READY4SmartCities - ICT Roadmap and Data Interoperability for Energy Systems in Smart Cities

Deliverable 5.3: Draft of Innovation and Research Roadmap

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1 Introduction

1.1 Purpose and scope

READY4SmartCities focuses on smart city energy systems and their interconnections, including centralised and distributed energy systems and connections both to the national level energy grids, as well as interconnection to the neighbourhood and building level energy systems. The proposed technologies are mostly applicable both urban and rural communities.

This report is a draft of innovation and research roadmap suggesting research and technical development (RTD) and innovation activities in short, medium and long term for ICT supporting energy systems of smart cities. This document is purposed to be used as a draft roadmap for expert consultations. The roadmap development continues until September 2015.

This report presents identified drivers, barriers and enablers of energy systems in smart cities. It also suggests RTD and innovation topics for short, medium and long term development and innovation of ICTs for holistic design, planning and operation of energy systems. In addition, synergies with other ICT systems for smart cities are considered.

1.2 Partners' contributions

The partners' contributions to this report is summarised in table 1.

Table 1. Partners' contributions to this report

Partner	Resources	Contributions to sections
VTT	4.5	Leading of work, collection of inputs, main responsibility of the deliverable. Sections: 2. summarising the vision 4.3.3 Controlling energy performance of buildings 4.4.2 Demand side management 4.4.9 Energy trading & brokering 4.5 Municipality 4.5.1 Electrical vehicles integration to city's energy systems 4.5.2 City planning enabling maximised energy efficiency
DAPP	1.5 PM	2. Vision summary based on D5.2 4.2 Citizens involvement
UPM	1.5 PM	4.6.2 Smarter use of energy data 4.6.3 Open energy data, ecosystem and regulations
CSTB	1 PM	2. summarising the vision 4.3 Building sector 4.3.1 Planning of buildings 4.3.2 Planning and implementation of building renovations

Partner	Resources	Contributions to sections
CERTH/IT	1.5 PM	4.2.1 Participation to building design 4.2.2 User behaviour & decision support for energy efficient living and working 4.6.1 Development and harmonisation of energy data models
INRIA	0.5 PM	3. Enabling technologies: Linked data for energy data interoperability in smart cities
AIT	1.5 PM	4.4 Energy sector 4.4.1 Planning of district level energy system 4.4.3 District level electricity management 4.4.4 District level thermal heating and cooling management
EMP	0.5 PM	4.3.4 Building energy performance validation and management 4.4.5 City energy performance validation and management

1.3 Road mapping methodology and relations to other work packages

The methodology for developing this road map is fine-tuned from the experiences that were got from previous ICT road mapping projects. Especially know-how from IREEN project[1] is reflected here. On the other hand, in IREEN the road mapping methodology was built on earlier ICT road map projects, such as REEB[2], ICT 4 E2B Forum[3], and REViSITE[4] projects.

Most relevant learnings to be considered from IREEN project were [Sepponen et al, 2013]:

- The roadmap template worked well, and it was well structured. However, perhaps different views of stakeholder groups could be added to the template.
- Implementation action recommendations included different points of views (for different stakeholder groups), which was useful.
- Length of the roadmap deliverables was too long. Chapters need to be shorter, approximately for each roadmap topic a maximum should be of 3 pages in total with a roadmap picture (0.5 pages).

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[1] ICT Roadmap for Energy Efficient Neighbourhoods project 2011-2013. http://www.ireenproject.eu/
[2] REEB project, the roadmap book: ICT Supported Energy Efficiency in Construction. Available at: http://ec.europa.eu/information_society/activities/sustainable_growth/docs/sb_publications/reeb_ee_construction.pdf.
[3]Full project title was "European stakeholders' forum crossing value and innovation chains to explore needs, challenges and opportunities in further research and integration of ICT systems for Energy Efficiency in Buildings. Project was implemented in 2010-2012.
[4] REViSITE: Roadmap Enabling Vision and Strategy for ICT-enabled Energy Efficiency. www.revisite.eu/

- It is useful to make a global picture of the roadmap that visualises the spear head issues and topics of the proposed roadmap, and summarises the project scope.

In the IREEN project one of the challenges was to structure the roadmap to support and show all the links and integration needs between different research and technical development and innovation (RTDI) topics of the roadmap. Furthermore, the relationship between scenarios and actual roadmap section could be strengthened. The expert engagement, feedback and inputs are crucial in the roadmap development, and thus there is a strong need for collaboration with work package 1 called Community Creation and Dissemination.

The steps for developing the roadmap steps are presented in table 2, including planned stakeholders' and experts' involvement to the work. In addition to developing the road map itself, another crucial target is to experts to validate the proposed road map.

Table 2. The planned road mapping methodology step-by-step and related actions for involving stakeholders (WS = Workshop, ON = online discussions, FF = Face-to-face interviews).

Step	Action	Stakeholders' role
1	Identifying and defining of different energy systems in smart cities.	expert WS for term definitions, further development and validation
2	Identifying links and integration possibilities between different energy systems in smart cities. This will be presented as a matrix showing linked energy systems, and it will visualise which energy systems need to be integrated or interoperable.	WS/ON: identify and validate the links
3	Identify and develop future envisioned scenarios / development paths for smart energy systems based on the identified links between different systems. Scenarios can be developed both based on bottom-up (what are next possible steps) and/or top-down (vision based) approaches. (These are reported in Deliverable 5.2 Vision of Energy Systems for Smart Cities.) Consider scenario based roadmaps i.e. alternative futures/trends (e.g. centralized vs distributed, very high vs moderate energy costs, …).	Develop and validate scenarios: WS (preliminary) and FF (mature)
4	Roadmap to present, how ICT can support and enable future scenarios for linked energy systems. Draft roadmap done for experts' feedback. Roadmap topics are the same as envisioned scenarios. Goal is to set the structure and topics for the roadmap, and make a first version.	FF, ON: to give feedback and inputs

Step	Action	Stakeholders' role
5	Finalising the roadmap with giving different viewpoints: what this means for ICT and energy system experts, end users, etc. The aim is to tell: what is important/essential for ICT/buildings/municipality/energy companies… It would be great, if this could be included in the roadmapping pictures.	Potentially WS and FF to validate the roadmap
6	Implementation recommendations based on the roadmap.	input & validation
7	Impact assessment. Enhance impact assessment from REVISITE. Consider rebound effects and cause-consequence interdependencies.	input & validation

This report is partially based on the findings from the other project work packages 1-4, and tasks 5.1 (framework) and 5.2 (vision). The following IREEN deliverables are used as a background material: D3.3.1 Strategy for European-scale innovation and take-up [Sepponen et al, 2013] and D3.3.2 Roadmap for European-scale innovation and take-up [Sepponen et al, 2014].

The road map is developed with a top-down approach, starting from setting up the framework and the main scope in Deliverable 5.1 Conceptual framework & methodology, and the main vision of the road map in Deliverable 5.2 Vision of Energy Systems for Smart Cities. The road mapping work in this report presents state of the art and RTD and innovation needs for ICT for short, medium and long term towards achieving the vision. Also drivers, requirements, barriers and expected impacts for each road map section are presented.

Relations between this task 5.3 and other work packages in the project are visualised in figure 1. Previous R4SC deliverables from tasks 5.1 and 5.2 set the base ground for the road map development. Experts' collaboration and inclusion to the work is arranged by work package (WP) 1. Other work packages 2 – 4 produce more specific information about linked data for energy systems of smart cities, and the results and findings of these are included in the road map.

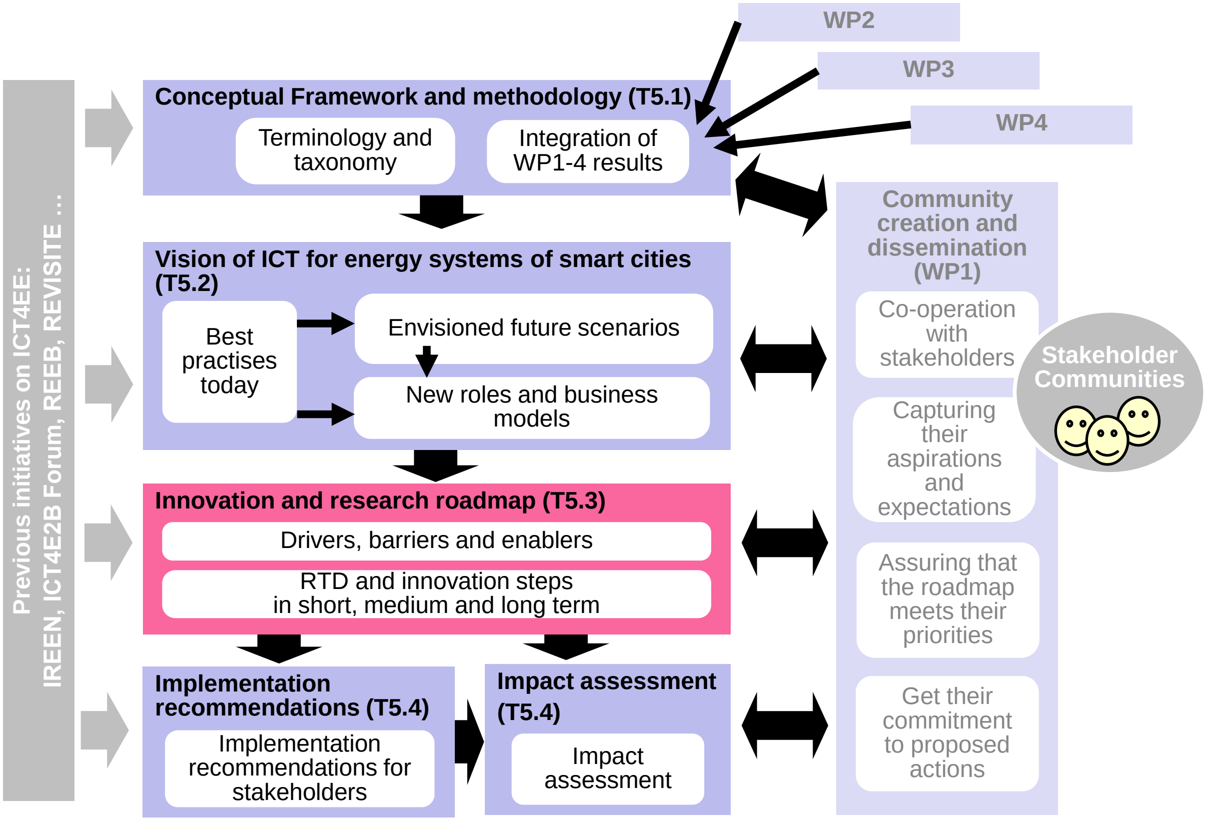

Figure 1. Relation of task 5.3 to other work packages

1.4 Background: Energy systems in smart cities and their integration possibilities

This section has two objectives: the first and second road mapping steps:

1) Identifying and defining different energy systems in smart cities.
2) Identifying links and integration possibilities between different energy systems in smart cities.

