IDEAS PROJECT FINAL REPORT

Grant Agreement number: 600071

Project acronym: IDEAS

Project title: Intelligent neighbourhooD Energy Allocation & Supervision

Funding Scheme: Collaborative Project

Period covered: from 01/11/2012 **to** 31/10/2015

Project website address: www.ideasproject.eu

This report was produced by Dr Tracey Crosbie on behalf of the project co-ordinator Prof Nash Dawood with input from the IDEAS consortium.

Table of Contents

1. EXECUTIVE SUMMARY

IDEAS gathered eight public and private organisations from the domains of ICT, Energy, Territories and Construction and Buildings. Their aim was to develop and validate the technologies and business models required for the cost effective and incremental implementation of Energy Positive Neighbourhoods (EPNs). These included:

- A neighbourhood energy management tool to optimise energy production and consumption;
- User interfaces to engage communities and individuals in the operation of EPNs;
- A decision support urban planning tool to optimise the planning of neighbourhood energy infrastructures;
- Business models to underpin EPNs that engage end users, public authorities and utility companies.

The tools and business models developed in the project were piloted at the Bordeaux University campus in France and the Omenatarha residential neighbourhood in Finland.

At the outset of the project there was no accepted definition of an EPN. Therefore the very first steps taken involved defining an EPN and a set of Key Performance Indicators (KPIs) to measure 'energy positivity', which were refined throughout the project's lifetime. The definition of an EPN was finalised as follows: ***EPNs are areas in which annual energy demand is lower than annual energy supply from local renewable energy sources. Their energy infrastructures are connected to and contribute to the efficient operation and security of the wider energy networks. The aim is to support the integration of distributed renewable energy generation into wider energy networks and provide a functional healthy user friendly environment with as low energy demand and little environmental impact as possible.***

The research conducted in the IDEAS project was broken down into three distinct periods: In the 1st Period, along with the work to define and measure EPNs, the specifications for the IDEAS Energy Management Solution and business models were developed; The IDEAS pilot tools and interfaces were developed during the 2nd Period; In the 3rd Period the tools were piloted at the demo sites and the most promising EU markets for EPNs to underpin the future exploitation of the projects innovations were identified.

The IDEAS project contributed to:

- The opening of a market for ICT-based district/community energy management systems.
  - ✓ The IDEAS Total Solution for an EPN can reduce energy costs by up to 58%.
  - ✓ IDEAS Energy Management System enables up to a 30% increase in the revenue generation from distributed renewable electricity and heat production and a 10 % increase in the efficiency of distributed renewable plant.
- Establishment of a collaboration framework between the ICT sector, the buildings and construction sector and the energy sector.
  - ✓ The results of the IDEAS project were presented at 31 conferences and 7 dissemination workshops with related RTD projects with a total audience of over 8565 people. In addition the IDEAS consortium published 10 peer reviewed conference papers & 5 professional journal articles.
  - ✓ Since October 2013 over 8000 users accessed the IDEAS website and there have been some 4728 views of the webinar that presented the findings of the project in less than a month.
  - ✓ As a result of the wide dissemination of the projects outcomes the operational concept of an EPN (the EPN definition, KPIs and energy positivity label) is informing discussions in other European projects involving stakeholders from the ICT, energy, buildings and construction sectors. (e.g. Design4Energy, CityKeys and DRBOB).
- Quantifiable and significant reduction of energy consumption and CO_2 emissions achieved through ICT.
  - ✓ The IDEAS Total Solution for an EPN is able to reduce CO_2 emissions by up to 58%.

2. DESCRIPTION OF PROJECT CONTEXT & OBJECTIVES

2.1. INTRODUCTION

The IDEAS project's main aim is to illustrate how communities, public authorities and utility companies across the EU can be engaged in the development and operation of energy positive neighbourhoods and the economic and environmental benefits of doing so. Therefore the main goal is demonstrate how energy positive neighbourhoods can be cost effectively and incrementally implemented by designing, testing and validating:

- A neighbourhood energy management tool to optimise energy production and consumption;
- user interfaces that engage communities and individuals in the operation of energy positive neighbourhoods;
- A decision support urban planning tool to optimise the planning of neighbourhood energy infrastructures;
- Business models to underpin energy positive neighbourhoods that engage end users, public authorities and utility companies.

The key idea is that the neighbourhood energy management system enables intelligent energy trading and operation of equipment and buildings along with local energy generation and storage [see Figure 1]. The components of the neighbourhood energy management tool include:

- An internet-based infrastructure to manage real-time information flows;
- An optimisation and decision support system for the management of energy production and consumption;
- Data management and storage services [see Figure 2].

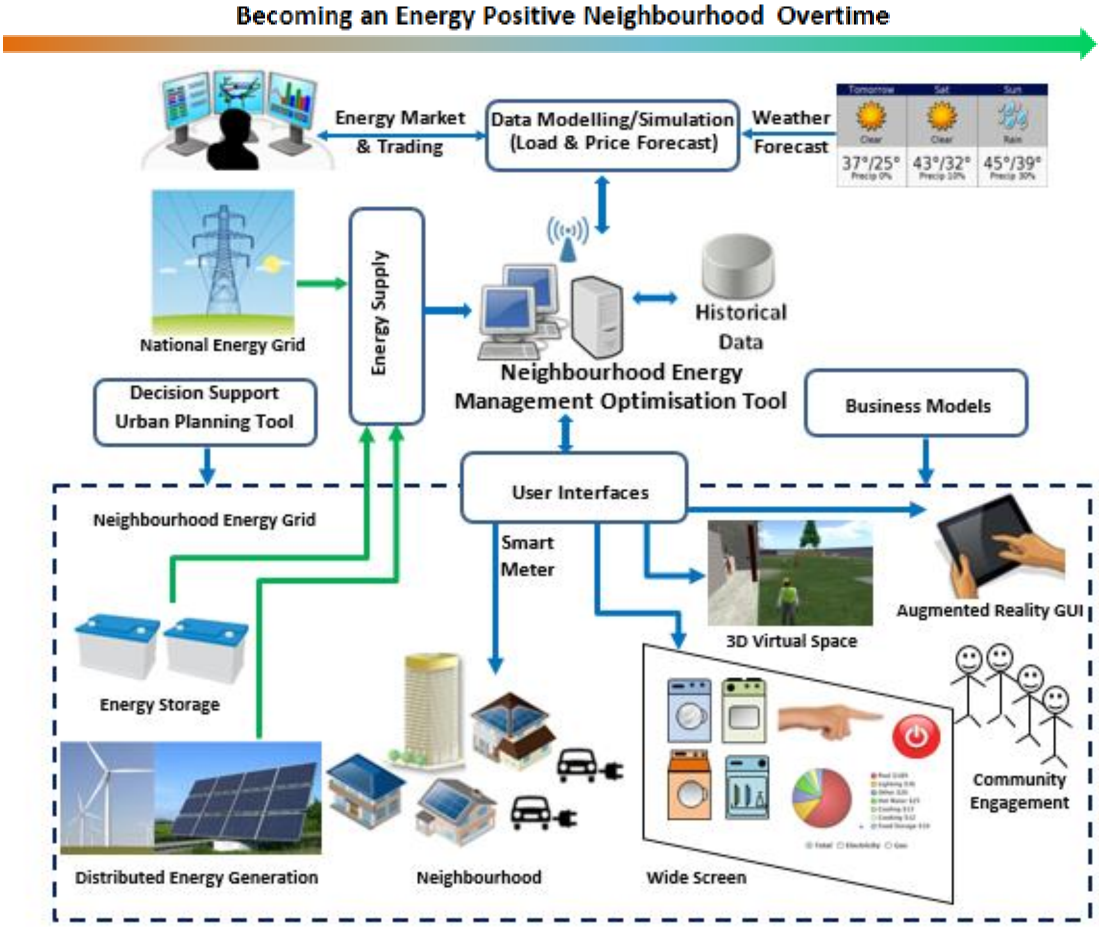


Figure 1 Neighbourhood energy management system

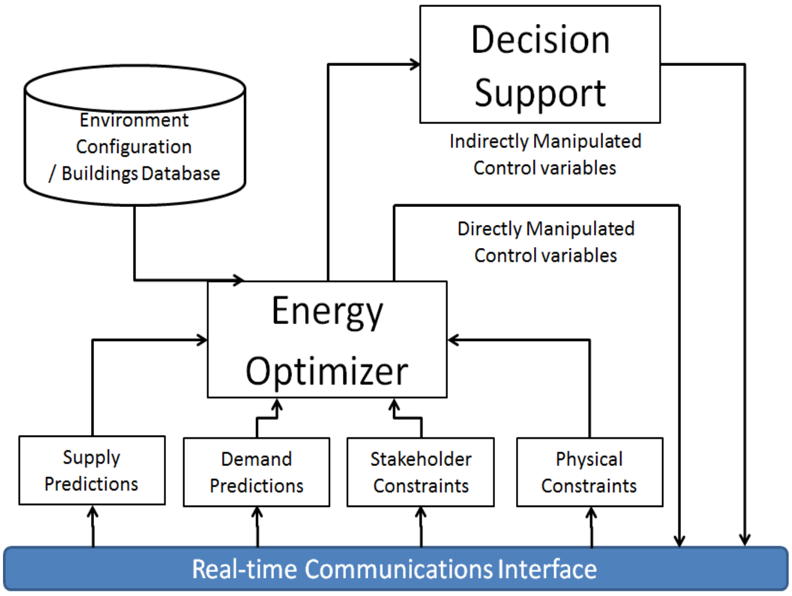


Figure 2 data management and storage services

It was also envisaged that the EMS would be integrated with:

► User interfaces that employ mixed reality technologies to provide intuitive environments that engage casual users and in doing so improve their energy literacy and energy consuming behaviours.

► A decision support urban planning tool designed to inform the future development and redevelopment plans for neighbourhood energy infrastructures.

All of the planned tools and interfaces were developed and tested during the lifetime of the IDEAS project [see details in Section 1.3 of this report].

Appropriate business models for the pilot sites were also developed during the project and how different Utility industry structures' and property markets impact on the viability of those business models in different EU countries was identified [see details in section 1.3.3].

2.2. SCIENTIFIC AND TECHNICAL OBJECTIVES

In order to achieve the main aim of the IDEAS project the following Scientific and Technical Objectives (STOs) were defined in the research plan and were met during the projects lifetime.

STO 1 The identification of the value proposition for the different stakeholders required for the implementation of energy positive neighbourhoods in the demonstration cases.

STO 2 The identification of how utility companies across Europe can be profitably engaged in the development and operation of energy positive neighbourhoods.

STO 3 The specification of the functionalities needed for the control and optimisation tools and the decision support tool.

STO 4 The development of an ICT platform to support real-time energy management and control in urban/rural communities and neighbourhoods.

STO 5 The development of efficient model-based optimisation and control schemes to support energy management in urban/rural communities and neighbourhoods.

STO 6 The development of decision making tool for planning the future development of neighbourhoods.

STO 7 Development of user-interfaces that engage individuals to increase awareness of energy use and influence energy using behaviours.

STO 8 Engage with communities in ways which increases awareness of neighbourhood energy use and influence communities as a whole to change energy using behaviour.

STO 9 Demonstration of the performance of the developments made on the user interfaces, control and support and management tools.

STO 10 Efficient dissemination & exploitation strategies to ensure the widespread dissemination of results and substantial impacts.

2.3. VALIDATION

The validation of the tools and business models was conducted in the three main phases envisaged at the outset of the project:

- The first stage used simulations of the case study neighbourhoods, to test the components of the energy management tool calibrated using monitored energy production and consumption data collected over a period of one year.
- The second stage involved the implementation and monitoring of the energy management tool and user interfaces in the two case study neighbourhoods over a period of eight months.
- The third stage involved using the decision support urban planning tool to model and optimise different planning options for renewable energy technologies etc. in the two demonstration sites.

The third stage of the validation was important to illustrate how the value proposition underpinning the business cases for all stakeholders increases with further investment.

In the second stage of the validation the tools developed were demonstrated at a University campus in France and a newly built residential area in Finland. In both cases the focus was on optimising the simulated or scaled production and consumption of both heat and electricity based on weather and energy demand data from the pilot sites.

The pilot demonstrations provided evidence of:

- The benefits in terms of total cost of neighbourhood operation, CO_2 reductions and improved services for users;
- The potential for scaling up the pilot cases.

The pilot demonstrations also permitted to test various aspects of the business models.

The analytical approach adopted within the validation measurements takes into account international green building standards such as BREEAM and LEED / LEED ND. Quantification of impacts is based on European Building Energy Performance Directive and the related CEN standards for the calculation of energy performance and builds on the lessons learned from the ICT PSP methodology for energy saving management[1].

2.4. RESEARCH TIME-LINE

The research conducted in the IDEAS project was broken down into three distinct periods: the First Period was 12 months in duration (01/11/12 to 31/10/13), the Second Period was 8 months in duration (01/11/13 to 30/6/14) the Third Period was 16 Months in duration (01/7/14 to 31/10/15)

In the 1st period of the IDEAS project, the research conducted focused on:

- Stakeholder requirements capture to ensure the tools and business models developed are fit for purpose;
- The development of business models within the context of the demonstration sites;
- The development of specifications for the tools and interfaces required to support an EPN.

In the 2nd period of the IDEAS project the research conducted focused on:

- Placing the business models developed for the demonstration sites in the wider EU context;

[1]See http://cordis.europa.eu/docs/projects/cnect/6/250496/080/deliverables/001-ARES975520CIPCommondeliverableeSESH.pdf

- The development of the following pilot tools based on the specifications;
  - A neighbourhood energy management system (EMS) to optimise storage/retrieving and buying/selling energy and supply energy demand predictions for energy trading;
  - A decision support urban planning tool to estimate the economic and environmental effects (e.g. ROI period and CO_2-ekv emissions) on different renewable energy supply options and future building development and redevelopment, which evaluates and gives guidance on the possibilities to meet local energy demand with local renewable supply;
  - Two broad types of innovative user interfaces to interact with the occupants of an EPN;
    - ✓ Interfaces required for energy consumers and producers to interact with the services required for the Demand Side Management (DSM), Supply Side Management (SSM) and energy trading energy etc.
    - ✓ Community based interfaces and virtual environments that 'promote' the concept of an EPN to the occupants of the EPN and the wider public.

