This publication was produced by the Energy Research Knowledge Centre (ERKC), funded by the European Commission, to support its Strategic Energy Technologies Information System (SETIS). It represents the consortium’s views on the subject matter. These views have not been adopted or approved by the European Commission and should not be taken as a statement of the views of the European Commission.

The manuscript was produced by Mary Ann Kong, Andreas Mitsios and Helen Ding under the supervision of Shailendra Mudgal from BIO by Deloitte. We would like to thank Sophie Nyborg for the review of the outline and Robin Vanner for the review of the draft.

While the information contained in this brochure is correct to the best of our knowledge, neither the consortium nor the European Commission can be held responsible for any inaccuracy, or accept responsibility for any use made thereof.

Additional information on energy research programmes and related projects, as well as on other technical and policy publications, is available on the Energy Research Knowledge Centre (ERKC) portal at: setis.ec.europa.eu/energy-research
Executive Summary

Key messages

• Current research focuses largely on raising awareness and enhancing communication activities (both through top-down and bottom-up influences).
• The application of sociological approaches to gain a deeper understanding of behavioural aspects in smart cities would increase the reliability of research findings for policy-making.

This report has been produced by the Energy Research Knowledge Centre (ERKC) funded by the European Commission, to support its Strategic Energy Technologies Information System (SETIS). The ERKC project aims to collect, organise and disseminate validated, referenced information on energy research programmes and projects and their results from across the EU and beyond.

The Thematic Research Summaries (TRS) are designed to analyse the results of energy research projects identified by the Energy Research Knowledge Centre. The rationale behind the TRS is to identify the most novel and innovative contributions to research questions that have been addressed by European and national research projects on a specific theme.

Smart city solutions and initiatives hold a great deal of potential for fulfilling the Europe 2020 Strategy’s targets for employment, research and development (R&D) and innovation, climate change and energy, education, poverty and social exclusion. This TRS aims to provide an overview of the research that bridges behavioural aspects and smart technology.

Information that derives from the development of smart technologies has both a bottom-up impact (e.g. when the behavioural change of individuals supports a more efficient use of city resources) as well as a top-down impact (e.g. when smart technology increases the capacity of municipalities to provide more sustainable services). The review of research results leads to a similar categorisation. Projects that follow a top-down approach focus on the levels at which decision-making takes place and the interactions that take place between the different actors in the decision-making (e.g. government, markets, households and society as a whole). Projects that follow a bottom-up approach investigate how technologies and individuals or small groups of people interact and behave in their efforts to become more efficient.
Research in the field addressed by the present TRS focuses largely on raising awareness and enhancing communication activities with a focus on highlighting the benefits of smart technology, both at the community level (e.g. through the development of roadmaps, strategic planning and training activities) and at the household or individual levels (e.g. by assessing the acceptance of citizens).

The overview of research findings suggests that what is missing is holistic monitoring to assess the collective impacts of behaviours from an aggregated perspective. Where behavioural aspects are concerned, the main focus of research in Smart Cities also relies on quantifiable data on human behaviour (using feedback data from smart meters). There is less interest in the underlying mechanism, through which behaviour emerges, evolves and could perhaps be changed more effectively in user-centred approaches. This highlights the need to link the research on Smart Cities more closely with sociological research. Such approaches would also allow the development of more reliable findings for policy-making, which are currently based on small samples and a shallow understanding of behavioural aspects.
BEHAVIOURAL ASPECTS OF SMART CITIES
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1 Introduction

This publication has been produced as part of the activities of the Energy Research Knowledge Centre (ERKC), funded by the European Commission to support its Strategic Energy Technologies Information System (SETIS).

The ERKC collects, organises and analyses validated, referenced information on energy research programmes and projects, including results and analyses from across the EU and beyond. Access to energy research knowledge is vastly improved through the ERKC, allowing it to be exploited in a timely manner and used all over the European Union (EU), thus also increasing the pace of further innovation. The ERKC therefore has a key role in gathering and analysing data to monitor progress towards the objectives of the European Strategic Energy Technology Plan (SET-Plan). It also brings important added value to the monitoring data by analysing trends in energy research at national and European levels, and deriving thematic analyses and policy recommendations from the aggregated project results.

The approach to assessing and disseminating energy research results used by the ERKC team includes the following three levels of analysis:

- **Project analysis**, providing information on research background, objectives, results, and technical and policy implications on a project-by-project basis;

- **Thematic analysis**, which pools research findings according to a classification scheme structured by priority and research focus. This analysis results in the production of a set of **Thematic Research Summaries (TRS)**;

- **Policy analysis**, which pools research findings on a specific topic, with emphasis on the policy implications of results and pathways to future research. This analysis results in the compilation of Policy Brochures (PB).

The Thematic Research Summaries are designed to provide an overview of innovative research results that are relevant to the themes, which have been identified as of particular interest to policy-makers and researchers. The classification structure adopted by the ERKC team comprises 45 themes divided into nine priority areas. Definitions of each theme can be found on the ERKC portal at:

setis.ec.europa.eu/energy-research
The purpose of the Thematic Research Summaries is to identify and trace the development of technologies in the context of energy policy and exploitation.

The TRS are intended for policy-makers as well as any interested reader from areas such as academia and research.

The present TRS aims to provide an overview of research results that are relevant to behavioural aspects in Smart Cities and Communities (SCC) (the research theme is included in the third priority area in the table above). Apart from behavioural aspects, the priority area includes eight other research themes, which are analysed in other Thematic Research Summaries developed under the ERKC.

Under the third priority area, the research theme on behavioural aspects is the only one that addresses socially related aspects. The eight other themes focus on research carried out to develop technical solutions to enhance energy efficiency in the various components of Smart Cities. Research related to social aspects is also addressed in the TRS on social acceptability and behavioural aspects, which focuses on projects identifying behavioural patterns (priority area 8) in a wide range of energy-related topics but outside the context of smart city infrastructures. Given the importance of social capital for enhancing the performance of Smart Cities, and the complexity of the social

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Table 1: ERKC priority areas and themes

<table>
<thead>
<tr>
<th>Priority area 1: Low-carbon heat and power supply</th>
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<tbody>
<tr>
<td>Bioenergy / Geothermal / Ocean energy / Photovoltaics / Concentrated solar power / Wind / Hydropower / Advanced fossil fuel power generation / Fossil fuel with CCS / Nuclear fission / Nuclear fusion / Cogeneration / Heating and cooling from renewable sources</td>
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<table>
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<tr>
<th>Priority area 2: Alternative fuels and energy sources for transport</th>
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<tr>
<td>Biofuels / Hydrogen and fuel cells / Other alternative transport fuels</td>
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<table>
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<tr>
<th>Priority area 3: Smart cities and communities</th>
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<tbody>
<tr>
<td>Smart electricity grids / Behavioural aspects - SCC / Small scale electricity storage / Energy savings in buildings / ITS in energy / Smart district heating and cooling grids - demand / Energy savings in appliances / Building energy system integration</td>
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<tr>
<th>Priority area 4: Smart grids</th>
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<tbody>
<tr>
<td>Transimission / Distribution / Storage / Smart district heating and cooling grids - supply</td>
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<tr>
<th>Priority area 5: Energy efficiency in industry</th>
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<tr>
<td>Process efficiency / Ancillary equipment</td>
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<th>Priority area 6: New knowledge and technologies</th>
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<td>Basic research / Materials</td>
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<table>
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<tr>
<th>Priority area 7: Energy innovation and market uptake</th>
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<tbody>
<tr>
<td>Techno-economic assessment / Life-cycle assessment Cost-benefit analysis / (Market-) decision support tools / Security-of-supply studies / Private investment assessment</td>
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<tr>
<th>Priority area 8: Socio-economic analysis</th>
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<tbody>
<tr>
<td>Public acceptability / User participation / Behavioural aspects</td>
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<table>
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<tr>
<th>Priority area 9: Policy studies</th>
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<tbody>
<tr>
<td>Market uptake support / Modeling and scenarios / Enviromental impacts / International cooperation</td>
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</table>
interactions in Smart Cities, the present TRS is developed to provide an overview of research results in an integrated and holistic manner.

The aim of the present TRS is to provide the reader with a structured, but not necessarily comprehensive review of research activities relating to this theme that are being carried out at the EU and national levels, within either EU- or nationally funded programmes. However as finalised research on behavioural aspects is limited, ongoing projects and pilots are also included in the analysis, as long as they provide relevant and sufficient documentation (e.g. interim results).

The report is organised as follows. Chapter 2 introduces the general characteristics of this theme and describes the current stage of development, current and future R&D challenges concerning the theme. Chapter 3 provides an overview of the relevant policy priorities at the EU level and some key developments at national level. Chapter 4 reports on the results from specific research projects and provides an overview of the gaps and topics for future research, which could be identified by the projects examined. The review of the results is structured by the sub-themes presented in Table 2. Chapter 5 introduces the most relevant international programmes related to the research topic. Chapter 6 provides a synthesis of the research findings presented in Chapter 4 and identifies key gaps and challenges for future R&D in this area. Chapter 7 gives an overview of public funding on related research areas. Finally, Chapter 8 draws together the key issues and recommendations from the TRS. The research projects identified for each of the sub-themes are summarised in the table in Annex 2 to this report.