In this the experts support is needed for setting and validating the used term and scope definitions, and for supporting the identification of the links and integration possibilities for different energy systems.

Energy systems in smart cities refer to all energy solutions and technologies for energy supply (in other words: production), energy distribution, storage and energy demand/consumption/ use in cities. In this project the improving of energy efficiency of transportation and transportation fuel supply is excluded from the project scope. Figure 2 shows a preliminary matrix of different energy systems considered in the project scope. It also shows a tentative identification of links and integration possibilities between different energy systems in smart cities (see Figure 2). This is presented as a matrix showing linked energy systems, and it will visualise possible integration opportunities between different energy systems.

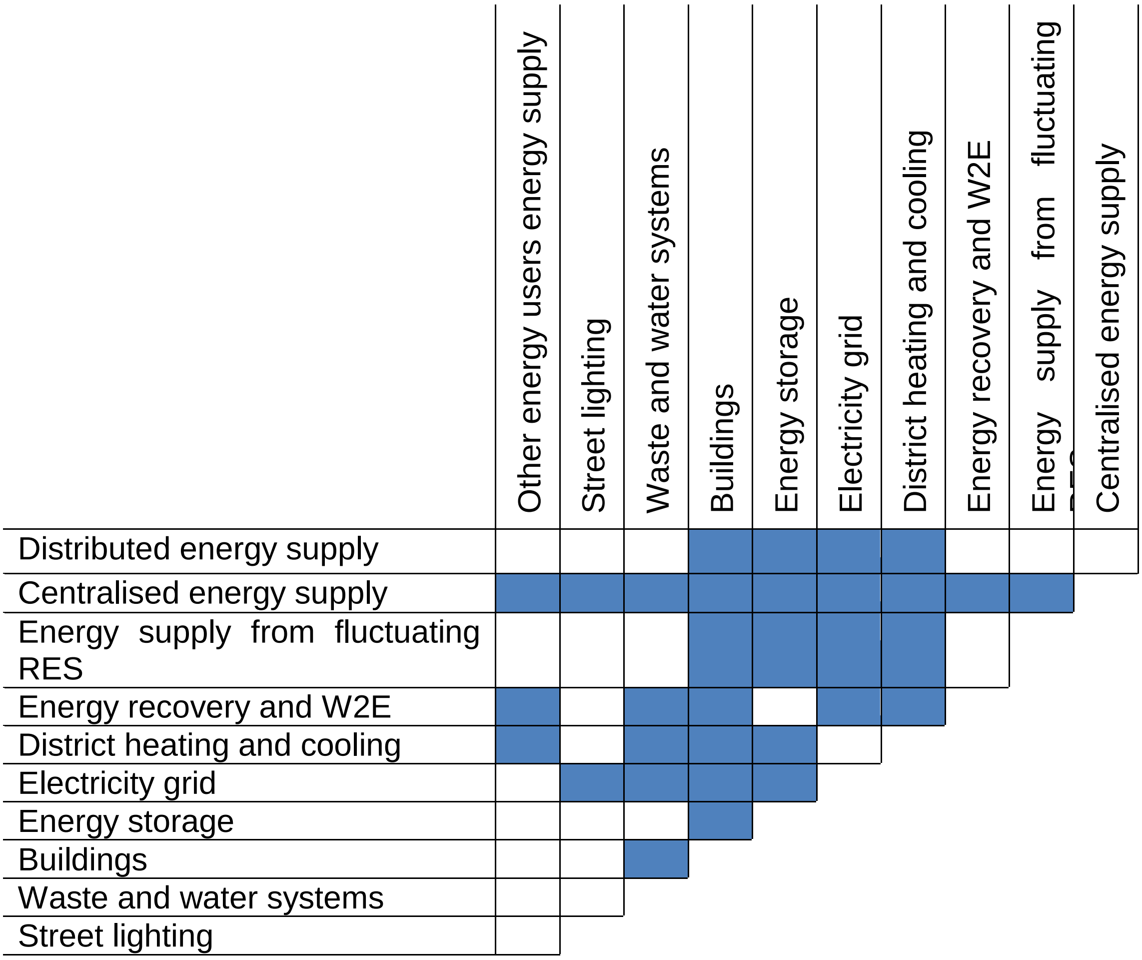

Figure 2: Preliminary matrix showing linked energy systems for smart cities (blue colour signals potential for integration or link points between different energy systems).

2 Vision for the ICT supporting energy systems in smart cities

This section summarises the third road map development step of identifying and developing future envisioned scenarios for smart energy systems based on identified links between different energy systems. Scenarios can be developed both based on bottom-up (what are next possible steps) and/or top-down (vision based) approaches. These scenarios are developed in task 5.2 and this work is reported in more detail in deliverable 5.2 Vision of Energy Systems for Smart Cities.
The Ready4SmartCities vision has been collected by stating the development needs for energy systems of smart cities and especially on how ICT is enabling it. The proposed scenarios represent the development needed and foreseen based on the 20-20-20 targets and 2030 and 2050 targets agreed in environment, energy efficiency and sustainability policies by European Commission (EC). This kind of development is needed to adapt to targets of lowering emissions, increasing energy efficiency and improving the overall performance of energy systems. The vision is structured into four main categories, which all are aiming towards the same future:

Citizens are taking an active role of a prosumer (energy consumer that also produces energy by themselves). In addition with the increasing use of "connected objects", citizens become the real actors of their own energy demand by making their own control settings for their use of energy appliances according to various indicators such as energy price levels, carbon foot print, being then also active participators in demand side management They are giving opportunity to decide, how much they are willing to pay for using electricity in different equipment and with what kind of environmental impacts during peak hours. Also gamification approach provides new opportunities for engaging especially young generations e.g. to improving energy efficiency, energy savings and improving of sustainability of daily actions and behaviour.

Building sector has energy efficient, nearly zero, net zero, and energy positive buildings with on-site renewable energy production, connected to the energy networks. Buildings have systems and tools for managing the building as an active consumer and producer in the city's energy system. Building Management Systems enable buildings to be also connected objects that are able to communicate and negotiate with the electricity and heat networks' systems. As the big producer of data the sector has also the opportunity to learn and fine tune (by developing auto adaptive algorithms) its own energy behaviour and usage for better planning of on-site energy production, e.g. is it better to start a peak power plants to meet the peak load demand, or can energy loads be decreased via demand side management, or are there energy storage available (and dimensioned accordingly) and feasible to use.

Energy sector is closely interconnected with the building sector at its city scale systems and is participating to the local energy production and distribution, and as such, their systems are able to communicate and negotiate with Building

Management Systems that are also considered as distributed energy suppliers interconnected with the rest via the energy networks. There are systems and tools for management and optimisation of the use of energy supply, storage and demand, based on better predicting of energy profiles and forecasting based on weather forecasts.
Energy sector operates the heat and cooling, and electricity supply, distribution and storage efficiently with the support of ICTs developed taking into account the intrinsic characteristics of various energy sources and networks (heat and cooling, and electricity supply). The use of different energy sources is balanced and optimised taking into account their own specificities, and predicted energy demand profiles and renewable energy yield forecasts. Heat and cooling networks are operated at the local and city level with the use of low temperature levels more efficiently, and increasing the overall sustainability and efficiency of district heating systems. On the other hand, electricity supply does not have clear city level systems or networks, but they work on national and international grids with various electricity distribution companies for different areas; and separately centralised large electricity producers. Electricity markets are global, e.g. European level electricity markets are foreseen. It is common to have energy brokers operating between global electricity grid and a group of consumers. However, electricity and heat networks have also linkages, for example via combined heat and power production (CHP), which operation and their better optimisation for different situations is easier via coordinated management of energy systems. New opportunities are rising for new actors in the local energy markets.

Municipality plays a role in energy efficient and sustainable city planning, smarter controlling of street lighting, and other city infrastructures such as waste and water management. Transportation planning and use of electrical cars is included in the coordinated and optimised operation of city’s energy systems.

In order for such futuristic scenarios to emerge, the ICTs as a set of pervasive enabling technologies have to play a major role especially in the following areas:

- Linked data/ Big Data: In order to optimise the use of energy, to balance such complex/ ramified networks the processing of the huge amount of corresponding data is also of key importance.
- Communication protocols, data models and standards for all ICT communication between energy system nodes. This enables the technical realisation of the interoperability.
- Security: The data exchanged could be private data (citizen behaviour) or strategic ones especially when smart grids are concerned. Thus the security and privacy of the exchanges is of key importance to prevent from any breach or leak.
- Internet of Things: All these systems will rely on sensors and actuators coupled to decision making mechanisms. These systems to be largely deployed must be easy to use and to interconnect to each other. It means the interoperability issues have to be solved from the hardware level up to the semantic level.

