EERA JOINT PROGRAMME ON SMART CITIES: STORYLINE, FACTS AND FIGURES

Scientific Board for EERA JPSC Special Issue 01 | 2018

Introduction

Since the beginning of this century, the rapid transition to highly urbanized populations has put societies and governments around the world in the face of unprecedented challenges regarding key themes such as sustainable development, education, energy and the environment, safety and public services among others. It has become clear that cities continue to play a key role in the lives of most Europeans, and that they have a crucial function in the social and economic development of European territories. Cities are generators of growth, yet at the same time they can foster unemployment and economic crisis; many cities show a significant loss of inclusive power and cohesion and an increase in exclusion, segregation and polarization[1]. During the same period, information and communications technologies (ICTs) have reported a dramatic growth and produced a huge amount of data, along with the belief that they can be a major instrument to solve the city's economic, social and environmental challenges. Cities have started to recognize that ICTs are essential for their vibrant social, economic and cultural life, and that they can play a central role in moving the energy system towards a more sustainable path while limiting the dramatic increase in urban energy consumption associated with CO_2 emissions.

Why a Joint Programme on Smart Cities?

Within this context, a number of players acting in this field have developed some considerations on Smart Cities. Amongst these players, EERA - the European Energy Research Alliance - organized a first awareness workshop on research and innovation challenges related to Smart Cities in Brussels in September 2010; afterwards, thanks to a series of further workshops held from December 2010 to December 2011[2], a research framework programme was shaped. In the early stage, the Joint Programme on Smart Cities (JPSC) comprised 18 full participants and 29 associated participants from 16 countries, contributing with 220 person years per year. The Joint Programme was originally structured in 4 sub-programmes (SP1 Energy in Cities; SP2 Urban Energy Networks; SP3 Energy-efficient Interactive Building; SP4 Urban city related supply technologies) with a clear focus on energy efficiency and integration of renewable energy sources within urban areas.

Today, thanks to the 2017-2019 workplan which completely redesigns EERA JPSC activities, we have 7 work packages in place to boost effectiveness on working with shared priorities and joint research projects. Furthermore, the coordination of the Joint Programme, that was performed by AIT with Brigitte Bach from December 2010 to June 2017, has now been transferred to NTNU with Annemie Wyckmans, while AIT is responsible for vice-coordination with Hans-Martin Neumann. Together, they are supporting and coordinating the R&I activities which now involve 23 full participants and 59 associated partners from 20 countries on a voluntary base and in-kind contributions.

Thanks to the 2017-2019 workplan, the aims and goals of the Joint Programme have been redesigned and readdressed. While the initial focus was only on RD&I sub-programmes and related topics, today all the activities have been structured in a more efficient way, with the identification of a coordinator for each work package (WP) and the promotion of WPs that are not only focused on RD&I (WP6 and WP7) but also on network capacity building (WP2, WP3 and WP4) and on a strong interaction with stakeholder groups (WP5).

The workplan of the JP on Smart Cities is currently organized into 7 work packages:

WP1 Management - under the coordination of NTNU - covering financial project management, organization of half-annual workshops, technical project management, monitoring and reporting for EERA secretariat and JP review;

WP2 Campfire - under the coordination of AIT - with the aim of providing contributions to the SET-Plan, to the EIP Smart Cities Market Place, to European Smart Cities Research & Innovation Roadmap;

WP3 Market Place - under the coordination of CTU Prague - whose aim is to support and promote brokerage activities, identification of H2020 proposals, Cost Action, EERA labeled project proposals;

WP4 Academy - under the coordination of ENEA - with the aim to boost academic interest and participation and to strengthen cooperation among RTOs and University partners as well as external stakeholders through different actions - including organization of symposia at the Barcelona Smart Cities Expo; setting up of an editorial strategy resulting in the first issue of the EERA Joint Programme on Smart Cities (JPSC) special issue 1/2018; setting up of a summer school and a Horizon 2020 Marie Sklodowska-Curie application;

WP5 City Advisory Board - under the coordination of VTT - which aims at organizing time-slots at EERA meetings with City Advisory Board - CAB as well as hands-on workshops with CAB to support interaction between cities and research organisations;

WP6 Expert Pool - under the coordination of NTNU - now includes the original 4 sub-programmes + the simulation task force;

WP7 Communication and dissemination - under the coordination of AIT - with the following tasks: maintenance of Web Site and Social Media, production and communication material, exhibitions, presentations and speeches.

ISSN online: 2239-0243 | © 2018 Firenze University Press | http://www.fupress.com/techne
DOI: 10.13128/Techne-23566

EERA Joint Programme on Smart Cities journey: response and contribution to societal challenges

Lesson learnt: 2010-2012

As above mentioned, the Joint Programme on Smart Cities officially started its activity late in 2010, while the Description of Work was released in October 2011.

The Summary of the Joint Programme on Smart Cities (10.2011) considered that achieving the Europe 2020 targets of the European Commission forced new challenges upon society and called for clear strategies in R&D in the field of energy. Because of the potential risks of worldwide climate change in 2011, there was, and there still is, a strong need for urgent actions, arguably the most important being to reconceive the way we consume and produce the energy that we need. In this context, the integration of renewable energy sources into urban energy networks and the increase in energy efficiency in cities became core topics to be addressed. These issues were also strongly emphasized in the European Industrial Initiative "Smart Cities and Communities" which was launched by the European Commission in June 2011. Experts continuously highlighted the importance of smart energy management at city level for achieving the ambitious targets with respect to CO_2 reductions in the long-term as outlined in the 2050 Roadmap of the EC.

