The IREEN ICT Roadmap for Energy-Efficient Neighbourhoods

Alain ZARLI[1], Régis DECORME[1], Martine TOMMIS[2],
Christian MASTRODONATO[3], Mari SEPPONEN[4]

[1]*Centre Scientifique et Technique du Bâtiment (CSTB)*
290, route des lucioles, B.P. 209, 06904 Sophia Antipolis cedex, France
alain.zarli@cstb.fr, regis.decorme@cstb.fr

[2]*Manchester City Council (MCC)*
Lower Ground Floor, 117-119 Portland Street, Manchester, UK
m.tommis@manchesterdda.com

[3]*D'Appolonia S.p.A.*
Innovation Consulting Division, Via S. Nazaro, 19 – 16145 Genova – Italy
christian.mastrodonato@dappolonia.it

[4]*VTT – Technical Research Centre of Finland*
Espoo, Finland
mari.sepponen@vtt.fi

Abstract: the IREEN (*ICT Roadmap for Energy-Efficient Neighbourhoods*) project is the European Coordination Action aiming to develop a comprehensive strategy for future European-scale innovation and take-up in the field of ICT for energy efficiency and performance in districts and neighbourhoods. This paper focuses on the primary IREEN achievements, namely an initial state-of-the-art cartography of case studies, current practices and ongoing living experimentations, together with future extrapolations (innovative scenarios) on expected innovations on the use of ICT systems and applications for energy efficiency in districts/neighbourhoods. It also introduces to the IREEN taxonomy matrix as a structured approach to classify priorities for future ICT R&D supporting energy-efficient neighbourhoods.

1. Introduction

Information and Communication Technologies (ICTs) have the potential to have a considerable impact on the transformation of production, distribution, management, supply and use of energy. It is now acknowledged that energy-positive buildings, districts, and neighbourhoods will be empowered by electronic (embedded) components, software and ICT systems and infrastructures [1]. These will not only simply meter the energy generated and consumed, but will have the potential to provide real-time information to building owners and managers, as well as final end-users, to save energy while maintaining comfort levels.

ICT is to be instrumental in enabling the design of new innovative solutions which will allow the integration of connectivity between buildings, distributed renewable energy, grids and other networks at a district or neighbourhood level. Smart systems that leverage modern computing, communications, and software offer the potential to make neighbourhoods and entire cities intelligent participants in an interactive energy ecosystem. Core enabling technologies are already being deployed to do this. Examples include advanced building controls, energy management systems, smart meters, grid automation and optimization technologies that taken together create an intelligent city infrastructure. Similarly, the planning, design and management of neighbourhoods can be radically influenced by the use of technology. The development of 3D and visualisation techniques holds the potential to change the way we develop and manage cities. And alongside this,

companies in construction, energy, ICT and equipment development a new market is being created. This will be achievable only by upgrading the innovation capacity of companies and their ability to transfer innovation to the market based on integrating aspects of successful experimentation, pilots and large-scale initiatives.
A fundamental change is needed covering every aspect of how we build our city. The need is to build in a way that reduces energy emissions, accommodates active and public transportation and ensures future quality of life. Energy efficient neighbourhoods can provide environmental, economic and social benefits:

- Environmental Benefits: The economies of scale and flexible infrastructure that can adapt to using a wide variety of renewable "waste energy" options that would otherwise not be available to an individual building heating system.
- Social Benefits: Through the use of renewable energy sources and flexibility to adapt to future energy technologies, it is anticipated that customers will enjoy rate stability that outperforms conventional options.
- Economic Benefits: The reduction in consumer costs continues to be key as well as the hidden cost of the carbon impacts.