Table 2 Behavioural aspects sub-themes in Smart Cities and Communities

<table>
<thead>
<tr>
<th>Sub-theme</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Top-down approaches</td>
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<tr>
<td>2</td>
<td>Bottom-up approaches</td>
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</table>

This TRS attempts to provide an overview of how behavioural aspects are tackled in the area of Smart Cities. The intention of this TRS is not to discuss sociological concepts and theories in depth. The same applies is true for the technical components of the research, which are described in a manner that is understandable to a wide audience, whilst providing at the same time a technical background sufficient for the analysis of the behavioural aspects.
2 Scope of the theme

2.1 Definition of the theme

According to EUROCITIES¹, the concept of a ‘smart city’ refers to ‘modern urban competitiveness that highlights the growing importance of social and environmental capital in profiling the attractiveness of a city’. This process entails the development and use of various technologies, such as information and communication technologies (ICT), which enable an increasingly efficient use and consumption of energy.

The overall performance of the urban energy system in terms of efficiency and sustainability depends to a large extent on the behaviour of individuals. In this context, research into behavioural change aims to identify the social, psychological and economic drivers underlying energy consumption patterns, and to define and evaluate measures – such as policy initiatives and incentive systems – that may influence those patterns in desired ways.

Communities have always been driven by such patterns. Smart technology is increasingly developed and applied, and cities are becoming ever more responsive to their populations. However, this process is not automatic. To become smart, a city must learn to direct its inhabitants towards a more healthy, productive and sustainable lifestyle. Thus, the analysis of human behaviour can be considered as a key component of any applied research in Smart Cities.

Where energy is concerned, behavioural change analysis covers a wide range of technologies: from the use of electric appliances to domestic heating. It tries to understand and explain the interaction between political, economic, social and structural contexts for the reorientation of consumption behaviours towards more sustainable patterns. The different options to achieve energy efficiency cannot be addressed through a simple division of measures into ‘behaviour change’ and ‘installation’ (AECOM, 2011). For example, a smart meter is not a behaviour; rather the installation and use of a smart meter is driven by behavioural change. Reducing the water temperature in washing machines is a behaviour but it might require the installation of a smart meter in order to understand the energy (and cost) savings that are achieved through this action. In this context, the present TRS aims to provide a integrated overview of the research that bridges behavioural aspects and smart technology.

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¹ http://www.eurocities.eu/eurocities/issues/smart-cities-issue
2.2 Definition of sub-themes in the R&D area of behavioural aspects in Smart Cities and Communities

Behavioural aspects play a vital role in the establishment of Smart Cities. In this context, a member of the secretariat at the Smart Aarhus initiative highlighted that the development of smart solutions should not be based solely on technological aspects as these will need to function in the real-life, social setting of the city: ‘If you only focus on technology and not on human behaviour, you will not become smart’ (Copenhagen Cleantech, 2013).

At a theoretical level, the research into the behavioural aspects of Smart Cities covers two types of research.

1. **Projects focusing on Smart Cities**, which focus on the development and uptake of new technologies (e.g. smart grids, smart meters, etc.). However, behavioural aspects (e.g. consumer’s interactions with their equipment, based on reaction patterns to price signals) are often considered only marginally and provide a very shallow understanding of the dynamics at play when households are interacting with new technologies and systems.

2. **Projects focusing on sociological research**, which investigate the dynamics concerning everyday life, consumption, domestication and interaction with new technology in a household. However, smart city aspects are hardly ever considered in the research. As highlighted in the TRS on social acceptability and human behaviour, the behavioural aspects is a cross-cutting topic in energy-related research. For example, there are research programmes dedicated to social research, such as the Socio-economic Sciences and Humanities Programme (SSH), but in this programme behavioural aspects that relate to Smart Cities or other energy-related topics are not treated separately.

The screening of potentially relevant projects indicated that finalised projects that focus on sociological research have low relevance for smart city aspects. For this reason, this category has been excluded from the scope of this TRS. As regards the research focusing on Smart Cities, Khansari et al. (2013) argues that the implementation of Smart Cities, and particularly the information that derives from their development, has the following effects:

- a **bottom-up** impact: the behaviour of individuals supports a more efficient use of city resources;
- a **top-down** impact: increases the capacity of the service providers (e.g. utilities and transit companies) and municipalities to provide more efficient and sustainable services.
The review of research results (see Chapter 4) leads to a similar categorisation of projects, which can be grouped under those which follow a top-down approach and those that provide findings through a bottom-up approach.

Projects that follow a **top-down approach** focus on the levels at which decision-making takes place, across a range of stakeholders, as well as the interactions that take place between the different actors of decision-making (e.g. government, markets, households and society as a whole). The development of Smart Cities requires the development and integration of new technologies. The rationale behind this theme is the fact that this integration is accompanied by the need for new types of governance (Copenhagen Cleantech, 2013). In contrast to the traditional modes of governance, the Smart Cities and Communities (SCC) concept calls for a more horizontal approach that entails more collaboration and networking between different actors and less of a ‘top-down approach’, compared to traditional governance.

Projects that follow a **bottom-up approach** investigate how technologies and individuals or small groups of people interact and behave in their efforts to become more efficient. This theme addresses behavioural processes, such as awareness of energy savings achieved through behavioural change at the individual or household levels. Modern cities are perceived as hubs of knowledge and creativity (Copenhagen Cleantech, 2013). Research under this sub-theme is built on the perception that the collective intelligence of large groups living in cities can exceed the knowledge of individual decision-makers. ‘This collective intelligence remains to a large extent unknown and the harnessing of it is what will eventually make a city smart. Much of the research on Smart Cities focuses on interventions occurring at the local level (i.e. households, offices, vehicles, etc.). The interventions examined often impact on the behavioural aspects of individuals or a small group of people.'
3 Policy context

3.1 EU policy framework

Smart city solutions and initiatives possess considerable potential to help fulfil the Europe 2020 Strategy’s targets for employment, R&D and innovation, climate change and energy, education, poverty and social exclusion. Cities and urban communities play a crucial role as they represent a significant proportion of the EU’s overall energy consumption and greenhouse gas emissions. Cities also have great potential for smarter solutions in respect of the use of energy, sustainable mobility and sustainable ICT infrastructures and services. In particular, innovation is of the utmost priority as an essential means of successfully tackling major societal, economic and environmental challenges.

3.1.1 The European Innovation Partnership on Smart Cities & Communities

The Europe 2020 strategy supported the creation of European Innovation Partnerships (EIPs), which are designed to mobilise actors across the innovation cycle and across sectors to speed up innovative solutions to societal challenges. With this context in mind, the European Innovation Partnership on Smart Cities & Communities (EIP SCC) was launched in July 2012 significantly to accelerate the industrial-scale roll-out of smart city solutions integrating technologies from energy, transport and ICT. At the EU level, this is the main piece of legislation governing Smart Cities and Communities. The Partnership pulls resources into a small number of demonstration projects, which will be implemented in partnership with cities. For 2013, EUR 365 million in EU funds have been earmarked for the demonstration of these types of urban technology solutions.

The EIP SCC incorporates inputs from relevant stakeholders in its governance structure. It is composed of two entities: the High Level Group and the Stakeholder Platform. The Platform is closely linked to the Strategic Energy Technology Plan (SET-Plan) Steering Group to ensure coherence between national and EU efforts.

The European SET-Plan establishes an energy technology policy for Europe. It is a strategic plan to accelerate the development and deployment of cost-effective low-carbon technologies. The plan comprises measures relating to planning, implementation, resources and international cooperation in the field of energy technology\(^2\). The

\(^2\) http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm
objectives of the SET-Plan are implemented through means such as the European Industrial Initiatives (EIIs), the European Energy Research Alliance (EERA), industry-led European Technology Platforms (ETPs) and a number of Joint Technology Initiatives; the latter are designed as public-private partnerships. The ‘Smart Cities and Communities’ topic is targeted by the instruments EII and EERA. Furthermore, national efforts towards smart cities are coordinated at the European level through initiatives such as the Smart Cities Member States Initiative and the Joint Programming Initiative (JPI) – Urban Europe. (More information on EII, EERA and JPI is provided in the Policy Brochure on Smart Cities).

3.1.2 Energy initiatives and consumption behaviours

Another key measure under the Europe 2020 Strategy is the Directive 2012/27/EU on energy efficiency (known as the Energy Efficiency Directive), which came into force on 4 December 2012. Full implementation of the Energy Efficiency Directive requirements within a cost-effective approach presupposes that consumers will change their energy consumption behaviours and that this will lead to persistent and long-term energy savings benefits. Some of the new measures that have been implemented under the Energy Efficiency Directive that are relevant to Smart Cities include:

- significant energy savings for consumers: this would include easy and free-of-charge access to data in real-time; historical energy consumption through more accurate individual metering will empower consumers better to manage their energy consumption;
- public sector to lead by example: starting from 1 January 2014 by renovating 3% of buildings owned and occupied by central government in terms of energy efficiency.

Other energy policies with specific reference to changing consumer behaviour and/or smart meter roll-out include:

- Directive 2005/89/EC on security of supply: encourages the adoption of real-time demand management;
- Directive 2006/32/EC on end-use energy services: encourages the introduction of smart meters;
- third liberalisation package (2009): requires transparency in energy billing information and encourages the introduction of smart meters.

