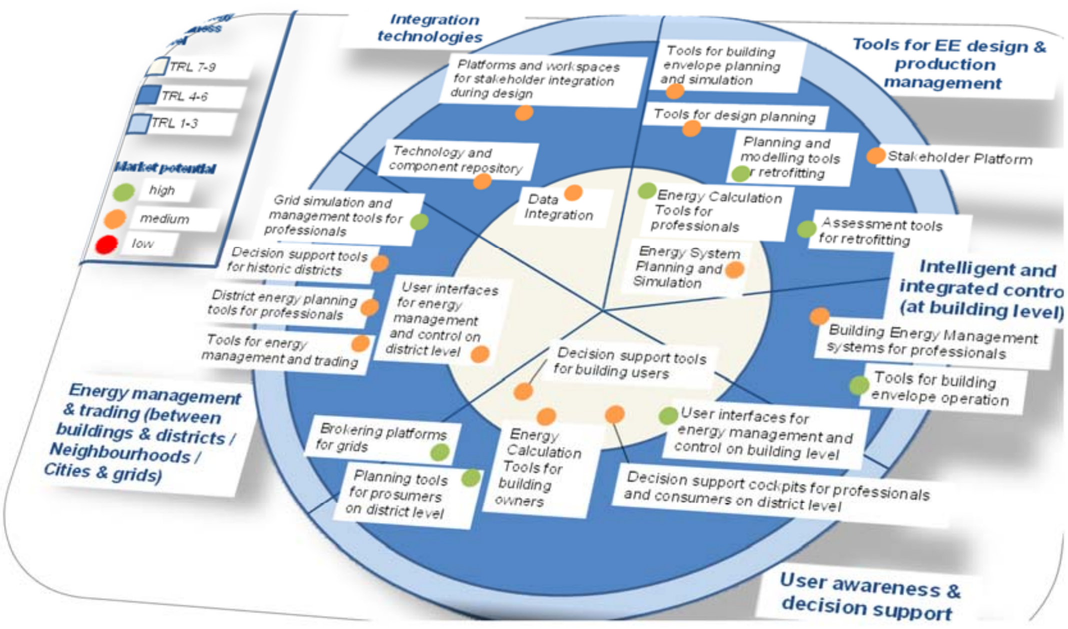
D. 2.2 Best practices, trends and visions



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D2.2 Best practices, trends and visions

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1. Introduction

EEBERS project mission is to identify opportunities for synergies in ICT related RTD in the EeB (energy efficient buildings) domain and to engage stakeholders in networking for future RTD and exploitation of results.

This document reports on the assessment of ICT in the EeB area concerning the technology readiness level (TRL) and market potential and the development of the EEBERS technology radar based on the assessment. The 5 technology fields of the radar are accordingly to the EEBERS taxonomy the 5 main clusters of the taxonomy. In addition, this report present the most important trends collected in an expert workshop and for some selected technologies an exemplary industrial application case. Finally this report provides a vision created by the EEBERS partners based on ongoing technological developments in the EeB area.

1.1 Purpose and target group

The main purpose of this document is to present the results of the EEBERS technology assessment. The assessment and structuring of the technologies in the technology radar will facilitate the provision of recommendations for future EeB priorities. The exemplary industry cases will give a deeper insight into application scenarios of selected technologies and also support the formulation of the recommendations. Finally, the EEBERS vision provides a target system to be reached in the future and will be the landmark or checkpoint for the formulation of the recommendations.

The target group is the European EeB research and innovation community, in particular, the participants of targeted EeB related projects and all stakeholders with interest in rolling out the innovations.

1.2 Contributions of partners

FhG developed the methodology and templates for the assessment of the technologies and formulated the vision; all other partner supported FhG. The assessment of the technologies was done by an expert group supported by all partners and the EEBERS advisory board. The exemplary industry cases were formulated by all partners. FhG developed 3, cases, VTT 2 cases, LOU 1 case and SOL also 1 case.

1.3 Baseline

Baseline for this report was the initial EEBRS project mapping (D1.1) and the technological solutions already described in the previous report of work package 2. The methodology used in this context is a well validated approach used several times by FhG in research and consulting projects but tailored towards the needs of EEBERS. Finally, an expert workshop was the main knowhow source for the assessment of the technologies.

1.4 Relations to other activities

This task benefited from the research work in work package 1, especially the taxonomy developed in task 1.1 and the pre-work done in Task 2.1.

Work package 3 will use this information and formulate recommendations for future EeB priorities on R&D and business development.

2. Approach

The following chapter describes the approach that was used to develop the EEBERS technology roadmap that is visualized by the EEBERS technology radar and extended by additional trends for each technology field.

Starting point for this research work are technologies that are currently developed in European research projects from the EeB area. The projects were analysed and most important technologies were documented. The identified technologies were assessed according to their technology readiness level (TRL) and their market potential. The TRL was analysed in collaboration with the EeB-CA2 project (joint questionnaire of the four CSA and more detailed investigation by Steinbeis). The market potential was analysed with experts from industry and research in a half-day workshop in Munich. Business trends were collected from latest publications and studies. The technologies were consolidated in the EEBERS technology radar structured according to the EEBERS taxonomy in five different technology fields. The business trends are structured according to the STEEP analysis. The STEEP analysis distinguishes between social, economic, ecologic, political (incl. legal) and technological aspects. The first four segments are considered in the EEBERS business trend radar. In a second step some technologies from the five different fields were selected and edited as exemplary industry cases. In a final step visions from the different energy, building and smart city initiatives were consolidated. Extended by the activities from Task 2.3 (deployment scenarios and impact) the results presented in this document will be the basis for the EEBERS recommendations.

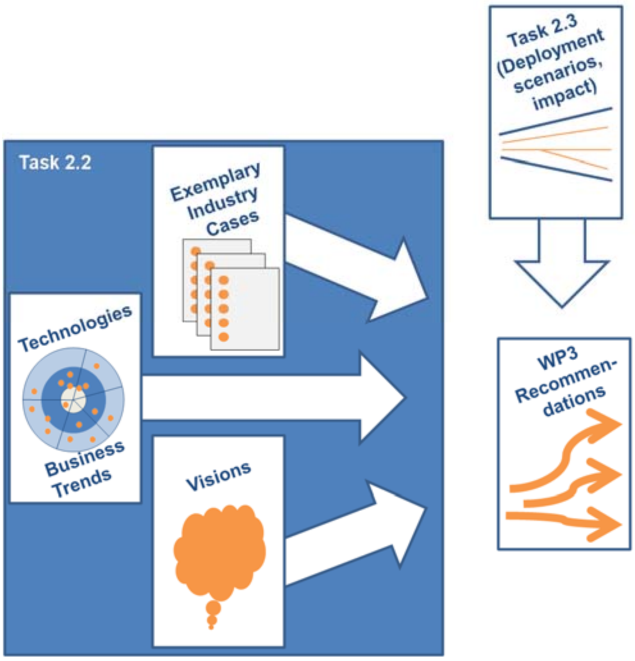


Figure 1 Approach

2.1 Technology and business trends

Based on the identification and consolidation of the technology trends the technology radar was developed (compare Figure 25).

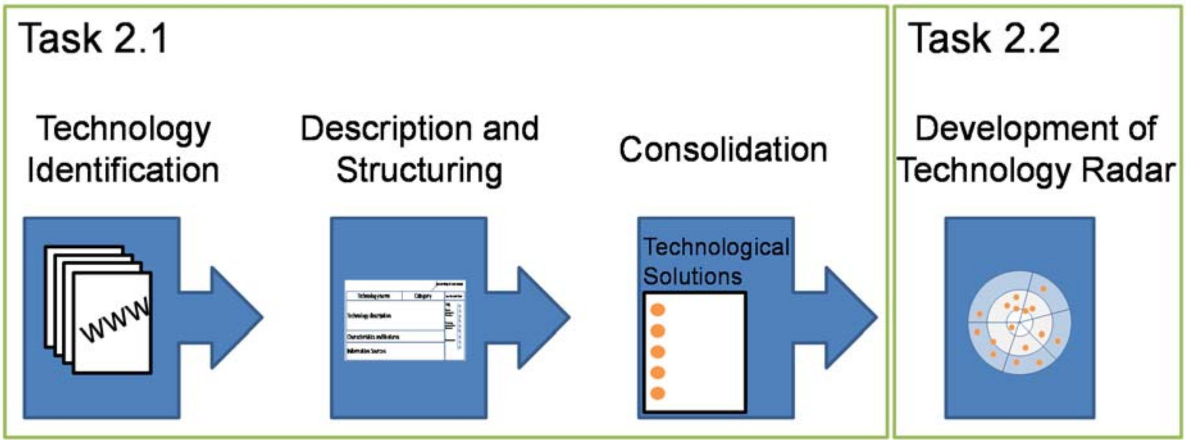


Figure 2 Overall approach for the technology analysis

TRLs were (as explained) identified in collaboration with the other CSA. The market potential was analysed together with experts from industry and research in a half day workshop. The illustration below presents the template that was used in the working groups for the assessment. The experts were advised to assess the market volume of the technology according to competitive technologies, substitutes or alternatives.

Name of the technological solution	

Market potential of the different technological solutions in the next 5-7 years

What is the market volume (large, medium or small)?	
Will the end-user accept the technology (end-user will accept, end-user will accept to some extend or end-user will not accept)?	
Will there be an increase of the cost-benefit ratio for the end-user compared to existing or competing solutions (increase of cost-benefit ratio, unchanged cost-benefit ratio or decrease of cost-benefit ratio)?	
Are the technologies compatible to existing solutions (compatible, compatible to some extend or not compatible)?	

What else should be considered or done to ensure full impact of the technological solution?

Figure 3 Assessment template

In addition, the experts recommended technologies that might play an important role in the future. These technologies are also part of this report.

Business trends are based on a desk research and reviewed by EEBERS partners. The trend analysis focused on most relevant trends and gives not a complete overview.

2.2 Exemplary industry cases

The idea of the exemplary industry cases is to give the reader a more detailed insight into some solutions that are currently developed in the EeB area.

The cases describe promising solutions for the construction industry (either very specific technologies or holistic approaches or concepts). The description explains the interaction of the technology with related stakeholders presents the beneficiaries of the technology and reveals changes in the value chain. The authors of the industry cases followed the following lead questions:

- Description of the technology in the context of the use case (application scenario)
- Interaction of stakeholders with the technology and impact on the value chain
- Beneficiaries of the technology
- Impact of the technology (Will it substitute some technologies, will the value chain change, will the business model of a company change?)
- Economic impact (if already measurable)

2.3 Visions

In an additional step visions from different roadmaps in the EeB area were analysed and consolidated. The EEBERS vision focus on the description of needed properties of a system but not of the system itself. The system itself should be described in detail using scenarios. The vision will help to set the target system for the future and thereby influence the recommendations of EEBERS toward the EC.

3. BUSINESS AND TECHNOLOGY TRENDS

This chapter presents the business and technology trends identified in the context of the EEBERS project.

3.1 Technology Trends

The figure below presents the EEBERS Technology Radar. 23 different technological solutions could be identified in the 5 technology fields. The closeness of the technological solutions to the centre is a measure for the technology readiness. The inner circle covers technological solutions from TRL 7-9, the middle circle from 4-6 and the outer one from 1-3. The different colours of the dots stand for the market potential of the technological solutions. It has to be emphasized that the identified technologies from EeB projects do not develop solutions with low market potential and that technologies are in general above TRL 4. 19 out of the 23 technologies have been assessed in the workshop. The remaining four technologies have been discussed and assessed by experts from Fraunhofer and VTT.

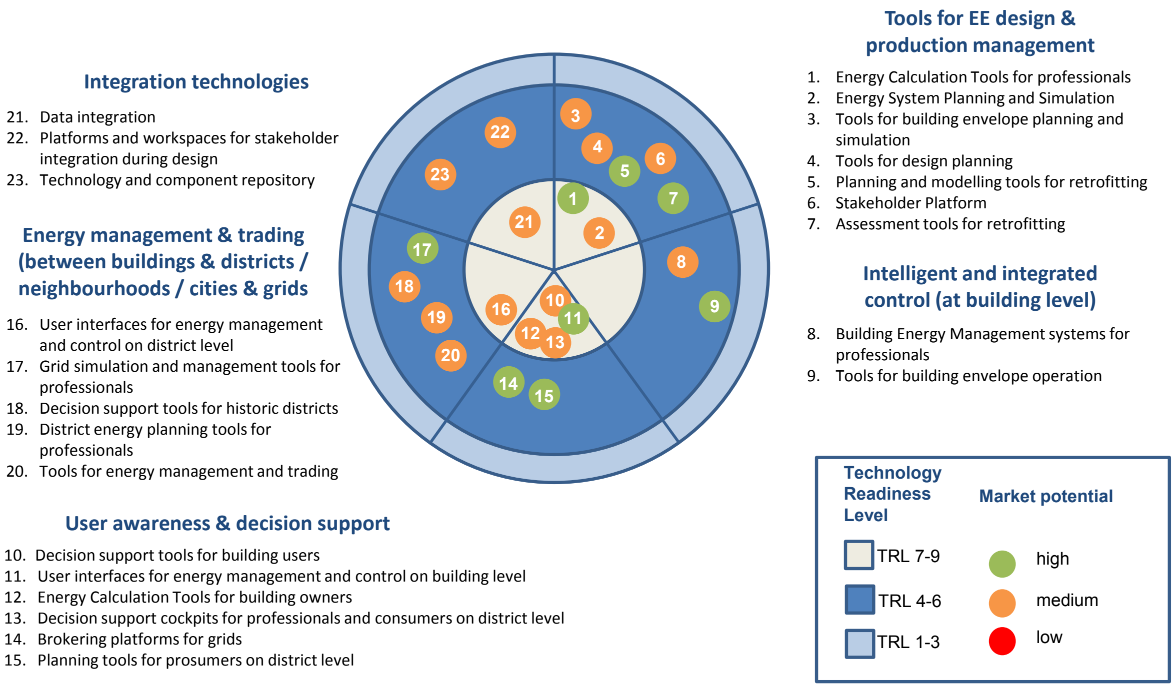


Figure 4 EEBERS Technology Radar

Detailed descriptions of the 23 technologies including the related projects have been presented already. However, the 23 technologies are additionally presented in the annex to ensure the completeness of this document.

The radar gives a very good overview concerning the readiness of each technology and the market potential. It has to be emphasized that only 2 technologies with TRL 7-9 were assessed with a high market potential and only 8 out of 23. The analysis reveals also that only the technology field integration technology has no technology with a high market potential. Leading technology fields concerning the assessed market potential of the currently developed solutions are the fields "Tools for EE design and production management" and "User awareness and decision support". However, it has to be mentioned that in the future development of the described technologies this might change. The table below summarizes the results.

Table 1 Technology fields and their market potential

Technology Fields	TRL 7-9 and market potential high	TRL 4-6 and market potential high
Tools for EE design & production management	1	2
Intelligent and integrated control	0	1
User awareness & decision support	1	2
Energy management & trading	0	1
Integration technologies	0	0

Additional and most important technology trends in the different technology fields were also collected in an expert discussion and summarized in the following section of this document. The figure below gives an overview on all trends. In each of the technology field important trends could be identified, even if the number differs from field to field. In the future all technologies that support implementation of BIM in the building lifecycle will be of high importance. BEMS will keep their importance in the construction industry and will be continuously improved and extended. Another focus is on solutions that address the interface between user and technical system. The integration of all different system, solutions and approaches will be realized by flexible and open software solutions and architectures.