In the 3rd period of the project the IDEAS project the research conducted focused on:

- Research to identify the most promising markets in different EU countries for the development of EPNs to underpin the future exploitation of the projects innovations.
- The testing and validation of the tools, user interfaces and elements of the business models developed in the earlier phases of the project at the two demonstration sites.

3. MAIN SCIENTIFIC & TECHNICAL RESULTS

3.1. OPERATIONAL CONCEPT OF AN ENERGY POSITIVE NEIGHBOURHOOD (EPN)

3.1.1. Defining Energy Positive Neighbourhood

At the outset of the project there was no accepted definition of an EPN. Therefore it was necessary to develop such a definition and a set of key performance indicators (KPIs) to measure 'energy positivity'[2] These were refined during the lifetime of the project to address the way in which the energy infrastructures of an EPN interact with wider energy networks. The key elements of the definition are presented in the Figure below.

Figure 3: The definition of an EPN underpinning the research in the IDEAS project

> Energy positive neighbourhoods are those in which the annual energy demand is lower than the annual energy supply from local renewable energy sources. *Their energy infrastructures are connected to and contribute to the efficient operation and security of the wider energy networks. The aim is to support the integration of distributed renewable energy generation into wider energy networks* and provide a functional healthy, user friendly environment with as low energy demand and little environmental impact as possible

While the concept underpinning the notion of an EPN in the IDEAS project is that local energy demand is serviced by local renewable energy supply, we are not advocating 'islanded micro grids' that operate separately from the national energy networks. It is envisaged that the energy infrastructures of EPNs are not only connected to the wider energy networks but that they contribute to the optimisation and security of those wider energy networks. In this regard the idea that the energy demand of the neighbourhood is predominantly serviced by local renewable energy supply is significant. This is because matching local supply (e.g. solar and wind power) with local demand can mitigate congestion on the electricity distribution network enabling savings on the investments in grid capacity and congestion management required to support distributed renewable energy generation (DREG) in the electricity industry.

3.1.2. KPIs To Measure 'Energy Positivity'

To operationalise[3] the IDEAS definition of an EPN, a set of Key Performance Indicators (KPIs) were developed. These enable the assessment of how well a neighbourhood is fulfilling the definition of an EPN, i.e. the 'energy positivity level' of the neighbourhood. Foremost among these is the overall balance between energy demand and renewable energy supply in a neighbourhood measured using an **On-site Energy Ratio (OER)**, which is the ratio between annual energy supply from local renewable sources and annual energy demand.

In addition to considering the overall annual energy balance it is important that the balance between supply and demand for different types of energy (i.e. heating, cooling and electricity) are taken into account along with the matching of the timing of the supply and demand of these different types of energy. The latter is necessary to avoid the challenges caused by peak demand hours particularly in relation to electricity. Therefore, the following indicators calculated for each energy type separately (x = h for heating, c for cooling, e for electricity) are suggested in addition to the OER:

- **Annual Mismatch Ratio (AMRx),** which indicates how much energy is imported into the area for each energy type on average;
- **Maximum Hourly Surplus (MHSx),** the maximum yearly value of how much the hourly local renewable supply overrides the demand during one single hour (by energy type) compared to the OER;

[2] For further details see IDEAS Deliverable D3.1 Case study scoping: at http://www.ideasproject.eu

[3] Define Energy Positive neighbourhood in terms of the operations used to determine or prove it

- **Maximum Hourly Deficit (MHDx),** which is the maximum yearly value of how much the hourly local demand overrides the local renewable supply each hour;
- **Monthly Ratio of Peak hourly demand to Lowest hourly demand (RPLx**) indicates the magnitude of the peak power demand.

3.1.3. Energy Positivity Label

For the concept of an EPN to be accepted and provide an impetus towards net energy positive design in the built environment it is necessary to have a method of clearly communicating the 'energy positivity level' of a neighbourhood. To enable this, an 'energy positivity label', based on the previously presented indicators, was developed to offer a clear and easily understood approach to visualising the energy performance of a neighbourhood [see Figure 4].

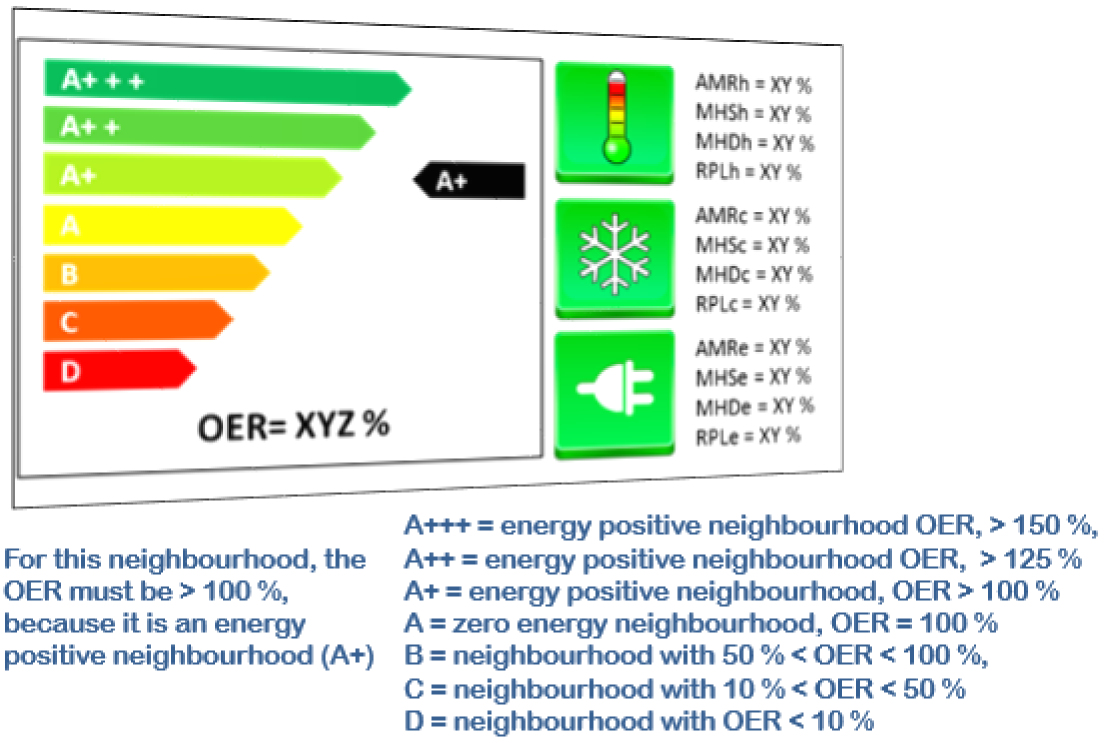


Figure 4: Energy positivity label.

The fundamental difference between existing labels related to sustainable construction and the proposed energy positivity label is the scale of analysis. Existing labels are largely designed to indicate the sustainable construction of individual buildings and on the whole focus on new construction. Whereas the 'neighbourhood energy positivity label' is designed to support the incremental development of sustainable neighbourhoods or districts which include pre-existing buildings as well as new developments[4].

---

[4] For further details see IDEAS Deliverable D2.5 Publication: which presents a conference entitled "Defining and Operationalising the Concept of An Energy Positive Neighbourhood." The paper was presented in a special session of the 10th Conference on Sustainable Development of Energy, Water and Environment Systems: September 27 - October 2, 2015, in Dubrovnik, Croatia.

3.2. IDEAS TECHNICAL SOLUTION FOR EPNS.

3.2.1. The Energy Management Tool

The Energy Management tool lies at the core of the IDEAS technical solution for EPNs. It provides the functionality for the cost-optimisation of production, storage/retrieval and buying/selling of energy at the neighbourhood level [see Figure 5].

The analytical functionality of the IDEAS Energy Management Tool lies in the IDEAS simulation prediction and optimisation models which:

- Accurately predict neighbourhood energy supply and demand;
- Enable user configured optimisation of the production storage and sale of renewable energy at the neighbourhood scale;
- Enable users to simulate the effects of further investment in renewable energy technologies[5].

The approach taken in the prediction and optimisation builds on approaches using Mixed Integer Linear Programming (MILP) models and non-linear boiler efficiency curves and extends this work into a rolling horizon context. In doing so **it provides a novel approach which accounts for load prediction inaccuracies in earlier optimisation approaches and therefore improves the optimisation process.** Findings indicate that when load prediction inaccuracies are also considered in the optimisation framework, a strategy interacting with both the spot (day-ahead) market and the balancing (intra-day) market is significantly more profitable than a strategy interacting with the spot market only[6].

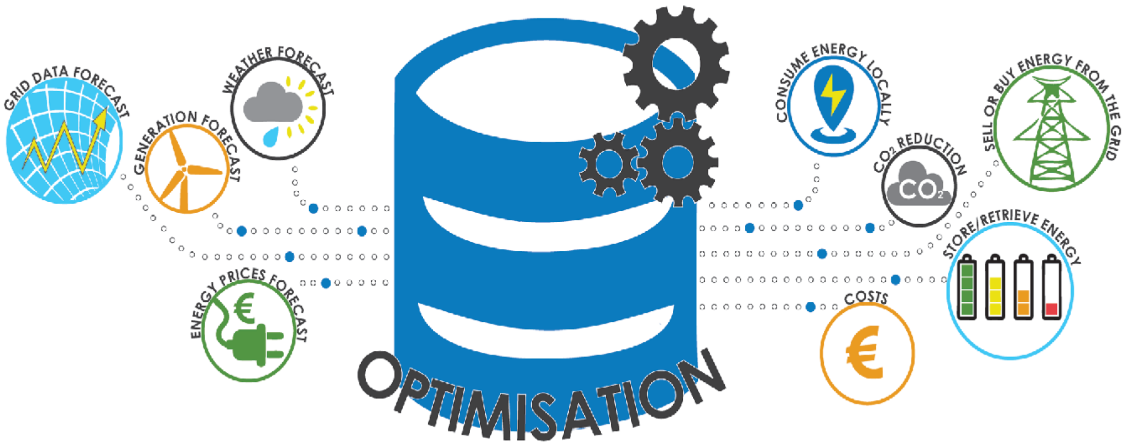


Figure 5: Analytical functionality of the Energy Management tool

Centralised data storage is provided by IBM's Intelligent Operations Center (IOC) a smart technical solution to querying, transforming, cleaning, storing and retrieving data. It provides the Energy Management Tool with an efficient approach for:

- Recoding and managing incoming data;
- Data integration;
- Timely access to data by multiple users;
- User configurable interfaces to organise and present data.

---

[5] For Further details see IDEAS Deliverable D3.1 Specification for the neighbourhood energy management too at http://www.ideasproject.eu

[6] For Further details paper presented as part of IDEAS Deliverable D4.4 Publications: *"Load Forecasting and Dispatch Optimisation for Energy Decentralised Co-Generation Plant with Duel Energy Storage*." This article has been submitted for peer review to the Applied Energy Journal. Avaible at http://www.ideasproject.eu

Data input: The Energy Management Tool collects data from external sources such as:

- Weather forecasts
- Energy meters
- Energy price feeds
- Urban planning tools (i.e. AtLas)
- National electricity grids

Data output: The Energy Management Tool supplies data to:

- The Home Energy Application – to enable residents to manage their energy use
- The Community Interfaces – to inform and engage the local community
- Service Providers Interfaces – to facilitate neighbourhood energy management
- The 3D virtual neighbourhood – to promote the concept of Energy Positive Neighbourhoods

3.2.2. User Interfaces

Community interfaces: a person who resides within an Energy Positive Neighbourhood (EPN) may influence the energy balance of the area without being aware of their impact. To address this IDEAS developed public interfaces with an educational purpose to both promote the concept of an EPN and help local people understand the impact of their energy related behaviour as illustrated in Figure 6.

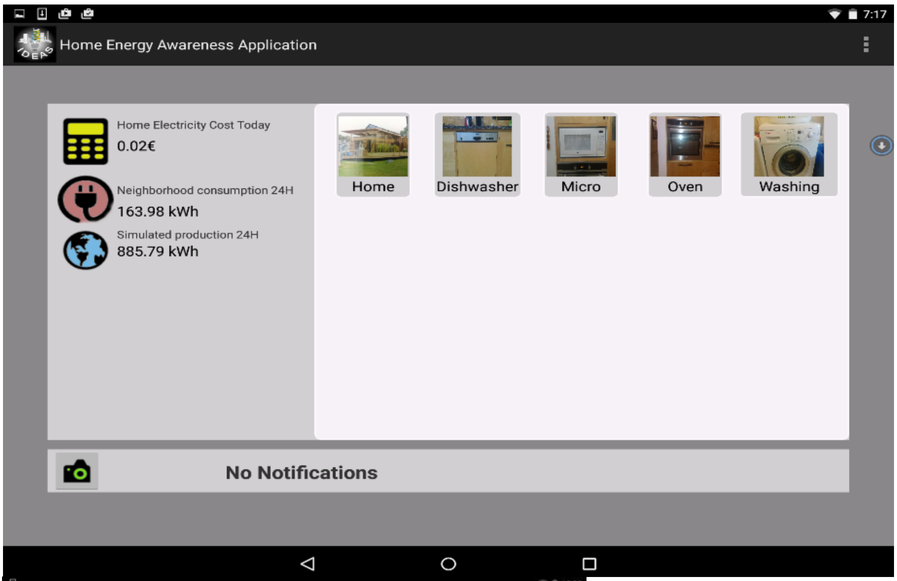
Figure 6: Community interfaces

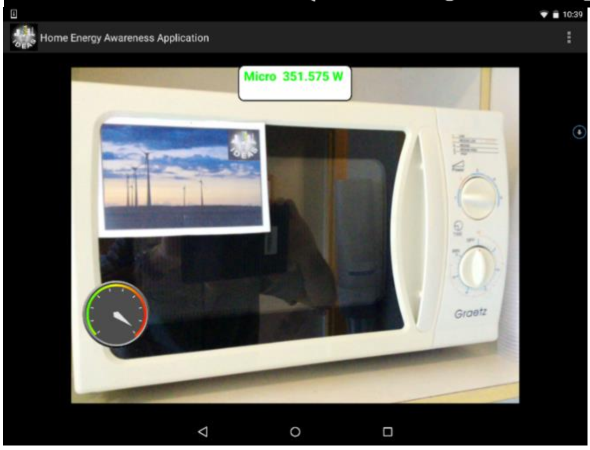
The community interfaces provide:

- ✓ Public and private access to data;
- ✓ Educational views about EPN with a quiz;
- ✓ Multiple charts / graphs showing their own neighbourhood energy monitoring data;
- ✓ The Energy Positivity level of the neighbourhood.