For these reasons, the main objective of IREEN is to develop a comprehensive strategy to maximise the take up and use of ICT to improve energy efficiency and performance in large areas to create neighbourhood and district energy communities. This includes the identification of drivers and gaps, future policies and operational support for their implementation, together with the identification of appropriate stakeholders, value chains and partnerships. Utilising expert hearings, workshops, and networking activities, IREEN will develop a research and innovation roadmap for ICT supporting energy-efficient neighbourhoods. Ultimately it aims to stimulate the development of a large leading-edge market for ICT enabled energy-efficiency technologies and holistic systems in neighbourhoods (and by extension wider urban environments, such as city-regions and rural areas) that will foster the competitiveness of European industry and create new business opportunities. At the same time the aim is also to offer options for a technology infrastructure that are flexible and adaptive to the requirements of deployment in different types of neighbourhoods to residents, building owners and local authorities.

As well as look at the objectives of the project and its methodology, this paper focuses on IREEN's principal achievements, particularly a state-of-the-art cartography of case studies, current practices and ongoing living experimentations for use of ICT systems and applications for energy efficiency in districts/neighbourhoods. The aim is to provide a map of potential good or best practices and associated ICT tools, including the identification of key actors and their relationships. Included is the IREEN taxonomy matrix as a structured approach to classify priorities for future ICT R&D supporting energy-efficient neighbourhoods. Using the analysis of data gathered from the projects and pilots together with the results of previous roadmapping activities (including REEB – Roadmap for Energy Efficient Buildings [2], ICT4E2B Forum [3], and REViSITE [4]), the IREEN taxonomy is defined allowing the classification of the various priorities for ICT supporting energy-efficient neighbourhoods in key ICT areas of future development. Future extrapolations (innovative scenarios) on expected innovations on the use of ICT systems and applications for energy efficiency in districts/neighbourhoods are also introduced. The scenarios identified by IREEN will be further exposed for refinements and weighted towards technology that is deemed to have the largest impact, considering factors such as technology maturity, drivers, policies, value chains, partnerships, deployment challenges and stakeholder development.

The IREEN project is being delivered between September 2011 and August 2013. The full results of the project will be available towards mid 2013.

2. The IREEN Coordination Objectives

The key priorities for IREEN are:

1. Providing the domain stakeholders and the research communities (ICT, construction, energy, districts/neighbourhoods) with a short-term focus on the state-of-the-art in ICT solutions, enabling early access to results which complement ongoing medium-term initiatives such as individual RTD projects, clusters and networks.
2. Assembling a coherent supply-side view of the state-of-the-art by adding value to discrete summaries obtained from RTD projects and, to a lesser degree, from the vendors of software and services and the suppliers of technology;
3. Collecting a number of independent demand-side visions of relevant state-of-the-art to the building and neighbourhood communities, and identifying the key aspects within these visions –leading to "innovative scenarios";
4. Upstream, providing a catalogue of reference technological platforms that ease the integration of many systems, favouring interoperability, allowing in-vitro tests and benchmarking, and preparing the technology-oriented and the process-oriented ground for in-vivo large-scale pilots;
5. Downstream, providing a path to future market-oriented innovation and usage centres, focused on large-scale pilots and preparing transfer to markets. Demonstrating, validating and certifying ICT solutions and packages for energy efficiency in neighbourhoods and cities and considering the potential transferability of lessons learned to regions and rural areas.

The implementation of these objectives will lead to a strategy to be further detailed in an innovation roadmap, linking and prioritizing all actions over the innovation life-cycle: RTD, experimentation and validation, transfer to market and deployment, and standardisation.

3. The IREEN Methodology

IREEN has utilised a classic methodology for building its roadmap, already successfully applied in projects such as REEB [2]. The methodology is described as follows and shown in Figure 1.