The 2011 EERA JPSC Description of Work clearly stated, for the first time, that the concept of Smart City involved innovative design and intelligent operation for the entire energy system at city level as two key topics. For this reason, the 2011 Description of Work identified four major research areas related to energy technology in the context of Smart Cities:

1. Integrated urban energy planning and transformation processes.
2. Intelligent planning, design and operation of urban energy networks (thermal and electric).
3. Energy-efficient buildings as interactive elements of the urban energy system.
4. Renewable supply technologies integrated into urban infrastructure.

Therefore, within the Joint Programme on Smart Cities, the highly complex structure of a future smart energy system has been investigated on an urban level by applying innovative solutions in an interdisciplinary manner based on a clear long-term research strategy. The fundamental research motivation is reflected in the strong need for a new approach for the design, operation and optimization of urban energy systems on the basis of renewable energy sources which can only be achieved through the development of radically new scientific methodologies (in this context, the interfaces between energy grids, buildings and supply technologies play a crucial role, which cannot be entirely captured by current scientific techniques).

In the 2010-2011 period, great attention to Smart Cities was paid by RD&I.

In 2011, one of the key vehicles of the EU to accelerate the large-scale deployment of low-carbon technologies was (and still is) the European Strategic Energy Technology Plan[3], followed, among other industrial initiatives, by the Smart Cities and Communities Initiative[4].

In parallel with the Industrial Initiatives, the European Energy Research Alliance (EERA) as part of the SET Plan brings together key European organizations in the field of applied research to align their individual R&D activities to the needs of the SET Plan priorities and to establish joint programming. To this purpose, several JPs were created, among which the Joint Programme on Smart Cities represents a major contribution to achieve the high ambitions all across Europe by applying an interdisciplinary and integrated approach based on a clear research strategy in the field of urban energy technologies.

Around the same period of time, the International Energy Agency (IEA) stated that radical innovations were needed and that an "energy revolution" had to be initiated together with dramatic changes in our attitude and investment priorities (World Energy Outlook, IEA, 2009).

In those years, in an effort to find a distinct definition for "Smart Cities", extensive discussions were held among experts covering many areas related to energy technology development, environmental issues, politics and socio-economic aspects. However, following the outline of the Smart Cities and Communities Initiative of the European SET-Plan, it was clear that Smart Cities are characterized by the extensive use of low-carbon technologies combined with a smart energy management based on innovative design and operation of the entire system at city level; there was also consensus that the implementation of CO_2-saving measures should be complemented by complex stakeholder processes and innovation concepts at city level involving all relevant partners in order to start the transformation of existing cities into "Smart Cities".

It was clear that a common vision needed to be developed at city level, leading to individual roadmaps and action plans for research and implementation accompanied by knowledge management and structured monitoring programmes.

Following these indications, a first step for research was the identification and understanding of "Smart Cities" as complex structures involving a continuous interaction between the major parameters and components related to the entire energy system of a city[5]. The highly complex structure and patterns of energy flows covering the entire chain from energy production, distribution and consumption in cities should be treated with an integrated system approach heavily supported by research and development.

Therefore, a strong need for smart planning, design and operation of energy systems was identified as a correct approach to achieve the highly ambitious target of (almost) zero carbon emissions for city areas in the very near future. Another key aspect appeared to be the smart management of the energy system by means of Information and Communication Technologies (ICTs) in order to support the stochastic energy supply deriving from renewable energy sources. As a consequence, the individual components of the entire energy system, such as energy distribution grids, buildings, supply technologies and even consumers, started to play a new and important role. The continuous interaction between those users and elements started to be considered in fundamentally new design and operation concepts based on city morphology, intelligent demand side management, energy storage and the potential shift between different energy sources (electric and thermal loads).

In the light of the above considerations, it was clear that the research areas related to the concept of "Smart Cities" covered a broad range: the merging of ICTs (information and communication technologies) and energy technologies was, and still is, of highly beneficial nature to solve the research questions arising in the context of future energy systems serving as a basis for new methods with respect to smart grids and Smart Cities. Therefore, it was emphasized that the main idea behind Smart Cities was the smart integration of a whole spectrum of various technologies into an urban environment by applying an integrated approach (EERA JP on Smart Cities RESEARCH AREAS in 2011 are listed below).

Lesson learnt: 2012-2014

In July 2012, the European Commission published a communication on the transformation of the European Industrial Initiative (EII) Smart Cities and Communities into a European Innovation Partnership on Smart Cities and Communities. This new policy instrument was intended to be located across the areas of energy, transport and information and communication with the objective to catalyze progress in areas where energy production, distribution and use, mobility and transport, and information and communication technologies (ICTs) are intimately linked and offer new interdisciplinary opportunities to improve services while reducing energy and resource consumption and greenhouse gas (GHG) and other polluting emissions. The focus was on industry-led innovation as a key driver to achieve economic and social change in urban areas and promoted actions across the innovation cycle and across different sectors.

In addition, lighthouse projects were designed to trigger strategic partnerships of innovation-driven companies from the three sectors acting across geographical borders, and to forge strong partnerships with local leaders and municipal authorities in order to gain the vital support and visibility that are necessary to engage and empower citizens and local stakeholders to reduce greenhouse gas emissions and energy consumption and - more widely - to improve the urban environment.