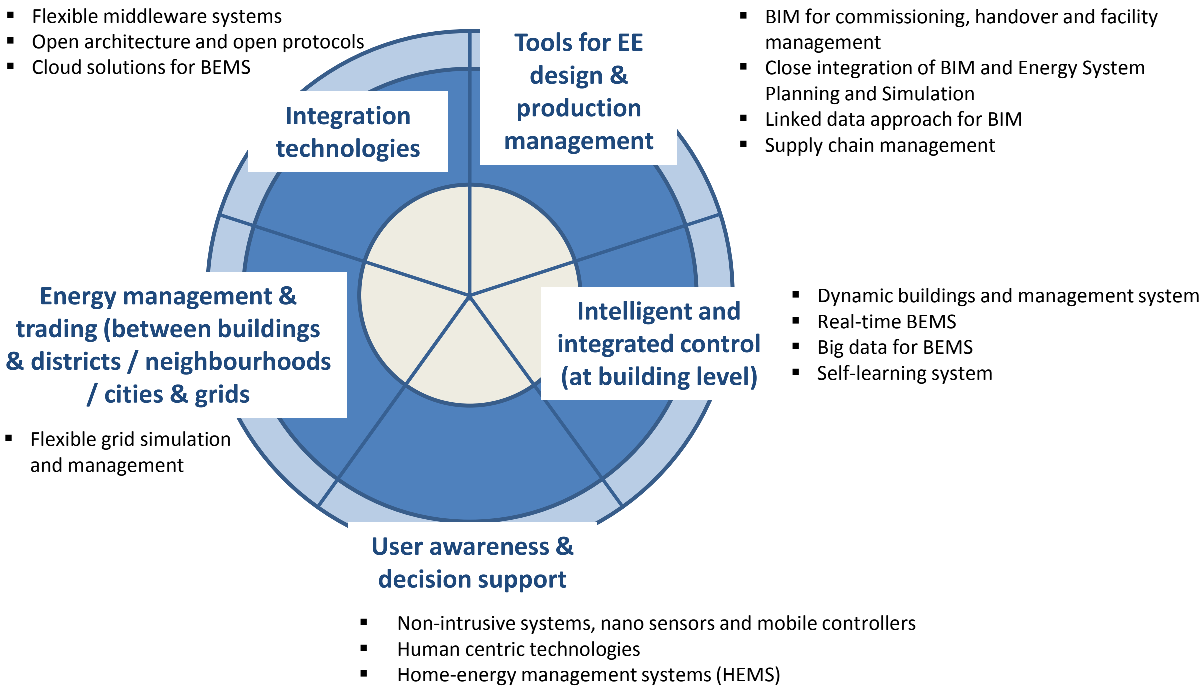


Figure 5 Technology Trends

3.1.1 Tools for EE design & production management

BIM for commissioning, handover and facility management

Clear requirements at the beginning of the project and the seamless use of BIM in the construction process will allow using BIM also in the late project stages. The BIM data used to design and construct the building can be further used in the commissioning, handover and use stage of the building. BIM will help to deliver a complete building handbook or will support the FM in the handover stage and help to reach the maximum performance of the building as well as to compare as-is with to-be status of the building. Important in this context is to ensure that as-build BIM model is handed over instead of the as-planned model and that the model is constantly updated. New business models that realize the update process are needed.

Close integration of BIM and Energy System Planning and Simulation

Good input data for energy simulation from BIM will be in the future an important factor for holistic and high-quality energy simulation. BIM allows consistency of the data during the whole building life-cycle but automation in the tool chain is needed to translate the BIM data into IFC or comparable formats that can be used by the established simulation tools. Another aspect related to simulation is the integration of user profiles into energy calculation on building but also on district level. Dynamic profiles that can be used in energy simulation allow an optimized operation of a building or district and at the same time ensures the user comfort.

Supply chain management

Complex buildings with high automation degree change also the value chain in the construction sector and increase the number of participants in the value chain. Better integration of the supply chain in all project stages is needed to constantly improve the magic triangle of quality, costs and time. In the future especially contract configuration tools that support all contract stages and provide workflows and collaboration environments will be of high interest.

Linked data approach for BIM

Distributed and modularized BIM models need an efficient and automated distribution and sharing management especially if models are shared beyond company borders and different views of the BIM model are needed by different stakeholders (e.g. owner/requirements model, engineer/structural model). The linked-data approach is a promising approach beyond comparing single models with each other or fusioning all models into one centralized main model. The linked data approach can be also used for further enhancement of a BIM model towards a web of data comprising various information about the building and the environment.

3.1.2 Intelligent and integrated control (at building level)

Big data for BEMS

Future BEMS will rely on different structured and unstructured data sources and a high number of data to optimize and operate buildings. The identification of usage patterns and the forecasting of energy usage are keys for success. The clear benefits are more efficient buildings, energy savings and the option to implement preventive maintenance approaches. Big data infrastructure that analyse these data has to be interconnected with the BEMS to ensure that the results of the analysis can be further used for decision making. One example in this context is an application for indoor positioning and location sensing of building users. The data are used to adapt the control strategies of the BEMS.

Self-learning system

Self-learning systems are systems that optimize themselves by controlling their actions and adapting according to the difference between as-is and to-be status. Self-learning systems can be used for improving building automation systems. Self-learning algorithms are needed for complex systems that are difficult to control with traditional rule-based systems. Self-learning systems are also able to adapt to different users and provide services (like providing a specific room temperature) in a quality the different users expect or prefer.

Dynamic buildings and management systems

The adaption of buildings towards the needs and comfort expectations of a user is gaining more importance. The ability of a building and its management system to act dynamic is already set during the design stage. Dynamic user profiles or more generic behaviour patterns are already needed in early planning stages to identify the optimal to-be configuration for the building. Especially non-residential buildings such as offices can benefit from this. Flexibility related to the comfort of individual users creates high acceptance for BEMS. An additional lever to optimize the energy consumption is the consideration of usage profiles from infrastructure such as meeting rooms or elevators.

Real-time BEMS

Realisation of real-time BEMS needs advances in controller technology, software solutions and especially algorithms for real-time decision making and continuous access to data from (cloud) infrastructure. To enable this type of decision-making mechanisms data from the building (sensor data) but also information from the building's environment is necessary. In the nearer future real-time performance measurement will be used in public-buildings, educational buildings or commercial buildings.

3.1.3 User awareness & decision support

Non-intrusive systems, nano sensors and mobile controllers

The next generation HMI for building automation and energy management will be supported by mobile devices or non-intrusive sensors instead of traditional manual switches. The new systems will need a control systems and related hardware and HMI to provide this functionality. Another trend will be the minimization of devices. Nano sensors are expected to be used in a first step in public places, shopping malls and office buildings.

Human centric technologies

Human-centric technology and approaches means designing buildings around people. The main objective is to ensure that the requirements of the building users have priority and building design, functions and systems of the building are selected in accordance to the requirements of the future user. Furthermore, of high importance in this context are devices and systems for the HMI. It has to be ensured that, if needed, the user can interact with all the technical systems in the building.

Home-energy management systems (HEMS)

Important for integration of tenants and building users is a timely and meaningful feedback. Inhome displays can successfully support this process and furthermore can path the way for fully-integrated HEMS and the European-wide roll-out of smart meters. The interface is very important since a lot of earlier approaches were only successful in the first weeks.

3.1.4 Energy management and trading

Flexible grid simulation and management

The next step after applying flexibility assessments and measures is to move from general dimensioning of the system to real-time management. Especially systems with a high share of renewables need flexibility in grid management to balance demand and supply and to react on the system's volatility. One important aspect to ensure and enhance system flexibility is to enable simulation-based real-time management and decision-making.

3.1.5 Integration Technologies

Flexible middleware systems

System operability is an important issue due to the rising complexity of the energy systems in the buildings and the rising number of stakeholders that interact with the building or collaborate with each other during the building lifecycle. Interoperability is related to two aspects: On the one hand the building equipped with different hard- and software systems and the neighbourhood. One the other hand the construction process itself. The evolution is pushed on by regulations but also by big contractors striving to introduce seamless process during design and construction stage. However, SMEs are often not able to adapt to these software landscapes for construction projects due to the high initial and maintenance costs. In both cases flexible middleware systems that connect the different systems with each other and use services to integrate and analyse data will become important.

<u>Open architecture and open protocols</u>

Due to the fact that the lifetime of the whole building, and building components vary massively and some components will be used for decades whereas others will be replaced every few years open architectures and open protocols are needed that allow to interconnect all systems independent of their origin and age. Only if all relevant data can be accessed, analysed and compared decision making will be integrated and local-optima will be replaced by global ones.

<u>Cloud solutions for BEMS</u>

Databases or software systems that offer cloud based services will enable companies, facility managers but also private owners to focus on their core business (related to energy-efficiency) and benefit from economy of scales by using service providers for data provision and handling.

3.2 Business Trends

The different trends are summarized in the illustration below. They could be extracted from different studies and publications that were recently published. The business trends are structured according to the segments of the STEEP method. The STEEP analysis is an approach commonly used in business analytics to determine external factors that impact an organisation. In the context of EEBERS the external factors impact a whole industry sector and not only an organisation.

STEEP means Society, Technology, Economy, Environment, Politics.

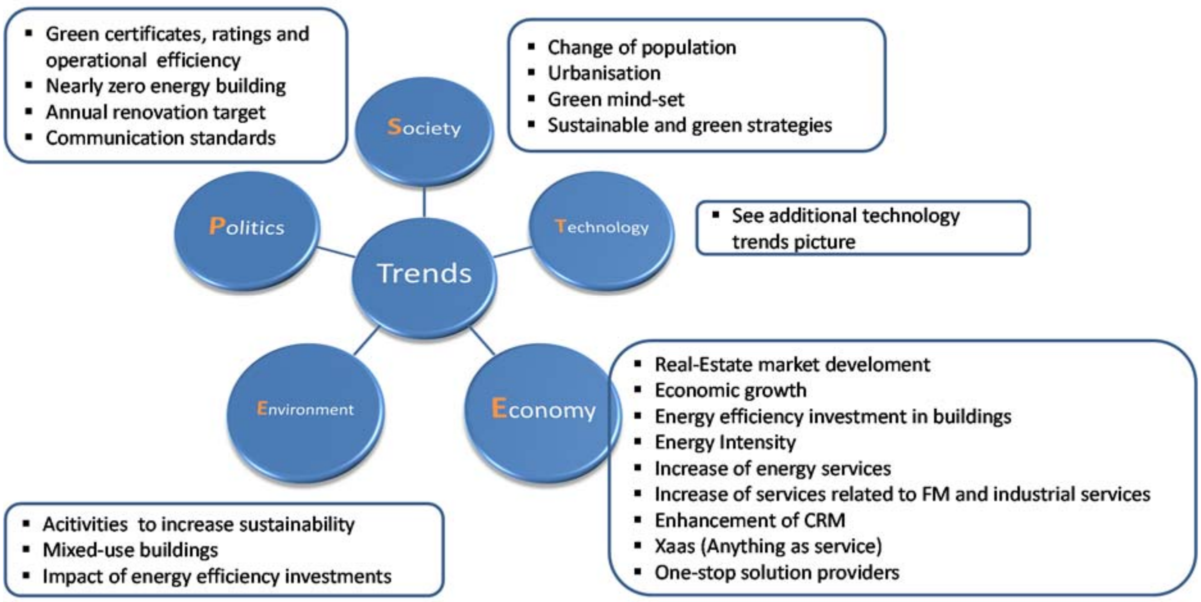


Figure 6 Business Trends

3.2.2 Society

Change of population (demographic change and migration)

The change of the population in Europe fosters changes in the real estate sector. Increasing importance are gaining buildings such as healthcare, serviced apartments or retirement homes (Laidlaw et al. 2014). The refugees from the middle-east requiring accommodation will also impact type and comfort standard of buildings that are renovated or built in urban areas (especially in Germany) (Morrison et al. 2016).

Urbanisation

The young generation prefers to life in social hubs or places with a good connection to the public transport within the urban core. The importance of student housing is increasing (Laidlaw et al. 2014). Investors emphasize that in the future investments are no longer made in countries but in urban areas and in the next years especially residential buildings and student accommodations will be in the focus of investors (Morrison et al. 2016).

Green mind-set

Green mind-set gains more importance. There is the will to pay higher rents for sustainable buildings and some large occupiers already react and establish minimum standards for buildings they would like to occupy. Also on the investor side the availability of efficiency rating and certificates will become mandatory in the future (Laidlaw et al. 2014).

Sustainable and green strategies

Investment in sustainable and green buildings is attractive and helps investors to realize profits. Tenants could be found easily for the buildings (Laidlaw et al. 2014, Schober et al. 2011).

3.2.3 Economy

Real-Estate market development

The market is still growing and the prices are increasing. However, there is still the risk that the market will overheat. Especially in some attractive urban areas the prices are going up too fast (Laidlaw et al. 2014).

Economic growth

The revenue generated from BEMS and HEMS is very high and will remain high during the next years. Other technologies such as BAS and AMI have also still a stable growth and will support the growth of BEMS and HEMS (Frost&Sullivan 2015, Ozimek&Fae 2012, Bryant et al. 2015).

Energy efficiency investment in buildings

Investments in energy efficiency will increase in the next years (Bryant et al. 2015)

Energy Intensity

OECD countries have successfully decoupled economic growth and energy consumption growth (Bryant et al. 2015)

Increase of energy services

Services related to energy (e.g. energy contracting, performance contracting) in the construction industry are gaining more importance. Due to the progress in technology and especially BEMS FM companies and large suppliers for building automation are changing their business model and increasing their service offerings. Building automation and related ICT is an enabler for this. Smaller companies are using partnerships with others to serve the market with holistic service offerings. (Frost&Sullivan 2013, Irrek et al. 2013)

Increase of services related to FM and industrial services

Activities related to FM and industrial services (maintenance, repair and optimization of production systems, technical cleaning, in-house logistics) are gaining constantly more importance (Schober et al. 2011).

Enhancement of CRM

Due to the increasing amount of data and the progress in the data analysis business services and business models can be much more targeted and tailored in the future. Customers can be addressed individually based on their preferences and user profiles (Ozimek&Fae 2012).

Xaas (Anything as a service)

The next stage after IaaS, PaaS and SaaS is XaaS which means delivering of anything or everything as a service. For customers this means a pay-as-you-go business model or charging model. This service offering is fostered by the technological progress in the cloud computing area and big data / deployment of data analysis services. IT-Services can be delivered in all life-cycle stages of the building.

One-stop solution providers

One stop solution provider supporting all stages of a building from design to EOL eliminates all interfaces and ensures a seamless process. This business model fosters the development of platforms and software systems that interconnect all lifecycle stages and the data used and produced in the different stages. Partnerships can enable also smaller market players to realize and offer holistic solutions.

3.2.4 Environment

Activities to increase sustainability

Increase of sustainability requires a broad interdisciplinary expert knowhow by the facility manager. Most important levers to increase it are the integration of efficient building technologies and improvement of the insulation. BMS are only a supplement (Henzelmann et al. 2010).

Mixed-use buildings

In line with the trend of urbanisation is the establishment of mixed-use environments to provide integrated working, living and leisure environments to people. The young generation strives to reduce their travel efforts and therefore is seeking for quarters or environments that offer all in one. During the day the work environment and child care facilities, in the afternoon shopping options, restaurants and bars and during the night their own apartment for sleeping (Morrison et al. 2016).

Impact of energy efficiency investments

Several saving strategies helped to avoid additional GHG emissions and CO2 emissions and helped to flatten consumption of electrical energy in the last years. Reduction of energy consumption in buildings is one of the reasons for the success (Bryant et al. 2015)

3.2.5 Policies, Regulations and Standards

Green certificates, ratings and operational efficiency

Certificates or green ratings, etc will become mandatory in the future for buildings (Frost&Sullivan 2015). Beyond certificates (sometimes ensuring positive footprints from cradle to cradle) operational performance and the rating of the performance will become more important. This will take place not only on building level but more and more on district or city level (Laidlaw et al. 2014)

Nearly zero energy building

European Union's Energy Performance of Buildings Directive (EPBD) mandates that all new buildings are nearly zero-energy buildings (nZEB) by end of 2020 (Frost&Sullivan 2015).

Annual renovation target

The annual renovation target owned and occupied by the central government is 3% (Gynther et al. 2015)

Communication standards

ZigBEE, WiFi or Bluetooth are only some examples of communication standards that are used for energy management. Standards are needed for the physical layer, transport layer and application layer. The interoperability between different standards and solutions will be ensured by open interfaces and gateways (Ozimek et al. 2015).

4. Exemplary Industry Cases

This chapter gives insight into 7 exemplary industry cases showing (potential) application cases for certain technologies. The ideas of this chapter was to show best practice application cases for the different technologies. However, due to the development stage of each technology the best practices cases are sometimes very hard to identify or assess due to missing experience with the technology or low diffusion degree of the technologies.

The following illustration summarizes the cases described in this chapter and assigns the different technologies to the respective technology field of the EEBERS taxonomy.