Table 3 lists the EU policies that have been described in this chapter.

3 A Joint Programming Initiative (JPI) is an approach introduced by the European Commission in July 2008 to involve individual countries to work together on research.
Table 3 List of relevant EU policy documents

<table>
<thead>
<tr>
<th>Relevant policy documents</th>
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</thead>
<tbody>
<tr>
<td>• Communication from the Commission, Europe 2020: A strategy for smart, sustainable and inclusive growth (2010)</td>
</tr>
<tr>
<td>• Communication from the Commission: Smart Cities and Communities, European Innovation Partnership (2012)</td>
</tr>
<tr>
<td>• European Innovation Partnership on Smart Cities and Communities Strategic Implementation Plan (2013)</td>
</tr>
<tr>
<td>• Commission Directive 2012/27/EU on energy efficiency</td>
</tr>
<tr>
<td>• Commission Directive 2005/89/EC on security of supply: encourages the adoption of real-time demand management</td>
</tr>
<tr>
<td>• Commission Directive 2006/32/EC: Energy Services Directive: on end-use efficiency and energy services, encouraging the introduction of smart meters</td>
</tr>
<tr>
<td>• Third liberalisation package: requires transparency in energy billing information and encourages the introduction of smart meters (2009)</td>
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</table>

3.2 Member State activities

At the Member State level, the Smart Cities Member States Initiative was established in 2011 and aims at putting the focus on EU Member States in terms of better defining their roles, responsibilities and coordinating actions in relation to the SET-Plan’s EII ‘Smart Cities and Communities’ (see the TRS on Social acceptability and human behaviour) and the European Innovation Partnership on Smart Cities, which involves Smart Cities and Communities. The initiative is meant to serve as a vehicle for partnership with the European Commission.

A recent study carried out by the European Parliament found that, out of the cities with at least 100,000 residents in the EU-28, 240 (51%) have implemented or proposed smart city initiatives. Countries with the largest numbers of Smart Cities include Italy, Spain, and the United Kingdom, although the highest percentages are in Austria, Denmark, Estonia, Italy, Norway, Slovenia, and Sweden (European Parliament, 2014). The study further analyses each city’s alignment to the Europe 2020 targets, taking account of how they perform in the context of their country’s national priorities and political and socio-economic circumstances. Findings of the analysis led to the selection of the six most successful cities: Amsterdam (NL), Barcelona (ES), Copenhagen (DK), Helsinki (FI), Manchester (UK) and Vienna (AT). Many of these smart city solutions focus on transport, mobility and smart governance (European Parliament, 2014). The key factors of success for these particular Smart Cities included the active participation of people to create a sense of ownership and commitment.

* The third liberalisation package includes a number of Directives and Regulations, which can be found here: http://ec.europa.eu/energy/gas_electricity/legislation/legislation_en.htm
4 Research findings

4.1 Introduction

The review of the research findings is based mainly on the Seventh Framework Programme (FP7), Intelligent Energy Europe (IEE) and national projects, as well as smart city projects (e.g. pilots or demonstration projects). Only finalised projects with publicly available results were selected for the overview. As the number of finalised projects on this theme is rather limited, a few non-finalised projects have also been reviewed in cases where the relevant results were publicly available (e.g. through specific deliverables).

The initial screening identified a total of 77 potentially relevant projects. It must be noted that the screening of national projects was not conducted for all Member States, but covered only projects cited in key publications or suggested by members of the Flash Focus Group (FFG). A thorough review of these projects identified a pool of 26 projects, which fall under the scope of this TRS. The final pool of projects includes 10 FP7, five IEE, six national and five CONCERTO projects and one project under the ICT Policy Support Programme.

The list of projects sorted by sub-theme can be found in Annex 2.

4.2 Sub-theme 1: Top-down approaches

A total of 10 projects were identified within this sub-theme. These projects can be grouped into four categories: (1) strategic planning and management systems; (2) infrastructure; (3) communication, dissemination and awareness raising; and (4) pricing mechanisms. Each of these areas is discussed in the sections below, referring to the project names in bold typeface.

4.2.1 Strategic planning and management systems

A total of two projects were identified under this cluster. They are aimed at helping city, regional or national authorities to develop strategies or action plans towards transitioning into a smart city by establishing or improving existing management systems to help authorities better manage such aspects as energy distribution (e.g. smart grids). These projects include behavioural aspects that would involve raising awareness and the participation of households and consumers in order to be effective. Many of the projects in this cluster concern and target decision-makers, such as national government, ministries, city councils or municipalities, or suppliers, such as energy service providers. The
projects under this cluster could potentially support policy initiatives relevant to the objectives (e.g. EIPs and EIP SCC), as they provide the appropriate tools for the mobilisation of various actors.

IREEN (ICT for Energy Efficient Neighbourhoods) is a FP7 project that examined the ways in which ICT for energy efficiency and performance can be extended beyond individual homes and buildings to the wider context of neighbourhoods and communities. The main deliverable of the project was the development of an ‘innovation roadmap’, which assesses the research, technical development and innovation needed for ICT to support energy-efficient neighbourhoods. The roadmap focuses on the main ICT development needs for planning, and decision support for six different application areas: neighbourhood planning; transport system planning; buildings, infrastructures and public spaces; and energy distribution, production and storage. Guidance on energy management at the neighbourhood level and integration technologies are also part of the roadmap.

Several conclusions and recommendations on behavioural aspects are integrated into the innovation roadmap. In particular, the roadmap argues that ICT can help increase the transparency and visibility of energy consumption, hence making a significant contribution to improving efficiency of both energy systems and individual behaviour. In other words, energy-efficient behaviour can be encouraged by increasing awareness and knowledge of energy-efficiency practices and cost savings, and the active use of ICT solutions. In particular, the Roadmap mentions the concept of ‘prosumers’, which refers to the optimisation of energy production through the widespread installation by inhabitants of small-scale renewable energy sources. The sustainability of the neighbourhood improves by placing value on existing neighbourhood communities and by building a ‘sense of place’.

The roadmap also highlights the importance of monitoring holistic energy performance at a neighbourhood level from an aggregated perspective. This approach is currently lacking in energy management at the neighbourhood level – behaviour change is currently addressed by the use of ICT tools on an individual consumer basis, e.g. smart meters. Therefore, the move towards integrated developments linking user activities within a holistic context, including peer information and the collective impacts of behaviours, is essential.

The S3C (Smart consumer, smart customer, smart citizen) project is a research project that aims to develop a new and optimised set of tools and guidelines to be used for the successful engagement of either smart consumers, smart customers or smart citizens. The project has not been finalised yet but, due to its high relevance to the topic of this TRS, it has been included in the review. The results of the project to date include recommendations on the uptake of smart technologies for the different phases based on various literature sources. At the phase of end-use engagement (activation phase) the following aspects are identified as particularly important success factors:
• achieving clear added value and overcoming barriers (e.g. provision of attractive financial incentives, ensure data privacy);
• understanding end-users (i.e. understanding the particularities of different groups of end-users);
• educating end-users to allow new consumers to deal with new technology;
• creation of commitment and appeal (e.g. develop trust across the whole smart grid process, develop effective marketing to enhance the desire for new products).

The success factors during the continuation phase are the following:
• effective feedback, pricing and communications (e.g. ensure a continuous flow of information to ensure consumer engagement);
• variety of intervention models (i.e. adaptation of a variety of methods and techniques to the needs of different end-users);
• ease of use (e.g. user-friendly design and provision of adequate service and support);
• social comparison (e.g. setting individual energy-saving targets and comparing those to others);
• reflection and learning (e.g. setting up evaluation mechanisms and creating communication platforms to allow the collaboration of different actors).

Finally, S3C identifies several key challenges in the areas of understanding covered by the target groups, namely:
• definition of effective incentives and pricing mechanisms;
• development of effective end-user feedback mechanisms;
• establishment of communication to recruit and engage end-users in smart energy behaviour;
• improvement of communication between stakeholders;
• empowerment of end-users;
• development of new market structures to enhance smart energy behaviour;
• facilitation of the scaling-up of smart energy projects.

In similar fashion to IREEN’s roadmap, which focuses on six different application areas, S3C’s toolkit will be adapted and the guidelines and recommendations will be optimised for different audiences (distribution system operators or DSOs, policy-makers, research institutes, regulators, etc.). To develop the optimised toolkit, an analysis of collected data and experience on best practice end-user engagement strategies is carried out, including tools derived from already existing theoretical literature and hands-on experience in concluded or ongoing smart grid trials.
Starting in 2014, the functionality of the toolkit and the guidelines will be tested and validated in demonstration projects within already existing test beds of other ongoing smart grid projects.

4.2.2 Infrastructure

Infrastructure projects are an essential part of urban planning and smart city development. Improved and smart building design, as well as making certain tools and technology available to households, e.g. provision of smart grids or a smart metering system, is an important step towards providing the necessary infrastructures to enable households and consumers to change their behaviour. The concept of ‘Smart Cities’ is a relatively new one and for that reason many projects related to Smart Cities infrastructure are still ongoing. Nonetheless, some projects exist that have recently finished, from which the lessons learned and other measureable results can be highlighted.