The home energy application: The IDEAS neighbourhood energy management system notifies the user through the home energy app about potential actions that they can take to reduce peak energy demand and shift energy demand to periods when renewable energy is available. The app provides fine grained energy consumption data using real-time augmented reality technology on hand-held see-through video to help people manage their own energy demand as illustrated in Figure 7. The development of the home energy application involved research in the area of computer vision and augmented reality. It involved the development of a real-time computer vision environment called "Augmented Reality Framework Library" (ARFL). This framework is able to detect and recognize in a real-time, in a video stream, many types of objects (such as home appliances), track them in the video images and augment information in text or graphics within the video stream. **This work moves beyond the state of the art in energy feedback technologies by using**

real-time augmented reality technology on hand-held see-through video to give alerts, interact with users and allow them to visualise real-time energy usage of various energy consumption appliances in the home.





The home energy application provides:

- ✓ Private access to home energy data
- ✓ Home appliances registration
- ✓ Alert notifications

Figure 7: Home energy application

Service Providers Interface: The EPN Service Provider (EPNSP) is responsible for energy management within the EPN. The information provided by the IDEAS Energy Management system through the service providers' interfaces enables them to do so: by providing real time data and energy predictions based on user selected energy optimisation approaches.

The Service providers' interface provides

- ✓ Private access to data
- ✓ A customised view of the neighbourhood
- ✓ A dashboard at the neighbourhood scale
- ✓ Multiple charts / graphs showing detailed data (historical data, predictions)
- ✓ The Energy Positivity level of the neighbourhood

Figure 8 Service providers' interfaces

3D virtual world: This shared 3D virtual space helps local stakeholders to host external visitors in the virtual neighbourhood to demonstrate the viability of building an EPN using the visual and data contexts of the physical site. The 3D virtual space enables the site's overall energy consumption to be visualised, using data provided by equipment installed on the site. In the 3D virtual world the energy production of the 'virtual' and physical energy plant are provided by the IDEAS Energy Management System: The former from monitored energy data and the latter from simulations based on current weather conditions etc.[7]

The 3D virtual world

- ✓ Promotes the concept of an EPN
- ✓ Promotes energy literacy
- ✓ Enables the visualisation of:
  - ❖ the operation of current energy plant and buildings;
  - ❖ renewable energy plant not currently installed e.g. wind turbines and PV panels.

Figure 9: 3D virtual world

3.2.1. AtLas: Decision Support Urban Planning Tool

The AtLas tool is a decision support urban planning tool designed to inform the future development plans for neighbourhood energy infrastructures [see Figure 10]. This tool enables comparisons of potential sustainable energy solutions related to different city planning options or renovation scenarios.

The development of the tool was informed by an analysis of users' requirements and a review of the advantages and disadvantages of existing tools. **The issues addressed, taking the development beyond state-of-the-art include the complexity of the existing tools, the detailed energy and building related knowledge required as data input, a lack of site level tools, the transparency of the processes and the lack of time and economic perspectives of the existing tools.** [8]

The AtLas tool provides the users the possibility to compare different scenarios during long future perspectives (up to 100 years), with the choice of different level of input details, from very generic data provided by the tool to hourly measured data, if available. The actions can be taken at user defined timing and duration. The scenarios can be compared regarding CO_2 equivalent emissions, costs or energy balance, relative to different variables, e.g. total for the area, per resident, per household or per square meter of floor area.

[7] For further details see Short et al (2015) Visualization Tools For Energy Awareness And Management In Energy Positive Neighbourhoods: Proceedings of 14th International Conference on Construction Applications of Virtual Reality 2014: At http://www.ideasproject.eu/IDEAS_wordpress/wp-content/uploads/2013/08/IDEAS-ConVR2014-paper.pdf

[8] For further details see IDEAS Deliverable D2.5 Publication: which presents a conference entitled "Defining and Operationalising the Concept of An Energy Positive Neighbourhood." The paper was presented in a special session of the 10th Conference on Sustainable Development of Energy, Water and Environment Systems: September 27 - October 2, 2015, in Dubrovnik, Croatia

Figure 10: Atlas urban planning tool

3.3. BUSINESS SOLUTION FOR EXISTING UTILITIES & ESCOS

3.3.1. Business Concept

The IDEAS project has developed business models to enable existing companies with expertise in the energy industry to evolve into a new type of service provider. We have called this new type of service provider an Energy Positive Neighbourhood Service Provider (EPNSP) [see Figure 11].

The key service required for the development of an EPN is the optimisation of the production, storage/retrieval and selling of local renewable electricity and heat in the local area. Distribution Network Operators (DNOs), Energy Service Companies (ESCOs) and District Heating (DH) Providers are the envisaged service providers in the business models developed to enable the roll out of EPNs in the IDEAS project. There is an overlap in the unique value propositions for these types companies of to extend their current business models and become EPNSPs. Although these can be summarised:
In the case of DNOs as;

- Up to a 100 % reduction in the investments required for the reinforcement of the wider electricity distribution network to service new urban developments[9],
- Significant reductions in the total investments in network reinforcement required to integrate DREG into current electricity networks,
- Supporting the incremental upgrading of the ‘dumb’ electricity distribution networks to the 'smart' networks required to integrate DREG into current electricity networks.

In the case of DH Providers and ESCOs as;

- Up to 30% increase in the revenue generation from distributed renewable electricity and heat production
- Up to 10 % increase in the efficiency of distributed renewable plant[10].

[9] The development of an EPN for a new urban development could feasibly completely remove the necessity of reinforcing the wider distribution network upstream to increase the capacity of the distribution network.

[10] For Further details paper presented as part of IDEAS Deliverable D4.4 Publications: *“Load Forecasting and Dispatch Optimisation for Energy Decentralised Co-Generation Plant with Duel Energy Storage*.” This article has been submitted for peer review to the Applied Energy Journal. Avaible at http://www.ideasproject.eu

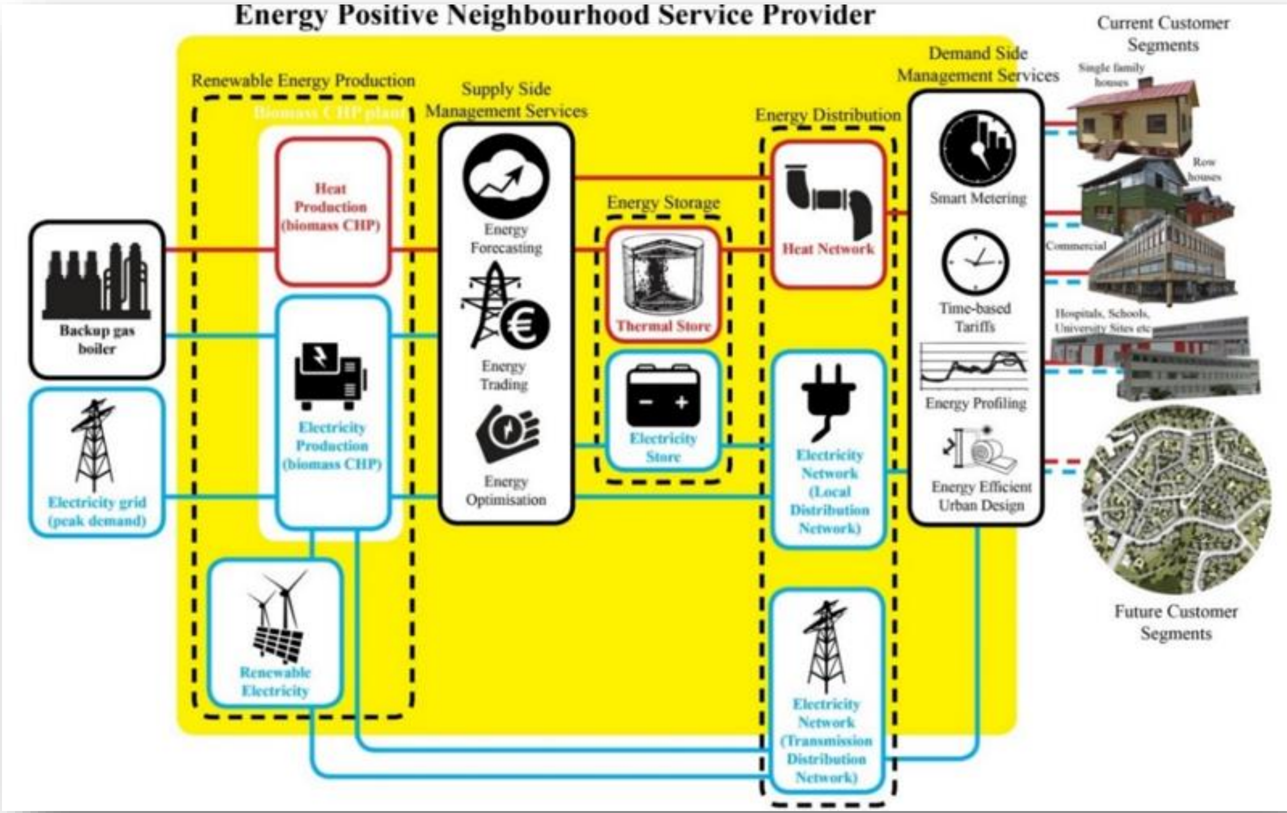


Figure 11: The concept of an Energy Positive Neighbourhood service provider

3.3.2. Business Models For The Pilot Sites

Two distinct types of business models for EPNSPs were developed during the project, one which we called a District Energy Supplier, and one we called an Integrated Energy Service Provider[11]. These were tailored to the requirements of the key stakeholders at the project pilot sites[12]. However they could be combined and a District Energy Supplier in a mixed use neighbourhood, with both residential, commercial and industrial buildings could also offer Integrated Energy Contacts (IEC) to their larger commercial customers as depicted in Figure 11 above.

3.3.3. District Energy Supplier

The business model developed in the context of the Finnish demonstration site is for a District Energy Supplier that generates, distributes and supplies heat and electricity from renewable resources (bio-fuelled CHP and wind turbines) in a predominantly residential area [see Figure 12]. The company has a contract to sell electricity and heat with most of the occupants in the neighbourhood. It interacts with the energy market (buying and selling electricity) and has the means to control local energy production and distribution. The production, storage/retrieval and buying/selling of energy is optimised to increase profits. The district energy supplier also provides DSM services to its customers to help them shift their energy demand to times when it is available from local renewable sources, and to help smooth out peaks in electricity or heat demand.

[11] see IDEAS Deliverable D2.2 Specific business models for demo cases at http://www.ideasproject.eu

[12] see IDEAS Deliverable D2.1 Business & community requirements analysis at http://www.ideasproject.eu

The business model is underpinned by the increased revenue from:

1. Reduced costs for energy production and increased profits from arbitrage, i.e. cost-optimising the production, storage/retrieval and buying/selling of energy;
2. Enhanced company green image which increases the customer base[13] reducing the average cost to supply services to each customer.

Key Partners

1.District heating provider-to implement run and maintain the CHP & DH network plus other forms of renewable energy generation.
2.Energy supplier- to bill customers and accept payment
3.Electricity distribution network operator

Key Activities

1. Local renewable heat & electricity generation distribution and supply
2. Optimizing the production, storage/ retrieving & buying / selling of energy
3. Supplying variable energy tariffs which reflect actual energy costs during the day
4. Predicting local electricity & heat supply/ demand
5. Buying electricity to cover inbalances in local supply & demand
6. Supplying variable electricity tariffs which reflect actual energy costs during the day
7. Supplying customers demand side management services

Key Resources

1. A bio-fuel powered CHP plant & heat distribution network
2. A local energy management system to optimise storage / retrieving and buying / selling energy in real time
3. A smart electricity distribution network
4. User interfaces to interact with customers
5. Professional staff with the required skills in marketing, engineering and finances

Value Propositions

Providing customers
1. affordable renewable energy
2.DSM services to help customers reduce their energy costs
3. Green, sustainable eco-friendly local neighbourhood/ community
4. Reduced carbon foot print

Customer Relationships

1. Energy supply contracts which offer a discount for buying both heat and electricity which reflect time of day energy production costs
2.Compulsory use of local district heating network - unless a more efficient heating option is available

Channels

1. Electricity and heat distribution networks
2. Local media, TV, newspapers and public screens etc.
3. Energy bills
4. Company websites
5. Smart meters and home based user interfaces

Customer Segments

1. Residential energy customers
2. Small commercial energy customers (small shops offices schools etc.)

Cost Structure

1. Energy production storage and distribution costs
2. Electricity purchased from day ahead market
3. Maintenance of heat and electricity networks and generation plant
4. Marketing costs to encourage people in the neighbourhood to buy heat and electricity from the company

Revenue Streams

1. Reduced costs for energy production and increased profits from arbitrage, i.e. cost-optimising the production, storage/retrieval and buying/selling of energy
2. Enhanced company green image increases customer base & in turn lowers production costs.

http://www.businessmodelgeneration.com

Figure 12: Business Model for a District Energy Supplier

The idea is that District Heating (DH) providers can profitably extend their Energy Service Contract (ESC) to their customers to include the generation, supply and distribution of locally produced renewable electricity. The current business models of DH providers encompasses the entire process of providing heat from the purchasing of fuel to the delivery and invoicing of the heat they supply. In the case of DH providers with CHP they also generate electricity which is most often sold to the national grid with no attempt to achieve the best price for the electricity produced using energy arbitrage. Here it is suggested that the current business model of DH providers is adapted to include the generation distribution and supply of locally produced renewable electricity as well as heat to customers within a given neighbourhood and that energy arbitrage is used to cost optimise the production storage /retrieval and buying and selling of energy. Thus leveraging the efficiency that can be gained through energy co-generation and co-optimisation of heat and electricity production.