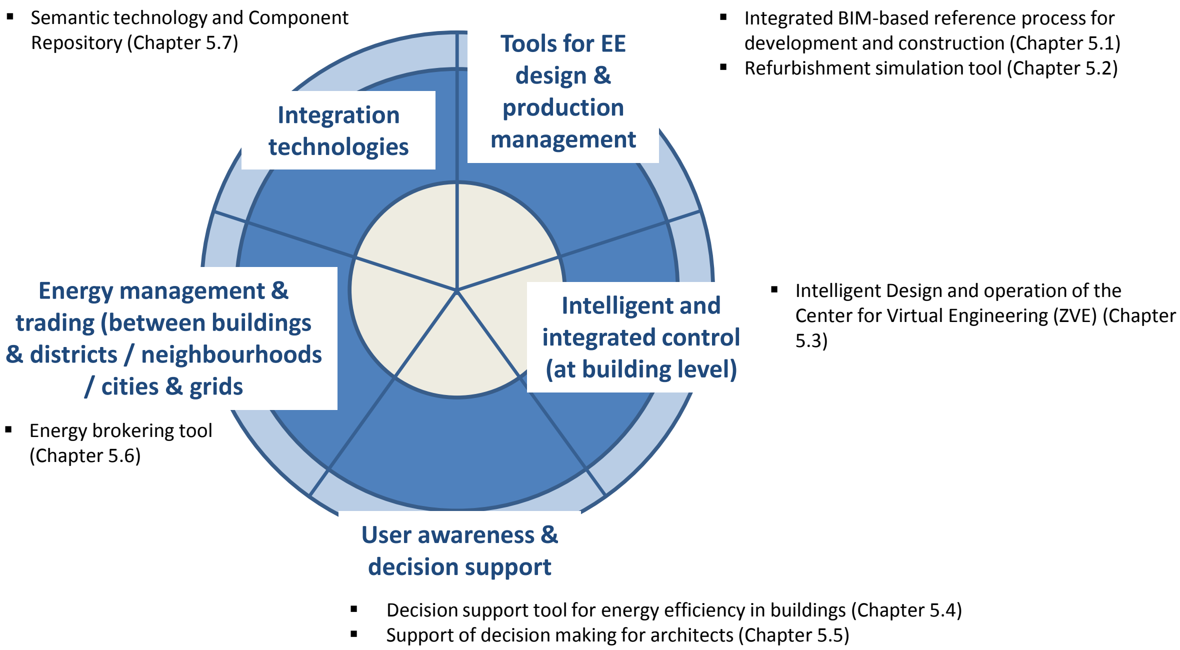


Figure 7 Exemplary Industry Cases

4.1 Integrated BIM-based reference process for development and construction

The basic idea of this industry case is a seamless BIM-supported process. Prerequisite for this is the availability of a reference process with one additional swim lane for all activities related to BIM. The focus is on the availability of different models (architectural models and expert model of the different (trade) planers) for different use cases and stages in the construction process. The activities in the BIM-related swim lane are synchronised with the project plan for construction projects and cover several (BIM-related) aspects that can be divided into aspects related to data exchange, related to the process itself and general services. For instance, roles and responsibilities are determined and synchronisation points for data, related data formats and models as well as strategies for data exchange are defined. Content-wise BIM-related process steps covers aspects such as BIM data provision, processing, verification but also the updating of the BIM execution plan. All activities are coordinated by the so-called BIM manager. One key to success is that the models are open and the different information that is created in the construction process can be reused in the subsequent steps or extended. The model accuracy is increased during the life-cycle from first sketches in the concept stage until validated and approved 3D models (considering already available life-cycle data) in the design review process. Currently IFC, IDF and gbXML are the common data formats that are used in the BIM context. The different models cover aspects such as statics, technical equipment, architecture, assembly, but also energy-related aspects. In addition, they are embedded in workflows and sometimes assigned with a timeline. The technical documentation is connected to the different models and building components. Together with the overall project documentation all information is available from one source.

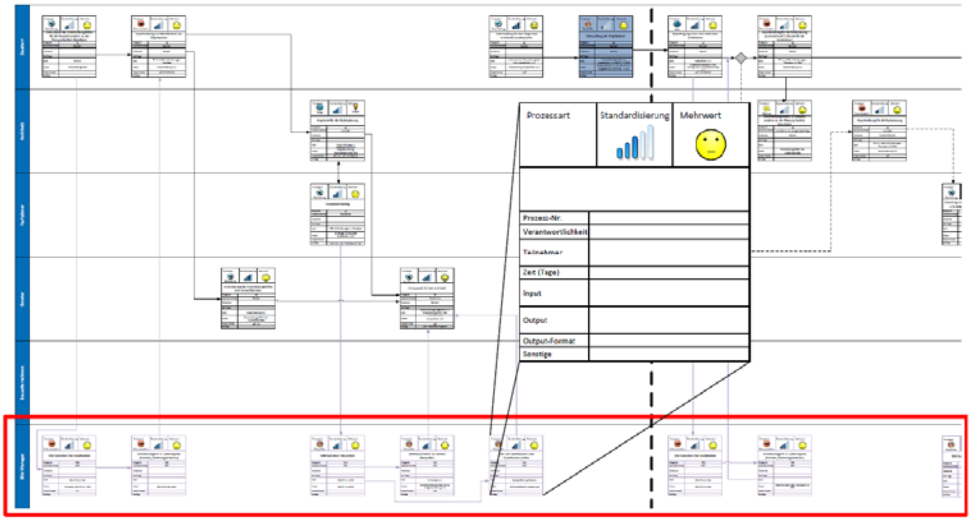


Figure 8 BIM Process (Liebich 2014)

To guarantee full use of the seamlessly integrated process a software environment supporting the whole process, proving a single-entry point for project managers and linking different solutions is the counterpart of the BIM process. An appropriate IT solution covers three different layers: the user interface, the service layer and the data layer and integrates different solutions such as CAD, simulation, decision support tools, technology and component libraries, project management tools, tools for requirements engineering or for quality management. Pioneer in this area are industry sectors such as automotive or machinery and plant industry that apply today middleware systems that process data from different sources. These flexible middleware systems allow avoiding highly integrated (and large) software solutions and avoiding direct interfaces between proprietary systems (e.g. Orchestra, orchestra.soffico.de or ARAS, http://www.aras.com). Motivation to synchronize the BIM process with a holistic system landscape are on the one hand very pragmatic reasons such as single entry point for all stakeholders or common database but on the other hand also the need to foster data exchange and synchronisation of the different partial models in order to gain full impact of BIM.

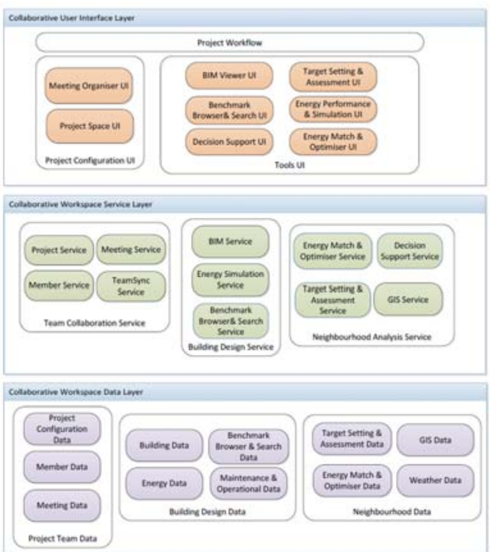


Figure 9 Software Landscape (Design4Energy Project)

Typical use cases for such integrated software landscapes are for instance: setting the target level, consideration of energy issues at early design stage, energy matching at early design stages, different activities in the detailed design stage, integrated collaborative design review, requirements for maintenance/retrofit, retrofit/maintenance modelling. A software landscape for this range of activities is presented in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

4.2 Refurbishment simulation tool

This exemplary industry case is related to a EE design & production management toolset assessing various refurbishment measures into the office or residential buildings.

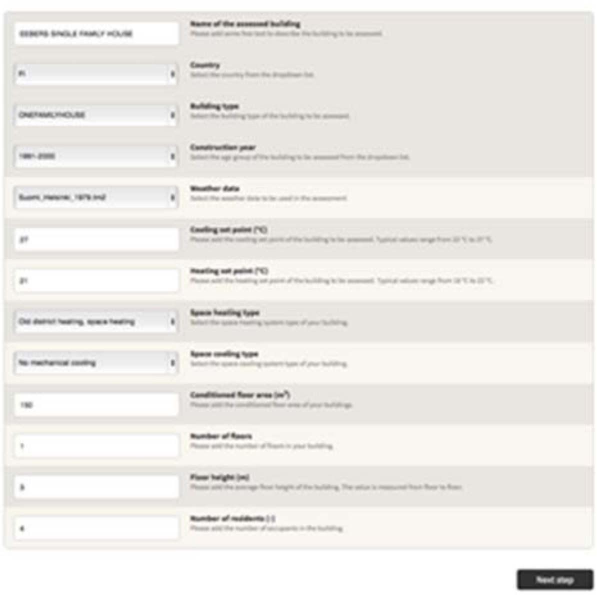
Energy performance assessment tool E-PASS was developed for the use of small companies in refurbishment projects.

The database of E-PASS includes data about building stock, refurbishment methods, life cycle cost and greenhouse gas emissions. At present, the Finnish database is available. However, E-PASS application can be localised by providing the local information with an Excel template.

The tool calculates energy consumption (for space heating and hot water, space cooling and appliance electricity), greenhouse gas emissions and life cycle costs. All included data is based on information collected by VTT within a series of European and Nordic research projects. The costs of refurbishment methods cover investment and annual energy costs. The assessment method is based on (ISO 15686-5 2008) (life cycle costing).

The user is supported to configure the modelled building easily in its "as is"-state and quickly apply a set of selected refurbishment measures to the "after"-state. The key performance indicators (kWh/m2, kgCO2/m2, operational costs, payback time) and the impact of the selected measures can be viewed in the same interface.

The first two figures shows the first input page with “single family house” selections and the energy use. The next two figures show the refurbishment selection and the Assessment of results before and after measures with E-PASS.



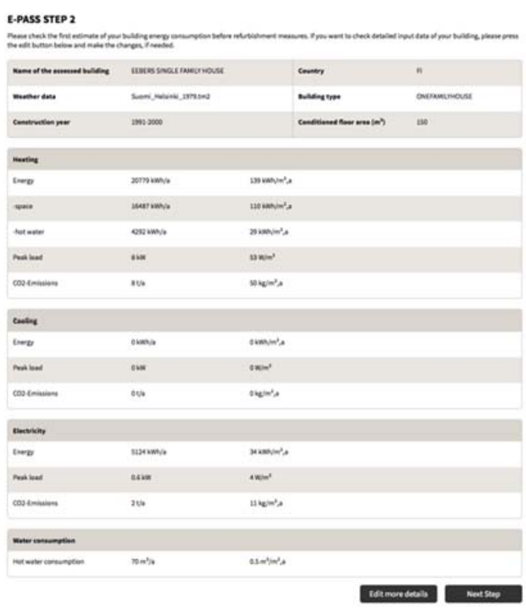


Figure 10 E-Pass Example house input selections

Figure 11 Energy use calculation

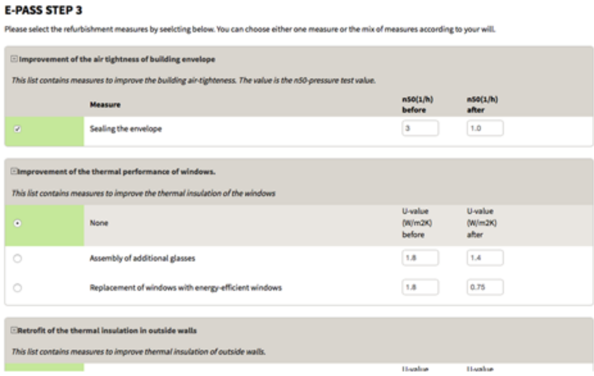


Figure 12 Selection of the sealing the envelope as refurbishment

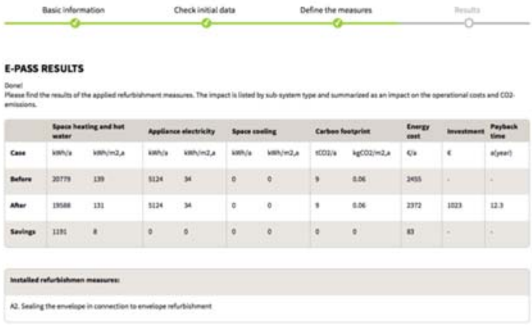


Figure 13 Assessment of results before and after measures with E-PASS

4.3 Intelligent Design and operation of the Center for Virtual Engineering (ZVE)

This industry case is a best-practise example for seamless integration of planning stage, construction stage and building operation and the role of simulation and virtual reality environments in this context.

The office and lab spaces in the ZVE are spread over four floors around an open atrium. This attractive vertical axis with carefully positioned connecting stairways closely interlinks workspaces located on different floors, greatly reducing the vertical barriers to communication that often exist in conventional building designs

Consequently, the ZVE does not strictly separate laboratory from office space. The primary domains of knowledge work - laboratory, office and group discussion– are spatially interlinked.

The energy concept for the site is a geothermal plant with several 170-meter-long probes that extract renewable energy from the earth's interior. The plant is complemented by heat exchangers and thermally activated ceilings for cooling and base load heating. Alongside water-filled pipes, the ceilings also contain air-filled plastic spheres. Less concrete is required to build these hollow block ceilings, reducing the static load and allowing the ceiling to span greater distances without further obstructive supports. The building received the DGNB (German Sustainable Building Council) certificate in platinum for its sustainability.

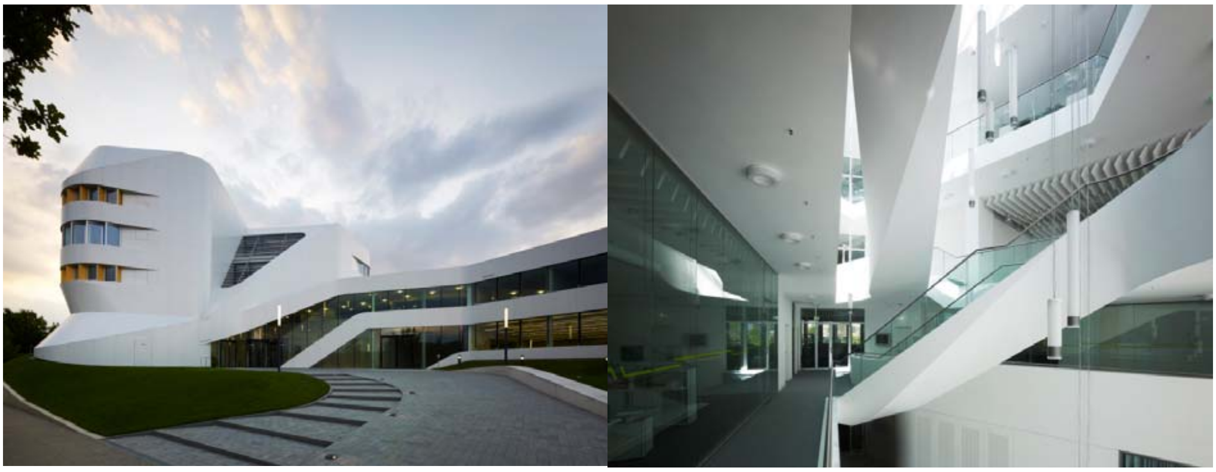


Figure 14 ZVE (Photos: Christian Richters, © Fraunhofer IAO, UNStudio, ASPLAN)

Fraunhofer IAO poured its scientific know-how in the fields of virtual engineering and workspace innovation into every aspect of the design and creation of its Center for Virtual Engineering ZVE. Combining a digitized planning and construction process with 3D visualization in virtual reality means that complex building structures could be parameterized, and the planning of alternate variants was made simpler. The use of virtual reality also enabled building components to be manufactured with semi-automated systems.

During the planning of the ZVE it was also possible to analyze simulations of acoustic, thermal, and lighting conditions based on 3D models. The results were then factored into further steps in the planning process. This meant that planning errors could be largely avoided.

The innovative building automation system also controls heating and cooling, air ventilation, and light. The tank for the sprinkler system is used to store waste heat energy coming from the building, for example from the computer rooms or the high-performance projectors in the virtual reality laboratories.

An energy measurement and monitoring system analyzes how effective these various measures are. The users are still able to control heating, windows and blinds in their rooms. The large meeting rooms and labs are controlled by means of touch panels. The BAS components are connected via their own network. A software interface enables the access to the BAS and is used to monitor and control the system.

The described approached allowed a perfect collaboration between owner, users and planners of the building. The operation of the building shows that used energy is even lower than originally expected. The new building operates nearly decoupled from the heating network of the University of Stuttgart (Originally it was planned that the network supports the geothermal plant).

4.4 Decision support tool for energy efficiency in buildings

This exemplary industry case is related to a decision support toolset providing energy efficiency and carbon reduction alternatives and solutions for different building typologies. This toolset is an innovative web based decision-support application allowing users to understand and visualise energy efficiency measures applicable to their building, with solutions aligned to optimise business information models across the whole life of the building.

It aims towards the improvement of buildings renovation rate, by making it easier for stakeholders to reach the right decision about renovation i.e. which materials, which business model, ease of interaction and sharing ideas between the design team and stakeholders, best practice – all integrated into a single online renovation portal. The toolset breaks the barriers to energy efficiency by allowing the latest technologies to be integrated easily into the system and showing its true value in the context of stakeholders design plans. It is suitable for every type of building – whether it is a residential house or apartment, a commercial office building or a shopping mall.