- Forming the IREEN stakeholders' community: the IREEN consortium is supported by an Advisory Expert Group of 20+ experts from a wide range of sectors (construction, energy, IT specialists, city representatives, etc.), invited to provide their ideas, review project results, and contribute to a widespread dissemination throughout the project lifetime.
- Establishing clear boundaries for the IREEN study framework: including a commonly agreed definition for an ICT-enabled energy efficient neighbourhood, which is then illustrated by a collection of exemplary design case studies identified throughout Europe and beyond. Using these case studies, the project then derives innovative generic scenarios for what is expected to be the future developments and technologies to enter the market. Results from this project phase are described in the following sections of this paper.
- Creating the roadmap: the previously identified scenarios are assessed and prioritized according to their level of impact and estimated time to market, taking into account technology maturity, drivers, policies, value chains, partnerships, deployment challenges and stakeholder development. They are then classified as a set of suggested research actions which form the IREEN roadmap. The roadmap

will address RTD on enabling technologies, applications and system integration, large scale use trials, knowledge capitalisation and standardisation. In addition issues such as the transfer to market, ICT-based service development and deployment, stakeholder engagement, long term sustainability will be addressed. This will also examine the increasing globalisation of the market and the need to prepare EU companies across the ICT, construction and energy sectors for both the challenges and opportunities provided by an international market.

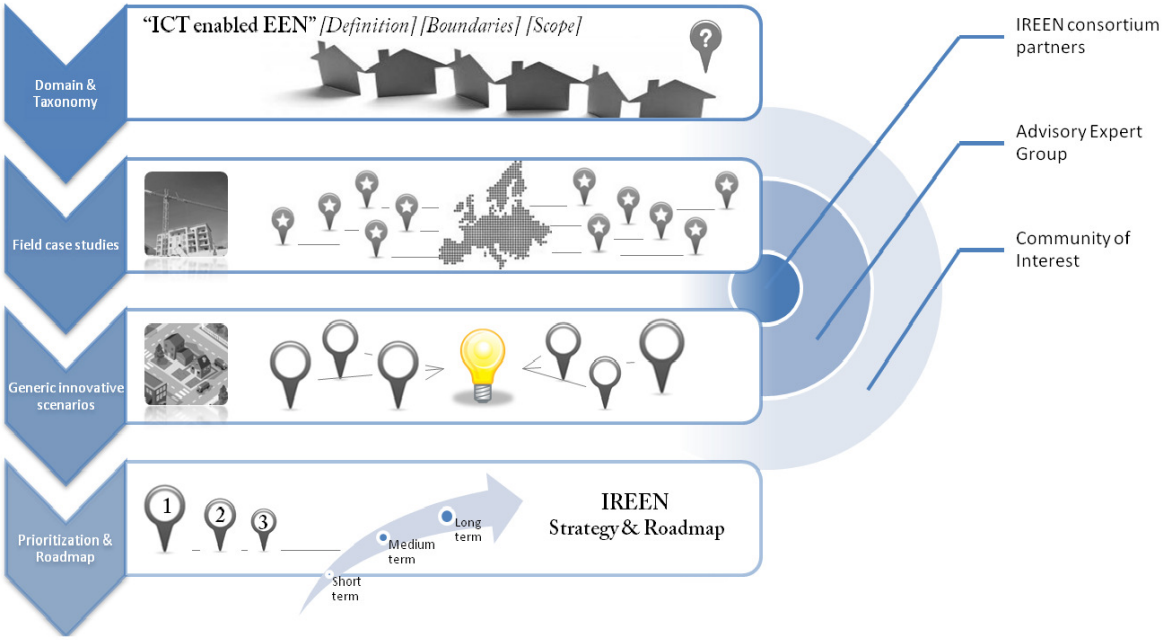


Figure 1. IREEN Methodology

4. State-of-the-art on ICT-based innovation projects and initiatives for Energy-efficient districts and neighbourhoods

A fundamental step for the IREEN project will be to extend the notion of energy-positive performance from small scale homes and buildings initiatives to large scale initiatives involving neighbourhoods and extended urban/rural communities in a holistic dimension. The key output of the project will be a roadmap i.e. a strategy which can be utilised towards achieving a common vision with a European consensus on targets to feed in the European Commission's future Horizon 2020 program [5].

Within this framework the activities under development are focused on achieving a comprehensive as possible, state-of-the-art cartography of current case studies and ongoing living experimentations about the use of ICT systems and applications to improve energy efficiency in districts/neighbourhoods. This will provide an up to date cartography of potential good or best practices and associated ICT tools, thus preparing for future industrial take-up activities and identifying opportunities for knowledge transfer.