Overall, the projects under this cluster could potentially support the objectives of relevant policy initiatives, in particular: the EU Directive 2012/27/EU on energy efficiency, which aims at developing and deploying new technologies that encourage consumers to change their energy consumption behaviour and ensure long-term energy saving benefits; and the Commission Directive 2006/32/EC on end-use efficiency and energy services, which encourages the introduction of smart meters.

Infrastructure projects often take a very techno-economic approach – i.e. technical studies that include some kind of accompanying research to look at the ‘consumer-side’, e.g. the ‘load-response’ to some sort of intervention, either by just measuring changed electricity consumption (load profiles) or carrying out quantitative surveys etc. This is seen in the projects under cRRescendo (Combined rational and renewable energy strategies in cities, for existing and new dwellings and optimal quality of life). Each community participating in cRRescendo projects implements an integrated strategy towards achieving an increase in the use of renewable energy sources (RES). The project has been implemented in four cities: Viladecans in Spain, Ajaccio in France, Almere in the Netherlands and Milton Keynes in United Kingdom.

The cRRescendo project in Milton Keynes is an example of a project that efficiently uses infrastructure technologies to adapt to the real energy-use behaviour of a building’s occupants. The project obtained quantitative and qualitative data on householders with changed attitudes towards energy efficiency and renewable energy services, covering quality of life and household expectations, and satisfaction with new/refurbished homes, as well as understanding householder behaviour. Key findings of the project highlight the important interaction between energy-efficiency measures built into buildings and occupant behaviour. For example, some ‘energy-efficient’ technological measures incorporated into the building design might be circumvented by occupants on the grounds of improving comfort. The project results therefore indicate that there is still work to be done
with regard to convincing some ‘built environment’ consumers; this could be done through education or promotion, in order to convince them of the merits – both collective and individual – of embracing ‘green’ principles. The project also highlighted the challenges of trying to measure the effects of technical interventions that are not readily apparent to occupants. Finally, another notable result of the project was the decision for Network Rail to connect to the combined heat and power (CHP) system, which is outside the perimeters of the original Project Development Agreement (PDA) area. This is a positive indicator of the ability of CHP to deliver cost-effective heat and power.

4.2.3 Communication, information provision and dissemination

The establishment of communication activities and raising awareness are key components of all smart city projects, even in cases where the main focus is on the technological aspects (see for example cRRescendo). In the projects under this cluster, the main focus area consists of communication and/or dissemination. The specifically aim is to provide the information necessary to encourage and influence behavioural change, as well as to develop relevant education or training programmes. Finally, such projects can also aim at raising awareness on the importance of changing certain behaviours. The rationale behind the provision of information is that it will influence consumer behaviour because of the assumption that when individuals make poor choices, it is due to misinformation or lack of information. Examples of information provision tools include education and training programmes, labels, websites, printed materials, marketing and advertising campaigns, and capacity building and training of sales personnel. Five projects were identified in this cluster.

In terms of policy relevance, the projects under this cluster could potentially support the objectives of relevant policy initiatives, such as the EIPs and EIP SCC, which encourage the establishment of stakeholder platforms and closely connect with the SET-plan to ensure coherence between national and EU efforts. Moreover, these projects also make an important contribution to the EU Directive 2012/27/EU on energy efficiency, which aims at developing and deploying new technologies that better control individual metering.

The European Intelligent Metering project aimed to demonstrate and promote the savings available by using intelligent metering and training occupants in public buildings, and to show that these savings can be achieved at little, or no, additional cost. Intelligent metering includes analysing half hourly energy and water consumption data to identify savings opportunities, for example by changing the behaviour of building owners, tenants and occupants to achieve energy and water savings. A major part of the project involved training building occupants on how to save energy and water through behavioural change (by changing their usage patterns) and how to relate to the data being provided to support behavioural change. Within the training programmes, a broad approach to changing behaviour was adopted.
Drivers were identified that can help citizens act more sustainably. The training considers mechanisms for enabling, engaging and incentivising building users.

About 70 public sector buildings in four European countries (Denmark, Germany, Austria and the United Kingdom) were involved in automatic, remote monitoring of energy and/or water consumption. The buildings included administrative offices, schools, sports facilities, community centres and nursing/care homes. This is a particularly interesting element, as the vast majority of the projects covered by the present review focus largely on households.

The results showed that both energy savings, resulting from the use of intelligent metering, and behavioural change, through training, were achieved.

- Of the 26 buildings in the United Kingdom that participated in the project, there were savings in electricity, gas or water of 20% in nearly half the number of buildings, and savings of 10-20% in three other buildings.
- Of the 13 Austrian buildings involved in the project, electricity savings were achieved in 12 buildings (from about 2% up to 80%), water savings in eight buildings (from 1% up to 82%), and heat savings (with a heat correction) in three buildings (from 3% to about 96%).
- Of the 11 Danish buildings that participated in the project, electricity savings were recorded in eight buildings (up to 27%), water savings in five buildings (from 5% up to 49%), and heat savings (with a heat correction) in five buildings (from about 10% to 78%).
- Of the 20 German buildings included in the project, savings were achieved in electricity, heat or water of 20% or more in two buildings, with savings of 10-20% in four other buildings.

Regarding costs and payback installation costs during the European Intelligent Metering project were between EUR 2 500 and EUR 5 000 per building, depending on the metering system, and there were short payback periods (e.g. up to one year) for the intelligent metering in some buildings. Furthermore, the use of intelligent metering information during training in the project helped to raise energy awareness of building users.

The RENAISSANCE (The Renewable ENergy Acting in SuStainable and Novel Community Enterprises) project in Lyon, France, aimed to reduce the consumption of conventional energy. The project involved the construction of 670 new apartments and 15 400m2 of office space in compliance with the RENAISSANCE objectives. Innovative methods concerning both technical (bioclimatic approach, power generation, integrated monitoring systems) and social issues (tendering procedures, relationships with private developers, promotion and training activities, social monitoring, etc.) were developed.
The project included socio-economic activities that mainly focused on the behaviour of the inhabitants. For example, residents were involved in the project once the flats were put up for sale. Experts, promoters and developers also worked together to organise information sessions to promote and explain the buildings’ particularities and what the residents’ contributions towards energy savings would be. Furthermore, the project included comprehensive monitoring to assess the actual energy performance of the buildings and to improve energy efficiency knowledge. For example, a very detailed monitoring campaign on energy demand and wood-fuel delivery and consumption was planned with the installation of hundreds of sensors. Finally, training on the operation and maintenance of energy-efficient buildings, ventilation and renewable energy systems were organised for O&M companies.

Key findings from the project indicate that it is essential to involve all the stakeholders in the neighbourhood in order to carry out the work on energy consumption awareness and disseminating energy-efficiency and saving measures. This action is important in order to change the role of the inhabitants (from a passive one to a proactive one), who are then able to provide information and to change their habits. It was also found that making citizens aware of the importance and impact of their daily behaviour on energy consumption is indispensable; this needs to be communicated in a meaningful and comprehensible way. Finally, efficient feedback to the inhabitants is the key to promoting best practice in energy saving.

The Intelligent Energy Europe-funded **BewareE** (Energy services: Reducing the energy consumption of residents by behavioural changes) aimed at stimulating behavioural change in residents in cooperation with relevant actors (e.g. housing organisations, energy suppliers, energy associations etc.). The central outcome of the project was a manual to support actors in implementing energy services. The manual suggests that the implementation of such services (including cases where such services include the installation of smart meters) requires a process that includes the testing of actions within a sample group of users, the development of communication in a timely manner and the training of staff involved in the implementation.

While the previous three projects focused on the demand side, the **TetraEner** project in Geneva, Switzerland, addressed energy supply by aiming to make the best use of the resources that are closest to hand – the water of Lake Geneva, which is an ideal source of energy for heating and cooling buildings in Switzerland’s second largest city. The TetraEner project refurbished seven buildings and constructed five more so as to take advantage of this renewable energy source. The low-temperature thermal exchange network uses water from Lake Geneva as a heat source/sink, which remains at a nearly constant temperature of 8 ºC at the bottom of the lake. The use of this specific network is combined with an intelligent design that enables the district to develop a highly efficient production and conversion system for heating and cooling (especially direct cooling). The TetraEner project
in Geneva was able to achieve an approximately 25% reduction in conventional energy consumption and obtain approximately 20% of energy from RES.

As in the case of the European Intelligent Metering project, the success of the TetraEner project can be attributed, to some extent, not only to the technologies applied but also to the provision of information and behavioural factors. For example, the project generated know-how concerning the use of hydrothermal networks through various training activities, including training on district heating in urban areas and lectures for students. Furthermore, the communication campaigns and training activities themselves played a decisive role in considering [or selecting?] Lake Geneva as a natural resource for the city’s sustainable development. The project was able to communicate information well enough so that future customers were convinced to ‘enter’ the project and change their user behaviour based on the project outputs.

The aim of the ECO-City project is to demonstrate innovative integrated energy concepts in both the supply and demand side in four different EU-countries: Denmark, Norway, Spain and Sweden. Some examples of the special eco-technologies applied include:

- optimisation of window type;
- passive solar;
- avoidance of thermal bridges;
- increased insulation in roof, floor and façade;
- demand-controlled ventilation;
- ventilation with heat recovery;
- intelligent control system;
- individual measurement system;
- improved air tightness of building envelope.