This decision support solution engages a range of stakeholders in the identification of suitable energy efficiency business models, and provides them with the necessary tools to create new high performance buildings and retrofit existing ones. The way the toolset is designed, allows every stakeholder to benefit from its features, regardless of their knowledge or experience in the building sector. It provides information with respect to buildings energy consumption and methods for implementation and incentive schemes for the solutions, benefiting from it all stakeholders involved.

Figure 15: Example of decision support tool from the Umbrella project (screenshots)

One of the main characteristics of the toolset is that it provides independent evaluation and decision tools built around adaptable business models. The business models are connected to the it via an online dynamic web portal. This generates and recommends different business model alternatives, while ensuring ease of access to information and enabling interaction and communication amongst the stakeholders based on current internet technologies. The main stakeholders that this kind of solution is oriented to are building owners, building occupants, management companies or public authorities among others.

This toolset provides the capabilities to examine a building at any stage of its life. With the information provided, stakeholders with a specific budget and expectations for performance and aesthetics can understand the different trade-offs between material costs, labour costs, ROI, lifespan expectancy, energy performance, operating costs, end of life costs, etc.

A wide use of such a solution by the stakeholders mentioned, is calculated to potentially be translated in an increase in the market share of energy efficient solutions of 15% within the next 5 years, resulting in carbon reductions over 3.096 Mtoe per year.

4.5 Support of decision making for architects

The decision making process being developed for architects and other stakeholders focuses on using building simulation to predict the effectiveness of various retrofit or maintenance measures (options). Decision support tools have been key in the provision of smartness of many design platforms for building practitioners, the system architecture in question here is the main engine of a software platform for architects.

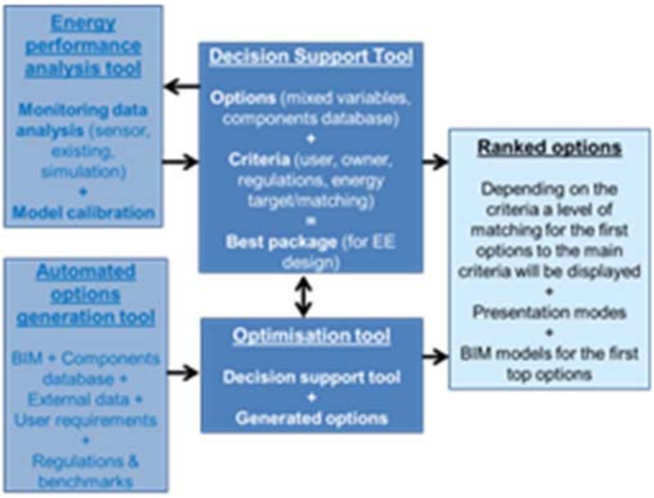


Figure 16 System architecture for decision making process

The decision support tool relies primarily on adequate definition and creation of databases of components, parameters and indicators to automatically generate all possible retrofit or maintenance options. A set of databases are developed for the decision support tool, this development includes identification of the requirements for IT systems, components, energy systems and, materials. Identification of databases' characteristics using focus groups of potential users (architects, energy designers and FM) and finally tuned to suite the type of decision support tool being developed.

At the heart of the decision support tool is Multiple Criteria Decision Making (MCDM) engine which, integrates multiple indicators into a single meaningful index to allow ranking and comparing options for decision making, see figure below (Fouchal, 2015). It is an efficient statistical method to combine component indices arising from all the information sources into a single overall meaningful index, therefore ranking and comparing are feasible. MCDM has the ability to weight different alternatives and make judgement on various criteria for possible selection of the best/suitable alternative(s). Analytic Hierarchy Process (AHP) method as proposed by Saaty (Saaty 1994) that is based on priority theory decomposes a complex multi-dimensional decision making problem into a system of hierarchies. It uses the relative importance of the alternatives in terms of each criterion. The AHP has the ability to logically incorporate data and expert's judgement in the model for measurement and prioritising intangibles. As a complex and unstructured situation is broken down, its components are arranged into a hierarchic order including criteria and alternatives.

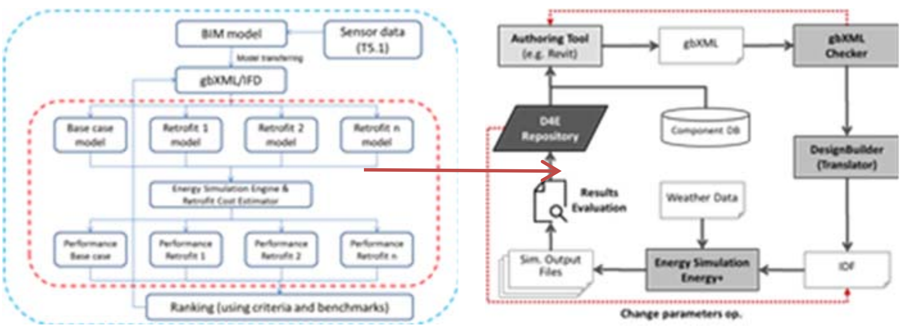


Figure 17 Decision Support process and tool for energy efficient buildings

The design platform is distinguished by the workflow, speed and quality, facilitating different teams and stakeholders contribution being integrated, and enabling rapid feedback on energy performance. Most of this is driven through a decision support tool that is capable to produce an optimised decision from a set of specific data being introduced into it.

Adequate tools and databases are pre-set to calculate the criteria and generate the alternatives (options). Component catalogues relational databases are accessible through internet protocols. Some databases are designed and constructed to enable the activities on the platform including the decision making process, while the readily available databases will also be made accessible. For example the Building Component Library (BCL) by NREL provides searchable information about EE related technologies and a list of measures to meet energetic issues. The included information can represent physical characteristics of buildings such as windows, walls, and doors, or can refer to related operational information such as occupancy, equipment schedules and weather information. Each measure and energy system can be downloaded as a XML, RB and OSM file describing these component. Data Repository ISES is another cloud-based data repository. It contains information such as climate data or stochastic templates but most interestingly energy product and material catalogues containing energy properties of products and materials (ISES D4.1, 2014) The library uses the PLIB ontology model (based on ISO 13584). All information is saved in the ifc file format (ISES D4.3, 2014). The MagiCAD Product Database is a product catalogue or database that contains over one million products from over hundred manufacturers. A designer can choose components through a plugin directly via the CAD-tool interface. This interface is connected to a plugin on the manufacturers' site (MagiCAD, 2014).

Building performance management has impact on several stakeholders; mostly the largest benefits are gained by the building owner. Their desires in terms of comfort and cost will be matched within the most optimised energy solution in the maintenance or retrofit of their buildings. They will have access to follow the progress of the solution being designed for them during which they have their say. Architects will benefit from the platform, tools and databases too. They will be empowered to conduct a more detailed energy performance analysis for quick comparative investigation of the possible design option they may think off during their design process. Access to databases will allow them to download energy systems to be embedded in their design and quickly evaluate their designs from EE point of view or other aspects such as comfort, cost or aesthetic. Facility managers will be able to quickly quantify the extent of the energy mismatch of the building versus benchmark values. They will be in position to make an estimate of the energy mismatch with less effort and time. Building services engineers and heating system engineers will be equipped with more power to quickly test and evaluate a larger number of options to approach the delivery of the clients request with less effort and cost. They will compress their intervention time too, by continuously bouncing different solutions with the architects, FM and building owners.

4.6 Energy brokering tool

This exemplary industry case is related to a user empowerment & decision support toolset providing energy information about consumption and local production (including renewable) and CO_2 emissions and acting as a brokering platform where tenants have the chance to directly buy energy contracting with the housing company or the energy supply company.

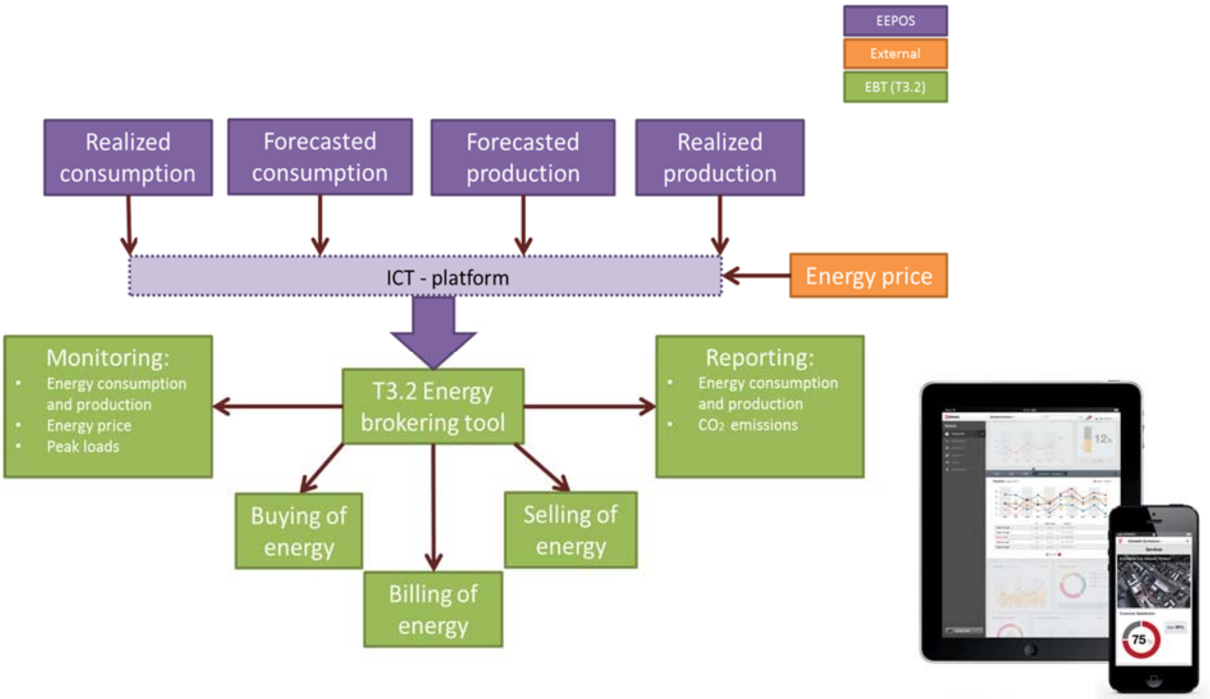


Figure 18: Flow operating diagram of the energy brokering tool

Using the energy brokering tool (EBT), operators can participate in energy trading on external energy markets on behalf of the members of the neighbourhood. It consists of different modules: Energy consumption, energy production, energy brokering and main module, which hosts all the aforementioned modules and acts as the visual interface.

The key function of the energy brokering tool is the anticipation of electricity sales and purchasing activities. Actual cost calculations, sales and purchasing of energy are carried out according to current consumption and forecast values.

The toolset have been demonstrated, in new high-quality blocks of flats, consisting of 7 apartment buildings accounting for about 240 apartments and located in Merenkulkijanranta. Lauttasaari, Helsinki.

Processing past, live and forecasted data of buildings energy consumption and local energy production the toolset inspects whether it is profitable to buy energy from the grid or sell it to the grid. When there is surplus of production capacity available energy brokering has been handled within a larger scale. Therefore, group of buildings has been targeted, however neighbourhood level or also grid level, depending if grid operators allows feeding energy to the grid, can be considered. Energy brokering tool provides user-friendly user interface (UI) for monitoring consumption, production and energy price, reporting and monitoring d report CO_2-emissions. Different UI have been created for each stakeholder’s use.

4.7 Semantic Technology and Component Data Base

This exemplary industry case gives insight into the application of semantic media wikis in the context of technology monitoring. Technology monitoring is a collaborative approach integrating different information sources and stakeholders supported by software systems.

The technology wiki can be used for the communication between expert and layman. Especially in early stages of a construction or retrofitting project the wiki can support the decision making concerning the future technologies used in the building. Advantages, functional descriptions or application examples could help the expert to direct the layman into a certain direction and the layman can ensure that his decision is based on a good information basis. Transparency and trust between principal and agent from the early beginning of the project is fostered. In addition to the technology itself, a wiki can provide best-practise solution on system level. For instance the semantics can help to find the best performing combinations for an HVAC system considering the latest technologies and products on the market and considering regional conditions and restrictions. In the operation stage the building owner can use the wiki to plan retrofitting activities, to find substitutes for existing equipment or can benefit from care and maintenance manuals that are provided by the wiki.

In another context, the technology database in a technical view can be an interface between engineers on the one side and technology providers on the other side. This database in a conceptual view is a support for engineers to identify and adapt new technologies and therefor overcome the challenges of the industry to gather technological competence and reach higher performances in energy efficient buildings. The database is a searchable content management system for text, files and links. It contains information useful for engineers to make decisions regarding the feasibility, applicability, and appropriateness of energy systems. An application layer on the database is used to sort the technology information and provide it in a structured way. The technology descriptions can be extended by a component catalogue. Components saved as three-dimensional, parametric CAD files are provided to directly integrate the suppliers' products into the building sketches. Engineers should not only be able to integrate the components into the sketches but rather evaluate them and make decision based on component attributes.

Beyond the two described application stages the wiki can be hosted and updated by an association to provide information on latest developments to experts. Especially small SMEs that are not able to finance technology scouting activities by their own can benefit from a wiki rhat is open and free accessible for all. A news function can be used to inform about latest technologies or developments. A technology radar that is connected to some semantic information in the wiki will help these companies to observe the market. The expert group that is adressed by the association for assessment of the technologies ensures that the information basis has a high-quality, presents all relevant state-of-the-art technologies and gives insight into future technologies.

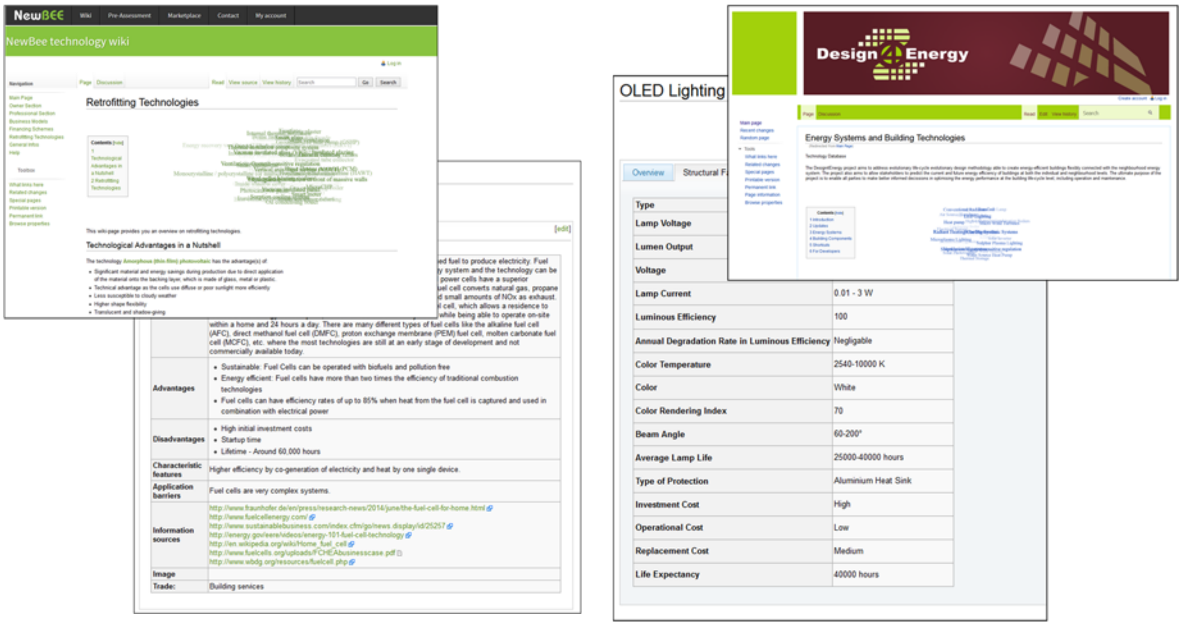


Figure 19 Examples of two technology wikis (screenshots)

In general, this software-supported approach of knowledge provision and distribution enables to streamline the value chain. Information are easily accessible for all relevant stakeholders, discussions are based on the same information level and it is ensured that decisions are based on a high-quality data base. Building owners, contractors and component suppliers can benefit from this; the technology wiki is part of a strong fundament for a reliable business relationship.