3 Linked data as an enabling technology for energy data interoperability in smart cities

3.1 Linked data

Linked data is the use of semantic web technologies to publish data on the web in such a way that they can be interpreted and connected together. At its core is the use of the Resource Description Framework (RDF) to express data. RDF simply represents data as a graph of resources linked together. It is thus a very flexible model (it can express more than tables). These resources are identified by Uniform Resource Identifiers (URIs which are well known on the web through URL). URIs have two interesting properties: (a) they are non ambiguous, so one can confidently refer to them, (b) they can be used for expressing relations across data sets, hence effectively linking data from various data sources. Additionally, the web ontology language OWL may be used in order to define the vocabulary used for expressing data. This can be considered as a formal documentation of published data. In particular, this allows interpreting linked data with some certainty.

When we talk about linked data (and even linked open data) this does not mean that all data should be made available to everyone for free. Certainly some data can be and some cannot, deciding this is up to the data provider. Issues such as privacy or secrecy may be treated by classical techniques that are put in place for any type of data exploitation. The same holds when security is at stake. There are now techniques for controlling access to linked data like there are access control in other parts of information systems [Costabello et al, 2013; Rodríguez-Doncel et al, 2013].

In the subsequent chapters, the roadmap will describe, activity per activity, the involvement of linked data for reaching better interoperability. Here we describe the general contribution that linked data and in particular linked open data can have to data interoperability.

3.2 Benefits of linked data for interoperability

The intrinsic benefit of linked data is that it is a model that is (a) internationally recognised (RDF, SPARQL, OWL, are W3C Recommendations), (b) not domain specific, it is used in many different domains and in particular in Smart Cities applications which exchange data from various sources, (c) scalable: using URIs avoids name clashes at the world level, (d) well-instrumented, as there are many reliable and open tools for dealing with linked data, and (e) open in the sense that adding information to open data is never forbidden by a schema: it is always possible to extend and merge data sources.

The traditional way to exchange data is the following: one party needs to obtain data from another party, they sit down around a table, decide of a particular format and modalities, and implement data exchange. Such a procedure is reasonably efficient for that purpose. However, in a world in which data exchange is permanent, it becomes costly to constantly have to agree among stakeholders.

The next step in this situation is to put all stakeholders around a table and to decide which standards to use, or if there is a need to create a standard for exporting such data. This definitely delays applicability and increases costs (and modalities still have to be discussed). This is especially true when data evolves: indeed, data evolve more often than buildings. Then, the standard is not perfectly adapted, the discussion must be reiterated, generating more delays and costs (not preventing to end up with several standards). The capability, in ICT, to react quickly to changes in the environment is often seen as a precious feature.

The approach which is promoted by linked open data publication is to replace this a priori exchange agreement or standard approach by a more agile “publish first, think later” (or “thinking does not subsume not publishing“) approach. A data owner exposes its data in RDF, creating or reusing an ontology for documenting it. If other parties are interested in these data, they will take the pain to adopt this ontology or to align it with their own. This is a lightweight process which does not need a preset agreement to work.

This process is ideal for public bodies which have to publish data by law (see data.gov, data.gouv.fr). It may be useful for companies as well. First because they can take advantages of such data published by public bodies, but also because they can contribute to the public wellfare (like they do when they sponsor some action for prestige).

Linked data adoption can be achieved progressively by first offering what is needed by others and ready to be exported in RDF. Once the skills for doing it are acquired, the further publication of other data is facilitated. These skills can also be put to work in order to exploit data published by others and, in the context of Smart Cities, there should be many occasions to do so. Moreover, once such techniques are mastered, it is likely that they will be used internally for exchanging data and not only for publishing data to the outside. This should also bring more fluidity internally.

3.3 Linked data in smart cities

Smart cities are primarily about fluid data exchange which can ease the life of citizens. Energy data is a part of this smart city data. Currently, energy providers tend to develop their own data format for collecting and reporting consumption. They do not exchange much data among them. They restitute it partially (in particular on bills) to consumers in a non-machine processable format. They communicate it, in an aggregated way, to public bodies and agencies. Nothing is done to provide other parties (building managers, urban planners, etc.) with such data. Nothing is done either to take advantage of data that others could offer (extracting RDF from open street map is not a problem for instance, neither technical nor legal).

This is, in fact, true for most data exchanged in smart cites and is not restricted to the given example.

Instead of a pairwise tuned data channels, it should be possible to establish a fair data ecosystem in which all parties could benefit. There could still be bilateral channels for reasons of security or privacy (typically all data involving directly citizens), but they should be intelligible: using wide open format provides this once and for all. Moreover, instead of considering that any data opening could in principle be used by competitors, it would be worth considering if reciprocated data sharing may not be beneficial to everyone. Again, this would create an open ecosystem.

By asking operators to provide data to citizens, we do not mean that all citizens will become expert in statistics and scrutinizing consumption plots, let alone RDF. Instead, they will be able to use appliances, made by third parties, for taking advantage of this data.

Many of the consideration above are political. On a technical ground, if data should be shared in whatever occasion, it should be easy. Then it should be achieved in RDF.

4 ICT road map for energy systems of smart cities

4.1 Target groups and the structure of the road map

This section concludes the 4th road mapping steps with introducing a road map on how ICT can support and enable future scenarios for interconnected energy systems. This version is the preliminary draft roadmap version for experts' feedback. In this version the goal is to set the structure and the main topics for the roadmap, which are structured similarly as in task 5.2 scenario work.

The road mapping work continues until September 2015, when the road map will be finalised. Some examples of the expected improvements to the final version are in giving different viewpoints: what the road map means for ICT and energy system experts, end users, etc. Experts' involvement is expected in the giving feedback and inputs to the roadmap, and validating it via workshops and interviews.

The scope and different layers of this roadmap are set in the deliverable 6.1 Framework [Fiés et al, 2014], as shown in the figure 3 on the right. It visualises the different layers that are taken into account in the road map and the four main target sectors of the road map as follows:

- Citizens
- Building sector
- Energy sector
- Municipality

Both the vision work in deliverable 5.2 [Cavallaro et al, 2014] and in this road map is structured according to these four main target sectors, and the actual road maps are in the following four chapters. The first one focuses on citizens (excluding professionals). The second and third sections focus on building and energy sectors, while the fourth road map sections covers the entire municipality and city level issues.

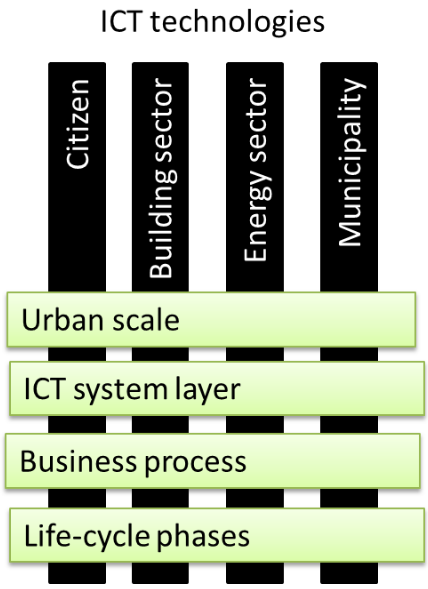

Figure 3. Layers of the road map

Each road map section begins by introducing drivers, needs and requirements, vision, barriers, expected impacts and key stakeholders. Each sector has their own RTD and innovation focus topics, with descriptions of the general background, state of the art, and suggested RTD and innovation needs identified in short, medium and long term as follows:

- State of the art: what is available and in use currently
- Short term: innovation actions, piloting, take-ups ~ 1-3 years usually.

- Medium term: incremental research and development needed ~ 2-5 years usually.
- Long term: research and more radical development needed ~ 4+ years usually.

4.2 ICT road map for citizens and their involvement

Drivers	Citizens are increasingly interested in social and environmental impacts of city evolutions. Furthermore web 2.0 capabilities and, more in general, emerging technologies like open data are opening more possibilities for citizens to influence and participate to city's decision making process. Finally new ways of communication enabled by ICT (e.g. gamification) can allow providing more effective messages to people.
Needs and requirements	There is a need to improve information sharing, not only by opening available information, but also adapting to the different levels of technical literacy of citizens, allowing them to understand impacts as well as potential of different actions and solution to be taken directly by them or by the city as a whole.
Vision	Citizens are fully involved in the decision making process by online collaborative platforms, which are able to explain at different levels of detail the social and environmental impacts of proposed city evolutions, as well as to collect contributions and feedback from citizens in a structured way. Applications and ICT infrastructures are able to help citizens to improve their energy behaviours on their daily lives by involving them and making them aware of the impacts of their actions.
Barriers	There can be difficulties for many citizens to access to ICT solutions, both for economical accessibility and technical preparation. Also difficulties can arise to communicate technical data in a meaningful way without losing their relevance.
Expected impacts	Impacts are expected on increasing energy efficiency by new infrastructures that are planned and designed in a participative way, and by improving the citizens' behaviours to be more energy efficient.
Key stakeholders	Citizens, decision makers, city planners, energy planners, infrastructure designer, and software providers/developers.

4.2.1 Participation to building design

There is a need to create high quality buildings (from utilities to households) that will support the dynamic needs for offering suitable working and living environments, and this requires users' participation. Buildings are more than ever considered as facilities for dynamic processes rather than passive physical constructions. ICT technologies need to evolve in order to better capture the knowledge towards more efficient building design. ICT can also enable users to see the effects of different design solutions to the energy efficiency of buildings.