The ECO-City demonstration sites in Helsingborg and Helsingør use an integrated transnational community approach to energy efficiency and sustainable energy supply. The ECO-City project set a reference for new standards in the community concerning retrofitting, new buildings, energy supply and the use of polygeneration. In particular, the project maintained close cooperation and participation with the whole community through the training of small and medium-sized enterprises (SMEs), the janitors’ corporation, and extensive dissemination. Similar to the TetraEner project, the ECO-City project in Helsingør and Helsingborg included training activities, socio-economic monitoring and dissemination. Information on the new energy metering and system was provided to schools and citizens. Training for janitors and housekeepers on building maintenance in relation to energy savings was also carried out.
4.2.4 Pricing mechanisms

Projects in this cluster integrate economic aspects, e.g. taxes and consumption charges, to influence consumer behaviour through pricing. Economic tools are market-based instruments, mainly employed by governments to influence and monitor the economy by adjusting taxes and/or public spending (expenditure). Economic tools often influence the price of goods and services and directly distort consumer preferences. In general, economic tools, such as taxes and charges, will only influence consumers, if the financial stimulus is strong enough to enter the decision-making process (i.e. taxes need to be set at a sufficiently high level to influence consumer-purchasing decisions). Most of the projects in this cluster are aimed at determining how pricing can be set so that it is both acceptable and influential for consumers, and profitable for businesses and suppliers. Three projects have been identified.

These projects could potentially support the EU third liberalisation package, which requires transparency in energy billing information and encourages the introduction of smart meters.

The ADEPT (Advanced dynamic energy pricing and tariffs) project was implemented in the United Kingdom and assessed how the information that was potentially available from smart meters may be exploited to the advantage of both the distribution network operator and the customer in terms of dynamic tariffs. In other words, at what price should energy services be set so that it is accepted by the public and offers clear enhancements and incentives for a reduction in energy demand? Electricity tariffs (and load control schemes) are established by experts but used by non-experts. Therefore, the aim is to understand what different tariff types mean in terms of everyday practices. The project covered 200 sample households in the United Kingdom and tested different focus groups, for example: all-electric customers; prepayment; credit customers, who had switched supplier in the previous year; customers with experience of three-band, time-of-day tariffs etc. It also considered various tariff choices, for example: ‘static’ tariffs, to moderate demand at specified times when high demand usually occurs; ‘critical day’ tariffs to reduce demand at times of prolonged shortage of supply; real-time tariffs etc.

Key findings of the project indicate that: a) a new tariff needs to be simple and visible -- easily displayed; b) utilities – or whoever sets the tariffs – need to gain and maintain trust; c) static tariffs were more popular than real-time tariffs, mostly because they were predictable and fitted with existing routines; d) there was some willingness to reduce usage at critical times in response to price or other signals, and interest in enabling technologies; e) non-financial, social and educational factors affect adoption of new tariffs and new technologies – not just prices; and f) customers need time to understand the reasons for new tariffs and get used to them.
The difficulties that were highlighted in the project, which could be addressed in follow-up projects, included expanding the sample size. Researchers felt that testing 200 homes was too small for a dataset but the challenges of using a mixed nationality dataset raised difficulties with different time zones and other national differences.

**E-PRICE** (Price-based control of electrical power systems) is similar to the ADEPT project in that it aimed to develop a reliable, efficient and a socially acceptable control concept for the EU energy market in terms of setting a feasible price-based control strategy. However, contrary to ADEPT, E-PRICE is theoretical and based on modelling, analysis and synthesis of the interplays between the interconnected physical power system and time-varying power requirements as the prominent signals; and on economic factors with time-varying price signals as the prominent information carriers. Behavioural factors are integrated into the modelling work by taking into account the local objectives of producers/consumers (prosumers). The project used case studies to test their theoretical findings and modelling.

### 4.3 Sub-theme 2: Bottom-up approach

The screening process identified 16 projects that correspond to this sub-theme. These projects are grouped under the following categories: (1) conditions for user engagement; (2) barriers for user engagement; (3) impact of smart technologies on behavioural change; (4) direct participation and living labs, and (5) willingness to change versus actual behavioural change.

#### 4.3.1 Conditions for user engagement

The projects in this cluster aim to obtain understanding of the conditions that are required to build trust towards smart technologies and to allow consumers to use them in an efficient manner. Such conditions can be technical (i.e. the efficiency of the devices) but are always accompanied by behavioural conditions that need to be known and enhanced, so as to maximise the uptake of smart technologies, and to enhance the energy savings during the use phase. These projects support the objectives established in the Commission Directive 2006/32/EC on end-use efficiency and energy services to encourage the promotion of smart technologies, such as smart meters and energy saving technologies, which directly target end-users.

The FP7 project **ADDRESS** (Active Distribution networks with full integration of Demand and distributed energy RESourceS) aimed to develop a comprehensive technical and commercial architecture of grids to enable active demand (AD) and, particularly, to enable and exploit the flexibility of small commercial and domestic consumers. The project developed a methodology for the assessment of the quantitative socio-economic benefits of the architecture developed, which was applied in four countries. Surveys were carried out to assess the conditions for consumer engagement and acceptance. The findings
showed that individuals are willing to make changes and adapt, as long as the interfaces and systems are easy to use.

The FP7 project BeAware (Boosting energy awareness with adaptive real-time environments) developed and evaluated modular energy-saving feedback programmes through trials in two countries (the methodology of the trials is described in detail in the TRS on public acceptability and behavioural aspects). The aim of the project was to assess the effectiveness of the programmes’ components. Findings show a higher appreciation for tailored versus non-tailored parts of the programme, with a particularly low appreciation for general energy-saving advice.

The FP7-funded BEYWATCH (Building energy watcher) aimed to design, develop and evaluate a flexible and user-focused system that would be able to provide interactive energy monitoring, intelligent control and power demand balancing at different levels (home, block and neighbourhood). The project highlighted that, where energy consumption is concerned, different users have different priorities, preferences and needs. An intelligent metering/remote control platform developed under BEYWATCH was able to capture and model the user behaviours and enable energy savings by taking into account different user preferences. The system was perceived as highly valuable by most users, who also expressed their interest in being able to manage the devices remotely. The cost savings achieved acted as the main driver for purchasing the system.

EDRP (Energy demand research project) was a suite of large-scale trials across the United Kingdom. The aim was to understand how consumers react to improved information about their energy consumption over the long term. Four energy suppliers conducted trials of the impacts of various interventions (individually or in combination) between 2007 and 2010. Overall, the trials were successful and this might be partly explained by the process of receiving the smart meter (e.g. the positive effect of acquiring a new technology), but also by the different options available once a smart meter was installed, e.g. more sophisticated real-time displays (RTDs), and more frequent and accurate historical feedback and billing. The project also highlighted that electricity savings can be promoted through the provision of advice and historical feedback but a combination of these with direct feedback is likely to have greater benefits. Overall, smart metering was considered as a technology platform that is necessary for developing measures for behavioural change.

The FP7 project SmartHouse/SmartGrid (Smart houses interacting with smart grids to achieve next-generation energy efficiency and sustainability) developed intelligent, networked ICT technology to allow communication, interaction and negotiation with both customers and energy devices in the local energy grid in smart houses. The aim of the project was to achieve a maximum level of energy efficiency as a whole. The project concludes that, at the end-user level, there is a requirement for the technology to be easy to use, and that installation
is either carried out by a technician or through ‘plug & play’. The project also concludes that manufacturers of appliances should produce ‘smart ready technologies’ to facilitate end-users. In addition, the uptake of the smart technologies would be increased through large marketing campaigns that would, in turn, increase consumer enthusiasm. SmartHouse/SmartGrid also points out that the research into the consumer behaviour aspects of smart grids is currently limited. This applies to the conditions of use for specific devices, as well as to acceptance and motivation for participating in smart grids.

Commissioned under the IEE programme, the project ESMA (European smart metering alliance) aimed to identify and disseminate best practice in smart metering across EU Member States and to maximise energy savings. The project concluded that a voluntary behavioural change is a crucial aspect for enhancing energy savings through smart metering. This behavioural change derives from accepting and understanding the information provided by smart metering, particularly as regards the energy and cost savings achieved. Specifically, users should be given access to metered data, whereas the smart metering functionality should include a local (non-proprietary) interface that supports real-time feedback to displays, and local information and automation networks. Smart meter data must be secure against unauthorised access and should not be used for purposes that are not accepted by users.

DEHEMS (Digital environment home energy management system) showed that people are motivated to change their behaviour (particularly their energy consumption patterns) when they are provided with the appropriate information, especially when this information is given to them with a user-friendly technology that also provides understandable information on their own behaviour. The project also suggested that, once users have an insight into their own consumption, they will reduce it and maintain it at low rates.

Smart-A (Smart domestic appliances in sustainable energy systems) examined the conditions under which consumers would be willing to use smart appliances to spread out the demand placed on electricity grids at peak hours. The project analysed consumer acceptance in EU countries based on case studies into the use of smart appliances. Overall, it concluded that consumer acceptance is a key success factor for the widespread use of smart appliances. In addition, Smart-A concluded that the more people engage in energy-saving behaviour, the higher their acceptance of smart appliances. Such behaviours are expressed only when comfort is not lost through the application of smart appliances and when users keep full control of the devices. The potential financial benefits act as the main reason for users to buy smart appliances, whereas the environmental benefits are perceived as positive side effects. Only a small number of consumers would buy these appliances solely for an ecological benefit. Overall, the conditions that have to be met in order to convince consumers to buy smart appliances are the following:
• it is a mature technology;
• control over the appliances is maintained;
• prices, or subsidies, and costs should be at acceptable levels;
• levels of comfort should be maintained or further enhanced;
• good quality information should be provided in a user-friendly manner;
• appliances are attractively designed.