[13] The customer base is the group of customers who repeatedly purchase the goods or services of a business. These customers are a main source of revenue for a company. The customer base is the group of customers who repeatedly purchase the goods or services of a business. These customers are a main source of revenue for a company.

3.3.4. *Integrated Energy Service Provider*

Key Partners

1. District heating provider -to implement run and maintain the CHP powered DH and other forms of renewable energy generation.
2. Electricity distribution network operator
3. Environmental consultant -to provide the information required to understand the ROI on the different renewable energy technologies
4. A building construction company to implement the building renovations

Key Activities

1. Local renewable heat and electricity generation distribution and supply
2. Optimising the production, storage /retrieving & buying/selling of energy
3. Consultancy services related to the assessment of most energy efficient option for building renovation and the renovation/replacement of energy infrastructures
4. Calculation of ROI on the required investments
5. Promoting the concept of an EPN to future customers and occupants of the EPN
6. Renovations to improve building energy performance

Key Resources

1. A bio-fuel powered CHP plant & heat distribution network and other forms of renewable energy generation
2 A local energy management system to optimise storage / retrieving and buying / selling energy in real time
3. A smart electricity distribution network
4. User interfaces to interact with building occupants
5. Professional staff with the required skills in marketing, engineering building construction and renovation finances and energy constancy
6. An energy decision support urban planning tool to estimate the ROI on different renewable energy supply options and future building development and redevelopment.
7. Professional staff with the required skills in marketing, engineering building construction and renovation finances and energy constancy,

Value Propositions

Providing customers:
1. guarantees for the total cost savings and overall performance of the energy services;
2 .affordable renewable heat and electricity;
3. reduced energy costs;
4. increased green, sustainable eco-friendly credentials;
5. reduced carbon footprint.

Customer Relationships

Performance based profit sharing Integrated energy contract

Channels

1. Electricity and heat distribution networks
2. Marketing channels include
   a) Company website
   b) community based screens to inform the occupants of the buildings of current energy consumption and promote the concept of an EPN

Customer Segments

1. Public and private organisations responsible for the management and energy costs of buildings in the same location. i.e. University Campuses, hospital sites, and larger schools etc.

Cost Structure

1. Energy production storage and distribution costs
2. Electricity purchased from energy supplier
3. Maintenance of heat and electricity networks and generation plant
4. Construction staff and equipment required for building renovation
5. Marketing costs for new customers

Revenue Streams

1. Reduced costs for energy production and increased profits from arbitrage, i.e. cost-optimising the production, storage/retrieval and buying/selling of energy;
2 Integrated Energy Contracts (IEC) which combine energy efficiency and renewable energy supply and management in large buildings and groups of buildings in the same locality

http://www.businessmodelgeneration.com

Figure 13: Business Model for an Integrated Energy Service Provider

The business model developed in the context of the French demonstration site is for an Integrated Energy Service provider that installs, maintains and runs renewable electricity and heat production for a public or private organisation that owns a group of buildings in the same geographical location. It is also responsible for the energy costs associated with running those buildings [see Figure 13]. Therefore prospective customers include universities, as in the case of the French pilot site, larger schools, hotel complexes, hospitals etc.

Essentially this business model is based on existing ESCos increasing their revenue by:

- Reduced costs for energy production and increased profits from energy arbitrage, i.e. cost-optimising the production, storage/retrieval and buying/selling of energy;
- Integrated Energy Contracts (IEC) which combines energy efficiency and renewable energy supply and management in large buildings and groups of buildings in the same locality.

In this case the EPNSP is not only involved in optimised energy supply, distribution and generation, but the company also supplies consultancy services and renovates buildings. The consultancy services help their customers to select the most energy efficient building renovation and energy infrastructure investments, and implement building renovations as part of an IEC. An IEC is a newly developed energy service business model that combines elements from both Energy Service Contracting (ESC) and Energy Performance Contacting (EPC).

3.4. TESTING THE IDEAS TOOLS INTERFACES AND BUSINESS MODELS

The research involved testing the IDEAS tools, interfaces and business models at two pilot sites:

- Part of a University campus in Bordeaux, France which houses the University Institute of Technology (IUT) [see Figure 14];
- The Omenatarha residential neighbourhood in the Skaftkärr area in Porvoo, Finland [see Figure 15].

Figure 14: French pilot site part of a university campus in Bordeaux

Figure 15 Finnish pilot site Omenatarha residential neighbourhood in the Skaftkärr

3.4.1. The Logic & Approach

The logic underpinning the pilot studies is to identify if the tools and elements of the business model tested at the pilot site could move the pilot neighbourhood towards a financially viable energy positive neighbourhood in the French and Finnish contexts [see Figure 16]. In the pilot studies the focus was on optimising the production and consumption of both heat and electricity. The methodology used to test the Energy management system is illustrated in Figure 17;

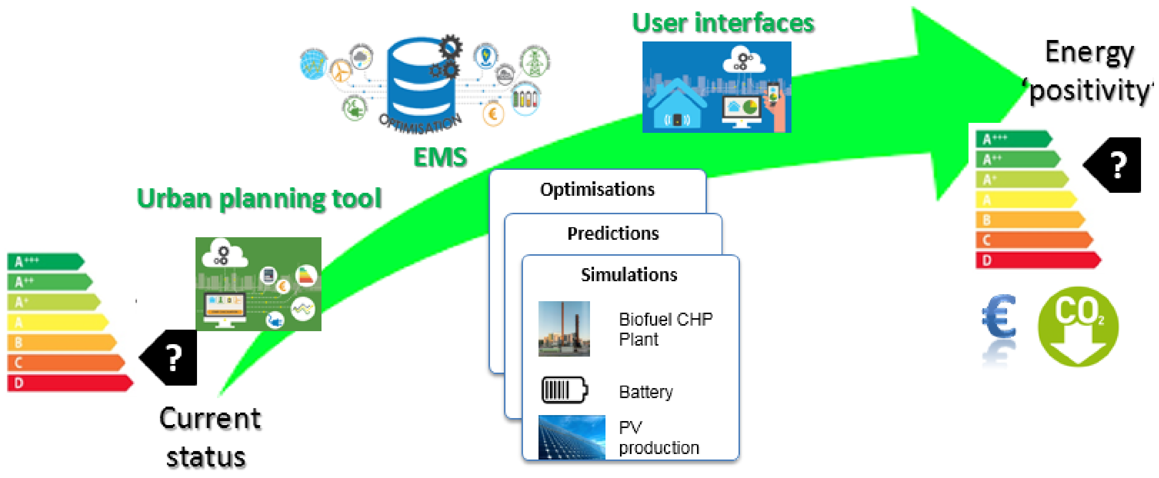


Figure 16: Logic of the demonstrations

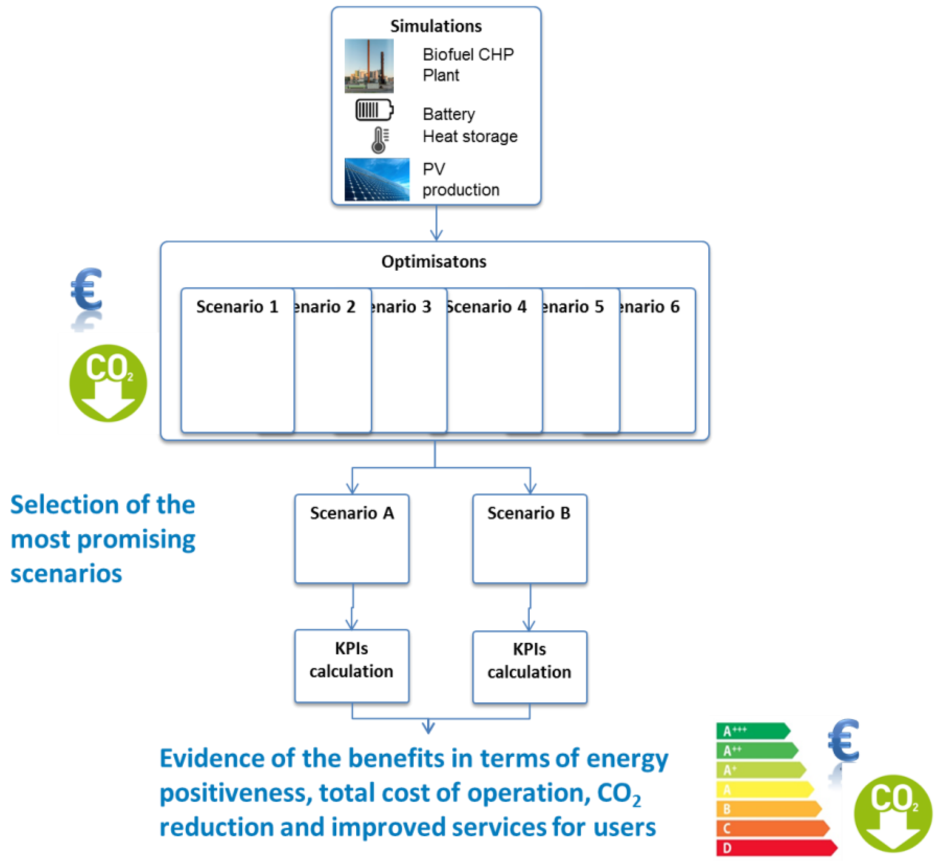


Figure 17: Methodology used to test the Energy Management System

3.4.2. The French Pilot

The research included simulations conducted to test the viability of one of the key revenue streams underpinning business models developed in the IDEAS project: namely reduced costs for energy production and increased profits from optimising the production, storage/retrieval and buying/selling of energy. User interfaces were also tested through their deployment and the assessment of their impact on the occupants and managers of the site through questionnaires, interviews and logging online activities.

The tools and interfaces implemented and tested in the French pilot study include:

1. A neighbourhood energy management system (EMS) developed to optimise storage/retrieving and buying/selling energy and supply energy demand predictions for energy trading.
2. Innovative user interfaces developed to interact with the occupants of an EPN:
    a. Community based interfaces in the form of a wide screen that raise energy awareness;
    b. A 3D virtual environment that provides a simulated environment for virtual visits to the French Pilot site promoting' the concept of an EPN to the occupants of the EPN and the wider public.
    c. Service Providers interface providing real time data and energy predictions based on user selected energy optimisation approaches.

The energy consumption data was monitored and stored in the EMS central data storage along with weather data and energy prices. The EMS can be adjusted to optimise either for minimal cost, minimal CO2 emissions or a mix of these. The schematic of the approach used to test the IDEAS tools interfaces and the key revenue streams for the business models is presented in Figure 18.

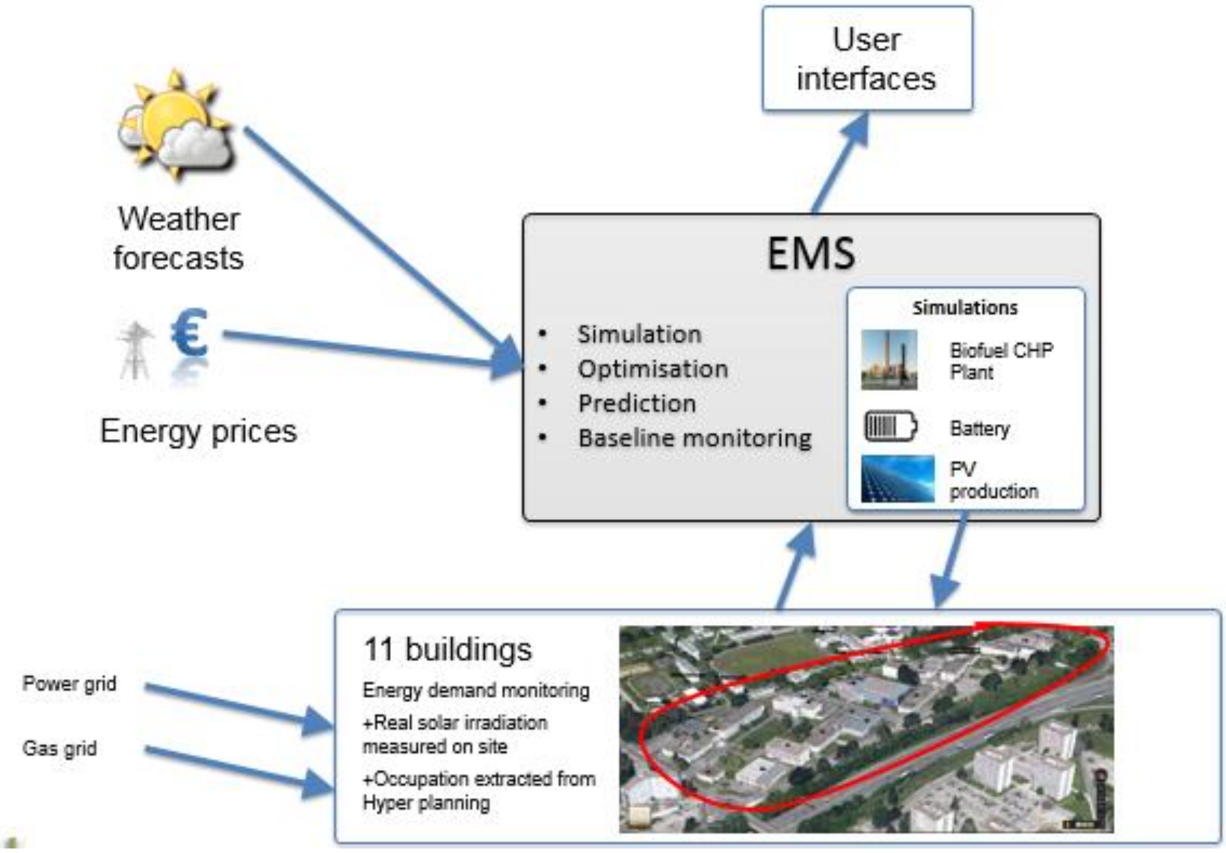


Figure 18: Schematic of the approach used to test the IDEAS tools interfaces in the French Pilot

3.4.2.1.Potential of the service providers' interface:

The local stakeholders at the pilot site found that the Service Providers interface provided an overview of the pilot site global energy consumption (electricity and gas) that was missing from the previous tools they had tried. The EPNSP interface was found to have numerous advantages over existing tools, such as the one provided by EDF the energy supplier at the pilot site, including:

- Continuous monitoring of energy use and the near real time information at the site scale supporting the detection of energy savings opportunities related to the energy consumption during the periods when the site is unoccupied;
- Predictions of site global energy demand and supply to support facilities management.