As a result of these newly-introduced programmes and actions, the previous thematic background (10.2011) slightly changed the overall research topic of EERA Joint Programme on Smart Cities, maintaining its original 4 sub-programmes with the addition (late 2014) of another relevant topic such as the "simulation task-force"[6] while underlining that others issues closely linked to environmental aspects in urban areas, such as transport, waste, water and pollution, were not the direct scope of EERA Joint Programme on Smart Cities itself and therefore were not considered as primary fields of interest within the research programme itself[7]. On this basis, a second edition of the Description of Work was

EERA JP on Smart Cities RESEARCH AREAS (2011)

Based on the framework presented at the launch conference of the Smart Cities and Communities Initiative in June 2011, the following 4 key research areas for EERA JP on SC were identified with respect to energy issues:

SP1 Energy in Cities: Design and planning of energy-efficient urban districts and smart energy systems; detailed understanding of the energy performance characteristics of urban areas; new simulation tools for the analysis of energy flows in cities; deep knowledge of the urban morphology such as building density, typology and end-use mix. Tools and methods for further use in future holistic energy master planning.

SP2 Smart Energy Networks: Smart energy grids responsible for the intelligent management and operation of energy networks in cities utilizing the potential shift between thermal and electrical loads; integration of decentralized renewable energy sources into existing energy grids (major technical issues); interaction between mathematical modeling techniques, numerical simulation environments and advanced communication infrastructure; potential storage capacity for both electrical and thermal energy within energy networks which can be achieved by intelligent demand side management.

SP3 Energy-efficient Interactive Building: Current research on large buildings focuses on the further development of building automation control systems that allow to increase energy efficiency by including new predictive control strategies; transition from single passive building technologies to fully integrated buildings acting as active hubs in the energy grid; overall energy performance of buildings with respect to new innovative building design concept; finally, the interaction between building and the smart grid is one key aspect for future research where ICT plays a major role.

SP4 Supply Technologies: smart integration of on-site renewable energy sources into buildings and networks; cascade use of resources or poly-generation; tools for the optimal use of hybrid supply systems; large-scale experimental testing and development of new procedures and standards.

Launch conference of the Smart Cities and Communities Initiative in June 2011: the 4 key research areas created in 03.2014. While the general setting of the previous edition was preserved, the new document featured an evolution of the definition of general research areas and activities related to the concept of Smart Cities and the identification of additional areas, along with a long-term strategy with clearly defined aims and objectives as key elements for a successful performance of any scientific program dealing with complex research areas such as energy technologies for Smart Cities.

The high-level research roadmap of the Joint Programme on Smart Cities is the result of a series of workshops held during the 2012/2013[8] period, indicating a well-thought-out underlying concept for R&D.

The consistent and continuous creation and formation of a European-wide research community in the field of Smart Cities should be regarded as a distinguished added value of the Joint Programme, as such a community has not been existing before in Europe. All the scientists involved in the foreseen research activities and coming from well-respected European research institutions agreed that the sophisticated transformation of European cities into Smart Cities in order to reach the Europe 2020 targets and the long-term goals of the European 2050 Roadmap could only be achieved by major contributions from R&D adopting a highly interdisciplinary approach focused on the system behaviour of future urban energy systems.

The complexity of future energy systems in cities can only be tackled within a multi-technology perspective based on an integrated approach that requires the further intensification of transnational research co-operations on a European level. Furthermore, there continue to be a clear trend that energy technologies and ICT will continuously merge in the near future, and new expertise will be required to unlock the full potential of this interaction.

Hence, the overall objectives of the entire Joint Programme on Smart Cities could be summarized as follows:

General level Strengthen and reinforce the strategic position of EERA Joint Programming as a key instrument for a successful implementation of the European SET Plan; provide major scientific contribution to reach the 20-20-20 targets as indicated within the SET Plan by focusing on research on the integration of low-carbon technologies dedicated to city-related energy issues; guarantee future leadership of European R&D in urban energy technologies through a clear long-term research strategy; promote a strong representation of the European research community in the field of Smart Cities towards other international research partners in markets such as US, China, India, etc. acting as a "one-stop-shop" by enabling a well-coordinated dialogue and cooperation framework; expand and optimise European-wide research co-operations by facilitating the use of common research infrastructure and intensifying the existing scientific exchange among all participating partners; establish strong links with relevant industries, public institutions or other stakeholders working in the field of Smart Cities; raise awareness among various stakeholders on the topic of energy and Smart Cities through specially dedicated dissemination measures.

City context Provide the scientific basis to unlock the full potential of energy efficiency in cities and urban areas as highlighted in the Smart Cities and Communities Industrial Initiative leading to significant reductions of CO_2 emissions; based on interdisciplinary research activities, enable and endorse a massive integration of renewable energy sources (centralised and decentralised) into urban energy systems and city infrastructures in the near future; support European cities in their transformation processes towards Smart Cities with new scientific methods and tools leading to innovative transnational implementation projects on a European level; create full understanding of the complexity of the entire energy system of cities at various scales of detail (from meta-level to component level) covering the entire chain from energy generation, distribution and consumption.

Research perspective Development of essentially new scientific methodologies for city-wide energy planning in the context of traditional spatial planning and/or other environmental issues for cities; development of scientific tools that enable relevant decision makers to estimate the economic and social impact of energy infrastructures, policies and regulations concentrating on renewable energy sources and energy efficiency; capture the complex interaction between cities and their energy management system, including all individual components at different urban scales (urban energy networks, buildings, supply technologies, consumers); design fundamentally new strategies that allow for an intelligent energy management system in the context of stochastic distribution of energy supply and demand applied to different elements of the entire energy system of a city; actively promote the new role of ICT in the field of Smart Cities as necessary for the continuous interaction of all incorporated system elements; incorporate the complex role and behaviour of individual energy end-users and their specific needs in the development of the next generation of energy technologies with a particular focus on urban applications; elaborate innovative solution patterns tailored to the needs of Smart Cities for addressing new arising research questions by adopting an interdisciplinary and multi-technology approach focused on system behavior; stimulate the next generation of researchers in the academic community to step into R&D in the field of energy (EERA JP on Smart Cities RESEARCH AREAS in 2012/13 are listed below).