The FP7 project REEB (European strategic research Roadmap to ICT enabled Energy Efficiency in Buildings and constructions) aimed at facilitating the development of energy-efficient smart building construction through the establishment of a dialogue between actors from different domains (including energy, environment and construction). The project identified establishing ICT as a social technology as a major research challenge in order to promote smart user behaviour. One characteristic of such ICT would be behavioural change through real-time pricing, and the provision and visualisation of energy consumption data that could be easily understood.

While the above projects examine behavioural aspects from a technological perspective (e.g. functionality of smart metering devices, type of information provided, level of interaction between user and supplier etc.), the S3C project also addresses behavioural change from a social science perspective. Apart from developing tools and guidelines for decision-makers and researchers (see also section 4.2.1), the project aimed to promote active user-participation that would foster the smart energy behaviour of households and SMEs in Europe. It focused on end-users by validating the development, use and evaluation of interaction schemes. When analysing end-user behaviour, the project distinguished between two schools of thought: the first, based on psychology-orientated approaches that focuses on individuals; and, secondly, the sociology-orientated approaches that take the social structure as the starting point. The project concludes that end-user energy behaviour is influenced by a wide range of behavioural and situational factors. Behavioural factors can be rational (e.g. monetary gains), non-monetary (e.g. beliefs and routines), social (e.g. norms) and personal (e.g. knowledge and financial means). Situational factors affecting energy behaviour include, amongst others, institutional factors (e.g. policy and regulations), cultural aspects, the existing infrastructure and social networks. This implies that a nuanced view of end-user behaviour is required, taking both behavioural and situational factors into account. S3C identifies different success factors for the uptake of smart technologies. The success factors are presented in section 4.2.1 as they mainly relate to top-down approaches.
4.3.2 Barriers to user engagement

Research into barriers to user engagement addresses the identification, understanding and removal of existing bottlenecks that prevent the uptake of these technologies. Overall, projects within this cluster could potentially support the objectives of relevant policy initiatives, such as the EU Directive 2012/27/EU on energy efficiency and the Commission Directive 2006/32/EC on end-use efficiency and energy services, which encourages the introduction of smart meters, as well as the Europe 2020 Strategy, which explicitly addresses the needs of pursuing smart budgetary measures and encouraging the adoption of smart technologies by consumers.

As part of the CONCERTO initiative, SESAC (Sustainable energy systems in advanced cities) seeks to accelerate innovation in renewable energy solutions. Under the project, competitions were organised in the city of Växjö (SE) by installing a smart metering box in the dwellings of participating end-users and by setting up an Internet platform through which the municipal utility informed the participants about their electricity and district heating consumption. The project resulted in significant benefits in terms of energy savings but it also identified specific social barriers. In particular, the project concluded that the required behavioural change needed more intense activities (e.g. awareness campaigns) than was initially expected and that users have a low incentive to reduce their electricity consumption due to the cheap cost of electricity.

The project ‘end-users as starting point for designing dynamic pricing approaches to change household energy consumption behaviours’ (see also the TRS on public acceptability and behavioural aspects), which was commissioned by Netbeheer, investigated dynamic price interventions (in combination with smart meters) and identified those that are the most appropriate to achieve a change in energy use among Dutch users at the household level. The study resulted in a segmentation of six consumer types, each requiring a different, tailored and dynamic pricing intervention. The findings stress that one size does not fit all for reducing or shifting energy consumption because consumers are motivated by many other things besides financial incentives. Specifically, users are influenced by contextual and social, as well as individual, factors. This finding is in accordance with the conclusions of ADEPT (see section 4.2.4), which stressed the significance of non-financial aspects on the uptake of new tariffs. For this reason, the causes of responses and non-responses to dynamic pricing are still not well understood.

The acceptance of the technologies applied in ADDRESS also relied on the time that was required for their use. The ability of households to adopt a technology, such as the one developed by ADDRESS, in the future depends significantly on how much time individuals spend at home and, most importantly, on how much of this time is required for household duties. The latter represents the core of shiftable loads that
ADDRESS seeks to control. Thus, these time demands and limitations also present a major barrier to the adoption of such a technology.

**Smart-A** also identified barriers that prevent the uptake of smart appliances by consumers. These can be summarised as follows:

- there are doubts about the safety and the maturity of smart appliances;
- consumers are afraid that control over the appliances will be lost;
- there are concerns about additional (hidden) costs and scepticism about the motivation of the main actors;
- there are doubts that ecological effects will be realised.

### 4.3.3 Impact of smart technologies on user behaviour

Smart technologies and behavioural aspects are strongly interrelated. The uptake of smart technologies requires a behavioural change, whereas the use of smart technologies can lead to further behavioural changes. Three projects were identified that focus on the type and intensity of behavioural changes that result from the use of smart technologies.

**Intelliekon** (see also the TRS on public acceptability and behavioural aspects) investigated whether energy can be saved via direct feedback on electricity consumption and examined the influence of the feedback on the energy-related behaviour of the participating households. A large field trial collected valuable data on energy savings resulting from feedback and smart meters. Only ‘objective’ measures of behaviour were used, such as the number of logins to the web portal, which showed that interest in the portal soon subsided but that energy savings persisted nevertheless.

**CBT (The Irish electricity smart metering customer behaviour trials)** were conducted in 2010 for a period of 12 months with a total of 4 300 residential participants. The overall objective of the CBT was to assess the potential for smart metering technology when combined with time-of-use tariffs and different demand side management (DSM) stimuli (Commission for Energy Regulation, 2011). The project also aimed to achieve a measurable reduction in peak demand and overall electricity use through consumer behaviour. In addition, the project identified a point at which the price of electricity would significantly change usage (‘tipping point’). Users were provided with a fridge sticker and magnet showing the times of the day when the price of electricity was cheapest and most expensive. An electricity monitor and informative billing were also used. Feedback was provided in the form of kWh savings, cost savings, historical consumption and peer comparison. An assessment prior to the trial revealed a lack of knowledge among consumers in estimating the share of their electricity use during peak hours, or linking a tariff and the impact on their bills. Consequently, users expected a greater impact from the trials. The trials resulted in a reduction of 2.5% in overall electricity usage and 8.8% in peak electricity usage. In terms
of user behaviour, the trial showed dispersed results. Specifically, 74% of users made minor changes and 38% made major changes to the way they used their electricity. Overall, awareness increased significantly, as about 78% became more aware of the amount and cost of electricity used by appliances. About 84% of users found the electricity monitor to be effective and stated that it helped them to reduce the amount of electricity they used and to shift usage.

The results of ADDRESS indicated the different effects of smart technology, as the field trials in Spain showed that the perceived level of knowledge of households as regards their energy consumption changed only slightly. This was not the case in the trial in France, where a significant change in the perceived knowledge was achieved, arguably due to extensive communication activities (i.e. town hall meetings, presentations and a demonstration). This indicates that the application of smart technologies needs to be accompanied by enhanced communication activities to enable a significant behavioural change.

4.3.4 Direct participation and living labs

Increased levels of energy efficiency can be achieved by developing a participatory process for users of smart technologies. The importance of direct participation was also recognised in RENAISSANCE (see section 4.2.3). Under this sub-theme, the results of three projects discuss the benefits of such direct involvement and two of them (DEHEMS and SAVE ENERGY) apply the living labs approach to enhance the participation of users in the development of smart technologies. Another project (CASUAL) is an ongoing project that has just started (2013) and also addresses the living lab concept.

The FP7 project DEHEMS (see also 4.3.1) aimed at developing and testing a home energy management system for households in five European cities. The project used living labs to move beyond the energy 'input' models that are currently used in smart meters, which monitor the levels of energy being used; instead, the project extended the technology into an 'energy performance model' by also considering how the energy is being used. In this context, one of the main objectives of DEHEMS was to monitor and assess the behavioural change in the context of energy consumption at the individual level. The living labs approach created a sense of ownership for many users and increased their interest in the project. ESMA also suggested that different options and some control must be given to users concerning the implementation and operation of smart metering services.

Through five pilots in European cities (Helsinki, Manchester, Lisbon, Lulea and Leiden), SAVE ENERGY used electronic sensors to measure energy usage via plug adapters placed between the wall sockets and

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5 Living lab is a research concept that integrates research and innovation processes based on a systematic co-creation approach.
the plugged-in devices. These adaptors used the mains electricity as both a power source and a means of communication, measured the energy used by the devices and communicated this to a local ‘gateway’ system with a web interface. The project used the living lab methodology to involve large communities and to motivate individuals to participate in the development of ideas, decisions and recommendations. The project developed a user behaviour toolbox (UBT) to allow a selection of appropriate tools (e.g. metered billing, social networks, real-time information) that can effectively change behaviour. The development of UBT was based on best practice and a wide range of lessons developed in the context of the project.