State of the art

The dominant **Building Information Model** (BIM) captures construction performance and constitutes the basic component of creating **Virtual Buildings** (VB). However, CAD tools do not emphasize on users involvement in order to ensure building functionality and services. Integrated ICT tools for decision support according to users' preferences, at early design phase, are still at an initial development stage. Moreover, current technologies in gaming world and virtual environments that would be more user friendly set further barriers as they do not offer interoperability that would support the import of building models created in external software programs. ICT technologies need to further develop in order to involve inhabitants together with building designers and finally accomplish their revealed or even unrealized needs. The extended adoption of open linked data standards by creators of buildings models, e.g. in the publication of CAD tool output, promises to accelerate progress beyond this state of the art.

Key research and innovation needs are:

Short term	ICT solutions could be developed in order to support and store **energy performance-based design** with broad competences collaboration. ICT solutions for citizens and users for comparing different building design choices and their effects to energy demand and energy costs. Users could build their own building models through **web interfaces**, which can be very flexible and easy to learn and use, while building designers could extract this knowledge and formulate it into a consistent design. Provision of web-based tools can be accelerated by adoption of web standards for knowledge publication. **Game console based solutions** could contribute in motivating end-users to provide valuable information to designers from the early design phase (but also during the management phase). In addition to this, the opportunity of adding in-built building design tools in these platforms will offer the interoperability needed for the actual collaboration between designers and end-users and evaluation of services. An alternative to building the functionality in is to provide application programming interface (API) access and open service provision enabling software collaboration in providing services to users.
Medium term	**ICT systems** supporting users to see and **compare different design choices** how building's energy performance could be adapted in different situations, such as varying energy prices and peak load times, and availability of local renewable energy supply. ICTs enabling easy comparison of different choices via key performance indicators (KPIs). Dynamic properties will be added in **ICT platforms** (containing virtual rooms, utilities etc.) and they will be able to change states and user demand over time and spaces making real time annotations through the whole life cycle process. Reuse of these properties will be made much

easier by presenting the entire model in open data structures.
ICT systems along with physical component systems will be continuously evaluated and performance usability will be tested via context sensitivity and built-in memories. Licensed information from these memories will be made available to third party system designers, enabling them to rapidly deploy new ways of supporting the different user groups.
Tele-immersive communication, through networking and media environments, could enable users at distributed sites to participate in real-time in a shared simulation environment as if they were into the same physical environment.

Long term ICT systems will evolve and interoperate and as a result different types of buildings and infrastructures will interact in a **virtual environment and its energy performance**. Interoperation will be supported by reference to agreed, shared ontologies and consistent use of web standards. City inhabitants' needs, wishes and ideas together with societal requirements could then be evaluated.

4.2.2 User behaviour and decision support for energy efficient living and working

The basic aim here is the optimization of comfort living and working provided by ICT solutions through **users' engagement**. ICT technologies should support people in their **behaviour and decision making, motivating** them to a more energy efficient way of life through a user-oriented environment.

State of the art
There is currently generic information in terms of collaboration between the energy efficiency issues and city inhabitants. It is remarkable that research progress has been made as there are concepts that **enhance user's behavioural change** through energy monitoring and advisory (e.g. ME'GAS[5], BEAWARE[6]). However, the existing CleanWeb solutions (e.g Opower[7]) target to energy consumption monitoring and saving **focused** on **domestic buildings** rather than utilities, public organisations, transportation system etc. Thus basic components that comprise a city are still ignored. Fragmentation and lack of interoperability between different ICT functions delay the creation of a common network where city inhabitants will interchange energy information, motivating each other for a greener behaviour. Virtually no use is made yet of the power of open data to integrate ICT-based services and functions.

Key research and innovation needs are:

[5] ME^{3}GAS project 2010-2013 http://www.me3gas.eu/
[6] BeAware project 2011-2013 http://www.energyawareness.eu/beaware/
[7] http://opower.com/

Short term	ICT tools will provide a **user-oriented, visualized environment** in order to collect energy information. Energy information will be made accessible while respecting data privacy requirements and shared in an intelligible way with end-users. The exploitation of open linked data, web services and innovating ICT applications could provide well-established targets in order to **motivate users** to participate in energy efficiency and energy use decisions based on the predicted available energy supply and energy prizing in the near future. Different means are needed for motivating and rewarding citizens from increasing their energy efficiency. **Open web platforms** based on common standards should be able to access information shared from individuals in order to foster noble competition among them and enhance energy friendly decisions.
Medium term	Use of enhanced internet addressing, the internet of things, will **correlate users with physical objects and devices,** extracting and storing real-time information for inhabitants' energy performance and making this accessible to authorised users using open data. Integration technology development should allow interconnections and interoperability between user profiling data and devices. In addition to this, **ICT tools,** drawing directly on the open data, will develop consumption patterns **giving** useful **advice** to inhabitants for decision support, according to their preferences and daily routine, and predicted energy prices based on open weather forecasts. Consumers will be able to have a more precise overview about their energy performance realizing that comfort living could be combined with energy efficiency and actual cost savings. Different means are needed for motivating and rewarding citizens from cutting their energy consumption during peak loads, but this is possible only after the ICT system is in place for real time energy pricing.
Long term	The adoption of ICT techniques and open linked data will lead city inhabitants in making conscious choices on energy resources improving EE living and working. The storage of **real time energy data** from citizens would lead to concrete analysis of the historical data through **integrated learning mechanisms** and **smart equipment**. This could also support energy performance benchmarking in increasing citizens' motivation and engagement. To allow further improvements, the performance in **comparison** to other cities with similar user profiling will be depicted.

4.3 ICT road map for the building sector

Drivers	Climate change is one of the main reasons for setting European and national regulation and policies has a large role for buildings and their energy efficiency, municipalities, transport and energy. Also increasing of energy prices drives to increasing energy efficiency.
Needs and requirements	From the point of view of the R4SC project, the needs are on data, which means data acquisition, data storage, and data processing from the building environment but also from other domains (energy grids, transportation systems, weather and urban activities at large). This implies that interoperability is ensured at different levels (physical level: the sensors, actuators, and acquisition systems are connected together, and communication protocols, data structures and semantics are shared).
Vision	The energy positive building is another connected object optimised to balance its energy behaviour to maximise the comfort of its inhabitant and to act as a power provider when required by external actors.
Barriers	Barriers are mainly technical barriers related to the lack of interoperability standards, restricting the access to operational/dynamic data and the exploitation of data at higher/bigger levels. But there are also unsolved issues about the privacy of citizens that hamper the “opening” of private data on energy behaviours.
Expected impacts	The expected impact is the generalisation of building energy management systems (BEMS) (and of course building equipped with them) designed to “connect” these building to the energy and information grid, publishing open energy related information to internal and external requests compliant with local regulations (especially with respect to privacy aspects). These BEMS will be able to learn from their occupants and from their surrounding environment in order to refine / adapt their own energy scenarios (when to store energy, when to sell back to the grid, etc…) in order to develop self-adapting capabilities. But these abilities/functionalities rely on the public availability of comprehensive and accurate information on energy production and consumption, and enhanced energy management at the building and city level. Reaching such a “big picture” about the energy situation at the city level will require an appropriate interoperability approach, based on standards including those for ontology and open linked data. The standards will emerge to guarantee a full interoperability over the various systems and applications.

Key stakeholders	Key stakeholders are building designers, urban planners, facility managers, inhabitants, utilities, energy suppliers and energy services companies (ESCOs), urban infrastructure manufacturers, local authorities, construction companies, and ICT tool development companies.

4.3.1 Planning of buildings

In the past decades, the activities around the building planning are mainly focused around the design of building itself. With the uprising use of Computer Aided Software, this activity has considerably evolved over the years. In a first time, it has mainly helped the different stakeholders to perform their own tasks in a more efficient way, secondly with the emergence of the BIM and the corresponding facilities, the collaboration aspects have taken an important part in the design phase. But it was still focused on the building itself. Now with the ever-growing number of tools able to perform simulations based on information retrieved from the BIM and especially with the notion of positive energy building, the planning of buildings turns into an holistic approach that takes into account the building in its environment. From an energy point of view it leads to consider the building as an active node in the energy grid and to evaluate the impact of such node in its area (and the impact of the area on the building itself).

State of the art

The great majority of buildings when they are equipped just benefit from energy related tools acting at their own level (the building itself or considering the different flats independently). From a design point of view, there are different integrated tools that allow calculate/simulate the energy behaviour of the considered building in its environment and use. Some studies have been carried out after the completion of new buildings underlying important differences between forecasted energy profile during the design stage and real energy profile during the exploitation stage. There is very little use of open linked data in the design of buildings.

Key research and innovation needs are:

Short term	Generalisation of studies to learn more about the gap between design figures and exploitation figures (including the development of an assessment method and the supporting tool). Analysis of these gaps and elaboration of rules / knowledge to minimise the gaps and thus produce more accurate figures during the design phase. Development of "**open BEMS**" following two mains axes: 1) **Standardisation of inputs and outputs and access to open data** in order to ease the integration of the data consumed and produced in the frame of an approach with "BIG DATA" capabilities. 2) Development of **"standard" simulation functionalities/algorithms** highly replicable to other building but also at different levels from building to city.

Medium term	Generalisation from previous experiments and proposals of building models including published real use characteristics and self-learning capabilities together with the integration of other external dimensions (transportation / energy grid / …) to open the scope of the energy efficiency not only to the building itself but in its environment. Enrichment of open linked data sets and traditional databases with energy related data (incl. measurements, user's behaviours, external constraints, etc.). Development of new functionalities in relevant ICT standards to ensure the interoperability along the whole value chain.
Long term	Provide rich building models (and the corresponding tools) aligned to comprehensive and accepted ontologies taking into account all dimensions (material, usage, local grid characteristics, etc.) and thus able to support accurate and realistic simulations and able to share these results with other domains. New BEMS able to act locally taking also various external criteria and following energy strategies that can evolve over the time due to learning capabilities.

4.3.2 Planning and implementation of building renovations

The European building stock is old and new constructions made over a year represent only 1% of the overall stock. Thus to meet the European targets, there is a strong need to focus on building renovation (especially from an energy efficiency point of view).