Lesson learnt: 2015-2018

European countries are faced with the huge challenge of increasing energy efficiency and reducing greenhouse gas emissions in order to achieve their ambitious climate protection goals. The characteristics of urban morphology and the growing trend toward urbanisation give cities enormous leverage in this respect. Smart cities use innovative technology and an integrated approach to provide high energy efficiency, sustainability and quality of life. Therefore, they play a prominent role in the European Strategic Energy Technology (SET) Plan as fundamental building blocks of tomorrow's low-carbon energy system. Concerted research efforts and innovation are required to achieve this paradigm shift in urban energy management and pave the way into the Smart cities era.

The research issues involved in transforming cities into Smart cities are highly complex and can only be solved by taking an interdisciplinary, transnational approach.

The EERA Joint Programme on Smart Cities collaborative approach, thanks to the 2017 Work Programme, now represents the added value for Europe, boosting energy expertise and positioning Europe at the forefront of international Smart cities research.

The aims of each sub-programme and the main outputs of last year are summarized below:

SP1 Energy in Cities (Coordinator: AIT; sub-coordinator: VITO)

Aims A detailed understanding of energy performance characteristics and energy flows in urban areas is of crucial importance for the design and planning of smart energy systems. This sub-programme follows a unique integrated approach to merge urban and energy planning. The scientific tools to be developed will support cities throughout the transition process towards a low-carbon energy system - from system analysis, vision development and pathway exploration through to experimenting, assessment and implementation. The sub-programme will provide best practice examples of smart city visions for others to emulate. The design of integrated database structures and output interfaces will facilitate the planning of smart cities and subsequent monitoring of their performance based on Key Performance Indicators (KPIs). Decision support and simulation tools will be developed to model economic scenarios and energy flows and thus support experts and authorities in developing urban energy roadmaps. A strong focus will also be placed on setting up a template for the implementation of the living lab concept and interaction with other smart city aspects such as mobility, waste or water.

Output A very important result of WP1 was the H2020 project CITYkeys. This project was a response to the SCC-02-2014 Call on "Developing a framework for common, transparent data collection and performance measurement to allow comparability and replication between solutions and best-practice identification". The proposal was a direct outcome of the Joint Programme Activities and brought together three JP Smart Cities partners (VTT as project coordinator, TNO and AIT), the Cities of Wien, Tampere, Rotterdam, Zaragoza and Zagreb as well as the EUROCITIES network. The project started in February 2015 and closed in January 2017. In CITYkeys, a transparent performance measurement framework for smart city strategies and smart city

In accordance with these objectives, the four sub-programmes evolved as follows:

SP 1: Energy in Cities

The main objective of the sub-programme Energy in Cities is the development of scientific yet customer-oriented tools and methods that support the transition process towards a CO_2 neutral energy system of an entire urban area. The transition process consists of several elements: global system analysis, envisioning, exploring pathways, experimenting, assessing and translating. For each of these components, relevant support tools will be developed. In particular:

1. The development of examples of visions for smart cities that can be used as a basis for tailor-made solutions and roadmaps for each individual city.
2. The design of integrated database structures that allow cities to plan a smart city and then monitor the performance of the city during and after the transition process on the basis of well- defined Key Performance Indicators (KPI´s). Proposing output interfaces to these databases (e.g. GIS layers) to assist in the choice of the measures that will form the energy concept is of crucial importance in this context.
3. The development of new simulations tools (static and/or dynamic) that, once an energy concept has been chosen, will help produce a more detailed design of those measures and their implementation (sizing of technical components, business models), particularly in the case of pilot projects.
4. The set-up of a template for the implementation of the living lab concept into practice. This is essential since urban areas clearly have the following needs: to set priorities in the energy technology choices of a city not merely based on ad-hoc, separate, bottom-up pilot initiatives, but also based on a long-term transition process (e.g. also taking into account urban spatial planning); to combine the several scales and functions in a city (micro, macro, meso level) in order to obtain on optimal use of city data; to set-up real organizational and technological structures to establish the learning process of implementation projects in cities often referred to as living labs.

SP 2: Urban Energy Networks

Each city can be considered as an organism, with its complexity and its interlinked networks, also and maybe primarily at the energy level. Each city has its own energy metabolism, characterised by energy production, storage and consumption with their corresponding "interconnected networks": they can work properly by means of suitable interconnected sensor networks to collect data aimed at optimizing the operational logics of a smart and energy-conscious management at urban level (organic management of mobility, energy production sites, energy transport network, energy consumption sites, water, waste, etc.). Additionally, each city is in direct connection with its surroundings and beyond that are embedded into superposed energy systems at larger levels projects was developed. The development was carried out in a co-creative process involving researchers and city representatives. The performance measurement framework entails a KPI system and KPI definitions, guidelines for data collection, and a prototype for a performance measurement platform. It was validated in several partner cities. Furthermore, recommendations for the implementation of the system were developed and discussed with stakeholders. The indicators and the performance measurement frameworks were developed in close collaboration between the research organizations and the city representatives and validated in partner cities. In addition, the project provided recommendations for the deployment of the performance measurement framework, including business models and recommendations related to urban governance. (www.citykeys-project.eu) The project outcomes were very well received by the European Commission and are now taken up by standardization initiatives and by European demonstration projects such as RUGGEDISED. The project, one of the ongoing Smart City Lighthouse projects, is another valuable outcome of the activities in WP1. It was developed by the Lighthouse cities of Rotterdam, Glasgow and Umea, in close collaboration with TNO and AIT, and the fellow cities of Parma, Brno and Gdansk. Working in partnership with businesses and research centres, the six cities will demonstrate how to combine ICTs, e-mobility and energy solutions to design smart, resilient cities for all. The aim is to improve the quality of life of citizens by reducing the environmental impact of activities and creating a stimulating environment for sustainable economic development. RUGGEDISED was started in November 2016 and will run until October 2021 (http://www.ruggedised.eu/project/about/)