To achieve this target it is fundamental to include:

- a collection of ICT standards, methodologies and tools related to the building and construction domain and analyse their relevance and possible evolution with a view to implementation at the level of extended urban/rural areas,
- an analysis of the relationships between producers, distribution companies and consumers of energy. The objective is to derive new business models and to identify opportunities for companies, including high value SMEs. This in turn can be

considered as an initial a framework (bringing key actors together) for future co-operation.

The classification and analysis will set up a mechanism by which key indicators can be identified and defined as part of a systematic, impact analysis of RTD and innovation projects, as well as large-scale pilots and action plans.

It is possible at this stage to provide preliminary insights from IREEN state-of-the-art cartography, based on the collection of data sets from 74 projects around Europe and, in some cases, beyond [6].

One consideration is the relevance of neighbourhoods-based ICT projects already in existence. Considering the huge investments usually required for these projects, finding so many already active initiatives is a clear signal of the relevance that energy management at district level is gaining. On the other hand it is worth mentioning that such initiatives are scattered across Europe, being mainly driven but regional/national initiatives, while projects at European level are still in an embryonic phase and not fully developed.

Other relevant outputs from the preliminary analysis are the project type distribution as mentioned above – it is possible to define an innovation project following its positioning in the innovation value chain:

- Action Plan – strategic project aiming at analysing current status and defining next actions in order to achieve effective results;
- R&D project – development project focused on the analysis and development of new solutions with high replication potential;
- Innovation project – large scale pilot projects focused on deployment into real cases of off-the-shelf technologies in order to demonstrate their market potential.

Within this classification (a single project can belong to one or more of the above), it is relevant to see how 20% contain an action planning phase (just 2 are only action plans), while almost 100% of projects can be considered R&D and/or innovation projects, equally distributed among the 2 options.

The final aspect to be considered is a general classification of the different activities with respect to technologies and potential impact. This exercise will give comprehensive information once the IREEN taxonomy (see following section) has been fully developed. At this stage it is possible to make a preliminary analysis taking into account REEB/ICT4E2B Forum taxonomy [2,3] regarding technologies and the European Smart City Model [7] impact areas. A classification under this taxonomy and model can provide just rough indications, since they have been developed for different purposes. However they provide interesting input to be taken into account in the forthcoming roadmapping exercise.

Considering technology areas, 60% of activities can be considered under Energy Management and Trading. This is a clear signal of how much smart local energy grids are relevant. On the other hand it is quite surprising to notice how integration technologies, even if considered of outmost importance at EU level, are related to only 2 of the 74 projects, spotting a clear barrier against a wide and effective diffusion of ICT for Energy Efficient Neighbourhoods solutions.

The analysis of impact areas led to less relevant results. The most relevant impact area is the one related to “Smart Environment”. However, that all other impact areas are of comparable level but “Smart Governance”, clearly showing how the problem of introducing ICT solutions for the governance support in energy efficiency (e.g. public procurement based on energy efficiency qualification) still has a far from an effective uptake.

As already outlined, the results of this analysis, which will act as baseline for the future roadmapping work, have to be taken as preliminary insight of a more detailed work, nonetheless they provide clear insight about the relevant running activities focused on the

implementation of R&D&I projects, with great regard to Energy Management and Smart grid application, that are considered the most relevant at this stage.

5. The IREEN Taxonomy

For the development of the IREEN roadmap, a structured approach is needed to manage the broad study area of the project. For this, a taxonomy was developed based on REEB [2], and modified to the neighbourhood level. The scoping matrix was refined with the help of the Advisory Expert Group of the IREEN project.

The focus area of ICT enabled energy efficient neighbourhoods is broad, including the entire energy chain from energy consumption in buildings and transportation, to energy production and distribution in a neighbourhood. In addition, ICT's have several different categories from design and energy management to decision support and integration technologies. ICT categories are adjusted into the neighbourhood level from the classification used in REEB [2]. The taxonomy is provided as matrix in Table 1.