State of the art
From a R4SC perspective, mainly two aspects have to be considered:
1) ICT solutions to ease the insulation of such building (with specific attention to historic buildings).
2) Better integration of ICT systems (BEMS, sensors, actuators,..) and energy related equipment (HVAC, heat pumps, storage systems, etc…) in existing building.
The aim is to turn as many as possible into positive energy buildings and by publishing their profiles and performance as "connected objects", enabling optimisation at neighbourhood and city level.

Key research and innovation needs are:

Short term	There is a strong need to develop new materials but also new manufactured products and components specifically designed for the energy efficient retrofitting of existing and occupied buildings. These new components should come along with new rules and building techniques that can be taken into account since the design phase of the retrofitting. Database about these best practices and pilots' initiatives should be established. In the same way, specific energy equipment should be defined offering enough flexibility to be adapted to existing structures at the best

	price and effort. The availability of open data and accessible databases of energy performance of retrofitted buildings should be greatly increased.
Medium term	Adaptation of building models and BEMS functionalities to take into account retrofitted specificities, making use of the new open data resource. Development of refurbishment packages at affordable prices in order to boost the renovation market.
Long term	Similarly to new buildings, the long term target is to issue a rich building model that takes into account the renovation aspects as well as the other already defined dimensions. Retrofitted buildings being considered as normal connected buildings like the new erected ones.

4.3.3 Controlling energy performance of buildings

Building automation and control systems (BACS) and building energy management systems (BEMS) are used for monitoring and controlling the energy performance of HVAC and lighting systems in buildings. Usually BEMS are included in the BACS, but in single family houses also unit controllers can be used for controlling building's HVAC systems. These systems can be connected remotely and some BEMS can be operated online.
Nowadays BACS can include for example following functions: control of lighting (day light switching, automatic lighting, and constant light control), air condition functions (night cooling, air heating/cooling related temperature control, and outdoor compensate control), load balancing, solar shading, and occupancy and time controls.

State of the art
BEMS are very rarely connected to building information models (BIM). The main data sources to BEMS are real time measurements from devices, instruments and sensors. In Finland, official energy metering data used in the energy billing goes directly from the meter to the energy company, and this data cannot usually be directly used by BEMS. However, some energy companies have enabled possibility for BEMS to get the measured energy data with the appropriate privacy level according to the legalisation about data privacy. Nowadays BEMS can be connected to additional energy measurements to monitor buildings' energy consumption. Often this is done in more detailed level with several energy measurement points, and hence a more comprehensive view can be formed from building's energy demand, its profile and the share among different types of energy uses. In large building complexes this can mean the use of several hundreds or even thousands of different type of measurement points, possibly including a web service or related application protocol interface (API).

Key research and innovation needs are:

Short term	BEMS are able to manage the energy consumption of a building based on the energy price level, for example by shutting down for a while the heating of hot water tank, room heating, or outdoor lighting. This is enabled by creating a connection between smart energy network, BEMS and energy equipment (and/or the switch of energy supply to the equipment) to enable balancing buildings' energy demand and e.g. the need for cutting of demand during peak load times.
Medium term	BACS is remotely connected to more advanced supervisory control and smart grid supported BEMS that is based on big data and simulation algorithms, and is maintained by a service provider.
Long term	BEMS are able to manage buildings energy performance in an optimised way, including its energy demand, on-site renewable energy production (building acting as a "prosumer"), and optimal use of available energy storage. User can set limit values for controlling the use of different energy using equipment, e.g. based on the energy price level. This is enabled by CEM (consumer energy management) standard and related ICT solutions.

4.3.4 Building energy performance validation and management

The quality of buildings in terms of their energy performance has to be verifiable and accurately measurable, a prerequisite relevant for many of the stakeholders involved in energy-related activities in Smart Cities: for energy contractors, particularly ESCO contracting, it is the basis for apportioning rights to revenue and agreeing metrics (key performance indicators (KPIs) and other metrics). For policy makers, it helps to manage and regulate public resources to achieve political targets.

State of the art

Currently the building energy performance requires a process that follows the steps described below:

1) Targets for the energy performance are set, usually referring to a decrease in the building's energy consumption.
2) Monitoring services are (if not already) put in place to measure the energy performance and record results. Performance indicators are calculated to allow for meaningful interpretation of the measured performance.
3) The outcomes of the measurement are compared to the targets (validation process) and used to prompt actions (decision support).

Target setting is used to compare actual consumption with expected one. Generally targets can be very subjective, as there aren't any widely accepted standards or guidelines for this.

Monitoring of energy performance is facilitated by BEMS, which have already been introduced in detail.

The outcomes of the process should be verifiable and accurate. The predictive models applied for consumption analysis use the consumption data as well as exogenous variables to correct for energy requirement variation (e.g. heating degree days).

Key research and innovation needs are:

Short term	Performance metrics deal with building energy consumption and on-site energy production. To be useful, industry must agree on standard **definitions** for these metrics and share **consistent procedures** for collecting and reporting data as well as ensuring data quality.
Medium term	**Interoperability and data exchange** for planning and designing tools that support energy management tools and systems (see section 4.3.3) and validation are key points to address in the mid-term. Based on best practices, the different solutions need to be **harmonised** in terms of expected inputs, outputs, and operation. Distributed energy production and local storage will lead to an increasing complexity of the energy grid. To utilise the benefits and to reduce potential risks (the unstability of the grid, and hence the power failures to building and city levels), exchange of data will become more important, for which ontologies, protocols and standards are needed for "interconnecting" buildings and energy grids.
Long term	Solutions supporting **collaboration** with the different stakeholders (utilities, tenants, etc.). **Standardisation** (both for interfaces and systems) is needed for cross-organisational operation.

4.4 ICT roadmap for the energy sector

Drivers	The Energy Sector is driven by an increasing share of volatile renewables in the energy market, and with an increasing amount of renewable energy production within the city. There is a need for local regulation of energy saving which e.g., leads more and more to the introduction of smart metering techniques. Furthermore there exists a drive to put off long term investments in energy infrastructure as long as possible by resorting to ICT based technologies.
Needs and requirements	Needed here are ICT standards for communication for all systems in the energy market and regulations enforcing those standards taking into account flexible energy markets.
Vision	A city is acting as a large power plant and virtual storage, being able to produce most of the energy needed by distributed renewable sources within the city itself, while being able to react flexibly on the availability of volatile renewables to enable their large scale generation also outside the city. Optimized and flexible thermal distribution, production and the increasing of energy efficiency of systems and interacting with the electrical grid bring mutual benefits.
Barriers	Barriers include inflexible regulations for the energy market. Also stakeholders have conflicting interests, of which some examples are building owners versus building tenants, and grid operators versus energy producers.
Expected impacts	Increase in distributed energy production from renewables within cities; ability to react to varying energy supply by volatile renewables.
Key stakeholders	Municipalities, distribution system operators (DSOs), energy service companies (ESCOs), energy retailers, energy consumers, building operators, and regulatory bodies.

4.4.1 Planning of district level energy system

Today's challenges are to design complex, interconnected energy supply solutions and dynamic considerations, in order to integrate fluctuating, distributed heat and electricity generation with a relatively inflexible load as well as to distribute renewable energy across long distances (e.g. north-south for electricity and from remote industrial areas to cities residential areas for heat and cold). ICT solutions with a high level of interoperability and shared databases are needed to plan and operate new smart cities networks and to identify energy demand and supply structure and potential energy storage options.

State of the art

Planning of electricity, district heating and cooling grids is based on existing tools supporting the dimensioning based on the energy demand density and worst case scenarios (with static considerations).
Although energy systems are more and more integrated into urban energy planning and smart city projects, most energy networks are still usually planned and operated in an isolated, centralized way and optimizations are considered at a district scale.

Key research and innovation needs are:

Short term In the short term electricity, district heating and cooling systems need to be integrated in a holistic approach including the interoperability of physical components. Each network should be modelled taking into account the evolution of the energy demand, which is likely to change because of new buildings usage and building renovations, new districts' development, and the evolution of standards. Implementation of demand side management measures are also expected to affect the energy demand in a near future and should be considered[8]. Tools that allow designing energy networks based on dynamic considerations and temperature requirements for heating and cooling are needed for the integration of decentralized and fluctuating energy sources such as renewables and energy prosumers (this means energy consumers that also produce energy by themselves).

Medium term In the medium term ICT solutions for planning and operating electricity, district heating and cooling networks should consider the evolution of the global energy context, for instance energy markets and regulations. In the planning phase, tools are also needed to take into account the life cycle and different scales of networks (e.g. micro-grids) in a sustainability approach, to build up integrated networks that are viable from energy, economic and environmental points of views. **Optimization tools require standardization of data exchange flows** at city scale between different stakeholders to improve the usability and provide relevant information throughout the life cycle of integrated district energy grids.

Long term In the long term, ICT solutions for sharing information at city scale are needed to optimize the planning and management of hybrid grids, as well as to increase the energy awareness from customers. Generating of holistically coordinated solution is necessary and should be done through an optimal co-operation of hybrid grids, where each interconnected single grid is optimally designed. This will support decision making and allow an efficient use of multi-energy sources at the city level.

[8] See chapter 4.4.2 Demand side management for more information.

4.4.2 Demand side management

Demand side management is one important part of cities' holistically coordinated energy systems. Increasing use of volatile renewable energy supply causes more and more fluctuation to the power generation to the electricity grids, and increasing thus more varying unbalance between energy supply and demand. In addition, local and on-site renewable energy generation in buildings are starting to become more common. Both of these create a need for ICT supported demand side management in balancing energy grids, especially from the point of view of peak load smoothing and minimisation.

State of the art
Demand side management (DSM) is already being deployed in the industry sectors with high energy intensity, but it is not typically used in cities, buildings, or organisations. Lately buildings' energy meters have become remotely readable and the use of smart meters has widely increased.