Evaluation frameworks for Smart Cities such as CITYkeys, and the monitoring of Smart City Lighthouse projects, such as RUGGEDISED, STARDUST and SMARTER TOGETHER were also addressed in the EERA JPSC Symposium on Key Performance Indicators, which was held on 19 November 2015 at the Smart City World Expo in Barcelona. In the following year (2016), another symposium on "The contribution of Smart City Solutions to the overall concept of the sustainable city" was held at the Smart City World Expo, this time in collaboration with the Urban Europe Research Alliance (UERA). On average, around 50 representatives from city administrations, industry and research attended these events.

SP2 Urban Energy networks (Coordinator: ENEA; sub-coordinator: AIT)

Aims Each city has its own energy metabolism, characterised by energy production, storage and consumption with their corresponding "interconnected networks". Smart cities, therefore, also require smart energy grids which are able to communicate with each other to balance thermal and electrical loads depending on supply and demand. The large-scale integration of distributed renewable energy sources into existing energy grids brings up additional challenges in the development of smart urban energy networks. This sub-programme has the objective to optimise these interconnected networks by intelligent planning, design and operation, integrating all accessible sources of renewable energy and providing flexible balancing potentials. This will be achieved by developing models for optimal management of low impact "Smart Energy Districts" and solutions for smart integration of electrical and thermal energy production, storage and

(e.g. continental). These interconnections provide a spectrum of renewable energy sources from other regions, but might also act as a sink for surplus energy from the city.
Within this scenario, the general objective of this sub-programme is to develop approaches, methods, technologies and pilot cases in order to optimize the energy metabolism of cities towards low-impact urban districts integrating all accessible sources of renewable energy and providing flexible balancing potentials, by means of an energy-conscious operation & management fed by data networks that are spread at urban level.
The research activities will mainly focus on three main tasks:

1. Smart Energy Districts – with the purpose of developing suitable models for optimal management of low-impact "Smart Energy Districts" (a settlement of various utilities such as private and public residential buildings, private and public office buildings, schools, hospitals, shopping centres, organized as a single user); solutions for a smart coupling of energy (both electrical and thermal) production, storage and consumption will be investigated and developed; mobility at district level will be also analysed in terms of energy consumption patterns.
2. Urban network integration – with the purpose of studying and developing opportunities related to the implementation of data acquisition systems at urban level (multi-information sensors networks), connected to data transmission, storage, processing and analysis; this structure will be synthesized through an integrated ICT multifunctional platform for network integration; this platform will feed an integrated management system to optimize the balance between energy offer and demand, also taking into account end-user expectations and behaviour.
3. Human factors: the citizen-city interaction – with the purpose of increasing knowledge of the human factors that influence energy uses and of developing "human oriented technologies" based on citizen needs and expectations to improve the quality of life oriented to low-energy impacts.

The milestones of the sub-programme may be synthesized as follow:
development of a methodological approach for the integration of energy networks at urban level; development of innovative solutions to optimize the link between energy offer, distribution, storage and demand (both electrical and thermal energy) in smart urban networks, taking into account the convertibility (e.g. heat pumps) and coupling (e.g. cogeneration) of different energy forms; development of multifunctional ICT platforms and integrated logics for electrical and thermal energy management in smart urban networks; ambient intelligence solutions to take into account citizen needs and expectations in low-impact cities; pilot experiments related to smart urban networks; based on the results of the experiments, understand and capitalize on human factors influencing energy uses so that a user model (all interactions affecting energy demand) can be envisaged at least on a statistical approach in order to attempt behavior prediction.

consumption at urban level. The integrated energy management systems of the future will rely on comprehensive sensor networks feeding energy-related data into a multifunctional ICT platform, which will enable a range of smart services based on real time data. The human factor will be taken into account by deepening the knowledge about citizen-city interaction and its influence on energy use to be able to design "human-oriented technologies".

Output The most important results of SP2 were an intensive dialogue among participants, improved capacity building in the direction of smart cities and smarter specialization in urban energy networks.
Basically, we have focused on the following:
- the need to build a common scientific language so that the integration of urban networks can be replicated not only within different domains of the same city but in different cities on the whole European territory. The advantage of achieving this goal is to avoid lock-in, the qualification of solutions, the reduction of costs and companies. To do this, it is necessary to define reference architectures and to share inter-operability logics. These logics are natural to develop in the research networks to then compare with companies and cities.
- sharing the solutions/criticalities encountered in smart cities projects, particularly in the SCC1 lighthouse projects, offering the opportunity to refine and reorganize given solutions in a clear and robust structure.
- the opportunity to work together in a setting where discussion and dialogue drive towards a re-definition of project proposals with more concrete, reliable and replicable solutions.