**The co-creating attractive and sustainable urban areas and lifestyles (CASUAL) project** will explore how to promote sustainable living and consumption patterns by engaging people as citizens and consumers in the governance of urban areas. To do this, the project will focus on the intersections between the built environment and the technical elements where individual preferences influence sustainability (e.g. choice of transport modes and related mobility patterns, housing preferences and lifestyles) through the concept of urban living labs. Three background case studies examining three closely related topics will be carried out:

- transit-orientated development and travel behaviour (NL);
- mobility patterns and lifestyles (AT);
- housing re-development and preferences (SE).

The neighbourhoods of In der Wiesen Ost in Vienna and Årstafältet in Stockholm have been selected to be the urban living labs. Both neighbourhoods are located just outside the edge of an inner city and are characterised by a somewhat chaotic urban structure. The project hopes to provide practical inputs and solutions for integrating citizens into the governance and planning of urban areas with respect to the above pilot cases in Vienna and Stockholm. Findings concerning the applicability and transferability of the urban living lab concept are also expected in terms of determining the extent to which the concept can improve the co-creation of knowledge to come up with more inclusive solutions for sustainable cities and integrate various lifestyles and consumption patterns into urban planning.

**4.3.5 Willingness to change versus actual behaviour change**

Research on Smart Cities often uses customer surveys to assess consumer willingness to accept a wide range of smart interventions, such as time-of-use tariffs, load control and interruption of appliance use. This cluster includes four projects, which address the relationship between the willingness of users to change their behaviour (before the interventions) and their actual behaviour (after the interventions).
Ofgem’s Consumer First Panel carried out a wide range of research on consumers in the United Kingdom to obtain an in-depth understanding of their behaviour and eventually to consider their views in the policy-making process. Also in the United Kingdom, the 2010 EPRG (Electricity Policy Research Group) Public Opinion Survey on Policy Preferences conducted a survey on attitudes towards energy and the environment. Respondents to the EPRG 2010 survey indicated a high willingness to accept hypothetical scenarios of energy-efficient measures (i.e. run wet appliances for a longer period of time, interrupt white appliances, pre-set wet appliances to operate after 21.00, and limit the use of a cooker or oven) for different levels of discounts. In Ofgem’s Consumer First Panel, the respondents provided their preferences concerning different levels of tariffs. According to Sustainability First (2012) these two surveys showed a significant difference between the willingness of users and their actual behaviour when faced with a real choice.

Smart-A also estimated a high willingness to accept the installation of smart appliances (see also above), but a gap was identified between willingness and actual behaviour as users were asked to estimate their future behaviour and attitudes related to appliances that are unknown to them. For this reason, their willingness towards sustainable behaviours might have been exaggerated.

The IEA project SAVE@WORK4HOMES (Supporting European housing tenants in optimising resource consumption) aimed to achieve a significant reduction in energy consumption in social housing through the provision of feedback on consumption and personalised advice. As a prerequisite, the project concluded that, for residents to achieve a behavioural change, they needed a good level of awareness of their habitual behaviour patterns. Even when tenants are highly aware of environmental and energy issues, their willingness to change towards more sustainable practices decreases, if the feedback provided is not appropriate and easily understandable.
5 International developments

Globalisation, together with trade liberalisation measures and fast technological change, is altering the relationship between production, distribution and consumption, and has very substantial effects on city development. Globally, there is a growing body of evidence in academic literature, which demonstrates that there is potential for energy savings from measures targeting behaviour change (EEA, 2013).

For instance, the International Energy Agency conducted a study on ‘Smart grid – Smart customer policy needs’ among its member countries in 2011 (Heffner, 2011). Based on pilot projects around the world, the research suggests that smart metering in terms of differentiated pricing can reduce peak demand by an average of 15%, which has attracted a great number of smart consumers to switch to smart meters.

One study argues that, with additional technology in the customer’s home or business, these effects could increase (Faruqui, 2011). In addition, electricity providers estimate that demand response and energy efficiency benefits made possible by smart customers will constitute one-third to one-half of total smart grid benefits (Southern California Edison, 2007; Baltimore Gas and Electric, 2008).

Achieving these benefits, however, requires large investments in new metering, communications and customer interface technology, together with policies and service offerings that create smart customers. For instance, in the United States of America, USD 600 million were awarded to 32 demonstration projects under the Smart Grid Demonstration Program (SGDP).

Most electricity customers are unaware of their electricity use, how much they use, when they use it and how it is priced. Compared with other industries (telecommunications, travel, retail, for instance), electricity consumers lack the service options and pricing information necessary to make informed decisions. Given the focus on technological solutions such as in-home displays and smart metering, the low-tech approach to feedback operated by the US energy company OPower is worth mentioning. In the USA, this approach has probably had a greater energy saving impact than in-home displays, reaching millions of customers with simple paper reports and achieving low but durable savings from a high proportion of them (Darby, 2010).
6 Technology mapping

6.1 Summary of the research findings

Research in the field addressed by the present TRS focuses largely on raising awareness and enhancing communication activities. The TRS also highlights the benefits of smart technology, both at the community level (e.g. through the development of roadmaps, strategic planning and training activities) and at the household or individual levels (e.g. by assessing the acceptance of citizens). Regardless of whether the research uses a top-down or a bottom-up approach, the perception of the role of communication in changing behaviour is particularly high. For example, IREEN considers the increased awareness and knowledge in energy-efficiency practices in the wider context of neighbourhoods and communities as an important step to achieving behavioural change, whereas SESAC highlights the importance of developing intense awareness-raising activities (at the household level) to overcome potential barriers (e.g. the low potential cost savings). The importance of communication for the societal aspects of behavioural change was also highlighted by the Advisory group on ICT infrastructure for energy-efficient buildings and neighbourhoods for carbon-neutral cities.6

Several projects concluded that effective behavioural change can be achieved when the information provided to consumers can be understood easily. The type, complexity and amount of information provided, and the way in which it is presented, all have a significant impact on the likelihood of people reading and understanding. Interestingly, BeAware concluded that there is a low appreciation of general energy saving advice compared to tailored information. Therefore, it is important to strike a balance between providing enough information to inform discerning consumers, while also meeting regulatory requirements (on information that has to be provided) and ensuring that less concerned consumers are not overwhelmed by information. The international developments on research indicated that a low-tech approach (i.e. paper reports instead of in-home displays) can have a greater impact in terms of reducing energy consumption.

Many projects (e.g. European Intelligent Metering project, EDPR, BeAware, RENAISSANCE) monitor or assess the energy performance of consumers through the application of smart technologies and behavioural change. However (with the exception of BEYWATCH, which aims to develop monitoring systems at the neighbourhood

6 Report of the meeting of the Advisory group ICT infrastructure for energy-efficient buildings and neighbourhoods for carbon-neutral cities, Brussels, 16 September 2011.
level), this type of assessment is carried out on a small-scale (i.e. households or individual buildings) and IREEN concluded that a holistic monitoring approach, from an aggregated perspective, to assess the collective impacts of behaviours is currently missing. This highlights the difficulty of upscaling research results when they are based on small samples. This factor is also highlighted by the project ADEPT, which assessed different types and levels of tariffs and concluded that 200 homes was too small a dataset and that follow-up projects should expand the sample size.

As expected, the cost-savings deriving from smart technologies appear to a key factor for behavioural change (BEYWATCH, Smart-A) but not the only one. This can be observed not only within the EU but also internationally. There are several non-monetary factors that need to be assessed holistically, which, amongst others, include social and educational factors (ADEPT, SESAC), beliefs and routines (S3C) and maintenance of comfort (Smart-A).

6.2 R&D challenges for future research

The Policy Brochure on acceptance and behavioural aspects concludes that, in existing projects on Smart Cities, and especially pilots and demonstration projects, the evaluation of research is often based on measurable outcomes (e.g. energy savings, reduced CO2 emissions etc.). Where behavioural aspects are concerned, the main focus of research in Smart Cities also relies on quantifiable data on human behaviour (using feedback data from smart meters). The Policy Brochure also concludes that there is less interest in the underlying mechanism through which behaviour emerges, evolves and could perhaps be changed more effectively in user-centred approaches. This observation is in line with the findings of the present TRS where only one project (SC3) addressed such underlying aspects, and only marginally.

The Policy Brochure on ‘Overcoming energy research challenges for Smart Cities’ highlights the negative impacts of rebound effects on the effectiveness of measures to increase energy efficiency. Projects reviewed in the present TRS (Ogem’s Consumer First Panel, 2010 EPRG Survey, Smart-A, SAVE@WORK4HOMES) indicated a difference between what is theoretically possible (i.e. through the assessments of the willingness of consumers) and actual behavioural changes. In addition, under the rebound effect, energy savings are invested in higher comfort (Sorrel et al., 2009), which might reduce or eliminate the energy savings. Indeed Smart-A concluded that one of the conditions for the uptake of smart technologies by consumers is that the levels of comfort should be maintained or further enhanced. Overall, smart technology is considered as a means to address these problems, but little evidence exists to suggest that a reduction in energy consumption will be achieved automatically without behavioural changes (Darby, 2010).
According to EEA (2013), there is a direct connection between behavioural changes in households and reductions in energy consumption and cost. Nevertheless, in the non domestic sector, such direct links to the personal wealth of individual employees do not exist. This points to a significant gap in research as, in the EU, non-residential buildings are responsible for approximately 14% of the final energy consumption (MURE ODYSSEE, 2012).