The Scope of IREEN: ICT for EE neighbourhoods	Application fields					
	Neighbourhood planning & operation	Transport systems	Buildings & public spaces	Energy production & storage	Energy distribution	People involment
1. Design, planning & realisation						
Design						
Modelling						
Performance estimation						
Production management						
2. Decision support						
Performance management						
Visualisation of energy use and production						
Behavioural change						
3. Energy management						
Intelligent monitoring and control						
Energy brokering systems						
Energy hub						
Smart grids						
EE services						
4. Integration technologies						
Process integration						
System integration						
Interoperability & standards						
Knowledge sharing						
Virtualisation of the built environment						

Table 1. IREEN Taxonomy Matrix: Application Fields and ICT groups

The application fields, presented in the columns of taxonomy matrix represent energy consumers (buildings, transportation and the entire neighbourhood), energy distribution, production and storages. In addition to these, a category was given to people and their involvement to ensure their significant role is included. The application fields are identified based on what aspects of neighbourhood are important for its energy efficiency. The similar approach has been used in many projects, such as [8, 9, and 10].

"Neighbourhood" includes all the required processes on a neighbourhood level, such as making of city and neighbourhood plans, designing of the area and its services, as well as operation and maintenance of a neighbourhood.

"Transport systems" are focused on decreasing the need of transportation, and especially usage of private cars. Another topic is how to encourage people to use more

bicycles or to walk. The target is to minimise transportation energy consumption and increase its energy efficiency. This encompasses solutions related to the structure of the neighbourhood as well as the transportation infrastructure. The use of technology for their reduction of congestion is an area of importance. Note that the energy efficiency of transportation engines (such as car motors) is excluded.

"Buildings" considers all kinds of buildings in the area: small buildings, apartment buildings, offices, services buildings etc, mainly in terms of how these are interconnected at the neighbourhood level. ICT roadmaps already exist in this field, e.g. in REEB (the roadmap for ICT supporting energy efficiency in construction), and in ICT4E2B [3]. The aim is not to rewrite these results, but to utilise the knowledge from these and focus on the priorities identified in these projects.

"Energy production and storage" consists of all energy produced, stored and converted in a neighbourhood. Energy production systems can be both centralised and distributed. It includes all forms of energy: electricity, heating, cooling, gas, and fuels. Overall energy efficiency has to be taken into account as well as the primary energy source. Renewable energy sources typically consume less primary energy than fossil fuels.

"Energy distribution" is targeted to maximise the energy efficiency of all energy distribution. This means the minimisation of distribution losses for heating, cooling and electricity. District heating and cooling, as well as electricity and gas networks are considered.

"People involvement" is a broad category, focused on behaviour and communication. It includes for example involving people into the planning process, sharing knowledge and awareness, as well as decision making situations and security. The key issue is to identify ICT solutions that inhabitants will need to improve energy efficiency of their neighbourhood.

In addition to application fields, ICT's are divided into four groups, modified from the classification of REEB [2]:

1. **Design, planning and realisation** includes designing, modelling and estimating the performance in various levels of neighbourhood planning (both concept and detail level), for example: energy-focused modelling of network components; integration and visualization of energy information into GIS systems; and multi-criteria decision process model, and smart decision support tools and algorithms for design of energy-efficient neighbourhoods. The use of 3D visualisation is also considered.
2. **Decision support** includes performance management, visualisation of energy use and production; and behavioural change; such as benchmarking; visualisation of neighbourhood plans; social media to increase awareness and engagement; user centric ICT systems, devices, interfaces, dashboards etc.
3. **Energy management** includes: intelligent monitoring and control, energy brokering systems, energy hub, smart grids, as well as business concepts and financing of energy efficient services. For instance, one development need is intelligent control, monitoring and visualization of heating and domestic hot water systems on a neighbourhood level.
4. **Integration technologies** are not technologies themselves, but ways to integrate the ICT systems in a neighbourhood level. This includes process and system integration, interoperability and standards, but also knowledge and data sharing as well as virtualisation of the built environment. Issues with communication, security and privacy are issued here. Examples are: ICT based tools for involving all stakeholders (including professionals and citizens), education, training and dissemination; access to knowledge and best practices; or replacing of physical assets with ICT.