5. VISION

The vision for EeB presented in this deliverable is based on the expert discussion of the EEBERS workshop in Munich (January 2016) and some visions described in different roadmaps that were developed in the last years. The following roadmaps were considered:

- CIB Smart City Vision (draft version)
- Ready4SmartCities (Vision of Energy Systems for Smart Cities)
- E2BA/EeB Vision
- ICT4E2B Forum Vision
- REViSITE Vision

Visions that have been formulated in the last years describe the city or building of the future as dynamic ecosystem. ICT is an enabler for realisation of such advanced ecosystems. Joint activities of research, municipalities, companies and citizens are leading towards integrated, sustainable and energy-efficient living and working environments considering mobility needs, expected quality of life and the wellbeing of the users.

ICT is the enabler for the municipality to manage and control different parameters of the city (e.g. energy consumption) accordingly and to plan and design infrastructure and buildings for the city of the future. Owners, tenants and users benefit from ICT and manage their own space, actively participate in the energy market and get the support needed for decisions-making. The crucial aspect in this context is the HMI connecting prosumers and operational system and the incentive systems that motivate to exploit the full saving potential. If successful, positive energy buildings and CO^2 neutral districts will dominate our townscape in the future.

Both, smart buildings and smart energy systems need ICT in all life-cycle stages from the early concept until end-of-life stage. Some key aspects of the vision that are described more in detail in the following are illustrated below. An overall concept and steering mechanisms in the below described system also supported by ICT that helps to plan, control and interconnect the different elements of the ecosystem and allow all subsystems and stakeholders to collaborate and communicate seamlessly.

The ecosystem in the case of EEBERS covers the single building but also its neighbourhood up to city level. In general the below described properties belong to all single entity of a system and also across hierarchical levels (e.g. building vs. neighbourhood).

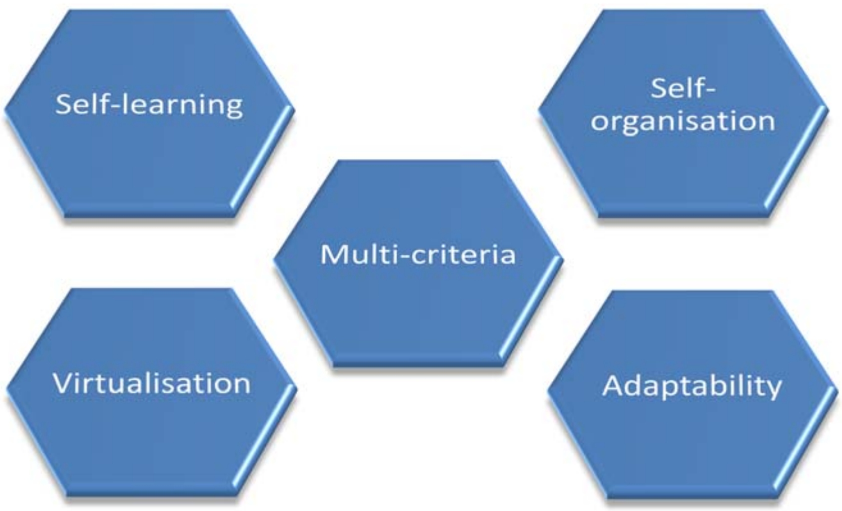


Figure 20 Core aspects of EeB visions

A key requirement to realize future ecosystems is the adaptability within the system. Adaptability of a building refers to the ability of the building to adapt without effort to certain needs or situations in real-time. The building is able to react to its users and change its properties. This can be for instance the colour but also change of the room size (due to moving walls) or change of components (e.g. smart glasses to adapt to the expected room brightness of the current user).

Self-learning and self-adapting systems are needed for this during operation but also in the design stage. However, to prevent complexity re-usable solutions and standards (for components, processes and ICT) that can be flexible customized and fast adapted are necessary.

Another key aspect of future solutions is related to the various requirements from different stakeholders and factors that influence building operation. Mastering them can be equated with working with multi-criteria frameworks. Multi-criteria as general aspect in the construction industry and especially in building configuration, decision making or building operation and optimization. Some examples multi-criteria frameworks are used for are building simulation, assessment of buildings but also development and refinement of e.g. control strategy. The idea is to sustain decisions on a broad information and data basis and in parallel use methods (e.g. semantics) and frameworks that can incorporate different information types and qualities, if needed, in real-time.

Virtualisation will appear in different manifestations in all life-cycle stages of a building. Virtual prototypes to test and visualize, augmented reality approaches to integrate stakeholders in design an operation, virtual plants will dominate the energy systems of the future, virtual sensor networks will help to control buildings and neighbourhoods, virtual enterprises can be found in various value chain related to any building life-cycle. All of them have in common that ICT is needed to realize the mentioned systems with its functions. Some of this systems will be also virtualized and even beyond rely on cloud-bases solutions.

Decentralised, agent-based systems with self-organising and self-diagnostic capability will become more important. Solutions that ensure improvement of energy-efficiency on district and city level and predictive control, early detection of malfunctions and performance oriented business models as well as systems that are able to support preventive maintenance service will be available.

6. Conclusions

This chapter gives an overview on achievements and their relation to the follow-up activities in EEBERS.

6.1 Summary of achievements

This deliverable mainly consolidated technological trend and business trend in the EeB sector. The research work shows that a lot of promising technologies are current under development. Most of them are not ready for market introduction but in a promising and quite mature stage. Eight out of the 23 technologies have a high market potential and are listed in the following:

- Energy Calculation Tools for professionals
- Planning and modelling tools for retrofitting
- Assessment tools for retrofitting
- Tools for building envelope operation
- User interfaces for energy management and control on building level
- Brokering platforms for grids
- Planning tools for prosumers on district level
- Grid simulation and management tools for professionals

In addition to the ongoing technological developments in the different EeB projects most important future trends could be identified. The two illustrations below present the technology trends and business-related trends.

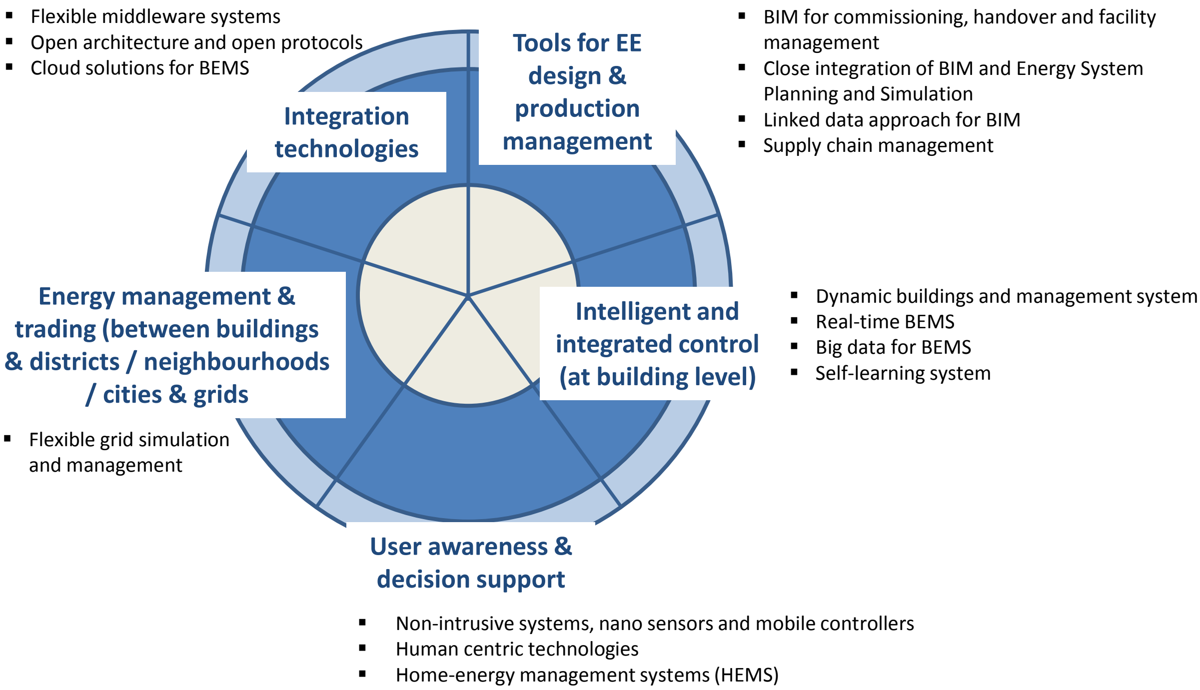


Figure 21 Technology Trends

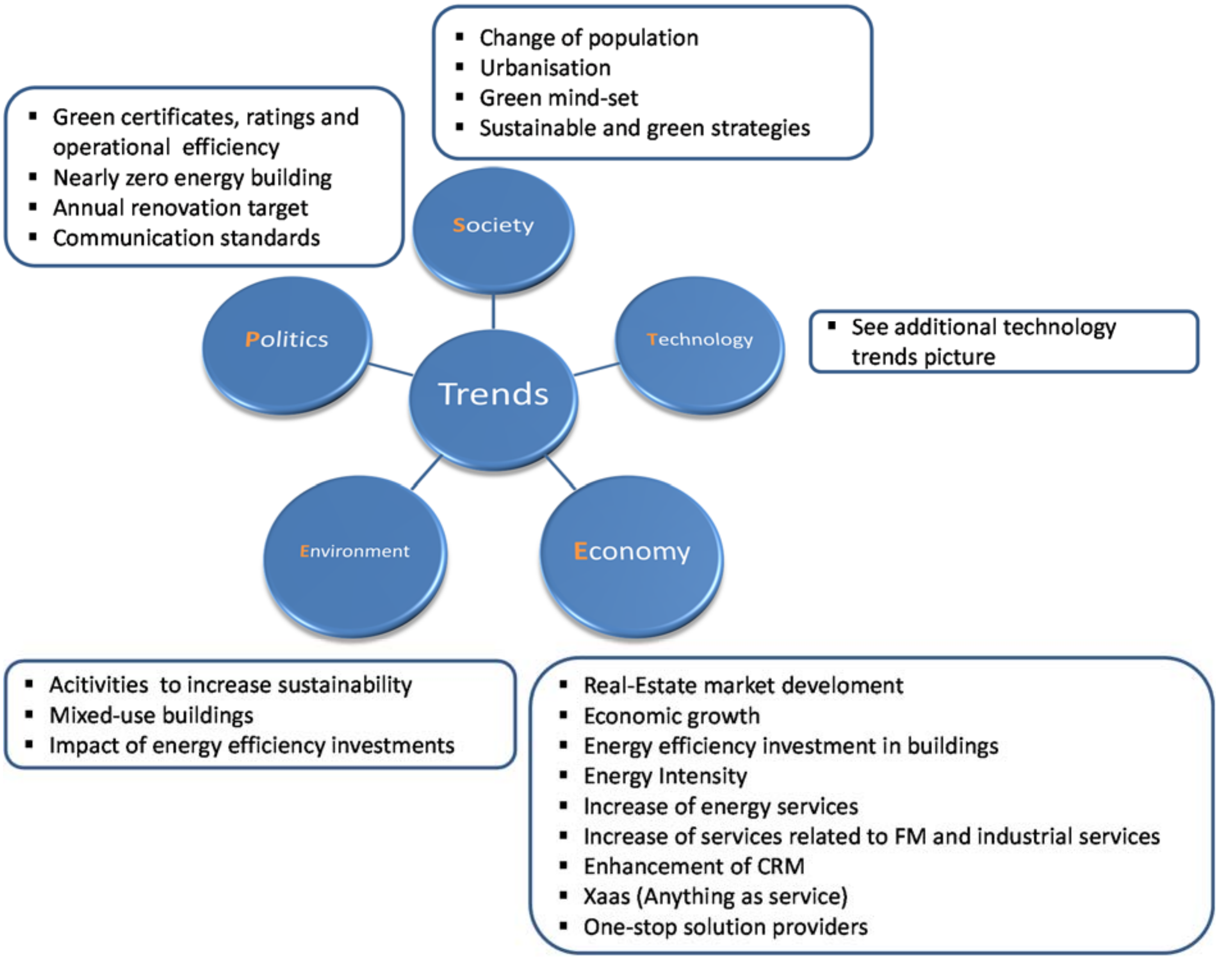


Figure 22 Business Trends

To facilitate a deeper insight in some of the currently developed solutions 7 exemplary industry cases that present one possible application scenario of the respective technology or system solution are described in this document.

Finally a vision was formulated based on the existing vision from previous research work. The main elements of the vision are shown below and will drive future scenarios in the EeB area.

Figure 23 Core aspects of EeB visions

6.2 Relation to continued developments

All information provided in this deliverable will be used to develop the recommendations in WP3.

7. Acronyms and terms

AMI	Advanced Metering Infrastructure
BAS	Building Automation System
BEMS	Building Energy Management System
BIM	Building information model
BMS	Building management system
CAD	Computer-aided Design
CIB	International Council for Research and Innovation in Building and Construction
CO	Confidential, only for members of the consortium (including the Commission Services)
CO2	Carbon dioxide
CRM	Customer relationship management
CSA	Coordination & Support Action
DGNB	German Sustainable Building Council
DoW	Description of work
E2B	Energy-efficient buildings
E2BA	Energy-efficient buildings association
EC	European Commission
EE	Energy efficiency
EeB	Energy efficient building
EOL	End of Life
EPBD	Energy performance of buildings directive
FhG	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
FM	Facility management
gbXML	Green buildings Extended Markup Language
GHG	Greenhouse gases
HEMS	Home-energy management systems
HMI	Human Machine Interface
HVAC	Heating ventilation and air conditioning
IaaS	Infrastructure as a Service
IAO	Institute for Industrial Engineering
ICT	Information and communication technology
IDF	Intermediate Data Format

IFC	International finance corporation
Mtoe	Million tonnes of Oil Equivalent
nZEB	Nearly zero-energy buildings
OECD	Organisation for Economic Co-operation and Development
PaaS	Platform as a Service
PM	Production management
PP	Restricted to other programme participants (including the Commission Services)
PU	Public
R&D	Research and development
RE	Restricted to a group specified by the consortium (including the Commission Services)
RTD	Research and technological development
SME	Small and Medium-Sized Company
STEEP	Society, Technology, Economy, Environment, Politics
SW	Software
TOC	Table of Content
TRL	Technology readiness level
WP	Work package
XaaS	Anything as a service
ZigBEE	Wireless Protocol
ZVE	Center for Virtual Engineering

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9. ANNEX

The EEBERS team identified different technological solutions reflecting the different types of systems and ICT that are currently developed in running and recently finished European projects. The technological solutions subsume cognate technologies or complementary technologies in one technological solution. Some technological solutions are very broad or address different stakeholder groups. These technological solutions were divided into sub solutions that will be used in the further analysis of this project. It can be summarized that the basis for the next steps in the project are 23 technological solutions. The technological solutions were also categorized according to the technology fields of EEBERS. The table below presents the categorization.

Table 2 Mapping of technological solutions with the technology fields

Tools for EE design & production management
Energy Calculation Tools for professionals
Tools for façade planning and simulation
Tools for design planning
Planning and modelling tools for retrofitting
Stakeholder Platforms
Assessment tools for retrofitting
Energy System Planning and simulation
Intelligent and integrated control (at building level)
Building Energy Management systems for professionals
Tools for façade operation
User awareness & decision support
User interfaces for energy management and control on building level
Decision support cockpits for professionals and consumers on district level
Energy Calculation Tools for building owners
Decision support tools for building users
Planning tools for prosumers on district level
Brokering platforms for grids
Energy management & trading (between buildings & districts / neighbourhoods / cities & grids)
User interfaces for energy management and control on district level
Tools for energy management and trading
District energy planning tools for professionals
Decision support tools for historic districts
Grid simulation and management tools for professionals

Integration technologies
Technology and component repositories
Platforms and workspaces for stakeholder integration during design
Data Integration

Some general ICT trends were mentioned in the Advisory Board meeting (Helsinki, 2015) and can be found (as enablers) in different of the described technological solutions. Since some of these trends are not construction industry specific but sector-independent (mega) trends, they are not listed as additional trends. Other technologies that have been mentioned in the AB meeting overlap with the technological solutions and were integrated into the descriptions below. The following table shows the different technological solutions and their origin.