The graphical design of the interface was appreciated as well as the global indicators displayed in the tool that correspond to the parameters monitored during the year to identify potential deviations or issues. This was felt to be a great improvement on the previous approach to energy management at the site which was mainly based on energy bills analysis conducted at the end of the year. Some improvements to the service providers' interface were suggested by research participants, these include historical displays of energy consumptions and more transparent information related to the calculation methods used.

3.4.2.2.Potential of the community interfaces:

The community interfaces were initially well received by the occupants of the IUT site. When interviewed, about the interfaces people mention their lack of means to act at the site scale and that they appreciated that the community interfaces try to fill this gap by providing tips in direct relation with the energy consumption measured on site. However, the site occupants already have a general knowledge of energy issues due to their academic fields of study. Therefore the impact of the community interfaces was more limited than might be the case in other cases where the site occupants are not as well informed. This conclusion is also backed up by the findings in the case of the Finnish pilot presented in section 1.3.4.3.1.

3.4.2.3.Potential of the 3D virtual world:

The 3D Virtual World was highly attractive for people new to this technology. 55% of the visitors to the site indicated that it had a positive impact on their energy awareness. This is surprising given that many of the visitors were students and academics working in domains related to renewable energy and energy efficiency in the built environment. Users indicated that the 3D virtual world could be used as a Neighbourhood Energy Management System allowing the monitoring of site and building energy consumption, energy production and occupation etc. at the neighbourhood scale with the ability to zoom down to the building scale and energy system scale (PV production for instance). They also envisaged a pedagogical role within teaching at the university (e.g. support for practical exercises).

3.4.2.4.Moving the pilot site towards energy positivity

As the French pilot site has no meaningful renewable energy technology two local energy sources were simulated and several optimisation scenarios were ran and analysed to identify the most promising or realistic approaches to move the neighbourhood towards energy positivity as illustrated in Figure 16 . For the two most promising optimisation scenarios, the Key KPIs developed in the IDEAS project to measure the energy 'positiviness' of a neighbourhood are calculated. These KPIs are compared to the current situation at the site based on a calculation of the same KPIs for the French Pilot site as it was at the beginning of the project. Table 1 summarises the results in terms of impact on the French pilot site of the different simulated scenarios that were tested in comparison to the baseline period.

	Baseline period no local energy supply	Reporting period no intervention no local energy supply	Simulated PV no optimisation	Scenario A optimised PV+CHP 2000kW	Scenario B Optimised PV+CHP 600kW
OER (%)	0 %	0 %	26 %	98 %	235 %
Energy costs (€)	104403	60157	47585.8	35709.51	25378.12
Costs savings (%)			20.9%	40.6%	57.8%
CO_2 emissions (g $eqCO_2/m^2$)	8109.4	5715.3	5574.9	2405.1	3791.9
CO2 emissions avoided (g $eqCO_2/m^2$)		2394,1	140,4	3310,2	1923,4
CO_2 emissions avoided (%)		29.5 %	2.5 %	57.9 %	33.7 %
Energy positivity label	D	D	C	Nearly A	A+++

Table 1: Results of the simulated scenarios

The primary KPI is the On-site Energy Ratio (OER) which is the annual energy supply from local renewable sources/annual energy demand (all types combined) expressed as a percentage. This is used to indicate the level of the area on the energy 'positivity' scale. In both scenarios, the pilot site reaches level A on the energy 'positivity' scale and so the tested optimisation scenarios raise the energy positivity of the site more than three levels. In terms of energy costs, the reductions calculated for the most promising scenarios are close to fifty percent (40.6% for scenario A and 57.8% for scenario B). In terms of CO_2 emissions, this is well above the 30% initial objective for the IDEAS project.

The income generated by selling the locally produced electricity back to the grid or the cost savings generated through the introduction of local energy sources could be used to pay for implementation of the IDEAS tools as well as for CHP, PV and energy storage installations required to bring the site to level A on the energy 'positivity' scale.

Table 2(on the following page) provides an outline the cost and benefit analysis conducted, the different cases compared are:

- Case 1: the CHP plant is sized to provide baseload thermal output, with any shortfall in heat during peak winter demand being provided by a gas fired back-up boiler.
- Case 2: the CHP plant is sized to provide thermal output to meet peak winter heat demand and therefore is larger.
- Case 3: the CHP plant is sized to more than meet the heat demand of the site enabling a greater percentage of the energy produced to be sold to the national grid.

The findings from the cost analysis indicate the following when employing an EMS to optimise local renewable energy production, storage and sale in the French context can be summarised as follows:

- In the current situation (selling price higher than buying price), the investment in large capacity CHP is economically justified because the ROI is the shortest for the 2000kW CHP presented in Case 3 scenario 1. However in this case much of the heat generated during the summer months is wasted as the CHP is running simply to generate electricity. This suggests that future work should look at the possibilities of combined cooling heat and power (CCHP) which could reduce the ROI further.

- However if the current Feed-in-Tariff (FIT) in France continues to be reduced as is likely, in the future it would not make economic sense to invest in larger CHP capacity to increase the OER and sell the excess electricity back to the grid as income generated in this way extends the payback period[14].

3.4.2.5. Cost and benefit analysis of the IDEAS solution

Case 1 / Scenario 1	
CHP 600 kW PV 367kWp γ=0, maximize profit, with current selling price. The CHP plant is run continuously during summer months in which the heat demand of IUT site is very low. The electricity generated by the CHP plant is sold to the grid generating an important income for this period	
	Cost (€)
ICT infrastructure	13586
CHP plant 600 kW	406850
Heat Storage 500 kWh	20000
PV 367 kWp	734000
Battery Li-ion 150 kWh	126540
Total investment	1287390
Yearly savings	55646,2
ROI (years)	23,1
OER (%)	235%

Case 2 / Scenario 1	
CHP 1200 kW PV 367kWp γ=0, maximize profit, with current selling price. The CHP plant is run continuously during summer months in which the heat demand of IUT site is very low. The electricity generated by the CHP plant is sold to the grid generating an important income for this period	
	Cost (€)
ICT infrastructure	13586
CHP plant 1200 kW	628850
Heat Storage 1200 kWh	48000
PV 367 kWp	734000
Battery Li-ion 300 kWh	253080
Total investment	1663930
Yearly savings	110188,8
ROI (years)	15,1
OER (%)	444%

Case 3 / Scenario 1	
CHP 2000 kW PV 367kWp γ=0, maximize profit, with current selling price. The CHP plant is run continuously during summer months in which the heat demand of IUT site is very low. The electricity generated by the CHP plant is sold to the grid generating an important income for this period	
	Cost (€)
ICT infrastructure	13586
CHP plant 2000 kW	914850
Heat Storage 1200 kWh	48000
PV 367 kWp	734000
Battery Li-ion 300 kWh	253080
Total investment	1949930
Yearly savings	161581,7
ROI (years)	12,1
OER (%)	722%

Case 1 / Scenario 4	
CHP 600 kW PV 367kWp γ=0, maximize profit and selling price set to 90% of buying price. The CHP plant is turned on intermittently to meet the heat demand of the IUT site	
	Cost (€)
ICT infrastructure	13586
CHP plant 600 kW	406850
Heat Storage 500 kWh	20000
PV 367 kWp	734000
Battery Li-ion 150 kWh	126540
Total investment	1287390
Yearly savings	25012,2
ROI (years)	51,5
OER (%)	69%

CASE 2 / Scenario 4	
CHP 1200 kW PV 367kWp γ=0, maximize profit and selling price set to 90% of buying price. The CHP plant is turned on intermittently to meet the heat demand of the IUT site	
	Cost (€)
ICT infrastructure	13586
CHP plant 1200 kW	628850
Heat Storage 1200 kWh	48000
PV 367 kWp	734000
Battery Li-ion 300 kWh	253080
Total investment	1663930
Yearly savings	36937,6
ROI (years)	45
OER (%)	96%

Case 3 / Scenario 4	
CHP 2000 kW PV 367kWp γ=0, maximize profit and selling price set to 90% of buying price. The CHP plant is turned on intermittently to meet the heat demand of the IUT site	
	Cost (€)
ICT infrastructure	13586
CHP plant 2000 kW	914850
Heat Storage 1200 kWh	48000
PV 367 kWp	734000
Battery Li-ion 300 kWh	253080
Total investment	1949930
Yearly savings	39116
ROI (years)	49,8
OER (%)	98%

Table 2: Cost/ benefit analysis of the different simulation scenarios

3.4.2.6. Scaling up the pilot

In addition to the analysis conducted in relation to the French Pilot site based on simulations of the operation of the Energy Management system, the decision support urban planning tool was used for comparing a selection of scenarios for the French pilot site: to identify the possibilities of scaling up the pilots and different routes to move towards energy 'positivity'. The difference between the two sets of analysis is:

- AtLas provides a rough estimate for this each scenario (CO_2, ROI, energy balance) that can be used in the initial phase of a project to select the most interesting solutions.
- The analysis conducted as part of the French pilot study using data from the EMS provides is more refined as it considers the temporal functioning of different scenarios for the implemented

[14] For further details see IDEAS Deliverable D5.4 Impact report French demo: at http://www.ideasproject.eu

systems as well as benefits from selling energy back to the grid at specific moment (while AtLas only considers the energy surplus as a whole without temporal consideration in this case). Therefore the difference is that the simulations conducted with the EMS consider the wider energy network beyond the area under consideration.

In the future it would be possible that the output of the EMS could be used as input for the AtLas tool. This could be done automatically by coupling both tools in future research. It was not possible to apply this approach in the case of the IDEAS project as the pilot study undertaken were on going at the same time as the tool development.

Which of the scenarios tested with the AtLas tool is the best case scenario for scaling up the energy positivity of the French pilot site depends on the priorities of the stakeholders involved. For example, cost could be the driving factor or CO_2 reduction or reaching energy positivity.

In the case of the French pilot site:

- The shortest payback period (10 to 13 years) is provided by a scenario in which district PV generation is installed on the site (CO_2 emissions 630 ton CO_2 ekv/year; Energy Positivity level D);
- The lowest CO_2 emissions (15 ton CO_2 ekv/year) are provided by a scenario in which a bio-CHP plant is built in the area (payback period 13 to 16 years; Energy Positivity level B);
- The highest Energy Positivity level (B) is also the scenario above which has the lowest CO_2 emissions[15].

3.4.3. The Finnish Pilot[16]

As is the case in the French pilot, the research included simulations conducted to test the viability of one of the key revenue streams underpinning business models developed in the IDEAS project: Namely reduced costs for energy production and increased profits from optimising the production, storage/retrieval and buying/selling of energy. User interfaces were also tested through their deployment and the assessment of their impact on the occupants and managers of the site through questionnaires, interviews and logging online activities.

The tools and interfaces implemented and tested in the Finnish pilot study include:

1. A neighbourhood energy management system (EMS) developed to optimise storage/retrieving and buying/selling energy and supply energy demand predictions for energy trading.
2. Innovative user interfaces developed to interact with the occupants of an EPN:
   a. Hand-held augmented reality based tools for visualisation and interaction with home oriented energy usage which consisted of the Home Energy Awareness Application (HEAA).
   b. Four public energy use awareness screens were installed three in the Omenatarha nursery school and one in an administrative building of the local authority.
   c. Service Providers interface providing real time data and energy predictions based on user selected energy optimisation approaches.

The pilot site is monitored by IDEAS EMS, which receives data from both the district heating billing meters and electricity billing meters via the local energy company Porvoon Energia. The EMS also receives electricity data, which is measured by additional z-wave energy measuring equipment installed in each pilot household. This measuring equipment provides less delayed more fine grained energy demand data including data at the household appliance level. The EMS also receives:

- Nordpool spot market hourly prices used for optimisation and simulated trading.
- Weather forecast for the area.

[15] For further details see IDEAS Deliverable D5.6 Potential for scaling up of pilots: at http://www.ideasproject.eu
[16] For further details see IDEAS Deliverable D5.5 Impact report Finnish demo: at http://www.ideasproject.eu

The main heat supply for the district heat network is a (wood chip) bio-CHP plant in Tolkkinen, 10 km south of Porvoo. For covering peaks in demand a gas fired backup heat supply is used. The renewable energy plant at the site extended in the pilot by simulating a wind turbine and heat and electricity storage. The EMS can be adjusted to optimise either for minimal cost, minimal CO2 emissions or a mix of these. In the simulations it was assumed that the EPN consists of 1350 single family houses. Detailed energy demand data was available for 23 households. Thus the energy supply and demand and storage elements were scaled down for 23 households for the purpose of simulations. The interfaces tested at the pilot site receive data from the EMS. The schematic of the approach used to test the IDEAS tools interfaces and the key revenue streams for the business models is presented in Figure 19 below.