It should be noted that the research challenges mentioned above are, at least to some extent, already being addressed by ongoing research. For example, the ongoing UserTEC (User practices, technologies and residential energy consumption), which is supported by the Danish Council for Strategic Research, and the project DEMAND (Dynamics of energy, mobility and demand) examine the social context of behavioural patterns and change (including issues related to rebound effects) more thoroughly. In addition, the recently launched Horizon 2020 will support research that will address social aspects in a wider manner. For example, the theme ‘Energy efficiency – market uptake’ supports research into the development of social innovation and smart technologies. In addition, the theme ‘secure, clean and efficient energy’ supports activities aimed at a better understanding of consumers’ perception, motivation and understanding in relation to the uptake of energy-efficient technologies and practices.
7 Capacities mapping

In the EU, a variety of policy initiatives and funding schemes are in place, revolving around the urban theme. Funding is available from the Framework Programme, as well as through transnational joint calls from Member States. Figure 1 shows the distribution of the funding sources for the different themes addressing urban development. For instance, the Joint Programme Initiative (JPI) Urban Europe has financed mainly research activities associated with the development of new methods, concepts and technologies, whereas the Smart Cities Member States Initiative provides funds for the development process up to the proof and pilot testing of new concepts and technologies. Furthermore, the SET-Plan provides funds to projects that bring pilot tests to the phase of large-scale demonstration and market implementation. Finally, the EIB (European Investment Bank) Structural Funds’ instruments finance projects looking at market deployment of new technologies and concepts.

Figure 1 European RDI Funding in the Urban Field

The behavioural aspects of Smart Cities are addressed in only a small number of the projects that deal with cross-cutting issues related to Smart Cities. Moreover, the information that is publicly available does not explicitly reveal the detailed budget allocation to research or actions concerning behavioural factors. For these reasons, it is very difficult to have reliable and comprehensive estimates of the amount of R&D expenditure allocated to the clusters of projects that are covered by this TRS and deal with specific themes dedicated to different aspects of behavioural research.

8 Conclusions and recommendations

**Key messages**

- Currently, the research that addresses behavioural aspects in smart cities is limited.
- The development of easily understood and tailor-made information for users of smart technologies is particularly important. Research in this area should be intensified.
- The application of sociological approaches to gain a deeper understanding of behavioural aspects in smart cities would increase the reliability of research findings for policy-making.

Currently, there is a limited amount of finalised research that addresses behavioural aspects in Smart Cities. This can be attributed to the fact that the concept of 'Smart Cities' and their relationship with behaviour is a relatively new one.

The drivers for the research projects reviewed are mostly technological as they focus on the development and improvement of smart technologies. Nevertheless, it appears that research is placing increasing focus on behavioural aspects as it has been recognised that the human factor and smart technologies cannot be enhanced effectively when they are examined separately.

Much of the research focuses on raising awareness and improving communication to highlight the benefits of smart technologies, as well as the conditions that need to be created (or the barriers that need to be reviewed and removed). The information on smart technologies needs to be easily understood by the users and, at the same time, tailor-made to their needs.

The research results in this field are based on a variety of methodologies (i.e. surveys, trials etc.), but these seem to use rather small samples upon which to draw their conclusions. This imposes difficulties in upscaling the research findings and informing policy-making in a more robust manner.

There are several aspects, other than cost-savings, that drive consumers to install smart technologies and change their behaviour towards less energy-consuming practices, many of which relate to a wide range of sociological aspects (e.g. social and educational factors). The research in this area relies largely on measurable information in a rather shallow manner (e.g. measurements of smart meters) but research on why and how people behave as they do is lacking. In
addition, none of the reviewed projects have addressed the rebound effects and this indicates a gap, which might jeopardise the research findings even further.

This highlights the need to link the research on Smart Cities more closely with sociological research. This would entail the application of sociological approaches (e.g. practice theories, social theories of consumption, material culture, domestication theories, cultural theories, histories of socio-technical change etc.). So far this type of research has been limited to research papers. However, more recently, new research projects have commenced (e.g. UserTEC and DEMAND) and future projects will be supported through the Horizon 2020 programme. It is expected that this new research will enable the application of the sociological approaches in real-life conditions, thus allowing a deeper understanding of the drivers of behavioural change. The practical application of sociological approaches could also assist, for instance, in explaining the gap between the willingness and action of consumers (see section 4.3.5). It would also enable a deeper understanding of the psychological and sociological life-style aspects, which undermine the technological advances of smart technologies (e.g. through the rebound effect).

Such approaches would also allow the development of more reliable findings for policy-making, which are currently mainly based on quantifiable data and small sample sizes.

Furthermore, there is a need better to understand the behavioural aspects of individuals in non-residential buildings, where the motivation for employees to engage in energy efficiency through smart technologies is lower compared to households, where there are direct benefits from behavioural change. This area is not currently being addressed by research.
References


## Annexes

### Annex 1: Acronyms and abbreviations

#### General
- **ERKC**: Energy Research Knowledge Centre
- **EU**: European Union
- **FP7**: Seventh Framework Programme for Research and Development
- **JP**: Joint programme
- **PB**: Policy Brochure
- **R&D**: Research and development
- **RD&D**: Research, development and demonstration
- **SETIS**: Strategic Energy Technologies Information System
- **SET-Plan**: Strategic Energy Technology Plan
- **TRS**: Thematic Research Summary

#### Technical and related to the theme
- **AD**: Active demand
- **CHP**: Combined heat and power
- **DSM**: Demand side management
- **DSO**: Distribution system operator
- **EEA**: European Environment Agency
- **EERA**: European Energy Research Alliance
- **EIB**: European Investment Bank
- **EIIs**: European Industrial Initiatives
- **EIPs**: European Innovation Partnerships
- **EIP SCC**: European Innovation Partnership on Smart Cities & Communities
- **EPRG**: Electricity Policy Research Group
- **FFG**: Flash Focus Group
- **ETPs**: European Technology Platforms
- **ICT**: Information and Communications Technology
- **IEE**: Intelligent Energy Europe
- **JPI**: Joint Programming Initiative
- **kWh**: Kilowatt hour
- **O&M**: Operations and Management
- **PDA**: Project Development Agreement
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>RES</td>
<td>Renewable energy source</td>
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<tr>
<td>RTDs</td>
<td>Real-time displays</td>
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<td>SCC</td>
<td>Smart Cities and Communities</td>
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<td>SGDP</td>
<td>Smart Grid Demonstration Program</td>
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<tr>
<td>SME</td>
<td>Small and medium-sized enterprise</td>
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<td>SSH</td>
<td>Socio-economic Sciences and Humanities Programme</td>
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<td>UBT</td>
<td>User behaviour toolbox</td>
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## Annex 2: Complete list of projects relevant to the theme

### Sub-theme 1: Top-down approaches

<table>
<thead>
<tr>
<th>Project acronym</th>
<th>Project title</th>
<th>Programme</th>
<th>Budget (EUR)</th>
<th>Project website</th>
<th>Dates</th>
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<td>S3C</td>
<td>Smart consumer, smart customer, smart citizen</td>
<td>FP7 – Energy</td>
<td>2 636 896</td>
<td><a href="http://www.s3c-project.eu/">http://www.s3c-project.eu/</a></td>
<td>11/2012 – 10/2015</td>
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<td>cRRescendo</td>
<td>Combined rational and renewable energy strategies in cities, for existing and new dwellings and optimal quality of life</td>
<td>CONCERTO</td>
<td>43 645 487</td>
<td><a href="http://www.crrescendo.net/">http://www.crrescendo.net/</a></td>
<td>08/2005 – 06/2012</td>
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<td>INTELLIGENT METERING</td>
<td>Energy savings from intelligent metering and behavioural change</td>
<td>IEE</td>
<td>858 814</td>
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<td>01/01/2005 – 31/12/2006</td>
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<td>BewareE</td>
<td>Energy services: Reducing the energy consumption of residents by behavioural changes</td>
<td>IEE</td>
<td>683 427</td>
<td><a href="https://projekte.izt.de/bewaree/">https://projekte.izt.de/bewaree/</a></td>
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<td>ADEPT</td>
<td>Advanced dynamic energy pricing and tariffs</td>
<td>EPSRC</td>
<td>GBP 695 472</td>
<td><a href="http://gtr.rcuk.ac.uk/project/DA8003DS-4D10-4224-8600-EB4A879254B8">http://gtr.rcuk.ac.uk/project/DA8003DS-4D10-4224-8600-EB4A879254B8</a></td>
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<td>ADDRESS</td>
<td>Active Distribution networks with full integration of Demand and distributed energy RESourceS</td>
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<td>16 541 647</td>
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<td>Energy demand research project</td>
<td>Smart Metering Implementation Programme</td>
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<td>Smart-A</td>
<td>Smart domestic appliances in sustainable energy systems</td>
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<td>1 351 202</td>
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<td>Supporting European housing tenants in optimising resource consumption</td>
<td>IEE</td>
<td>2 459 150</td>
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<td>2 711 816</td>
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<td>IEE</td>
<td>1 207 735</td>
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<td>25 605 888</td>
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## Behavioural Aspects of Smart Cities

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