Table 3 technological solutions

Technological solutions	Sub solutions	Derived from analysed projects	Mentioned in the Advisory Board workshop
9.1 User interface for energy management and control	• User interfaces for energy management and control on building level • User interfaces for energy management and control on district level	X	X
9.2 Technology and component repository		X	
9.3 Stakeholder Platform		X	
9.4 Planning support tools for retrofitting	• Assessment tools for retrofitting • Planning and modelling tools for retrofitting	X	X
9.5 Planning, simulation and operation of building envelope	• Tools for building envelope planning and simulation • Tools for building envelope operation	X	
9.6 Grid Simulation and Management	• Brokering platforms for grids • Grid simulation and management tools for professionals	X	
9.7 Energy System Planning and Simulation		X	X

9.8 Energy Calculation Tools	• Energy Calculation Tools for professionals • Energy Calculation Tools for building owners	X	
9.9 DSS for historic districts		X	
9.10 District Energy Planning	• Planning tools for Prosumers on district level • District energy planning tools for professionals	X	X
9.11 District Energy Monitoring and Management	• Decision support cockpits for professionals and consumers on district level • Tools for energy management and trading	X	
9.12 Design Planning	• Tools for design planning • Platforms and workspaces for stakeholder integration during design	X	X
9.13 Data Integration		X	X
9.14 Building Energy Management	• Building Energy Management systems for professionals • Decision support tools for building users	X	X

9.1 User interface for energy management and control

User interfaces for energy management and control comprises the following sub solutions. These sub solutions will be presented in the technology radar of EEBERS (compare deliverable 2.2) and can be mapped to the Taxonomy of EEBERS.

- **User interfaces for energy management and control on building level** (3 User awareness & decision support / 3.2 User empowerment)
- **User interfaces for energy management and control on district level** (4 Energy management & trading (between buildings & districts / neighbourhoods / cities & grids) / 4.3 Energy system operation)

9.1.1 Description

User interfaces for energy management and control are mobile or permanently installed interfaces. There are some commercial applications already available such as apple homeKit or Philips Hue White. State of the art control panels are normally touch screens but also voice control and gesture control gain more importance. Samsung plans a solution that uses voice control for light control, temperature control and door locking.

Google Now can be used to control the Nest system, color LEDs from Philips Whirlpool washing machines or cameras from Dropcam. Future systems will be integrated in home automation solutions that, beside the energy management, also allow the control of blinds, safety systems, home appliance or entertainment systems. The interface provides also useful information, such as weather forecast, that are necessary to support decision making of the FM or the tenant. An example from recent research activities is a clock that is highlighting the renewable surplus over the next 12 hours. Other initiatives developed a district game or enabled benchmarking of the energy consumption between schools. There are also projects focusing on collecting and providing energy load information not only for citizens but also for public institutions or energy providers to influence the decision making.

Google already presented its first Internet of things OS for smart home devices that, in the future, will allow the communication between different devices. A similar approach from Apple allows the integration of different brands. The interface allows a customised data provision and presentation according to the experience level of the user. Control systems from Controme and Tado for the heating are connected with the local weather forecast and equipped with a self-learning algorithm that allow heating control according to the typical use profile of each room. Future systems consider also push-functions to alarm the tenant in case of heating malfunction.

Research activities focus on empowerment of users and better integration of the different stakeholders. In the research focus are, for example, web-based mobile applications to encourage energy saving behaviour within a community of citizens. The application promotes the reduction and/or shift of power consumption in homes according to instructions issued by the utility company during peak loads. Behaviour changes are monitored through the analysis of the load curves provided by a smart meter. Participants are rewarded for their efforts in response to the utility's requests with points, a virtual currency, which they can convert, using the crowd funding mechanism, to support the realisation of community projects for their city. Instead of using additional and punctual energy production from thermal power plants, end-users will "learn" through the operational application how to consume energy in a better way and at the same time they will benefit from these economies of scale for their community. Crowd funding gives the opportunity to transform customers into investors through an innovative service platform.

9.1.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Smartphone and tablet as control panel for all intelligent devices at home
- Systems that are connected to different internet services (e.g. weather forecast) to increase the comfort of the user
- Manufacturer-independent control systems
- Some open source solutions
- Competitions, crowd founding mechanisms and other mechanisms to create awareness and to integrate all relevant stakeholders

9.1.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 4 Technologies for user interface for energy management and control

Technology name	Project name	TRL
Operational application: mobile app for residential customers to reduce their electricity consumption during peak loads	CITYOPT	7
Awareness and engagement tools on neighbourhood level	DAREED	7
ICT service platform for energy optimization in neighbourhoods	DAREED	7
User/social profiling, visualization and feedback	DIMMER	5
District Game developed as cloud components of the INTrEPID system and as a mobile app	Intrepid	6
End user interface	Origin	7
Information tool	School of the future	7

9.2 Technology and component repository

This technological solution is assigned to the EEBERS taxonomy cluster 5 Integration technologies / 5.4 Knowledge sharing.

9.2.1 Description

From a technical view, the technology and component database is an interface between engineers or building owners on the one side and technology and component providers on the other side. This database in a conceptual view is a support for engineers to identify and adapt new technologies and therefore overcome the challenges of the industry to gather technological competence and reach higher performances in energy-efficient buildings.

The databases developed in the research projects are, for example, a searchable content management system for text, files and links. It contains information useful for engineers to make decisions regarding the feasibility, applicability, and appropriateness of energy systems. An application layer on the database is used to sort the technology information and provide it in a structured way through e.g. diagrams.

The databases can cover technical information on components, e.g. describe characteristics such as energy consumption, generation and storage in neighbourhoods, provide parametric CAD files or provide information related to costs, ROI or the environmental impact. Current research activities consider the building level but also solutions on district level.

Databases are normally online solutions that are open source and can be used by all interested stakeholders. The information provided in the repositories are the basis for decision making in the planning of buildings and planning of retrofitting activities.

9.2.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Information base that is normally online, free of charge and open source
- Decision-support for stakeholders in the planning stage
- Basis for discussion between professionals and private building owners without deep technological know-how in the planning stage
- Information considers building level but also district level

9.2.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 5 Technologies for technology and component repositories

Technology name	Project name	TRL
Modelica Library for electrical systems	Cooperate	4
Energy System and Component Catalogue Tool	D4E	6
Solution Repository	FASUDIR	7
Knowledge Repository	NewBEE	6

9.3 Stakeholder Platform

This technological solution is assigned to the EEBERS taxonomy cluster 1 Tools for EE design & production management / 1.2 Production Management.

9.3.1 Description

Stakeholder platforms strive to connect different stakeholders with each other and support and ease the construction process. The core of a platform is always an advanced business model with a strong focus on improved collaboration. Platforms give several services to architects, business owners, companies in the construction and retrofitting industries or building owners. This is, for instance, the provision of information, tools for energy calculation, provision of a market place or the engagement platform for collective self-organised housing projects.

Information provision may comprise legal information, information on funding schemes, support for business model implementation or project management support.

9.3.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Integrated platform to support building owners and retrofitting companies in early project stages
- Different entrance paths for owner and construction company
- Easy to handle tools for building owner-concerning evaluation of different renovation scenarios and financial options

9.3.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 6 Technologies for stakeholder platform

Technology name	Project name	TRL
INTEGRATED RETROFITTING PLATFORM	NewBEE	5
CSO Housing platform	PROFICIENT	4

9.4 Planning support tools for retrofitting

Planning support tools for retrofitting comprises the following sub solutions. These sub solutions will be presented in the technology radar of EEBERS (compare deliverable 2.2) and can be mapped to the Taxonomy of EEBERS.

- **Assessment tools for retrofitting** (1 Tools for EE design & production management / 1.1 Design, 1.3 Modelling, 1.4 Performance estimation)
- **Planning and modelling tools for retrofitting** (1 Tools for EE design & production management / 1.1 Design, 1.3 Modelling, 1.4 Performance estimation)

9.4.1 Description

Current research initiatives develop software based tools using input from simulation runs and tools to calculate the optimal technical solution based on demand and supply simulation or thermal comfort simulation. The objective is to consider the whole building lifecycle already in the planning stage and identify the optimal technical system for each building. Optimisation algorithms can be constraint-based and consider aspects such as costs or ROI. Other projects develop a so-called stochastic-hybrid solutions framework for building diagnostics and prognostics. Based on the data basis provided by a virtual sensor network maintenance, decisions can be taken and faults leading to maintenance activities can be detected. It has to be emphasised that a well-developed BIM model that is interoperable with the energy calculations highly impacts the quality of the results. Solutions developed for application on building level are currently extended towards district level to support also the refurbishment of existing buildings towards zero-energy districts.

9.4.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Mathematic algorithms to support decision making for retrofitting
- Consideration of the building lifecycle in the planning stage
- Enable planning on district level

9.4.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 7 Technologies for planning support tools for retrofitting

Technology name	Project name	TRL
Stochastic Hybrid Systems (SHS) framework for building diagnostics and prognostics	AMBI	6
Virtual sensors	AMBI	6
Integrative Modelling Environment for Retrofitting	CommONEnergy	6
Retrofitting assessment	Herb	7
Lifecycle performance assessment tool	PROFICIENT	4
Integrated project delivery tools (residential district focused)	R2CITIES	8
Optimization algorithm for building solutions (Life-Cycle Optimization)	Umbrella	6

9.5 Planning, simulation and operation of building envelope

Planning, simulation and operation of façade comprises the following sub solutions. These sub solutions will be presented in the technology radar of EEBERS (compare deliverable 2.2) and can be mapped to the Taxonomy of EEBERS.

- **Tools for building envelope planning and simulation** (1 Tools for EE design & production management / 1.1 Design, 1.4 Performance estimation)
- **Tools for building envelope operation** (2 Intelligent and integrated control (at building level))

9.5.1 Description

Façade planning comprises two different aspects: the simulation and the configuration of the building envelope or parts of the envelope such as windows. Currently, configuration tools are developed that support architects and other designers dealing with façade energy efficiency retrofitting. One new tool will support selection and placing of the related technical units, checking the errors of the installation plan, showing e.g. preliminary pipe installations and estimating installation materials. Another research initiative develops a decision support tool to make information on secondary raw concrete in Europe available for waste processors and to make information on a newly developed concrete available for construction companies and architects. Finally, another project focuses on the modelling of new light-weight sandwich elements, including the modelling of mechanical load scenarios and hygro-thermal as well as thermal modelling.

Other projects perform a holistic evaluation of a façade/building envelope through 3D simulation software (e.g. thermal comfort) linked to designing software or they use a combined CFD (Computational Fluid Dynamics) – HAM (Heat Air and Moisture) approach for optimal positioning of the PCM (phase change material) in the panel. All layers of the façade are modelled with their thermal properties analysing the optimum thickness distribution, PCMs optimum localisation and volume fraction, thermal bridging effect and final thermal performance. In the future, sensor networks will allow to monitor façades and, based on the data input, operate the building. Others are focussing on the conditions in the façade to improve the comfort of the tenant and user of the building. Currently, there is for example a moisture monitoring and control system for façades developed to prevent the growth of microorganisms on ETICS. A control system based on a sensor network will measure moisture and liquid water. Data from the sensors will be combined with an intelligent system for moisture prediction and the system responds by activating a ventilator system incorporated into the building's heating, ventilation and air conditioning (HVAC) system to dry target areas of the façade.

Furthermore, projects focus on energy and material footprint analysis upon production for a new window type. Different models are established and used to simulate the thermal and mechanical properties of the new polymer-glass composite materials and the properties of components made from glass panes as well as the composite materials used as reinforcing interlayers. The performance of laminate glazing integrated into the light weight frame is also simulated in order to analyse the performance under building relevant conditions. In the operational stage, these complex high performance windows (e.g. quadruple glazing containing ultra-thin glass membranes dedicated as frameless openable windows for direct application in facades) with printed organic photovoltaics (OPVs), solar thermal collectors and micro mirrors require tools for management and control.

9.5.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Planning support for façade and façade elements
- 3D Simulation considering airflows and moisture exchange
- ICT to operate and manage high performance windows

9.5.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 8 Technologies for planning, simulation and operation of building envelope

Technology name	Project name	TRL
Retrofitting Planner: Evaluation of a façade/ building envelope through 3D simulation	EASEE	7
Moisture monitoring and control system	FoAM-BUILD	5
Modelling of glazing constraints	HARWIN	7
Façade Configuration Tool	MEEFS	7
Façade web based Remote Monitoring Tool	MEEFS	6
Operation of IG unit	MEM4WIN	7
Simulation and modelling of panel performance (thermal performance)	MF-Retrofit	5
Numerical models for PCM (phase change material) positioning in the panel	MF-Retrofit	3
Numerical models for light-weight sandwich elements	SEBSE	8
Decision Support Tool for secondary material in concrete	SusCon	6

9.6 Grid Simulation and Management

Grid Simulation and Management comprises the following sub solutions. These sub solutions will be presented in the technology radar of EEBERS (compare deliverable 2.2) and can be mapped to the Taxonomy of EEBERS.

- **Brokering platforms for grids** (3 User awareness & decision support / 3.1 Performance management, 3.2 User empowerment)
- **Grid simulation and management tools for professionals** (4 Energy management & trading (between buildings & districts / neighbourhoods / cities & grids) / 4.1 Modularity of energy systems, 4.2 Energy system integration, 4.3 Energy system operation)

9.6.1 Description

Technologies developed in this segment focus on grid management in general or the management of single components. There are platforms that focus on the planning of energy systems, some look into the management of grids, some into the integration of different stakeholders and some provide brokering functionalities. Advanced platforms are cloud- and service-oriented or set-up on an (open-source) middleware that allows the integration of multiple devices and different stakeholders.

The overall aim of the systems is to optimise the use of energy and interconnect production DER (e.g. solar panels), storage (e.g. electric cars) and consumption on district level towards zero energy districts and energy infrastructure optimisation. The decision making process can be supported by systems that are working optimisation-based (strategies for balancing loads using real-time energy load data) or fall back on model predictive control. It can be differentiated between tools that support the individual prosumer presenting actual consumption and generation data and supporting him with billing functionalities or systems that enable authorities and grid managers to control and monitor their systems. In addition to the development of management systems itself, models for virtual power plants are developed.

Current research activities develop systems that allow the combination of micro-grids where renewable energy production and storage capacity systems are hooked up in addition to the loads, by means of a distributed ICT based solution. Task schedulers shifting the workload allow a higher self-consumption rate of the produced renewable energy within the targeted neighbourhood and reduce the exchange with the public power grid. Some of the tools do not only focus on electrical grids but support also the management and control of thermal grids. In addition to overall management systems, solutions such as control systems for smart grid integration of heat pumps are also developed.

9.6.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Overall optimisation and load balancing for smart grids
- Enabling new business models for utilities and prosumers
- Cloud- and service-oriented software systems

9.6.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 9 Technologies for grid simulation and management

Technology name	Project name	TRL
Forward-looking information for optimal decision-making process based on optimization-based or model predictive control (MPC).	Buildnet	4
Distributed integrated energy system to manage communities	CIVIS	6
Multi Agent System for micro grids	CoSSMic	6
Operation and management tool for thermal and power grids (incl. billing tool)	E+	6
E-balance balancing method: provides means for Demand Side Management	e-balance	5
Balancing and resilience mechanisms: Load balancing	e-balance	6

Energy Brokering tool platform	EEPOS	6
Smart Energy Platform	FINESCE	7
Smart grid integration of heat pump	GREENHP	5
SMART urban Decision Support System (smartDSS)	iURBAN	5
Model development of Virtual Power Plant (VPP)	iURBAN	5
Open Dynamic System (ODYS)	Odysseus	

9.7 Energy System Planning and Simulation

This technological solution is assigned to the EEBERS taxonomy cluster 1 Tools for EE design & production management / 1.1 Design, 1.3 Modelling, 1.4 Performance estimation.

9.7.1 Description

Energy system planning and simulation of the energy performance is relevant in the planning stage of a building but will gain also more importance for facility managers during building operation. The range of tools is from simulation of a physical phenomenon (e.g. simulation models for boiling on nanostructured surfaces and heat exchange to elaborate the flow and conjugate the heat transfer in a real size heat exchanger), simulation for optimisation of a single component such as a heat pump (i.e. numerical condensation and icing models for all air-touched parts in the evaporator unit), integration of an energy component into an energy system (e.g. Decision support tool for selection, design and evaluation of STES (Seasonal Thermal Energy Storage) integrated system for existing buildings) or the simulation and planning of a holistic energy system for a building.

The objective is to reduce energy consumption and balance different aspects such as air exchange, air temperature or air quality, develop strategies for optimal illumination, define the placing of the building to reduce the energy consumption or to optimise the water consumption and the use of energy for this and all other technical installations in the building.

The tools support engineers, planners and operators of a residential or commercial building as well as an energy component and, according to the needs of users, provide an appropriate user-friendly interface. Planners apply the tools for designing new buildings but also for retrofitting a building and improve the energy performance. The idea is also to support better introduction of certain energy systems such as STES in all European climate areas.

In the design stage future simulation systems will rely on BIM data and validated thermal models considering the building properties and the performance of the different components. In the operational stage the aim is to introduce dynamic models based on data gathered from the BMS (Building Management System). The consideration of metered data, building control settings, weather forecast data or even tariff information enables the facility manager to optimise and adapt the control strategies (model predictive control) of a building. To ensure interoperability with other modules of the BMS, cloud-based solutions are currently developed.