6. The IREEN approach to innovative scenarios

The incremental assemble of state-of-the-art supply-side ICT projects, large-scale pilots and solutions, as well as the identification of demand-side objectives and strategies, is regarded in IREEN to be the basis of demand-side visions and innovative scenarios. These scenarios should lead towards future large-scale trials to further allow appraisal of solutions from the ICT supply-side on how this can better meet demand-side needs and expectations.

IREEN is looking for the key to creating energy efficient neighbourhoods. Scenario building, with the assistance of a team of EU experts forms part of this process. Such scenarios should take into account elements related to regulation, costs, technology, security, standards, and energy supply structures. The scenarios (and potential IT-based support solutions) are at their most compelling when addressing the entire value chain for energy production, storage, delivery, and consumption. IREEN advocates that this is to be done via collaborative and integrated solutions, allowing stakeholders to share and exploit data and information generated by linking an unprecedented number of intelligent devices and systems, for example from the Internet of Things arena (IoT). These include sensors, meters, IT-based equipments and components, distributed energy resources and energy assets, and software.

The IREEN user case studies and scenarios consider a move from pilots to scaled deployments, in order to indicate a path towards larger deployments. The idea being they should provide proof of robust technologies and scalability. They should also give provision for revisited and new business cases that work for all stakeholders, with the purpose of removing bottlenecks which stop ideas reaching the market, including lack of finance, fragmented research systems and markets, under-use of public procurement for innovation and slow standard setting.

At the time of writing, 15 scenarios are already described (around 30 innovative scenarios being targeted in IREEN) presenting extrapolations on expected innovations in the field of ICT for Energy Efficiency in large areas (neighbourhoods and extended urban/rural communities) to appear in the horizon in the next 10 years. As mentioned, these scenarios rely on the state-of-the-art on ICT-based innovation projects and initiatives (as introduced in Section 3 above), on the findings of the previous REEB and ICT4E2B projects [2,3] and on industrial requirements derived from conducted workshops with European experts. The analysis of the feedback and refinement of the scenarios will be the basis to identify ICTs that are deemed to have the largest impacts and to define the IREEN strategic roadmap.

The Table 2 below exhibits one example of such a scenario, in the IREEN “neighbourhood” application domain (and more precisely in the neighbourhood planning).