SP3 Energy-efficient Interactive Building (Coordinator: NTNU; sub-coordinator: ENEA)

Aims Buildings account for around 40 per cent of European primary energy demand. In tomorrow's smart cities, energy-efficient buildings will make use of energy conservation measures and on-site renewables to reduce their energy demand and will play a key role as interactive elements of the urban energy system. This sub-programme will develop and validate innovative, competitive holistic concepts, tools and demonstration cases for a new generation of buildings in the urban context. The main aim is to further increase their energy efficiency, enable coordinated exchange of energy with thermal and electrical grids while providing a comfortable healthy indoor environment to their users. Research in this sub-programme will mainly focus on distinctive fields such as design concepts for resource-efficient buildings, novel envelope materials and technologies that provide an optimal interface between the building and its environment as well as the integration of renewable energy systems into buildings. Emphasis will also be placed on innovative building and energy management, the energy interface between building and urban infrastructure ("building-to-grid"), smart interaction with the user as well as support strategies to achieve a multiplier effect within the broader stakeholder community.

Output In the past few years, SP3 partners have frequently discussed the role of buildings and building stock in smart cities – as places of energy consumption, generation, storage, exchange, distribution and so on. The new paradigm of community engagement mixed with decentralized energy generation and highly interconnected urban infrastructures was integrated in a wide

SP 3: Energy-efficient Interactive Buildings
The purpose of sub-programme 3 is to analyse the role and added value of energy-efficient interactive buildings for Smart Cities, and to develop a knowledge platform for Key Performance Indicators, methods, solutions and cases that contribute to their large-scale penetration. This activity cannot be managed at the national level alone. This strategic research and development activity needs to be supported by efficient coordination of EU research activities and funding, to combine the following actions: development of adequate policy and market instruments to foster demand for Energy-efficient Interactive Buildings; analysis of feedback from case studies to validate (or discard) existing models and tools; exchange of knowledge and experiences among sector stakeholders.
The research activities will primarily focus on five main tasks:
1. Optimising interactivity with real-time energy demands, climate, people, cultural heritage and urban networks to procure locally-adapted, high-quality energy-efficient buildings (WP1 Building Design).
2. Developing and validating materials and technologies that can provide the optimal interface between buildings and their surrounding site and climate (WP2 Envelope Solutions).
3. Developing and validating the energy interface between buildings and urban infrastructure, to ensure optimal energy efficiency in a larger societal perspective (WP3 Energy Management and Grids Interaction)
4. Understanding energy consumption patterns in buildings (WP4 User Interaction).
5. Close co-operation with industry, public government, media and users to help identify and improve critical success factors in business models, education and policy, which can create a multiplier effect within the broader stakeholder community and contribute to a green European economy (WP5 Support Strategies).

SP 4: Urban City-related Supply Technologies
One of the principal ideas behind smart cities is the efficient integration of on-site renewable energy sources into buildings and networks. Energy supply technologies such as heat pumps, solar thermal, photovoltaics, energy storage units, etc. play a key role in this context. The development of smart integrated energy networks will require both new components and systems, as well as a better understanding of how to integrate distributed supply technologies into urban infrastructure in an efficient and cost-effective manner.
The overall aim of SP4 is to create an integrated analytic framework that identifies tailored pathways to smart, sustainable cities from the perspective of energy supply technologies and as-

range of European projects. SP3 partners contributed to develop data, tools and verification methods of integration of robust design and smart technologies, allowing buildings to become interactive nodes of larger networks and enabling a coordinated exchange of energy with the grids while providing a comfortable healthy environment to their users.
The continued importance of energy-efficient interactive buildings in smart cities was confirmed by the SET-plan and its recent development of a roadmap for "Positive Energy Blocks/Districts" as key elements for smart sustainable cities - with strong participation of the EERA JP Smart Cities in the Temporary Working Group.

SP4 Urban City-related supply technologies (Coordinator: Campus Iberus)

Aims One of the principal ideas behind smart cities is the efficient integration of on-site renewable energy sources into buildings and networks. Energy supply technologies such as heat pumps, solar thermal, photovoltaics, energy storage units, etc. play a key role in this context. The development of smart integrated energy networks will require both new components and systems, as well as a better understanding of how to integrate distributed supply technologies into urban infrastructure in an efficient and cost-effective manner. This sub-programme aims to develop a methodology capable of dealing with complex integration of thermal and electrical energy technologies, and enabling the design and evaluation of renewable technologies integrated at district or city level. This will require the development of an appropriate modelling and simulation framework including numerical component models and libraries and an integrated, flexible and adaptive multi-level decision support framework. In addition, the city-industry interaction will be investigated to optimise available synergies such as the use of waste heat from industrial processes.

Output The main output of this sub-programme is the successful participation in the call H2020-SCC-2016-2017, SCC-1-2016-2017, Smart Cities and Communities Lighthouse projects. The project STARDUST was approved and started in October 2017. The objective of the project is to pave the way towards the transformation of carbon-supplied cities into Smart, highly efficient, intelligent and citizen-oriented cities, developing urban technical green solutions and innovative business models, integrating the domains of buildings, mobility and efficient energy through ICT, testing and validating these solutions, enabling their fast roll out in the market. Some of the main objectives of this project are:
- To develop common energy supply strategies based on the overall district energy demand (including buildings, mobility and urban services) to be followed by lighthouse cities and further replication in follower cities.
- To evaluate priorities for the smart buildings approach by taking into account the whole impact on energy savings, cost-effectiveness, integration with the built environment, and the requirements of building users.
- To assure integration and interoperability between software components, data sources, services and devices, to facilitate accessibility by third parties to STARDUST solutions, and to promote open innovation through the design and deployment of an open city information platform.