For control design, “fast-models” that are able to capture sensitivities to parameter variations (state-space models of particular form, e.g. bi-linear) are developed. The fast-models are used if there is a lack of data for validation or if the simulation task can be done with the simplified models.

9.7.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Simulation solutions or models that are integrated in a holistic control platform and concept
- Cloud-based solutions for planning and building operation considering the integration of renewable energy sources
- Fast-models for control purpose

9.7.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 10 Technologies for energy system planning and simulation

Technology name	Project name	TRL
Energy Models for Performance Estimation and for Control Services	BaaS	7
BIM-based holistic collaborative design and simulation platform	eeEmbedded	5
Decision Support Tool (DST) for selection, design and evaluation of STES (Seasonal Thermal Energy Storage)	Einstein	5
Simulation models for boiling on nanostructured surfaces and heat exchange	ENE-HVAC	8
Simulation Reference Model	Energy in Time	7
Condensation and icing models	GREENHP	6

9.8 Energy Calculation Tools

1.1 Energy Calculation Tools comprises the following sub solutions. These sub solutions will be presented in the technology radar of EEBERS (compare deliverable 2.2) and can be mapped to the Taxonomy of EEBERS.

- **Energy Calculation Tools for professionals** (1 Tools for EE design & production management / 1.3 Modelling, 1.4 Performance estimation)
- **Energy Calculation Tools for building owners** (3 User awareness & decision support / 3.2 User empowerment)

9.8.1 Description

The energy calculation tools can be sophisticated solutions used by experienced planners but also very simplified solutions that support the building owner. They support the building owner to make a first rough estimation how a new energy concept could look like or provide energy profiles that allow a first overview concerning the performance of products and components that have no energy label. Some of the tools consider also economic aspects.

Tools can be used for refurbishment planning of a building and calculate key performance indicators (such as kWh/m2, kgCO2/m2, operational costs, payback time).

9.8.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Energy calculation tools with different complexity according to the user
- Decision support and provision of information on products and components to reduce the efforts for retrofitting planning
- Consideration of economic aspects in addition to the energy performance

9.8.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 11 Technologies for energy calculation tools

Technology name	Project name	TRL
Energy-Economic Evaluation Tools	CommONEnergy	6
Energy Savings Calculation App	ENBUS	7
Simplified Energy Profiles	ENBUS	7
PRE-ASSESSMENT TOOL	NewBEE	5
ENERGY-PERFORMANCE-ASSESSMENT	NewBEE	7

9.9 Decision support systems for historic districts

This technological solution is assigned to the EEBERS taxonomy cluster 4 Energy management & trading (between buildings & districts / neighbourhoods / cities & grids) / 4.2 Energy system integration.

9.9.1 Description

The Decision Support System is a software tool that helps to take decisions about improvement measures suitable for historic urban districts. It balances location-specific data on building stock and historic urban districts (including data on heritage values, climatic conditions and energy generation and energy use) with information on improvement measures. The DSS software tool integrates a multiscale data model, the European building stock categorisation database, the historic district geo-graphical information system and an energy efficiency solution repository. The multiscale data model includes geometric and semantic information at district scale, as well as building scale and its structural components. Its role is to storage all the information to support sustainable energy assessment and management at districts level. The data model comprises also a repository of technologies which are suitable for use within historic urban districts and which will improve their energy efficiency or generate energy from renewable sources.

9.9.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- DSS and multiscale data model for historical districts
- Geometric and semantic information on district and building level

9.9.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 12 Technologies for DSS for historic districts

Technology name	Project name	TRL
Decision Support Tool	EFFESUS	5
Multiscale data model and Categorization Tool	EFFESUS	6

9.10 District Energy Planning

District Energy Planning comprises the following sub solutions. These sub solutions will be presented in the technology radar of EEBERS (compare deliverable 2.2) and can be mapped to the Taxonomy of EEBERS.

- **Planning tools for Prosumers on district level** (3 User awareness & decision support / 3.1 Performance management, 3.2 User empowerment)
- **District energy planning tools for professionals** (4 Energy management & trading (between buildings & districts / neighbourhoods / cities & grids) / 4.2 Energy system integration)

9.10.1 Description

District Energy planning systems target different stakeholders in all life-cycle stages of a district. There are solutions that provide a holistic overview on the energy performance in a certain district. Most solutions are web-based to ensure that all stakeholders can access the needed information and participate actively in district projects. 3D based output visualisation of results (e.g. simulation results) is provided to the users. Beside the simulation results, tools for decision support can analyse the results and generate KPI for the decision makers or support the generation of what-if scenarios. Solutions comprise not only the software landscape but also methodologies and guidelines for users and decision makers.

Systems combine different monitoring (for operational planning) and planning tools and facilitate and integrate stakeholders such as facility managers and owners, NEMS operator, ESCO, energy brokers or city authorities. The tools support the decision makers with results generated by their simulation engine. There are also solutions especially designed for retrofitting purpose or for supporting design teams in the very early stages of a project.

Specific (open source) smart city data bases will collect all the data related to public and private buildings and the renewable resources in the city and provide these information for simulation.

Virtual environments can be used to demonstrate the planning alternatives to different stakeholders and to visualise planned supplements (e.g. a field of PV collectors) in the existing environment.

Systems, for example, are based on the CityGML (City Geography Markup Language) approach and link geodata with energy simulation and sustainability assessment for building and district. In detail, future systems will rely on information such as climatic conditions, district geography, building geometries and use patterns, existing service networks and surrounding infrastructure (mobility, traffic, services, etc.). Tools are supporting the analysis, simulation, optimisation and communication of planning alternatives. Approaches integrate energy dynamics of local grids and buildings, consumption behaviours, energy storage, and local energy production (incl. renewables) to ensure energy efficiency of supplementary construction and to improve renewable integration. To identify the optimum, some solutions will be based on genetic algorithms.

Solutions for the early design stages are for instance semantics-driven with interoperable tools for geo and building information modelling (Semantic BIM and GIS) to assess and validate the energy performance during the design stage. It has to be emphasised that the results in that early design stages are not based on a holistic simulation due to missing data but, however, provide KPIs for energy efficiency, financial, and operational quality.

Other systems focus only on the optimisation of the energy flows to ensure that there is an optimal balance between supply and demand. Hybrid approaches optimise the demand-side by applying suitable demand side strategies and the supply-side by reducing the overall energy imports for a given load based on the energy hub model. Current research focuses on multi-energy carrier systems, i.e. electrical, heating and/or cooling systems. A lever for optimisation on district or city level is the improvement of occupation profiles. Public buildings are often used only some hours per day which leads to high energy waste. Planning systems that improve the usage rate of public buildings will lead to more energy-efficiency on district level.

9.10.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Energy performance optimisation on district level in different design stages
- Interoperability between data bases, simulation and decision support systems

- Semantics and genetic algorithms to improve the planning

9.10.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 13 Technologies for district energy planning

Technology name	Project name	TRL
Decision support system to provide coordinated management of public infrastructures in Smart Cities (Energy Management)	Besos	7
Simulation based planning application for energy systems	CITYOPT	7
Energy performance monitoring and operations planning tools	EEPOS	7
Models for analysis and optimization of multi-energy carrier systems	Epic-Hub	7
Integrated Decision Support Tool	FASUDIR	7
District Retrofitting Energy Model	FASUDIR	7
3D virtual space to demonstrate new technologies to stakeholders	IDEAS	8
Interactive Decision Support and Information Exchange Platform for Smart Cities	INDICATE	8
Smart City Database	iURBAN	5
Dashboard	Streamer	7
Interoperable design tools	Streamer	6
Decision Support Tool for Retrofitting a District	URB-GRADE	7

9.11 District Energy Monitoring and Management

1.1 District Energy Monitoring and Management comprises the following sub solutions. These sub solutions will be presented in the technology radar of EEBERS (compare deliverable 2.2) and can be mapped to the Taxonomy of EEBERS.

- **Decision support cockpits for professionals and consumers on district level** (3 User awareness & decision support / 3.1 Performance management)

- **Tools for energy management and trading** (4 Energy management & trading (between buildings & districts / neighbourhoods / cities & grids) / 4.2 Energy system integration, 4.3 Energy system operation)

9.11.1 Description

District energy monitoring and management systems balance energy generation, storage and use on district level. From a technical point of view, two main aspects are important in this context: the energy monitoring and management system itself and corresponding optimisation algorithms.

There are two main management strategies common for controlling a district energy system. The implicit approach gives incentives to the actors of the system in order to influence their behaviour. The integration of the different (private) actors is typically done with mobile apps. Opposed to this, the explicit management strategy makes centralised decisions concerning consumption and production parameters on district level for public infrastructure in a smart city. Some approaches go beyond this and makes centralised decisions for (private) actors concerning consumption and production based on a certain flexibility range given by the actors.

From a technical perspective, the monitoring and management systems are often cloud-based with open interfaces that allow the integration of different software solutions needed for district management, of multiple energy management systems and new services for the smart city of the future.

A common information model is able to integrate the different components, building profiles and surrounding conditions such as weather data or energy prices and uses, e.g. semantics to identify the optimum strategy. This integrated virtual model of a city or district is based on BIM data, results from energy flow simulation and the behaviour of the inhabitants and allow the identification of energy patterns for production and consumption on district or city level.

In addition to the planning aspects, other systems cover functions for the operational management such as fault detection engines and real-time monitoring and management applications.

9.11.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Energy monitoring and management on district level and algorithms for system optimisation
- Semantics and genetic algorithms to improve the planning

9.11.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 14 Technologies for district monitoring and management

Technology name	Project name	TRL
District Energy Management and Information System (DEMIS)	AMBASSADOR	5
Behavioural mobile app for consumers and citizens	Besos	6
DSS Cockpit	Besos	7
Algorithms for neighbourhood energy optimisation	Cooperate	4
Neighbourhood Information Model (NIM)	Cooperate	5
Simulation and virtual visualization of districts	DIMMER	5
Cloud-based software platform to collect, register, monitor and share energy data and respective connectors	DOF	5
Energy performance monitoring and operations planning tools	EEPOS	7
Energy Monitoring Platform for neighbourhoods	Epic-Hub	7
Smart decision support system for optimized energy use in cities	OPTIMUS	6
Weather prediction algorithm	Origin	6
Renewable prediction algorithm	Origin	6
Building/District Management System for the control of energy generation / storage/ use	R2CITIES	8
Open Energy Service Platform incl. business Cockpit and Monitoring and Control Cockpit	SMARTKYE	6

9.12 Design Planning

Design Planning comprises the following sub solutions. These sub solutions will be presented in the technology radar of EEBERS (compare deliverable 2.2) and can be mapped to the Taxonomy of EEBERS.

- **Tools for design planning** (1 Tools for EE design & production management / 1.1 Design, 1.4 Performance estimation)
- **Platforms and workspaces for stakeholder integration during design** (5 Integration technologies)

9.12.1 Description

Tools for Design Planning support multidisciplinary, collaborative design processes for new constructions and retrofitting in the construction industry. The tools are typically designed as virtual workspace. Often they are cloud based and focus on the integration of already existing software solutions. The virtual workspace allows various actors to collectively simulate and assess the impact of various energy solutions in order to improve energy efficiency. Using appropriate tools and the knowledge provided will enable team members to explore "what-if scenarios" individually, examine the impact of various parameters on the design, and discuss these options collaboratively.

Holistic design planning tools provide a user interface, a service layer (e.g. performance based requirements setting, provision of multi-physics simulation at certain design stages) and a data layer (e.g. BIM, prefabricated components) and are able to synchronise different views and models (e.g. geometric model, energy model, integrated BIM, data on neighbourhood level, wireless propagation properties) for the building.

BIM in FM is not very common today and therefore a first step to improve the situation could be the definition of use cases that determine missing information and specify data maintenance needs. There are requirements from different stakeholders in construction for systems with a good information updating capability. In addition to technology data, knowledge on material and products should be available in future BIM Models. Applications should be designed for the use on mobile devices to ensure that the data and systems can be used also on-site.

Decision points in the design stage are supported by specific methodologies ensuring that the buildings are sustainably embedded in their neighbourhood. Of high importance in this context is the setting of key design parameter and key performance indicators as well as, based on this, the evaluation of the parameters and the decision making itself.

Solution configuration systems will allow speeding up of the design process, foster standardisation and the re-use of proven configurations. The establishment of such systems will reduce the entrepreneurial risk and can reduce the efforts for funding application at banks.

9.12.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Multidisciplinary, collaborative design processes support
- Integration of different design tools and models
- Provision of methodologies and guidelines for building design
- Dedicated support for the respective decision points

9.12.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 15 Technologies for design planning

Technology name	Project name	TRL
Collaborative virtual workspace	D4E	6
Integrated information management framework	eeEmbedded	5
Multi-model design methodology (KP controlled)	eeEmbedded	6
BIM-based holistic collaborative design and simulation platform	eeEmbedded	5
Cloud-based collaborative building design software platform	Holisteec	
Components of Design configurator	PROFICIENT	7
RetroKIT Decision Support System (Prefabricated Moduls for Retrofitting)	RetroKIT	7
Methodology to design wireless friendly buildings (3D Modelling enhancement and simulation support)	WIFEEB	5

9.13 Data Integration and Sensor Networks

This technological solution is assigned to the EEBERS taxonomy cluster 5 Integration technologies / 5.1 Process integration, 5.2 System integration.

9.13.1 Description

Data integration services are often realised with service middleware platforms that connect the physical layer with the data and service layer. So-called high level services are today often cloud-based. The physical layer comprises components that are integrated into the BMS (e.g. sensors, actuators) but also sensors that provide e.g. weather data. Applications of the service layer aims to optimise energy consumption. On data layer solutions are needed that are able to align data and ontologies that support better data structuring. Extended data warehouses collect all the information from BIM and monitoring systems and exchange information with the service layer by using for instance IFC and ifcXML. The integration of different data sources will lead in the future to the availability of a holistic and nearly complete web of building data, district information and others such as climate data bases.

Sensor networks for energy monitoring are normally wireless networks that sense data in the buildings and their neighbourhood. Each sensor should use as minimum energy as possible. The networks should be robust against node failures, self-organising, scalable (up to high number of nodes), and ensure data privacy.

Middle ware platforms are characterised by standardised interfaces that connect hardware with the service layer. Their openness will allow self-organised networks and predictive control in the future. Many platforms (such as the open source bases OGEMA platform) are refined for use on neighbourhood level.

Related to holistic design processes, an important aspect is a better integration of the needs of the facility manager during the design stage. Use cases for building operation are a starting point to consider operational and maintenance needs already in early phases. Virtual representations of the building should be constantly updated if actual building configuration deviates from the originally planned one. Configuration software will be improved based on relevant experiences with components, materials and system configurations during operation. This approach is traditionally used in the machinery and plant industry and state-of-the art PLM (product lifecycle management) systems are providing the needed functionalities and work environment. PLM for construction can benefit from these already existing solutions and approaches in the future.

During the construction process itself a better integration of the different ERP from construction companies, component manufacturers and FM will lead to an optimised order fulfilment process.

9.13.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Interconnection of physical layer and energy services
- Open and standardised connectors for the platform
- PLM for construction industry

9.13.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 16 Technologies for data integration

Technology name	Project name	TRL
Extended Data Warehouse	BaaS	7
Service Middleware Platform	BaaS	7
Advanced middleware technology for data integration	DIMMER	5
Common BIXS (Building Information eXchange System)	DIRECTION	8
Neigbourhood automation platform for energy management	EEPOS	7
Middleware for Communication in Neighbourhoods	Epic-Hub	7
open integration platform	Odysseus	
Building legacy and monitored data storage and computing infrastructure	PERFORMER	6

Alignment Server for Energy Systems	READY4SmartCities	6
Ontology and dataset catalogues	READY4SmartCities	8

9.14 Building Energy Management

Building Energy Management comprises the following sub solutions. These sub solutions will be presented in the technology radar of EEBERS (compare deliverable 2.2) and can be mapped to the Taxonomy of EEBERS.

- **Building Energy Management systems for professionals** (2 Intelligent and integrated control (at building level) / 2.1 Monitoring, 2.2 Data analysis and diagnostics, 2.3 Automation & control)
- **Decision support tools for building users** (3 User awareness & decision support / 3.1 Performance management)

9.14.1 Description

Building energy management systems cover the aspects surveillance, monitoring, building management and user information. The systems can be used for the management of a dwelling, parts of the buildings or the whole building, independent from the building type (residential, non-residential). Accordingly, the building will be equipped with hardware (sensors, actuators, intelligent smart meter, user information interface etc.) and all collected data will be used to optimise the energy consumption of the building without decreasing user comfort.