Key research and innovation needs are:

Short term	In a simple form, DSM could already be realised in the consumer side via multi-tariff supporting smart meters with the capability for bi-directional information flows. These smart meters would be the connection between buildings and smart grid, and they would communicate the DSM request from the smart grid to BEMS or BACS, or as a lighter solution directly to smart fuses, which possibly adapt energy use based on the request if the limit setting values are met.
Medium term	Development of standards, methods and tools as well as devices for interaction between different energy nodes (supply, storage, and demand) and how the entire energy system and its flows could be managed resulting an optimal energy balance and control of peak load times. This is supported by energy profile estimates for energy demand, supply and optimal use of storage, based on weather forecasts and historical data of energy profiles.
Long term	In the long term the electrical equipment in buildings could react itself to up-coming DSM requests, enabling more specific control of equipment' energy use. DSM can enable the negotiation between energy supply and demand to balance them.

4.4.3 District level electricity management

Archiving zero- to plus-energy buildings, neighbourhoods and districts leads to the need of local distributed energy generation (DER) using renewable energy sources in large scale with high density. Electricity management on district scale can be reduced to managing the low voltage grid with respect to frequency and voltage to mitigate the effect of the DER, mostly by demand response measures.

State of the art

Electricity management on district is currently mostly done by traditional voltage and frequency control on the grid level to assure electric energy supply, with the only active element beyond the substation represented by inverters able to produce both active and reactive power, based on the local grid conditions. RES integration is realized only as optimized on site use. Automated demand response solutions are only used for large customers, while for smaller customers only open loop systems, e.g. broadcasting of emergency signals or request for the reduction of energy consumption are implemented, due to financial reasons.

Key research and innovation needs are:

Short term	Medium to **large scale experiments/demonstrations for district energy management** are needed **to asses to actual potential** for the European cities, with the focus on usage types and urban morphology, (types commercial activities, building energy systems and climate zones), to supplement the theoretical studies about the potential of district energy management already available. This holds for the **use of existing system**, using the building thermal mass or suitable industry processes as storage or flexibility and adding only ICT components, as well as for including DER into **retrofitting** approaches, e.g. by **adding dedicate storage equipments**.
Medium term	**Standards for communication** between the different entities (grid, building, ESCO) have to be decided on to foster the creation of **open systems**, allowing for **flexible relations between stakeholders**. This goes a long with **safety, security and privacy protection** for the end users.
Long term	**Cost reduction** to enable wide spread roll out of energy management solutions have to be archived, as the margins for most of the stakeholders involved will always be quite low. Management of **electricity** has to be **coupled to existing thermal grids**.

4.4.4 Thermal heating and cooling management at the district level

The vision for the future of smart cities is in hybrid energy grids, which integrate different district energy networks (electricity, heating and cooling grids), with decentralized energy producers and fluctuating energy sources with various temperature levels and which are able to solve technical limitations (such as hydraulic limitations). Energy management of such integrated networks, in a cost efficient way, requires new ICT solutions that can handle a large amount of data for real-time monitoring and supervisory control of interconnected systems. New energy regulations offer market opportunities, for which efficient planning and operation can be achieved through intensive collaboration between stakeholders and ICT solutions.

State of the art

Existing ICT solutions for heating/cooling monitoring at district level do not provide many functions that deal with interconnected producers and consumers energy systems. Optimizations are implemented at local level so that the global scale is not considered. Currently centralized energy production is very common and there is no coordinated management of hybrid grids, but specific isolated management of each single grid. Regarding business issues, such as prosumers integration in the economic chain, flexible energy pricing and temperature dependent tariff systems, there is a lack of relevant business models, which could allow expanding energy market access.

Key research and innovation needs are:

Short term In the short term, the amount of data to be shared between the different stakeholders at city scale is expected to grow radically. Thus there is a need of more reliable and complete datasets (considering cost-benefit ratio) for decision making and efficient energy management. In this perspective it is important to be able to collect and share large amount of information regarding consumers stocks (type of energy generation/distribution system, building usage, user behavior, etc.) Development of ICT tools for large scale identification and efficient implementation of demand side measures (e.g. load profile and temperature adaptation, hydraulic balancing, etc.) and supply side measures (e.g. supply temperature adaptation) are necessary. Services for increasing energy efficiency and share of renewables also require business models, which should allow overcoming the regulations and policy barriers.

Medium term In the medium term, to manage complex grids at city level with decentralized energy producers, it will be necessary to use and develop new appropriate ICT tools to evaluate in advance new control strategies and to integrate new components in the overall hybrid city grid. Elements of a smart city should be interconnected on various scales to communicate and cooperate in balancing energy supply and demand. Moreover, clarifying the interactions between stakeholders will allow creating new business models to promote flexible energy markets.

Long term In the long term at city scale, it is important that hybrid grids are operated, monitored and controlled in a coordinated way. To improve energy and cost efficiency, as well as to allow a better integration of renewable energy sources a deep collaboration is needed between stakeholders. This can be done through the development of planning tools at city scale enabling simulation and optimization of complex interactions between electric, thermal and gas networks. Energy monitoring of structural (consumer stock) and operational indicators (energetic performances of systems) is becoming necessary to deal with the complex issues of interconnected networks (from an energetic, economic and legislative point of view). In the same way, real-time control tools that can share and handle a large amount of data are needed for systematic control and optimization.

4.4.5 City's energy performance validation and management

City's energy performance can be seen to include both managing and assessing its energy efficiency, not only in (public and private) buildings, but also in neighbourhoods, and streets (traffic). Management takes place today with the help of ICT and for all these activities the active participation of citizens is required or recommended. The greater scope of cities compared to building level analysis and management calls for a strategic approach and clear prioritisation.

The Strategic Implementation Plan of the European Innovation partnership on Smart Cities and communities[9] (October 2013) concentrates on three areas – sustainable mobility, sustainable districts and built environment, and integrated infrastructure. Eleven key actions are proposed to speed up the transformation of European cities into 'Smart Cities', including:

- Agree a common Smart City indicator framework to help cities self evaluate, monitor, and progress and more reliably compare themselves with other cities – providing certainty for long term industrial investments in innovation.
- Make relevant data widely available in the urban domain through culture change towards "open data by default" with public and private actors.

State of the art

In the energy domain, cities can validate and manage their energy performance using indicators. If these indicators are harmonised across Europe, cities could benchmark with other cities and gain insights into how to improve their systems and processes. Such key performance indicators (KPIs) need to be developed using a framework that allows for comparability and common data collection processes to be applied. The approaches undertaken so far have not addressed the aspect of a common framework. For example, a new call by the EC urges organisations to develop a framework for collecting data and performance measurement that builds upon projects with different methodologies that haven't achieved that goal, such as CONCERTO[10], CIVITAS[11] and the Green Digital Charter[12].

Key research and innovation needs are:

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[9] European Innovation Partnership on Smart Cities and Communities: "Strategic implementation plan", 14.10.2013

[10] http://concerto.eu/

[11] http://www.civitas.eu/

[12] http://www.greendigitalcharter.eu/

Short term	The relevant stakeholders need to better **understand** the importance of city energy performance validating and management activities. They need to be **motivated** to provide results for analysis, and in an open format. The take up of such activities proves very successful when using **pilots**. The metrics such as KPIs needed to monitor and evaluate cities have to be clearly **defined**. **Guidelines** as results of EU projects clearly stating the value proposition for each stakeholder group together with detailed description of steps to take in order to replicate the project success are also very beneficial for their wider uptake.
Medium term	Activities towards **inter-city exchange** should be fostered. For that, the developed metrics and indicators need to be **harmonised** to allow for benchmarking and comparison. **Interoperability and data exchange** for tools that support energy management and validation in cities are key points to address in the mid-term.
Long term	Solutions supporting **collaboration** with the different stakeholders (utilities, tenants, etc.). **Standardisation** of data exchange (both for interfaces and systems) is needed for cross-organisational operation.

4.4.6 Energy trading and brokering

The foreseen changes in the operation environment of energy systems of smart cities (e.g. energy positive buildings as prosumers, demand side management and CEM) are setting the fruitful starting point for enabling more active energy trading. It is foreseen that new business opportunities will rise in energy trading and brokering, including energy selling, buying and pricing: where to buy energy and when, and how to utilise the flexibility in energy demand and supply better. It is still open who could take the energy brokering role, whether it is for traditional energy companies, or new operators joining in to emerging energy trading business. Energy brokering supports also the Europe competitiveness e.g. via maintaining the reasonable energy price levels even with increasing share of renewable energy.
There are two base conditions enabling energy brokering business on the wider scale. First requirement for the emerging of wide scale energy brokering opportunities is the increasing number of prosumers and local/on-site renewable energy supply, which creates the need for active energy trading. This development has already been fostered by EC's Energy Performance of Buildings directive, which guides the development of buildings towards (nearly) zero energy buildings and even beyond towards energy positive buildings. The second requirement is to set up the needed ICT systems and protocols, which are suggested in this section.

State of the art
Currently simple energy brokering is possible already now with buying of energy at the right time and selling it further. There are a few energy brokering operators in

Europe, and some aspects of such business can be found from current energy companies. In the large scale their roll-out is still yet to come. Some energy brokering companies exists, such as TheEnergyBrokers[13], who use a variety of in-house developed IT solutions, such as websites and reporting tools for fixed price and volume usage, in addition to systems tailored to specific clients. Currently these kind of companies focus on selling of energy, and not to buying of distributed energy from prosumers. As another example, Finnish people can buy electricity that is priced according to Nordpool[14] prices via electricity companies. In addition, there are some companies providing ICT solutions for better energy management (e.g. for following current energy demands and the actual energy price levels), but often these systems are still separate and they offer only a minor level of support for following and deciding how and when it would be most profitable to use electricity. Some smart meters can already take into account the real time energy pricing tariffs (e.g. in Germany).