Two members of the Joint Program, VTT and UPNA (that belong

sociated sub-systems. SP4 framework is devoted to work out an improved short-term performance of our urban energy supply infrastructure via (a) an enhanced control of existing supply sub-systems and (b) an optimised operation of appropriate new sub-systems in the new building or renovation real-world contexts. More specifically, it is a means to achieve medium- and long-term forecasting of possible scenario pathways to sustainable cities based on clear taxonomies, KPIs and benchmarks. This does suggest modelling from sub-system to district scale, considering that detail level and careful selection of appropriate modelling approaches (empirical, stochastic, probabilistic, deterministic, etc.) is required, along with measured data integration.

The main objectives, within the context of the 'energy performance gap', are to evaluate the fitness-for purpose of current sub-system models, and where appropriate to develop improved approaches; given the needs of key end-users, to create an integrated adaptive 'whole system' approach that incorporates holistic factors (both technical and non-technical) related to supply sub-systems, and is interoperable with approaches taken in other SPs/JPs; to develop the 'state-of-the-art' in terms of system performance measurement, testing, QA/risk; to perform management, benchmarking and control activities within the context of existing and emerging EU standards; to test and validate the new framework by applying it to large-scale case studies in conjunction with other SPs/JPs.

SP4 is structured into 6 working packages, namely:
- WP 1: Framework for development of multi-purpose component-oriented models
- WP 2: Development of component-oriented model libraries
- WP3: System Integration
- WP 4: City-industry interaction
- WP 5: Technology Assessment
- WP 6: Scientific methods for quality assessment for urban related-energy supply technologies

to Campus Iberus), are partners in this project. UPNA plays an important role in the design and application of TIC technologies to improve city management and public engagement. After the project, Pamplona will join a new Stardust Open City Information Platform (SOCIP) that will provide data collection, data analysis, decision support tools and open data infrastructure services. Some of its citizens will have detailed information about energy recommendations for their home as personalized energy saving tips, next-day energy price profiles and customized strategies for demand using gamification techniques For the remaining citizens, a new City App will be available with integrated and georeferenced information of city infrastructures: parking lots, e-charging devices for electrical vehicles and public transportation (taxi and bus) in order to reduce energy consumption and improve city life.

An additional activity is the participation in the future Summer School organized by the University of Newcastle. Two workshops have been proposed by Campus Iberus:

- Thermal energy storage systems (TES) Workshop: This technology plays a central role in the strategies to reduce energy consumption due to heating, cooling and domestic hot water demands, increasing the efficiency of the energy systems in which they are integrated and the potential utilization of new RES. Although TES themselves do not save final energy, they are able to "move" heat and cold in space and time, correcting the mismatch between supply and demand by allowing:
  1. energy conservation by exploiting new RES;
  2. peak shavings both in electric grids and DH grids;
  3. power conservation by reducing the required power of energy conversion machines;
  4. reduced GHG emissions. Thermal Energy can be stored in the form of sensible heat, latent heat and chemical reaction.

Despite the most commonly used method remains based on sensible heat, latent heat storages, based on the employment of phase change materials (PCM), are an attractive solution as they provide higher storage density and smaller temperature difference between the absorbed and the released heat as compared to sensible heat storage.

- IoT Workshop: The advent of Smart Cities and Smart Regions demands highly interactive context-aware environments, capable of gathering large volumes of data as well as potential tele-control of multiple devices, within an IoT framework. In this context, wireless communication systems play a fundamental role in providing such interactive capabilities, due to inherent ubiquity as well as large degrees of adaption to user dynamics and demands. In this presentation, an overview of the communication systems employed in order to enable IoT systems and applications will be provided. Requirements, planning guidelines, challenges and real deployment designs will be presented, providing a comprehensive description.

Looking at the future

A review of EU27[9] cities with at least 100,000.00 residents shows that 240 (51%) have implemented or proposed Smart City initiatives[10]. It is clear that the phenomenon applies to large cities better than smaller ones. It's a matter of fact that there are Smart Cities in all EU27 countries, but these are not homogenously distributed[11]. This was also analysed by different cities and stakeholders and resulted in the Action group of "small giants" within the European Innovation Partnership on Smart Cities and Communities (EIP SCC).

Over two-thirds of sampled Smart Cities projects are still at the planning or piloting testing phases, and this is why the numbers of mature successful initiatives remain relatively low.

An analysis conducted on this topic[12] highlighted that successful projects are those with clear objectives, goals, targets and a baseline measurement system in place from the outset, followed by a strong governance, a sound business case and a strong local government. Successful projects also tend to be embedded in a comprehensive city vision where public-private partnerships are highly important, especially where the private partners bring in developer expertise, finance, technology capabilities and the involvement of citizens or others end-users. Some implementations have shown a clear gap between the involvement of a minority of pioneer users and the whole population. New methods and protocols to increase end-user collaboration could be a critical element for a successful implementation of large scale Smart Cities.

It is clear that all these aspects are needed to move towards Smart Cities but it is a fact that technological progress and innovations are at the core of Smart Cities and prompt new approaches to the management/development of cities/districts: a growing urbanization and the increased demand for efficiency in the provision of services is calling for more efficient urban management solutions. Thus, innovative technologies in urban investment have the potential to reshape the way resources are exploited to provide services.