The solutions can be distinguished into centralized and decentralized system. The decentralized systems give more decisive power to users and tenants which leads normally to a higher comfort level of the user. The ROI is longer compared to centralized systems operated by the facility manager.

Data collection will be done in the future by means of unbundled smart meters that enable the user to dispose the data created by the meter. An unbundled smart meter has two components: a metering part, which is a closed intelligent application with high security mechanisms and an open-access interface. This could be, for instance, a powerline WLAN adapter to read-out the data. The energy provider needs the owner's permission to record the detailed consumption information and, based on the data, provide user-individual services. The consolidated metering data from all utility clients are the basis for optimising the grid. Due to the open interface, the house owner can sell his data to third parties. Utility companies can offer discounts if the meter owner sells his data for profiling to the energy provider. Another option is that the owner offers his data to third party companies with focus on user-profiling (e.g. provision of anonymised and consolidated user data).

A good example for this profiling business model is a client using a washing machine at night. The utility company which is tracking his consumption can provide his data to a third party service provider. The service provider could offer him a new and very silent washing machine and calculate the amortisation time based on the current consumption profile.

Energy management systems do not only collect and display values and information but process them and allow building control. Simulation tools and analysis software are interacting with the databases of the system and provide forecast calculations (for consumption and production) and thereby support for decision makers. Building automation will use the results to control the building or single devices like a control platform for energy generation devices. Depending on the user group and their skill level, all systems in the system landscape can be sophisticated solutions or simple solutions for laypeople. Especially simulation systems that support the building operation (comparable to approaches used in smart factories) will gain importance in the future. The constant balancing of current building status and simulation forecast is comparable to control stands that are used in smart factories.

Current systems are normally rule-based systems (a way to store and manipulate knowledge to interpret information in a useful way) with a limited performance. Next generation solutions will profit from dynamically trained software systems, i.e. self-learning systems.

Some systems provide only information to the user (status information, consumption information, to-be values or operation times), others allow strong interaction with the user and the option to configure a large number of set points.

Fault detection and diagnostics (FDD) tools are designed to help building managers proactively to discover anomalies and equipment performance issues before they lead to alarms, occupant discomfort or even system failure. FDD tools can recognise when a condition is starting to deviate from the norm or when a system is operating not optimally so that the facility manager can solve the problem before the alarm actually occurs. FDD software not only detects faults; it can instantly provide information based on analytics (e.g., energy or cost impacts of the fault) to help the building operator to screen and prioritise which faults to fix. Sophisticated systems allow an automatized recognition of failures or maintenance needs based on pre-configured patterns which increases the availability of the whole system solution.

9.14.2 Characteristics and features

The box below summarizes the most important characteristics and features of the technological solution.

- Building management systems for surveillance, monitoring, building management and user information
- Self-learning control mechanisms
- Pattern-based fault detection systems that allow preventive and conditional maintenance

9.14.3 Related projects and technologies

The following table summarizes the projects and technologies in the EeB area that can be subsumed under this technological solution.

Table 17 Technologies for building energy management

Technology name	Project name	TRL
Energy Management System	BEEM-UP	7
Equipment and control systems (individual energy consumption measurements)	Buildsmart	7
Monitoring platform	DIRECTION	8
Building performance remote monitoring platform	EASEE	7

Integrated solution with Intelligent Automation Unit (IAU) concept and Mobile Robot	ECOSHOPPING	6
Building Intelligent Control System	Energy in Time	5
Control Platform for the GreenHP	GREENHP	5
Energy Management System	Herb	7
Energy Monitoring System	Inspire	
Surveillance and Fault Detection	Inspire	
IoT platform and flexible data model defined	Intrepid	6
Demand controlled ventilation	Next Buildings	7
Energy feedback system	Next Buildings	8
Energy Simulation Environment	PERFORMER	6
Energy instrumentation kit	PERFORMER	6
Performance monitoring solution	RetroKIT	5
Energy performance calculation tool	School of the future	7
Decision support tool for building users	Umbrella	6

EEBERS project mission is to identify opportunities for synergies in ICT related RTD in the EeB (energy efficient buildings) domain and to engage stakeholders in networking for future RTD and exploitation of results.

This document reports on the assessment of ICT in the EeB area concerning the technology readiness level (TRL) and market potential and the development of the EEBERS technology radar based on the assessment. The 5 technology fields of the radar are accordingly to the EEBERS taxonomy the 5 main clusters of the taxonomy. In addition, this report present the most important trends collected in an expert workshop and for some selected technologies an exemplary industrial application case. Finally this report provides a vision created by the EEBERS partners based on ongoing technological developments in the EeB area.

9.15 Purpose and target group

The main purpose of this document is to present the results of the EEBERS technology assessment. The assessment and structuring of the technologies in the technology radar will facilitate the provision of recommendations for future EeB priorities. The exemplary industry cases will give a deeper insight into application scenarios of selected technologies and also support the formulation of the recommendations. Finally, the EEBERS vision provides a target system to be reached in the future and will be the landmark or checkpoint for the formulation of the recommendations.

The target group is the European EeB research and innovation community, in particular, the participants of targeted EeB related projects and all stakeholders with interest in rolling out the innovations.

9.16 Baseline

Baseline for this report was the initial EEBRS project mapping (D1.1) and the technological solutions already described in the previous report of work package 2. The methodology used in this context is a well validated approach used several times by FhG in research and consulting projects but tailored towards the needs of EEBERS. Finally, an expert workshop was the main knowhow source for the assessment of the technologies.

that was used to develop the EEBERS technology roadmap that is visualized by the EEBERS technology radar and extended by additional trends for each technology field.

Starting point for this research work are technologies that are currently developed in European research projects from the EeB area. The projects were analysed and most important technologies were documented. The identified technologies were assessed according to their technology readiness level (TRL) and their market potential. The TRL was analysed in collaboration with the EeB-CA2 project (joint questionnaire of the four CSA and more detailed investigation by Steinbeis). The market potential was analysed with experts from industry and research in a half-day workshop in Munich. Business trends were collected from latest publications and studies. The technologies were consolidated in the EEBERS technology radar structured according to the EEBERS taxonomy in five different technology fields. The business trends are structured according to the STEEP analysis. The STEEP analysis distinguishes between social, economic, ecologic, political (incl. legal) and technological aspects. The first four segments are considered in the EEBERS business trend radar. In a second step some technologies from the five different fields were selected and edited as exemplary industry cases. In a final step visions from the different energy, building and smart city initiatives were consolidated. Extended by the activities from Task 2.3 (deployment scenarios and impact) the results presented in this document will be the basis for the EEBERS recommendations.

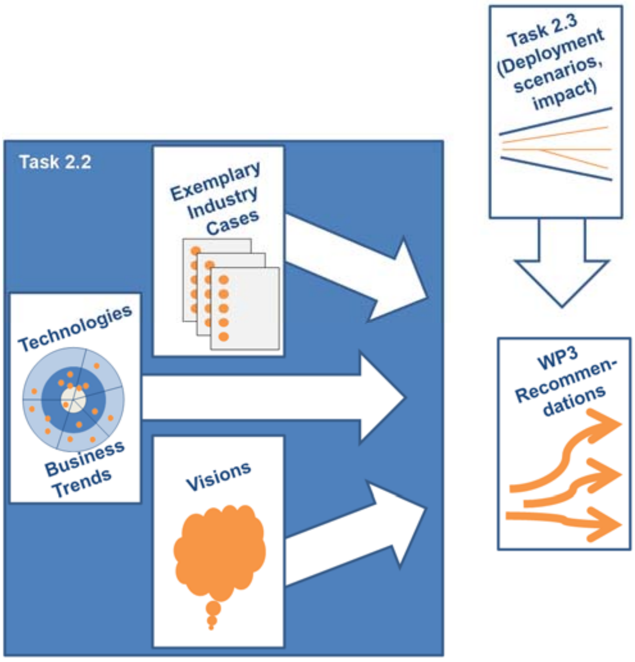

Figure 24 Approach

9.17 Technology and business trends

Based on the identification and consolidation of the technology trends the technology radar was developed (compare Figure 25).

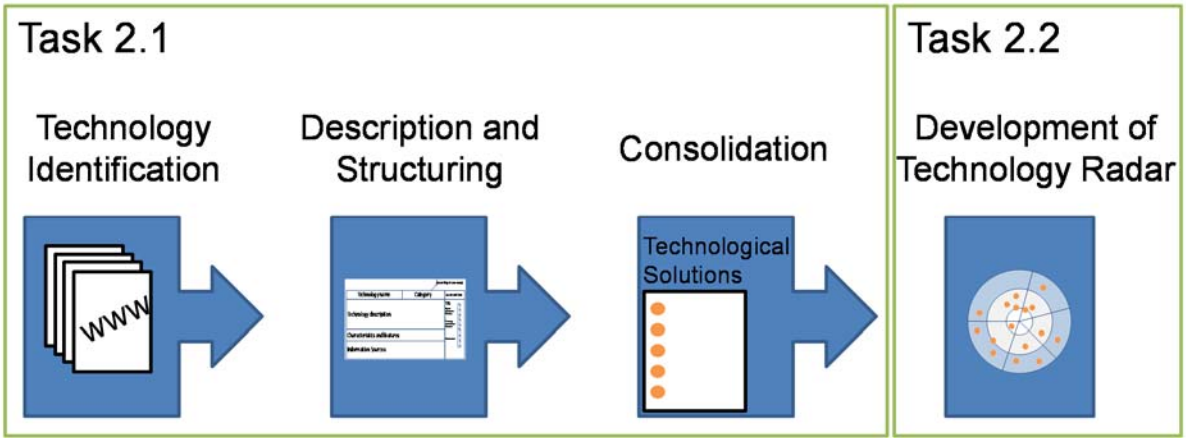

Figure 25 Overall approach for the technology analysis

TRLs were (as explained) identified in collaboration with the other CSA. The market potential was analysed together with experts from industry and research in a half day workshop. The illustration below presents the template that was used in the working groups for the assessment.

Name of the technological solution	

Market potential of the different technological solutions in the next 5-7 years

What is the market volume (large, medium or small)?	
Will the end-user accept the technology (end-user will accept, end-user will accept to some extend or end-user will not accept)?	
Will there be an increase of the cost-benefit ratio for the end-user compared to existing or competing solutions (increase of cost-benefit ratio, unchanged cost-benefit ratio or decrease of cost-benefit ratio)?	
Are the technologies compatible to existing solutions (compatible, compatible to some extend or not compatible)?	

What else should be considered or done to ensure full impact of the technological solution?

Figure 26 Assessment template

In addition, the experts recommended technologies that might play an important role in the future. These technologies are also part of this report.

Business trends are based on a desk research and reviewed by EEBERS partners. The trend analysis focused on most relevant trends and gives not a complete overview.

9.18 Exemplary industry cases

The idea of the exemplary industry cases is to give the reader a more detailed insight into some solutions that are currently developed in the EeB area.

The cases describe promising solutions for the construction industry (either very specific technologies or holistic approaches or concepts). The description explains the interaction of the technology with related stakeholders presents the beneficiaries of the technology and reveals changes in the value chain. The authors of the industry cases followed the following lead questions:

- Description of the technology in the context of the use case (application scenario)
- Interaction of stakeholders with the technology and impact on the value chain
- Beneficiaries of the technology
- Impact of the technology (Will it substitute some technologies, will the value chain change, will the business model of a company change?)
- Economic impact (if already measurable)

9.19 Visions

In an additional step visions from different roadmaps in the EeB area were analysed and consolidated. The EEBERS vision focus on the description of needed properties of a system but not of the system itself. The system itself should be described in detail using scenarios. The vision will help to set the target system for the future and thereby influence the recommendations of EEBERS toward the EC.

10. Vision

There are some visions from different roadmaps that were developed in the last years and that are consolidated in this chapter. The following roadmaps were considered:

- CIB Smart City Vision (draft version)
- Ready4SmartCities (Vision of Energy Systems for Smart Cities)
- E2BA/EeB Vision
- ICT4E2B Forum Vision
- REViSITE Vision

Visions that have been formulated in the last years describe the city or building of the future as dynamic ecosystem. ICT is an enabler for realisation of such advanced ecosystems. Joint activities of research, municipalities, companies and citizens are leading towards integrated, sustainable and energy-efficient living and working environments considering mobility needs, expected quality of life and the wellbeing of the users.

ICT is the enabler for the municipality to manage and control different parameters of the city (e.g. energy consumption) accordingly and to plan and design infrastructure and buildings for the city of the future. Owners, tenants and users benefit from ICT and manage their own space, actively participate in the energy market and get the support needed for decisions-making. The crucial aspect in this context is the HMI connecting prosumers and operational system and the incentive systems that motivate to exploit the full saving potential. If successful, positive energy buildings and CO^2 neutral districts will dominate our townscape in the future.

Both, smart buildings and smart energy systems need ICT in all life-cycle stages from the early concept until end-of-life stage. Some key aspects of the vision that are described more in detail in the following are illustrated below. An overall concept and steering mechanisms in the below described system also supported by ICT that helps to plan, control and interconnect the different elements of the ecosystem and allow all subsystems and stakeholders to collaborate and communicate seamlessly.

The ecosystem in the case of EEBERS covers the single building but also its neighbourhood up to city level. In general the below described properties belong to all single entity of a system and also across hierarchical levels (e.g. building vs. neighbourhood).

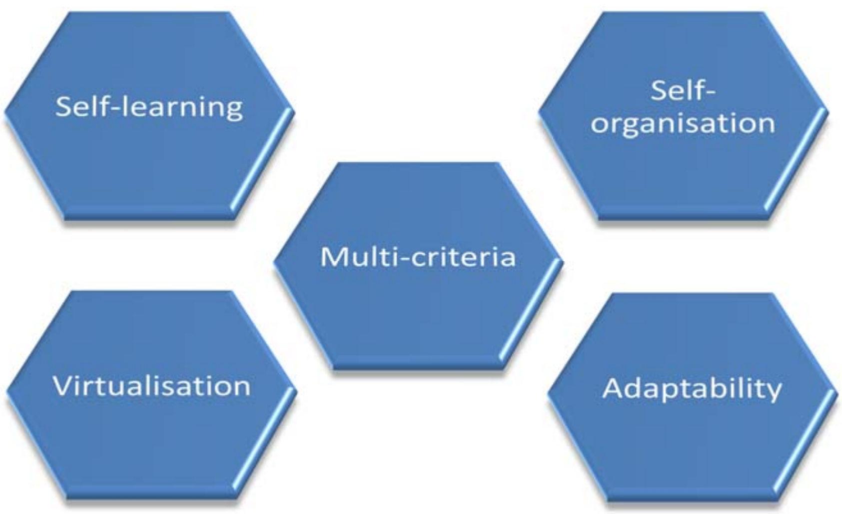

Figure 27 Core aspects of EeB visions

A key requirement to realize future ecosystems is the adaptability within the system. Adaptability of a building refers to the ability of the building to adapt without effort to certain needs or situations in real-time. The building is able to react to its users and change its properties. This can be for instance the colour but also change of the room size (due to moving walls) or change of components (e.g. smart glasses to adapt to the expected room brightness of the current user).

Self-learning and self-adapting systems are needed for this during operation but also in the design stage. However, to prevent complexity re-usable solutions and standards (for components, processes and ICT) that can be flexible customized and fast adapted are necessary.

Another key aspect of future solutions is related to the various requirements from different stakeholders and factors that influence building operation. Mastering them can be equated with working with multi-criteria frameworks. Multi-criteria as general aspect in the construction industry and especially in building configuration, decision making or building operation and optimization. Some examples multi-criteria frameworks are used for are building simulation, assessment of buildings but also development and refinement of e.g. control strategy. The idea is to sustain decisions on a broad information and data basis and in parallel use methods (e.g. semantics) and frameworks that can incorporate different information types and qualities, if needed, in real-time.

Virtualisation will appear in different manifestations in all life-cycle stages of a building. Virtual prototypes to test and visualize, augmented reality approaches to integrate stakeholders in design an operation, virtual plants will dominate the energy systems of the future, virtual sensor networks will help to control buildings and neighbourhoods, virtual enterprises can be found in various value chain related to any building life-cycle. All of them have in common that ICT is needed to realize the mentioned systems with its functions. Some of this systems will be also virtualized and even beyond rely on cloud-bases solutions.

Decentralised, agent-based systems with self-organising and self-diagnostic capability will become more important. Solutions that ensure improvement of energy-efficiency on district and city level and predictive control, early detection of malfunctions and performance oriented business models as well as systems that are able to support preventive maintenance service will be available.