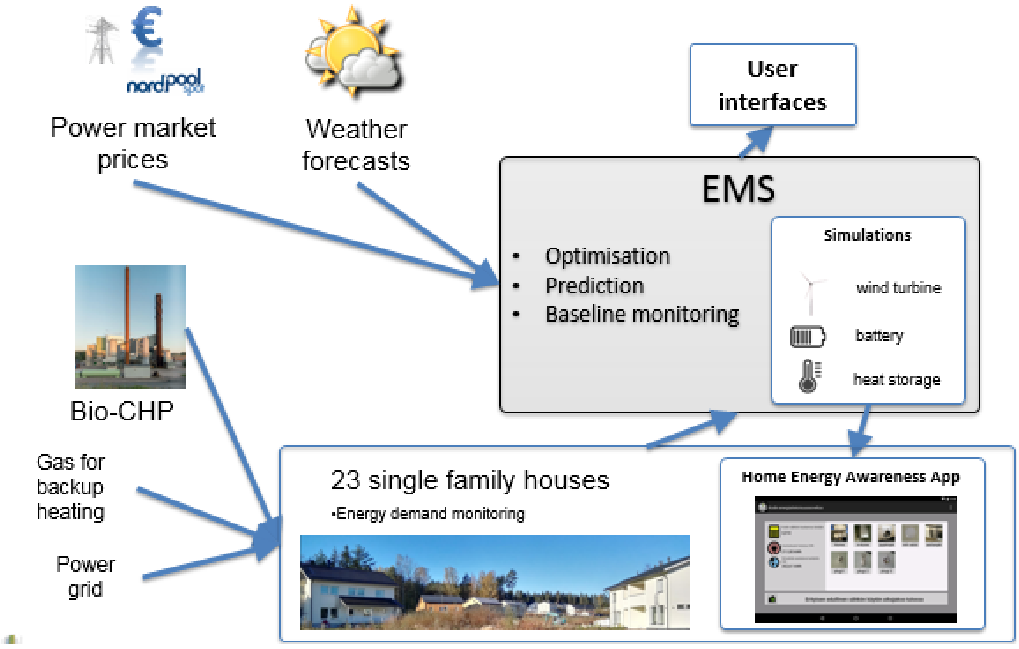


Figure 19: Schematic of the approach used to test the IDEAS tools interfaces in the Finnish pilot

3.4.3.1. Potential of the home energy awareness application

The findings from the usability testing of the HEAA suggest that it can support demand side management as the people surveyed said it would almost always shift their energy use according to advice provided by notifications from the HEAA as illustrated in their responses in Figure 20.

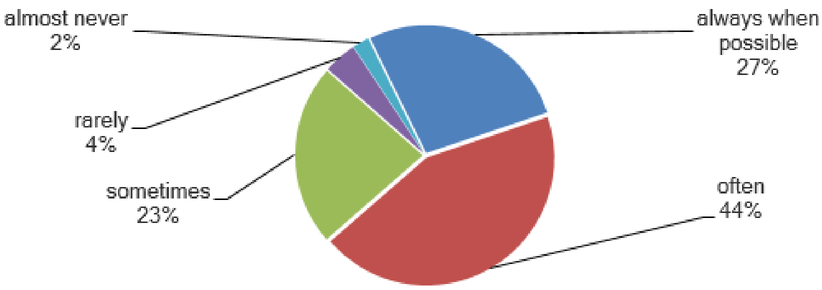


Figure 20: People are ready and willing to shift their demand based notifications provided by the HEAA

3.4.3.2. Potential of the community interfaces

83% of people found the content of the community interfaces included information that was new to them and found this new information interesting and inspiring. Over 59% were inspired to get more information. The layout and navigation was well received.

3.4.3.3.Moving the pilot site towards energy positivity

In total five scenarios were simulated:

- The first is the business as usual (naive) scenario, in which there is a bio fuelled CHP plant supplying heat and electricity. The CHP operation is based on the outdoor temperature. Any excess heat demand is met by a biogas fuelled plant. Excess electricity demand is met by the grid.
- In the second scenario (naive+WT) a wind turbine is added to the system.
- Three scenarios assumed the existence of heat and electricity storage elements and are based on the application of the optimisation algorithm embedded in the EMS:
  - In optimisation scenario A the goal of optimisation is to maximise profit;
  - In optimisation scenario B the goal is a balance between profit and CO_2 emissions reduction;
  - In optimisation scenario C the goal is to minimise CO_2 emissions.

The results of the analysis of the simulations are presented in table 3 below

Supplied energy	***Business as usual (naïve)***	***Naïve + WT***	***Optimised for profit***	***Balanced profit / CO_2***	***Minimised CO_2***
bioCHP-electricity MWh	***105,9***	***105,9***	***112,0***	***110,1***	***105,5***
bioCHP-heat MWh	***322,0***	***322,0***	***340,5***	***334,7***	***320,6***
Gas heating MWh	***10,4***	***10,4***	***61,6***	***54,3***	***15***
Grid electricity MWh (negative = sold more than bought)	***26,2***	***-137,7***	***-128,8***	***-131,7***	***-128,5***
Wind turbine MWh	***0***	***163,9***	***163,9***	***163,9***	***163,9***
Total	***464,5***	***464,5***	***549,2***	***531,2***	***476,3***

Table 3 Comparison of simulated scenarios

The total heat demand of the neighbourhood was 332 MWh. In the optimised for profit scenario and the optimise to balance profit and CO_2 emissions scenario, the CHP plant produced heat was 340.5 and 34.7 MWh respectively. Thus, in these scenarios, the heat demand is fully met by the bio fuelled CHP plant, making the neighbourhood fully energy positive in case of heat energy. The total electricity demand of the neighbourhood is 131.6 MWh. In all the scenarios where the wind turbine was used, this energy demand was met by the wind turbine alone hence making the area energy positive in terms of electricity. This is reflected in the On-site Energy Raito (OER) for each of the optimisation scenarios which is the KPI developed in the IDEAS project to measure energy positivity. Table 4 presents the OER and Energy positivity level indicator for each of the simulation scenarios.

	Business as usual (naïve)	***Naïve + WT***	***Optimised for profit***	***Balanced profit / CO_2***	***Minimised CO_2***
OER	***92 %***	***127 %***	***133 %***	***131 %***	***127 %***
Energy positivity level indicator	*B*	*A++*	*A++*	*A++*	*A++*

Table 4 Comparison of simulated scenarios

3.4.3.4.Cost and benefit analysis of the IDEAS solution

In optimisation scenarios A and B, more CHP electricity was produced compared to naive, naive+WT and optimisation scenario C [see table 3]. This resulted in more electricity being sold to grid resulting in larger profit than other strategies. This also increased the CHP heat energy generation compared to other strategies. Gas heating was also increased in case of optimisation scenarios A and B. This was due to more active use of storage elements (for energy trading) in these cases. No storage element was present for the naive and naive+WT strategy; hence gas heating was less used. Gas produced heat is lower in the optimisation strategy C because it was assumed in the optimisation that gas heating has higher CO_2 emissions than CHP generated heat.

In all optimisation scenarios and in the naive+WT scenario, more electricity is sold to the grid than bought from it. This was due to the addition of wind turbine generated electricity.

It is clear that the best scenario for reducing CO_2 emission is the optimisation scenario C (minimise CO_2 emissions). As shown in table 3, the wind turbine produces a significantly greater amount of energy than the CHP plant, which can be sold to the grid with profit due to the generous feed in tariff applicable in Finland. The optimisation could be improved with the inclusion of the electricity produced by the wind turbine. However this would necessitate a larger storage capacity increasing the initial investment costs. Thus the wind turbine electricity production was independent and was not influenced by the optimisation algorithm.

The findings illustrate that the proposed EPN with the EMS optimiser achieves a clear reduction in the CO_2 emissions, but the cost of the supplied energy is slightly higher than the baseline scenarios without energy optimisation. This is due to the feed in tariff in Finland for wind energy. As long as the wind turbine Feed-in-Tariff (FITs) is favouring grid connected turbines with huge subsidies (price guarantee 83.50€/MWh when power market average price is 30.80€), the market is distorted and does not leave room for innovative business models like neighbourhood level turbines that bypasses the national grid when the local demand is high enough. However it would be simple to resolve this issue if FITs were paid to energy producers regardless of whether the energy is sold outside of an EPN or sold directly to customers within the EPN and premium based FITs (PFITs) which pay a premium on top of the variable market price are applied.

3.4.3.5.Scaling up the pilot

In addition to the analysis conducted in relation to the Finnish Pilot site based on simulations of the operation of the EMS an planning tool was used for comparing a selection of scenarios for the Finnish pilot site: to identify the possibilities of scaling up the pilot and different routes to move towards energy 'positivity'. The difference between the two sets of analysis is:

- AtLas provides a rough estimate for each scenario (CO_2, ROI, energy balance) that can be used in the initial phase of a project to select the most interesting solutions.
- The analysis conducted as part of the Finnish pilot study using data from the EMS is more refined as it considers the temporal functioning of different optimisation scenarios.

In the future it would be possible that the output of the EMS could be used as input for the AtLas tool. This could be done automatically by coupling both tools in future research. It was not possible to apply this approach in the case of the IDEAS project as the pilot studies undertaken were on going at the same time as the tool development.

In the Finnish case different geographical scales of analysis were undertaken to look not only at the pilot site in Omenatarha, but also the neighbouring Toukovuori area and the whole of the Skaftkärr development area in which they are situated, as these were or particular interest for the project partners taking part in the Skaftkärr development, the City of Porvoo and Porvoo Energy. Which of the different scenarios tested is the best case scenario depends once again on the priorities of the stakeholders involved as costs or CO_2 reduction or reaching energy positivity could be a priority.

In the case of Finland:

- The scenarios with the shortest payback period (6 to 18 years for the different scales) involve improvements in housing energy efficiency (from C-class to A-class), keeping the sizing of the CHP for the less energy efficient buildings. This results in CO_2 emissions 35 ton CO_2 ekv/year in Omenatarha, 115 CO_2 ekv/year in Toukovuori and 388 ton CO_2 ekv/year in Skaftkärr; Energy Positivity class A++ in all cases. This scenario and costs apply mainly to new areas.

- The scenarios with the lowest CO_2 (35 ton CO_2 ekv/year in Omenatarha, 115 CO_2 ekv/year in Toukovuori and 388 ton CO_2 ekv/year in Skaftkärr) are the scenarios where the energy production in the area is increased with solar thermal to achieve 100 % local renewable heating and PV production to achieve 100 % local renewable electricity. (Payback period 32 years for Omanatarha, 22 years for Toukovuori and 27 years for Skaftkärr; Energy Positivity class A for Omenatarha and class A+ for Toukovuori and Skaftkärr)
- Highest Energy Positivity level (A++) are the same scenarios as the one with shortest payback period, for all three scales in Porvoo.

3.5. BUSINESS POTENTIAL ACROSS EUROPE

In IDEAS the business concept for an EPNSP is underpinned by the notion that the DREG in an EPN will not put extra pressure on congested electricity networks, while electricity can be stored within the EPN and sold outside of the EPN when national energy demand is high. The development of an EPN which operates in this way requires efficient energy markets and service providers that:

- Supply, distribute and generate renewable energy within the neighbourhood.
- Optimises the balance between energy production, storage /retrieval and import/export (buying and selling) at the neighbourhood level;
- Engages the relevant communities in Demand Side Management (DSM) and Supply Side Management (SSM);

Essentially there are two key ‘revenue streams’ which represent the source of profits for an EPNSP:

1. Energy arbitrage and efficiency gains obtained through optimising the production, storage/retrieval and selling of local renewable electricity and heat production.
2. Integrated Energy Contracts (IEC) which combine energy efficiency and renewable energy supply and management in large buildings and groups of buildings in the same locality owned by the same organisation.

The more innovative of the two revenue streams is that which concerns energy arbitrage and optimisation as Energy Service Companies (ESCOs) offering IEC already exist in some countries in the EU. It must also be noted that as markets for heat trading are both limited and in their infancy, the business models developed in IDEAS focus on trading in electricity markets.

To assess the applicability of the IDEAS business models beyond the IDEAS pilot sites the research identified how the different structures of the utilities industry and property markets in different EU states impact on their key revenue streams. The best case scenario for EPNSPs are summarised in table 5.

Key structures	Role in supporting EPNSPs	Prevalence in the EU
Time based tariffs for the electricity EPNSPs purchase and sell	Providing a potential to optimise neighbourhood energy supply resources based on their market value.	Most prevalent in Finland, Norway[17] and Sweden where spot price tied contracts are commonly marketed.
Distribution network charges which	Offering a financially viable method of distributing electricity to consumers in the	This is not implemented in the EU. A lack of differentiated local and national network tariffs

[17] Norway is not a member state of the European Union (EU), but is closely associated with the Union through its membership in the European Economic Area (EEA), in the context of being a European Free Trade Association (EFTA) member.

reflect the distance of electricity transported	neighbourhood and avoiding the duplication of current electricity distribution networks with private wire networks.	does not necessarily negate the IDEAS business models. However it does mean that the cost optimisation of the production may not work in favour of the local consumption of distributed renewable energy.
'Active' or 'smart' local electricity grid	Providing the monitoring, control and advanced protection systems required for the supervision and operation of bidirectional power flows in a distribution network.	Most countries in Europe are moving toward the development of 'active' or 'smart' electricity distribution networks. Countries with national implementation plans include Austria, Belgium, Cyprus, Denmark, Finland, France, Greece, Luxembourg and Norway.
Exploitation of the economies of heat/cooling and electricity cogeneration supplied by CHP or CCHP.	Enabling the economical provision of both heat/cooling and electricity within an EPN. It must also be noted that should other forms of renewable energy production be available that can supply the heating/cooling and electricity demand of a neighbourhood more cost effectively than CHP or CCHP then the business models could be adapted as required.	In line with the EU RES-Directive 2009/28/EC an increasing number of national governments have identified District Heating and Cooling (DHC) as an efficient technology to achieve the main objectives of the European legislation regarding sustainable energy. The current market opportunities are greatest in North, Central and Eastern Europe where market shares of DH often reach 50% and more of the total heat demand.
Regulatory and voluntary instruments to encourage high standards of building energy efficiency	Reducing energy demand making it easier to be met by renewable supply and reducing the need to invest in new generation facilities.	The Energy Performance of Buildings Directive ((EPDB recast, 2010/31/EU) is the key regulatory driver. Rates of implementation of the different elements of the directive vary between countries in the EU. In addition to mandatory energy certification schemes, arising from the EPBD, there are voluntary building certification schemes used throughout the EU. The uptake of these schemes is greater in the countries that have developed their own schemes compared to those which apply schemes developed in other countries.
Legal, regulatory & business contexts that enable PPP (public sector) to fund Integrated Energy Contracts (IEC)	To underpin life cycle approaches that offer financial rewards to those responsible for the design, construction and management of buildings if they reduce the running costs.	With the increasing interest in community energy finance, IECs, PPPs, green leasing and other forms of life-cycle contracting across the EU, the possibilities for funding an EPNSP is growing in most EU countries.