Key research and innovation needs are:

Short term The user and building level ICT systems and protocols are needed for the communication between buildings and energy network, and their operation need to be monitored.

At first energy brokering could trade energy based on known historical data about buildings' typical energy demand. Other basic ICT solutions enabling energy brokering are buildings' smart metering and their protocols. The real time energy tariffs (e.g. 24 hours) needs to be communicated to smart meters. Then BEMS and/or BACS can adjust the energy performance of the building according to the energy tariff in real time.

Medium term Energy brokering can be enabled among others via multi-level energy tariffs (e.g. energy price tariffs from levels 1 to 10) and supporting demand side management platform. Information and estimates bring further benefits for energy brokering:

- Prediction of upcoming energy supply profiles (next 24-48 hours) and forecasting of near future energy pricing.
- The forecasting of near future energy demand in building nodes based on weather forecasts and from measured historical data of buildings' energy demand profiles.
- Predicted unbalance between energy supply and demand, and how much of unbalance can be taken care of with available energy storage.

This enables energy brokers to forecast near future unbalances, and to take care of the energy pricing between energy users and suppliers of peak power and/or adjusting energy utilities for balancing energy supply and demand. Energy broker can optimise the buying of energy from local

13 http://www.tebl.com/FAQs.aspx
14 http://www.nordpoolspot.com/

	energy suppliers or prosumers, and from national grid, and how to use direct local suppliers versus national electricity supply. Main input data needed for this is buildings' energy demand (history data & forecasts), and right pricing, but also communication protocols, data models and tools must be in place.
Long term	An energy brokering system can be further improved by negotiating the energy price tariffs between the smart meter/building and the energy grid via related protocols. In the long term, buildings reacting to energy brokering related pricing can also be supported by electrical equipment, if they would have their own tariff based power on/off switch. Then user could set the limit tariff value when the equipment gets power or not.

4.5 ICT road map for the municipality level

Drivers	Cities have increasing focus on improving sustainability among others by political pressure, cities' own targets and action plans. Also image of the city as a forerunner and smart city supports the business environment and attracts companies to the city. Opportunities are seen for improving energy efficiency via integration and linking of different energy systems. ICT literacy of people and emerging technologies such as open data and internet of things offer new opportunities for wide engagement of citizens and system integration.
Needs and requirements	There is a strong need for broad collaboration, communication and interoperability within the municipality and with other stakeholder networks. Standardisation (both for interfaces and systems themselves) is needed for cross-organisational operation.
Vision	Efficient energy use and sustainable energy supply are included in the cities targets and realised in their planning, decision making, daily operation and development projects. Efficient energy use and supply are strongly linked and integrated to other operations and actions by municipalities by various ICT solutions. Municipalities foster the integration of different city systems to maximise their synergy impacts.
Barriers	Municipalities have difficulties to estimate the profitability and other benefits of investments, and they also have difficulties to make long term budget commitments in order to achieve life cycle optimum.
Expected impacts	Impacts can be expected to improve energy efficiency and reduce environmental impacts. Also increased synergy benefits raise from collaboration among different stakeholders on the planning, development and operations.
Key stakeholders	Key stakeholders are decision makers, and city/transport/energy system planners.

4.5.1 Electrical vehicles integration to city's energy systems

It is possible to use electrical vehicles as energy storage (in extreme situations). One barrier here can be how many people are ready for potentially restricting the immediate availability of their cars and with what battery charging levels.

State of the art
Usually charging of electrical vehicles is done immediately when it is plugged in to the charging station.

Key research and innovation needs are:

Short term	The timing of the charging of electrical vehicles could be controlled more actively as a one node in the energy system and its energy balancing, and in demand side management for cutting of peak loads (e.g. based on historical data about timing of peak loads). Also, if possible, charging times would be focused on low energy tariff times. In both cases, user should be able to set the (default) car usage times: when the car is needed what is the minimum operation radius needed to the next charging point).
Medium and long term	A further development point could be ICT systems and related standards supporting the usage of electrical vehicles as storage in the energy system in collaboration with demand side management and energy balancing. Then user would need to be able to set (default) times when car would be available to be used as storage.

4.5.2 City planning enabling maximised energy efficiency

In the city planning there is a need for planning and design tools with energy efficiency evaluation/suggestions, and solutions for easy and quick evaluation and visualisation of energy and emission performance of potential city plans and scenario tests.

State of the art

Currently city planners have map applications and CAD tools for drawing city plans. The needed base data exists in various data bases and distributed locations in different formats (existing city and regional plans, targets for the area, city's action plans etc.). This base information city planner often needs to check manually, which can require a lot of time. City planning and design tools rarely have possibilities to assess energy and environmental impacts of the plan, and comparing different scenarios is time consuming. There exists some check lists and separate tools (e.g. based on spreadsheet calculation) for assessing the environmental impacts of city plans, but typically different city plan options need to be manually input to these assessment tools. Often these tools are also complex and interpreting of results need special expertise.

Key research and innovation needs are:

Short term	City planners need planning and design tools, which have possibility for quick and easy **evaluation and performance estimation** to assess energy and environmental impacts. Tools need to enable comparing different scenarios against each other, regulations, city plans and key performance indicators. Clear visualisations of the expected impacts are also required, because this enables the presentation of plans and their impacts to decision makers and other stakeholders. Tools need to support the engagement of citizens and other stakeholders and handling of

	feedback from them (see also roadmap topic 4.2.1 Participation to planning).
Medium term	**Interoperability and data exchange** for planning and design tools for city planners and databases. Tools also need to have an easy access and transfer to the various data sources, such as areal and city plans, GIS files, demographics, ground water area maps, renewable energy potential maps and data bases, city system and network information (e.g. existing district heating and cooling networks), etc.
Long term	Solutions supporting **collaboration** within the different municipality departments as well as with other external stakeholders, such as construction and energy companies. **Standardisation** (both for interfaces and systems themselves) is needed for cross-organisational operation.

4.6 Energy data road map

4.6.1 Development and harmonisation of energy data models

Conceptual barriers set both **syntactic** and **semantic** differences of information to be shared. Based on the findings of Ready4SmartCities project WPs 2 and 3[15], multilingualism, license policies as well as optimisation of content negotiation mechanisms require the selection of a unified strategy in order to represent cross-domain energy data. The exchange of heterogeneous information and the interoperability between ICT systems requires the development of a **common vocabulary and metrics**. The Linked Data initiative[16] requires formal models that will ensure interoperability and exploitation of the structured data.

State of the art

There has been remarkable progress in the development of **ontologies** (e.g. W3C[17] developments in Web Ontology Language) across different domains that allow the **incremental interoperability** between ICT systems offering a starting point for **Linked Data** generation. However, a new ontological formalism is still considered to be far easier than developing the content to populate it in a satisfactory depth and make it applicable. Hence, the reliability of already existed models in terms consistency and reusability is still restricted. Although some first attempts of ontological models published via Web, support the exchange of energy information between remote and heterogeneous ICT systems, there is still inadequacy of mechanisms that promote **ontologies searching**. The different domain-oriented rules influence the generic character of knowledge setting further constraints in the agreement of a common ontological approach that will lead to the exploitation of Linked Data.

Some prominent representatives of currently used standards/data models related to energy systems in smart cities are the Common Information Model (CIM)[18], developed by the electric power industry, aiming to allow application software seamlessly exchange electrical network information, the ASHRAE/NEMA Standard 201/Facility Smart Grid Information Model[19], and the IEC 62056 (DLMS/COSEM specifications)[20] targeting at data exchange for electricity meter reading, tariff and load control etc. These data models either follow different data formats or follow a specific-aided design rendering difficult the capability of making them extensible.

Key research and innovation needs are:

Short The collection of all the existent energy related ontologies in an **open**

[15] Related Ready4SmartCities deliverables D2.2 and D3.2
[16] Linked Data-Connect Distributed Data across the Web http://linkeddata.org
[17] http://www.w3.org/standards/semanticweb/ontology
[18] http://en.wikipedia.org/wiki/Common_Information_Model_(electricity)
[19] http://spc201.ashraepcs.org/
[20] http://en.wikipedia.org/wiki/IEC_62056

term	**online informed platform** accessible to all the stakeholders from different domains will create the opportunity to structure their data collected from different case studies and experiments (e.g. energy consumption/production/storage). **ICT tools** will be used for this scope in order to motivate educate and train the experts from the different Smart City aspects. Furthermore, ICT expertise tools will be developed in order to identify new ontologies as well as to evaluate their performance in data modeling and harmonization through several criteria and metrics. Moreover, ICT techniques will not only contribute to the **assessment** of these ontology representation formats by reassuring their applicability and reliability in real life scenarios but also will **create data repositories** for further exploitation
Medium term	The collaboration among the different stakeholders will further improve the **knowledge consolidation** on energy efficient cities. ICT applications could further improve their interoperability by having access to **structured cross-domain energy data** in **repositories** as well as developing **know-how services**. The ICT tools could further evolve in order to achieve **concurrent processing** of data models, through graphical interfaces (descriptive languages are much more complex) and across the different domains, a matter of crucial importance in a city level scale.
Long term	The vision of **high quality sharable and reusable expressive languages** will be accomplished. Data models will be formalized according to standardized city ontologies under a **common linguistic frame**. Consequently, ICT tools will interact and exchange information between stakeholders and citizens, in a seamless way, covering multi-disciplinary aspects of the Smart City domains

4.6.2 Open energy data, ecosystem and regulations

There is a need for a critical mass of open energy data, which is stable and accessible on the Web. Such open energy data will require improving current regulations and legal frameworks and will open the path to new business models based on them.