That is probably why in the next future (2025), in EU and national RD&I programmes to come, the general orientation about Smart Cities will be on the one hand towards solutions that can be scaled (increased in size) and replicated (rolled out in a different environment as compared to the one where they have been applied in the first place), and on the other hand it will be based on smart technologies and solutions which have been designed, deployed and rolled out in Smart Cities projects to pave the way towards net-zero energy/emission districts ZEED thanks to the Positive Energy Block (PEBS)[13].

The question is: if this is the future scenario for coming EU27 cities, how does the EERA Joint Programme on Smart Cities need to evolve and transform? Undoubtedly, in the near future all EERA Joint programmes will play an advisory role for European

Commision implementing and developing SET-Plan; then JP on Smart Cities is expected to strength on JPs' members capacity building to obtain, improve and retain skills and knowledge on specific goals as well as to transfer excellent research to urban stakeholders (government, construction/design, real estate, urban services, e-commerce, analyst-IT project and Big Data, financial/funding, social/civil society).
According to this, the EERA JP on Smart Cities in the future will concentrate its efforts on a joint R&I agenda and on the development of a clear identity in the European research and innovation landscape on smart cities.

NOTES

[1] Cities of tomorrow. Challenges, vision, way forward, EU Regional Policy, October 2011; The Urabanisation of Europe and the World, Annex 1, Urban 2014; State of Euroean Cities report, EC 2010; 8th Progress report on Economic, Social and territorial Cohesion, EC 2013; World Urbanization Prospects: the 2011 revision, UN-Department of Economic and Social Affairs, N.Y. 2013.

[2] March 2011-Wien; June 2011-Wien; December 2011-Wien.

[3] Within this strategy document of the European Commission, a technology roadmap was highlighted as a basis for strategic planning and decision making, stimulating a collective approach in research, development and demonstration planning and implementation with a clear focus on large scale programmes, such as the European Industrial Initiatives (EII).

[4] This was launched in June 2011 and highlighted the importance of intelligent energy management systems in cities in order to achieve massive reductions of greenhouse gas emissions by 2020 as outlined in the "20-20-20 targets". One specific object was the sufficient market take-up of energy-efficient and low-carbon technologies and the effective spread of best practice examples of sustainable energy concepts at city level across Europe.

[5] One important aspect of "Smart Cities" appeared to be the switch from single technology applications to a multi- technology perspective combined with energy management in order to make existing energy systems of urban areas more intelligent. International experts from various fields continuously emphasize that in order to solve the complex problems of future energy systems, old co-operations and state-of-the-art solution patterns even in research will no longer be adequate strategies.

[6] A detailed and systemic approach is required to understand, simulate and optimise the emergent properties of complex urban energy systems. The key aim is to support stakeholders' decisions to maximise cities' energy autonomy and thus minimise their associated greenhouse gas emissions. This support can be provided by simulations that address and integrate all key elements of the urban energy system at appropriate spatiotemporal resolutions. As simulation-based decision support cuts across all topics of the Joint Programme, the Taskforce on Simulation Platform Development spans all four sub-programmes. Its key task is to evaluate the state-of-the-art in the modelling and simulation of urban energy systems, to identify gaps in simulation capabilities based on user requirements and to provide an overview of the data available and required for future simulation tools. The overall aim is to maximise synergies and complementarities between the individual sub-programmes in this field.

[7] However, the thematic link and exchange with these aspects, particularly with the topic of mobility and transport, have been obviously taken into account when dealing with energy-related research questions.

[8] December 2012-Rome; July 2012-Wien; December 2013-Wien; July 2013-Madrid.

[9] Directorate general for Internal Policies, Policy Department - Economic and Scientific Policy: a study, 2014.

[10] i.e.: Smart Cities and Community Lighthouse project: 10 Lighthouse Projects with 28 lighthouse cities and 24 follower cities; https://www.smartcities-infosystem.eu/scc-lighthouse-projects

[11] "Countries with largest numbers are in the UK, Spain and Italy, although the highest percentage can be seen in Italy, Austria, Denmark, Norway, Sweden, Estonia and Slovenia. Smart Cities are spread across all six characteristics but most frequently focus on Smart Environment and Smart Mobility; Data from Directorate general for Internal Policies, Policy Department - Economic and Scientific Policy: a study, 2014.

[12] Analyzing the potential for wide roll out of integrated Smart Cities and Communities solutions, A final report for DG Energy, 2016; Directorate General for Internal Policies, Policy Department - Economic and Scientific Policy: a study, 2014.

[13] Districts which consist of buildings (new, retro-fitted and historic - including offices, residential, commercials, schools, universities, hospitals, etc.) of various size which can be used as innovation-pushing "seeding-point" for these districts to showcase in highly concentrated form the integration of all aspects that are needed for net-zero-energy/emission district. Their concept is intrinsically up-scalable and they are well embedded in the spatial, economic, technical, environmental, cultural and social context. They are by design an integral part of the district/city energy and mobility system.

[14] C. Clemente, P. Civiero, Report RdS/PAR2016/033, Accordo di programma MISE-ENEA, Smart Cities and Communities, D6-Sviluppo di un modello integrato di Smart Distict Urbano - Diffusione dei risultati e Network JPSC workshop: January 2018-Genk; June 2017-Bologna; November 2016-Barcelona; July 2016-Prague; November 2015-Barcelona; June 2015-Trondheim; December 2014-Espoo; July 2014-Nottingham; July 2013-Madrid; December 2013-Wien; July 2012-Wien; December 2012-Rome; December 2011-Wien; June 2011-Wien; March 2011-Wien.