Table 5 Key property market and utilities industry structures and prevalence in the EU

3.5.1. EU Countries which offer the best market conditions

The findings presented in table 5 illustrate that no European country currently offers the best case scenario for the structures of the utilities industry and property markets for the development of the IDEAS business models for EPNSPs.

However some come close enough to offer markets for EPNSPs. In particular Denmark, Finland, Norway and Sweden offer good market conditions for EPNSPs. They all have mature district heating markets. They are moving towards smart distribution networks, while in Sweden Finland and Norway spot price tied electricity contracts are commonly marketed. Denmark, Finland, Norway and Sweden are also among those EU countries that are implementing the different elements of the Energy Performance in Buildings Directive (EPBD) in earnest suggesting a national policy commitment to the development of energy efficient buildings.

In addition they have residential market structures which favour the development of efficient housing and commercial and regulatory practices which support IECs and lifecycle approaches[18].

3.5.2. Implications of the findings for energy policy

However there are some regulatory and policy obstacles to be overcome if EPNs are to attain their potential to reduce congestion on Electricity Distribution Networks:

- The research illustrated that **current renewable energy subsidies**, in the form of Feed in Tariffs, can distort the energy markets and reduce the amount of locally produced renewable electricity that is consumed locally in an EPN, when cost optimisation is applied to energy management. However it would be simple to resolve this issue if FITs were paid to energy producers regardless of whether the energy is sold outside of an EPN or sold directly to customers within the EPN and premium based FITs (PFITs) which pay a premium on top of the variable market price are applied.
- **Costs associated with electricity distribution**. If an EPNSP has a significant level of reliable electricity generation capacity then they should be able to benefit from the 'unbundling'[19] of the local distribution network. Taking this approach an EPNSP could be charged an appropriate cost-reflective tariff for the use they actually make of a DNO's network. A simple approach to this would be to differentiate between 'locally generated electricity' and 'non-locally generated electricity' based upon transactions remaining inside or crossing the EPN geographical boundary, and use an appropriate two-tiered distribution charge. Research conducted as part of the IDEAS project suggests this approach both encourages the use of local generation, and reduces the net amount of electricity handled wholesale and requiring transportation over transmission and distribution networks by up to 50%[20].

In relation to unbundled electricity distribution tariffs, while there is much current debate about network distribution charges for electricity there is a certain level of stagnation in relation to implementing new innovation in this area. DNOs in France and Finland have a strong resistance to the idea of a differentiated distribution network charge that favours the local consumption of DREG. However those in the UK are more amenable to the possibility especially in the case of Independent Distribution Network Operators (IDNOs)[21].

It must be noted that the lack of dynamic network tariffs which favour the local consumption of DREG does not necessarily negate the business models for EPNSPs. However it does mean that the optimisation of the production, storage /retrieval and selling of local renewable electricity and heat production may not always work in favour of the local consumption of distributed renewable energy; as the distribution charges do not differentiate as to the extent that the distribution network is actually being employed. Dynamic distribution network tariffs which favour the local consumption of DREG have the potential to reduce the net amount of electricity requiring transportation over transmission and distribution networks by up to 50% in an EPN[22];

Finally the idea that 'community energy project' financing offers a route to community engagement in the development of EPNSPs is supported by research undertaken in the IDEAS project. A survey of Finnish people living in and around the Omenatarha residential neighbourhood in Finland, found that 75 percent of people felt they were more likely to invest in co-operative community renewable energy projects than they were to invest in renewable technologies in their houses such as PV panels on their homes. The possibilities of community energy project financing for funding EPNSPs also seems to be supported by the growth of community energy projects across the EU.

---

[18] For further details see IDEAS Deliverable D2.3 Generalised Business Models: at http://www.ideasproject.eu

[19] Disaggregating electric utility services into its basic components and offering each component separately for sale with separate rates for each component.

[20] see IDEAS Deliverable D2.3 Generalised Business Models: at http://www.ideasproject.eu

[21] Ibid

[22] Ibid

4. THE POTENTIAL IMPACT

4.1. THE WIDER IMPACTS OF THE PROJECT

The IDEAS project contributed to

- The opening of a market for ICT-based district/community energy management systems.
  - ✓ The IDEAS Total Solution for an EPN can reduce energy costs by up to almost 58%.
  - ✓ IDEAS Energy Management System enables up to:
    - 30% increase the revenue generation from distributed renewable electricity and heat production;
    - 10 % increase in the efficiency of distributed renewable plant.

- Establishment of a collaboration framework between the ICT sector, the buildings and construction sector and the energy sector.
  - ✓ The results of the IDEAS project were presented at 31 conferences and 7 dissemination workshops with related RTD projects with a total audience of over 8565 people. In addition the IDEAS consortium published 10 peer reviewed conference papers & 5 professional journal articles.
  - ✓ Since October 2013 over 8000 users accessed the IDEAS website and there have been some 4728 views of the webinar that presented the findings of the project in less than a month [see Figure 21 and Figure 22 below]. The global reach of the dissemination is also impressive with people in most countries accessing the IDEAS website [see Figure 23].
  - ✓ As a result of the wide dissemination of the projects outcomes the operational concept of an EPN (the EPN definition, KPIs and energy positivity label) is informing discussions in other European projects involving stakeholders from the ICT, energy, buildings and construction sectors. (e.g. Design4Energy, CityKeys and DRBOB).

- Quantifiable & significant reduction of energy consumption and CO_2 emissions achieved through ICT.
  - ✓ The IDEAS Total Solution for an EPN is able to reduce CO_2 emissions by up to almost 58%
  - ✓ The KPIs developed in the project give a provide a clear method of measuring and monitoring the energy consumption and CO_2 emissions over time in an EPN

Figure 21: IDEAS website statistics

The wider impacts of the project so far lie in the dissemination of the definition and operationalisation of the concept of an EPN and the tools and business models required to underpin the development of EPNs. In particular the possibilities of the IDEAS project findings are very significant for the energy industries in general and the electricity distribution industry in particular.

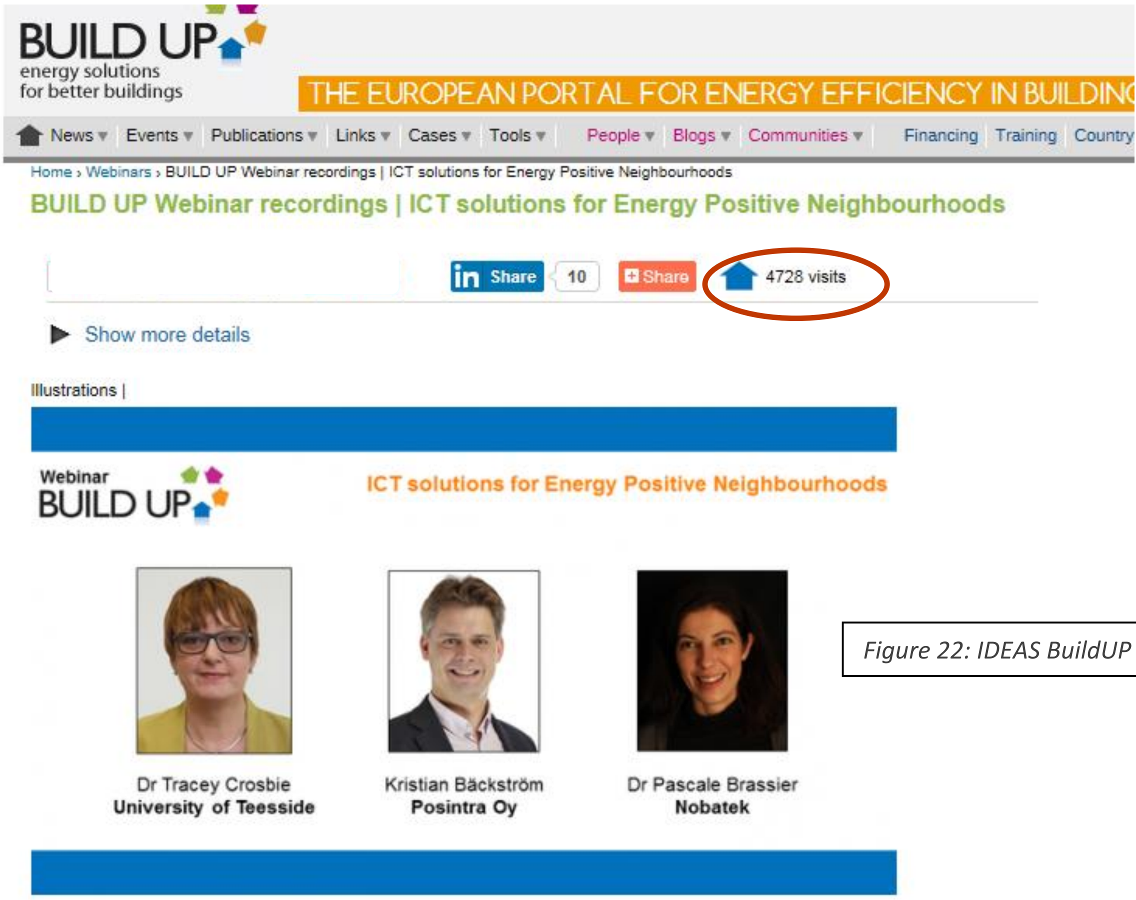


Figure 22: IDEAS BuildUP Webinar

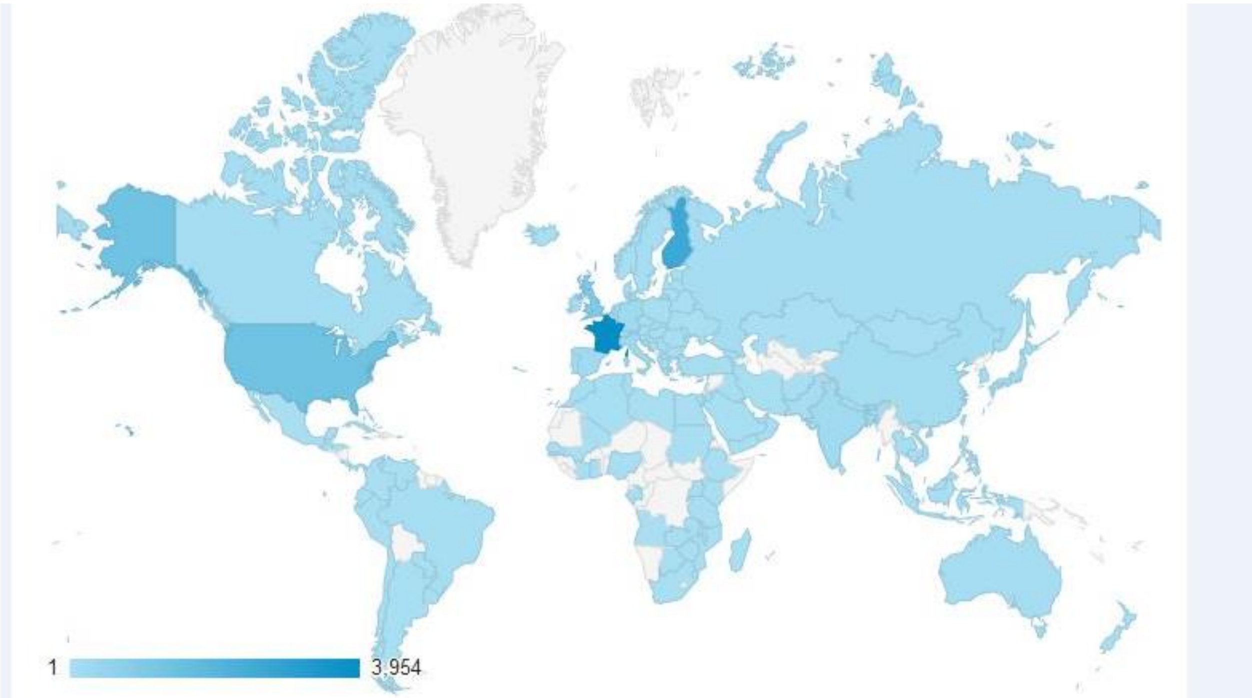


Figure 23: IDEAS throughout the world: the darker the blue the more users in that county have accessed the IDEAS website

Eurelectric[23] estimate that European electricity networks (EDNs) will require six hundred billion Euros of investments by 2020, with two thirds of these investments required in EDNs. By 2035 the distribution share of the overall network investment is estimated to grow to almost 75 percent and to 80 percent by 2050. When thinking about these figures it becomes clear that the prospect that EPNs reduce the need for investments in the wider reinforcement of distribution networks required for DREG becomes significant. **The IDEAS total solution for EPNs could reduce those investments by up to almost 100% in some cases.** This suggests that EU and national energy policy should be shaped to encourage the development of EPNs particularly in the case of FIT polices and the regulation of the distribution industry. The IDEAS research suggests:

- Dynamic distribution network tariffs which favour the local consumption of DREG have the potential to reduce the net amount of electricity requiring transportation over transmission and distribution networks by up to 50% in an EPN[24];
- FITs should be paid to energy producers regardless of whether the energy is sold outside of an EPN or sold directly to customers within the EPN;
- Premium FITs which pay a premium on top of the variable market price should be applied.