State of the art

Open data are data that are generally accessible online, machine-readable using a common format, and practically and legally reusable. Initiatives towards opening data have flourished mainly in the government and science fields. Analysing the case of energy data, such data are currently stored in isolated silos and the existing cases of open energy data are mainly related to the publication of energy data by public authorities. Open energy data, as well as open data in general, are still in their infancy and making it a reality goes beyond merely publishing data on the Web. For example, one motivation for organizations to publish their data openly is to be compliant with transparency and accountability regulations; however, organizations are afraid of being legally liable in cases of privacy violation or misuse of the data they have published.

Key research and innovation needs are:

Short term In order for open energy data to be a valuable asset the first step it to have more **open energy data** available on the Web. Care must be taken on the particular characteristics of energy data, such as the need for **ensuring privacy** through methods and principles to support anonymisation and/or pseudonymization and to avoid the reidentification of individuals via the published data. Besides, generating open energy data is a complex and ill-understood activity and there is a need for **guiding principles** derived from practical case studies, educational material, training, and support for opening data.

Medium term The current trend is to make data available in the Web; therefore, there is a need for ensuring **stability and accessibility** of energy data to people and to machines by using the Web standards. There is also a need to improve **regulations and legal frameworks** for the management and processing of open energy data (rights of ownership, access and aggregation) as well as to harmonise such regulations and legal frameworks across countries. The availability of open energy data will also lead to the definition of new **business models** that make value from such data.

Long term Our scenario of cross-organisational energy data management goes beyond the need of having some datasets. It requires reaching a **critical mass** of open and accessible energy data published in common interchange formats. For it to be successful it requires to encompass the whole range of actors involved in the **data value chain**: data producers, who generate and publish their energy data; data intermediaries, able to take such data and turn them into products with social and economic value; and data users; who will access and work with data in different ways. To this end, we need to understand the **energy data ecosystem**, the flow of data from consumers to producers (through a number of intermediaries and according to legal and contractual frameworks), the lifecycle of energy data and their governance, as well as how this ecosystem is influenced by external factors.

4.6.3 Smarter use of energy data

There is a need for a smarter use of energy data, which are distributed across sectors, by enhancing such data with explicit semantics and by supporting their processing with ICT that is able of satisfying business-level and real-world requirements.

State of the art

The common scenario in cross-organisational energy data management is that in which different stakeholders need to share their energy data using the Web as a platform. Requirements for data sharing will be different depending on the type of stakeholder (e.g., public authorities, companies, citizens) and its individual interests (e.g., housing provider, energy provider, and tax payer). Furthermore, this heterogeneity will also appear in the ICT required to manage energy data in the different stages of their lifecycle (generation, combination, publication, discovery, and exploitation). Processing of energy data must be performed across organizations, sectors, borders, and languages. To this end, work has started to develop semantic models (i.e., ontologies), which allow developers to reuse and share domain information using a common vocabulary across heterogeneous systems or environments; and to define new architectures, models, and middleware for the integration of distributed energy data across ICT systems (e.g., modelling, simulation, planning, Building Energy Management Systems). Nevertheless, the adoption of distributed energy data will depend on the facilities provided to data producers and consumers to manage such data and their underlying technologies and on the maturity of such technologies.

Key research and innovation needs are:

Short term	Energy data needs to be represented according to **shared ontological models** that support the exchange of energy information and the interoperability of ICT systems; these ontologies need to cover the complex interactions between different domains and to model information at different scales and viewpoints. The ICT systems that manage and process energy data need to satisfy **business-level requirements** taking into account **real-world data** (such as large sizes, real-time processing, dynamicity, consistency, security, or accounting). Furthermore, there is a need for affordable mechanisms to assess the **quality of data** (e.g., consistency, completeness, accuracy) from different viewpoints and tools for **visualizing and analysing data** across domains that take into account the specific characteristics of such data (e.g., spatial, temporal) and allow extracting knowledge patterns and energy KPIs.
Medium term	In order to support a meaningful processing of energy data, energy data need to be accompanied by **contextual information** (quality, licensing, provenance, trust) that nowadays is not attached to the data and in most cases not even specified. Apart from this, it is difficult for the consumers of distributed energy data to find, select, access or combine such data. There is a need for usable tools for **consuming distributed energy data**, including not only interfaces adapted to end users (web, mobile, social networks) but also APIs for developers. Work still has to be done to analyse **new business models** based on the use of energy data and to show the value of such data to the different stakeholders. Open energy data could also be used for demand side management and smoothing of peak loads in the energy system, and balancing energy supply and demand.

Long term	In the long term, there is a need for public and/or private **software infrastructures** that support the distributed storage, sharing and processing of energy data as well as the preservation and update of such data in the long term. Furthermore, energy data must be modelled according to international **standards** that ensure consensus and the long-term maintenance of the ontologies defined in them.

5 Conclusions

This road map suggests research and technical development and innovation activities in short, medium and long term development and innovation of ICTs for holistic design, planning and operation of energy systems in smart cities. In addition, synergies with other ICT systems for smart cities are considered.

The Ready4SmartCities vision suggests development needs for energy systems of smart cities and especially on how ICT is enabling and supporting it. Vision envisages future scenarios and development for smart energy systems based on identified links between different energy systems and interconnection needs and possibilities to broader smart energy networks. This kind of development is needed to adapt to EC's political targets for lowering emissions, increasing energy efficiency and improving the overall performance of energy systems.

The road map is structured in to four main domain area roadmaps and one integrating section related to energy data and its usage. The domain areas are: citizens, building sector, energy sector and municipality level. Each road map section introduces relevant drivers, needs and requirements, vision, barriers, expected impacts and key stakeholders. Each sector has their own RTD and innovation focus topics, with descriptions of the general background, state of the art, and suggested RTD and innovation needs identified in short, medium and long term.

The repeating theme throughout the road map is a strong need for broad collaboration, communication and interoperability within various stakeholder networks. This requires standardisation (both for interfaces and systems themselves) to enable cross-organisational operation. Also the role of open energy data and its utilisation is included here.

This road map has multiple goals. Among others, it aims to increase citizens involvement and their active role in the daily operation, use and decision making related to energy aspects. On the building side, among others the Energy performance of Buildings Directive adopted by EC drives buildings to become (nearly) zero energy buildings that are actually active prosumers that both use energy efficiently, and also produce renewable energy on-site. In the road map the vision is that energy positive buildings are connected objects that are optimised to balance their energy behaviour to maximise the comfort of inhabitant and to act as energy provider when required by external actors of the energy systems. This again requires among others the smart use of data, which means data acquisition, data storage, and data processing from the building environment but also from other domains (energy grids, transportation systems, weather and urban activities at large). This implies that interoperability is ensured at different levels (physical level: the sensors, actuators, and acquisition systems are connected together, and communication protocols, data structures and semantics are shared).

The energy sector road map is developed based on the expectations for increasing share of volatile renewables in the energy market, and with an increasing amount of renewable energy production within the city. At the same time, there is a need for local regulation of energy saving which e.g., leads more and more to the introduction of smart metering techniques. Furthermore there exists a drive to put off long term investments in energy infrastructure as long as possible by resorting to ICT based technologies. All this requires ICT standards for communication for all systems in the energy market and regulations enforcing those standards taking into account flexible energy markets. Additional ICT solutions are need for cities that are developing and starting to act as a large multi-source power plant and virtual storage, being able to produce most of the energy needed by distributed renewable sources within the city itself, while being able to react flexibly also on the availability of volatile renewables to enable their large scale generation also outside the city. As a consequence, optimised and flexible thermal distribution, production and the increasing of energy efficiency of systems and interacting with the electrical grid will bring mutual benefits.

European countries and cities are increasingly adding to their agendas targets to improve sustainability. Also image of the city as a forerunner and smart city supports the business environment and attracts companies to the city. Opportunities are seen for improving energy efficiency via integration and linking of different energy systems. ICT literacy of people and emerging technologies such as open data and internet of things offer new opportunities for wide engagement of citizens and system integration. The project vision is that efficient energy use and sustainable energy supply are included in the cities targets and realised in their planning, decision making, daily operation and development projects. Efficient energy use and supply are strongly linked and integrated to other operations and actions by municipalities by various ICT solutions. Municipalities foster the integration of different city systems to maximise their synergy impacts. Even with these future goals, the current reality is that often municipalities have difficulties to estimate the profitability and other benefits of investments, and they also have difficulties to make long term budget commitments in order to achieve life cycle optimum. Also this challenge can be supported by ICTs.

This version is the preliminary draft road map for experts' feedback. The road mapping work continues until September 2015.

6 Terms and acronyms

API application programming interface
BACS Building automation and control systems
BEMS building energy management systems
BIM Building Information Model
CEM consumer energy management
CHP combined heat and power production
DER distributed energy generation
DSO distribution system operators
DSM Demand side management
EC European Commission
Energy systems in smart cities refer to all energy solutions and technologies for energy supply (in other words: production), energy distribution, storage and energy demand/consumption/ use in cities. In this project the improving of energy efficiency of transportation and transportation fuel supply is excluded from the project scope.
ESCO energy services companies
GIS geographic information system
HVAC heating, ventilating, and air conditioning
KPI Key Performance Indicator
Linked data Linked data is the publication of (structured) data using semantic web technologies and, in particular RDF which represents data as graphs. In addition, data be made accessible by identifying resources with HTTP URIs (dereferencability), intelligible by describing it through ontologies and interoperable by linking its resources to other data sources. However, linked data may be offered by other means such as SPARQL endpoints. [Heath and Bizer, 2011]
Linked open data refers to the opening of linked data, i.e., making it accessible to anyone.
OWL web ontology language
Prosumer energy consumer that also produces energy, e.g. (nearly) zero energy building
RES Renewable energy source
RDF Resource Description Framework
RTD research and technical development
RTDI research and technical development and innovation
R4SC Ready4SmartCities project
URI Uniform Resource Identifier
VB Virtual Buildings

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