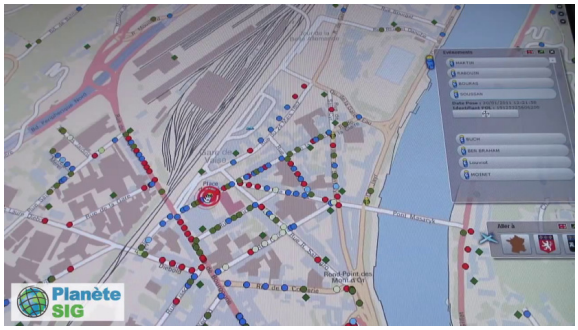
Scenario title	***Urban area renovation***
Description *A story how new ICTs could be used in the future. It does not describe what needs to be developed, but imagine that necessary RTD has already been done and the results are deployed into practice.* *It mentions:* • *Stakeholders using the new ICT solutions;* • *Impacts / benefits from the new ICTs;* • *Related new business / service models / ways of working enabled by ICTs.* *The story should give inspiring examples how ICTs will exceed the SotA. It does not need to cover everything in the area.*	John is an urban planner at the "EPCOT" City Administration. He is in charge of refurbishing an existing neighbourhood, named "Eco", composed of several buildings of different types (residential buildings, offices, a shopping centre, public buildings like a school, a library and an hospital), public areas (like green parks), and several car parks. "EPCOT" City has signed up to the Green Digital Charter, and is engaged in a pluriannual programme to reduce the carbon footprint and improve the energy efficiency of the city thanks to ICT. In this context, John must work on solutions to renovate "Eco" and make it an energy-efficient neighbourhood empowered by ICT, with the overall goal to reduce the overall energy demand from outside sources by 50%, and decrease carbon emissions by 30%. In a first step, John, with the assistance of his technical team, launches the urban GIS platform of the city where he can visualize in 3D the location of the different components (network energy nodes) of the neighbourhood, and the real-time energy balance for each of them. Indeed, during a previous campaign, all buildings of the neighbourhood, as well as the street lighting system, have been equipped with energy meters to inform in real-time on the energy consumption (or production) of the nodes. This energy information has been integrated in the GIS. In order to decide how the neighbourhood will be renovated to meet all the constraints and particularly the energy-efficiency objectives (50% reduction of primary energy consumption, 30% reduction of CO_2 emissions), John can use different design software tools to help him in the decision-making. Some configuration tool, following a lego-like approach where pre-defined components/nodes can be taken from a container, specified and assembled together, allows him to test and assess different solutions. For instance John can easily change the energy characteristics of some nodes (e.g. installing RES in some buildings), introduce new nodes (e.g. centralized storage unit) or new transportation systems (e.g. electrical vehicles), and modify the neighbourhood layout (street network). For each new design configuration the tool evaluates the energy performance of the neighbourhood by assuming an optimized energy management. An add-on to the tool can also help John in choosing the best configuration (e.g. dimensioning some components) under a set of constraints and objectives, by running an optimization engine based on genetic algorithms. All solutions can be visualized with the GIS platform for an easier assessment. 
Technology areas involved in the scenario (rows of the IREEN matrix).	Design, modelling, performance estimation
Application areas involved in the scenario (columns of the IREEN matrix).	Building & Public Spaces

Table 2. Example of IREEN Innovative Scenario

7. Conclusions

IREEN is still a work in progress (final results are due mid 2013). It is, however, already producing some interesting results which we are keen to disseminate in this paper. A roadmap is essentially a strategy. For a strategy to be successful it has to have two clearly defined components. One is a complete understanding of what is happening at the starting point i.e. where you are now and the other is a well thought out scenario - or set of scenarios - as to where you might like to be in the future. Unless both are both present the strategy is flawed.

IREEN is putting considerable time and effort in documenting and analysing what is current and happening now. A state-of-the-art cartography of case studies and current practice has been drawn up. The listing current practice is of limited use unless the data can be analysed in a meaningful way. This was confronted from the start and a thorough and well documented methodology was drawn up, starting with a commonly agreed definition of what exactly constituted an ICT Enabled Energy Efficient Neighbourhood. This was not simply a formal academic exercise and drew on the knowledge and experience of expert practitioners in ICT, construction and energy management from the private sector as well as both city and community representatives.

Running in parallel with the development of a classificatory methodology was a taxonomy matrix which, when fully populated, should allow meaningful conclusions to be drawn as to what works in which context. As can be seen from this scoping matrix, the operation field of ICT for energy efficient neighbourhoods is broad; and includes a range of stakeholder groups. Therefore, the importance of co-operation between different actors, but also the system and process integration as well as the need for holistic energy management increases in the near future. This has the potential to open possibilities for new emerging business and service concepts.

It follows that this should also offer some insight into scenarios to avoid when seeking to create energy efficient neighbourhoods. The categories in the IREEN taxonomy could also be used in a risk analysis. The importance of this is difficult to overstate. The technologies that underpin a roadmap may be tried, tested and state of the art. People have to be positively involved in the realisation of the project for those technologies to be effectively implemented. Moving forward, there are indications that issues around the legal framework and governance differ significantly within and between EU member states. A multiplicity of energy providers and users has implications for procurement and the creation of public/private partnerships and other business models which are needed for more energy efficient neighbourhoods to be realised.

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