4.2. IMPACT AT THE FRENCH PILOT SITE

Introducing an EPN at the French demo site was not possible in the timeframe of the project. However, the energy consumption information made available to staff through the different interfaces developed and implemented as part of the IDEAS project has underpinned new initiatives in energy management and energy efficiency at the French pilot site.

In terms of energy efficiency it has supported the staff at the French Pilot involved in building management to decrease energy use and CO_2 emissions by 29% [see table 1]. In terms of energy management the pilot site administration is currently investigating the option of hiring an external facility management enterprise (COFELY) to manage the site (P3 take care of the maintenance contract). Thus the French pilot site is evolving in terms of site management. This could have a significant impact on the way an EPNSP approach can be implemented in the future. As the need for a site facilities manager was highlighted during the implementation and use of the tools at the French pilot site. If the approach taken is successful there is every chance that it could be taken up by other schools and departments at the University.

The IDEAS project has shown that there are cost savings to be made as well as CO_2 emissions reductions which may offer impetus to the management at the French Pilot site. In terms of energy costs, the reductions calculated for the most promising scenarios, tested with the EMS, at the French pilot site are close to fifty percent (40.6% for scenario A and 57.8% for scenario B see table 1). In terms of CO_2 emissions the scenario's tested also offer potential, 57.9% scenario A and 33.7% scenario B, this is well above the 30% initial objective for the IDEAS project [see table 1].

4.3. IMPACT AT THE FINNISH PILOT SITE

As a result of taking part in the IDEAS project Porvoo Energy, the local district heating provider and electricity supplier is currently exploiting the methods and data developed in IDEAS project to:

- Revise production optimisation methods,
- Analyse the different possibilities for heat storage for the district heating network,
- Maximise the use of bioenergy at best cost efficiency in their energy production portfolio.

[23] Eurelectric (2013). Power distribution in Europe: facts and figures. Union of the Electricity Industry –EURELECTRIC aisbl, Belgium. Available at: http://www.eurelectric.org/media/113155/dso_report-web_final-2013-030-0764-01-e.pdf
[24] For further details see IDEAS Deliverable D2.3 Generalised Business Models: at http://www.ideasproject.eu

The City of Porvoo, a partner in the IDEAS Project, can take advantage of Atlas tool, which has been developed according to their work objectives. They will be able to use the tool to compare different planning alternatives and support their decision making by providing the information on CO_2 emissions as well as costs for different urban development options.

5. EXPLOITATION OF RESULTS

5.1. SCOPE OF THE BUSINESS MODELS

Both business models for EPNSPs involve the use of biofuel powered CHP combined with other forms of renewable electricity production. This is because it is inherently more efficient to generate heat and electricity together[25]. **Although the business models are not limited to bio fuelled CHP.**

A natural extension would be the use of Combined Cooling Heat and Power (CCHP) which uses thermal energy for both heating and cooling, as well as electricity generation. It must also be noted that **should other forms of renewable energy production be available that can supply the heating/cooling and electricity demand of a neighbourhood more cost effectively than CHP or CCHP then the business models can be adapted as required.**

However as the IDEAS business models for EPNSPs, involve the use of biofuel powered CHP combined the question becomes what is the size of the current District Heat market and how likely is it to expand. District **Heat covers 10% of the total heat demand in Europe. There are more than 5,000 medium and large scale district heating systems, with an annual turnover of 20 billion Euros and 556 TWh heat sales.** However, market penetration of district heating is unevenly distributed. While district heating has an average market share of 10% in Europe, it is particularly widespread in North, Central and Eastern Europe where market shares often reach 50% and more. **On average, over 80% of heat supplied by DH originates from renewable energy sources or heat recovery (i.e. from electricity production or industrial processes).** The combined heat and power share of total heat generation in 27 EU states is shown in Figure 24.

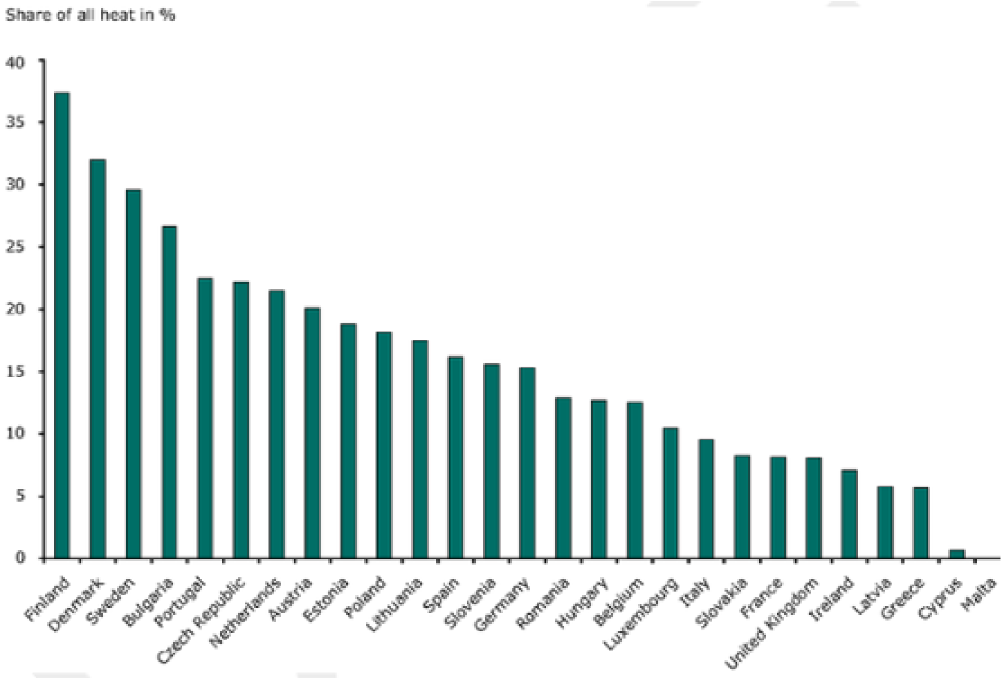


Figure 24 Combined heat and power share of total heat generation in 27 EU counties[26]

[25] Connolly, D.et al. (2013) Heat Roadmap Europe 2050: Second pre-study for the EU27. Department of Development and Planning, Aalborg University

[26] Ibid

This figure clearly shows that Finland, Sweden and Denmark are the leaders in this area once again highlighting their suitability for the development of EPNSPs underpinned by the business models.

The CHP powered district heating market is also set to grow. Increasing the use of renewables and the share of CHP powered District Heat is one target of the EU RES-Directive for 2020.[27] In line with this an increasing number of national governments have identified district heating and cooling as an efficient technology to achieve the main objectives of the European legislation regarding sustainable energy[28].

5.2. CURRENT EXPLOITATION EFFORTS

Figure 25: Posters developed for the IDEAS final event (exhibition at Nordic Edge Expo)
Now on permanent display at Teesside University

Two final dissemination events, one physical exhibition [see Figure 26] and one virtual webinar in partnership with BUILD UP [see Figure 22], were organised at the end of the project to support post-project exploitation of the final results

---

[27] European Commission (2009c) Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

[28] Carbon Trust (2010) Introducing combined heat and power: A new generation of energy and carbon savings. Available at: http://www.carbontrust.com

Figure 26: IDEAS final event - exhibition at Nordic Edge Expo – demonstration of the Atlas tool.

By the end date of the project different organisations within the project consortium were exploiting IDEAS project assets as outlined in the table below:

Asset	Current exploitation
Operational concept of EPN	The definition and KPIs for EPN are currently being discussed and further developed in two European projects: Design4Energy and CityKeys. CityKeys selected one of the KPIs as an indicator for Smart cities, and Design4 Energy is looking at meaningful numbers for the mismatch indicators in different situations.
Energy Prediction and optimisation models	Teesside University is currently working with SIEMENS to embed the energy management models within a commercial product as part of a recent H2020 Innovation project. Called DR-BOB Topic: EE-06-2015
Computer Vision and Augmented Reality CV&AR	IBM is exploiting the CV&AR in: • An Industrial (proof of concept) project - detection of industrial machinery and devices, and showing relevant information on each detected device using hand held or wearable device; • Smart home (proof of concept) project - Detecting smart home devices (e.g. doors or windows) and showing the ability to enable associated controls (lock, unlock, shed, etc.); • Retail projects - Detection and tracking products on shelf and retrieving related data; • Document processing project - Detection and recognition of documents and apply rectification using form recognition and OCR.
Advanced data treatment for an optimised energy and especially renewable energy resources management of Omenatarha area, neighbourhood and small houses	Porvoo Energy is currently exploiting the methods and data developed in IDEAS project to: • Revise its production optimization methods • Analyse the different possibilities of heat storages for the district heating network. • Maximise the use of bioenergy at best cost efficiency in their energy production portfolio.
Consulting offers to the actors involved in French "eco-cités" and/or "éco-quartiers	CSTB consulting offers are being fine-tuned and extended based on the concepts and findings from the IDEAS project: they include for instance a support to French "éco-cités" & "éco-quartiers" stakeholders to define their roadmap toward energy positivity, advising on energy awareness and behavioural change strategies, etc.
AtLas tool	VTT is exploring the opportunities to develop the AtLas tool into a web based tool instead of the Excel tool format in the prototype. The current Excel based prototype has been presented to potential users and stakeholders, and it has raised a lot of interest.

Table 6: IDEAS Project Assets currently being exploited

6. IDEAS: PROJECT CONTACT DETAILS

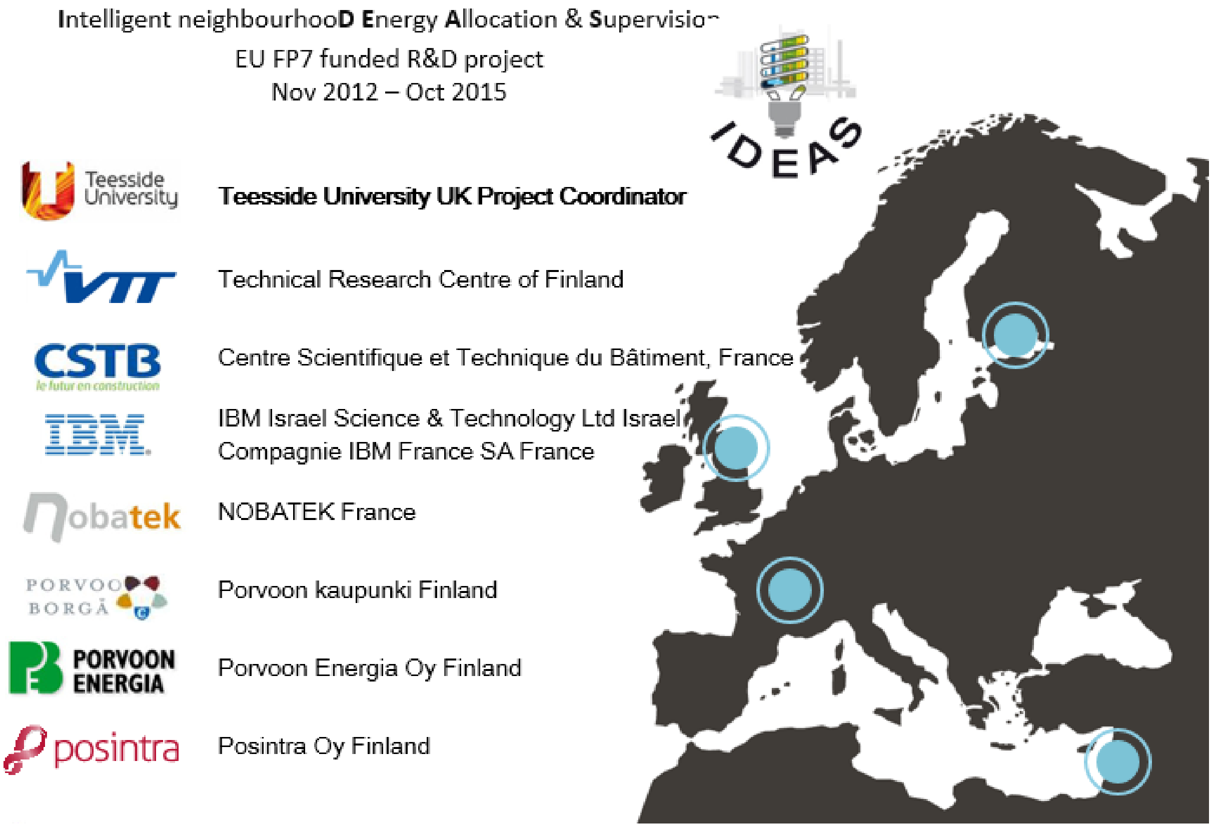


Figure 27: IDEAS Consortium

For further details see IDEAS project website at httpwww.ideasproject.eu
All IDEAS public deliverables can also be found on
ResearchGate platform at https://www.researchgate.net.

❑ Are you

- a municipality,
- a utility company
- an ESCO
- a district heating provider
- a facilities manager
- or do you own and run a group of buildings

❑ Our multidisciplinary expert group can:

- Tailor the IDEAS technologies for the development of your future Energy Positive Neighbourhoods.
- Help you develop strategic roadmaps towards Energy Positive Neighbourhoods

info@ideasproject.eu

For inquires related to:

IDEAS Business Models contact Dr Tracey Crosbie
E-mail T.Crosbie@tees.ac.uk

IDEAS Optimisation and Prediction Models contact Dr Michael Short
E-mail M.Short@tees.ac.uk

IDEAS interfaces contact Uzi Shvadron
E-mail SHVADRON@il.ibm.com

The AtLas Urban Planning Tool contact Mia Ala-Juusela
e-mail Mia.Ala-Juusela@vtt.fi

The Finnish Pilot Site contact Kristian Bäckström
E-mail kristian.backstrom@posintra.fi

The French Pilot site contact Pascale Brassier
E-mail