This project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649397

SMART BUILDINGS GENERAL ROADMAP

D3.2 Report — Timelines for the topics in Smart Buildings

28 August 2017

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ROADMAPS FOR ENERGY®

SMART BUILDINGS GENERAL ROADMAP

D3.2 Report — Timelines for the topics in Smart Buildings

Work Package title: WP3, Roadmap Smart Buildings

Task: 3.3, Roadmap interviews, and 3.4, Creating timelines per topic

WP coordinator: UPC

Submission due date: August 2017

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Abstract

This report (D3.2) ccontains the results of the roadmap interviews held with more than 20 European experts (representing industry, knowledge institutes and governmental organisations) in the field of sustainable energy for buildings. The aspects covered are technology, behaviour and organisation. The information collected from the desk study (D3.1)) and the roadmap interviews was used in an expert meeting to identify the most relevant topics and to create a timeline for each topic, showing when relevant options become available on the path to meet the needs of the cities (as described in report D2.2). The timelines of Smart Buildings (D3.2), Smart Mobility (D4.2) and Smart Urban Spaces (D5.2) were then aligned in a cross-theme expert meeting to gain understanding of the interlinking areas and potential options across several focus areas. This report presents the resulting General Roadmap Smart Buildings, together with accompanying information from the desk study and the interviews. The creation of the general roadmap is part of the WP3 Roadmap Smart Buildings for the R4E project.

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Versions of this report:

15 November 2016	Concept for roadmap workshops in partner cities (limited distribution)
23 March 2017	Concept for internal use by R4E partners (limited distribution)
28 August 2017	Final version for public distribution

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FOR
ENERGY®

WP7. Project management

Project coordination
quality management, project coordination, financial & administrative activities

SC Sant Cugat | SC Palermo | SC Istanbul | SC Tallinn | SC Newcastle | SC Forli | SC Murcia

Joint project kick-off & SC
2-day workshop in Eindhoven with all partners to sart project (WP7) and to prepare for ambition workshops and future telling interviews (WP1)

WP1. Ambition setting

Ambitionworkshops
3-day workshop in each city to define specific ambitions per focus area

EINDHOVEN | ISTANBUL METROPOLITAN MUNICIPALITY (public transport, traffic mgt) | Newcastle City Council (domestic, non-domestic) | Ajuntament de SantCugat | Tallinn | Murcia

Ambition sharing & selecting drivers for change
1-day meeting in Palermo to share the results of the ambition workshops and future telling and to select the drivers for change for WP2

Future Telling
20 interviews with experts on the future of energy in the city in general and especially w.r.t. buildings, mobility and urban spaces, and analysis of the results to define the most important drivers for change

WP2. Vision development

Scenario workshops
3-day workshop in each city to develop specific desired future scenario's per focus area

EINDHOVEN | Murcia | Newcastle City Council (domestic, non-domestic) | Ajuntament de SantCugat | Tallinn | ISTANBUL METROPOLITAN MUNICIPALITY (public transport, traffic mgt)

Scenario sharing & selecting topics for roadmaps
2-day meeting in Istanbul to share the desired future scenario's of all cities with all partners and to select the topics for the roadmaps (covering sustainable technologies, behaviour and organisation)

Scenario preparation
defining generic elements for future scenario's as preparation for the workshops with cities to develop specific desired future scenario's

WP3, 4 & 5. Roadmapping

Roadmapping training session
2-day training session for expert partners on methodology and way of working

Desk study
analysis of the available information on the selected topics for the roadmaps and to identify relevant experts

Roadmap interviews
collecting expert insights with 20 experts for each focus area

SMART BUILDINGS
- Sustainable technologies
- Sustainable behaviour
- Sustainable organisation

SMART MOBILITY
- Sustainable technologies
- Sustainable behaviour
- Sustainable organisation

SMART URBAN SPACES
- Sustainable technologies
- Sustainable behaviour
- Sustainable organisation

Creation of timelines
making timelines for each topic to indicate when relevant options become available on the path towards the desired future

Expert meeting
cross team expert meetings to share and align timelines for the focus areas and prepare roadmap workshops with cities

Roadmap workshops
2-day workshops in each city to develop specific timelines for the realisation of the desired future scenario's

EINDHOVEN | Tallinn | Murcia | Newcastle City Council (domestic, non-domestic) | Ajuntament de SantCugat | ISTANBUL METROPOLITAN MUNICIPALITY (public transport, traffic mgt)

WP6. Project portfolio

Current projects
each city identifies projects it has running that will contribute to the realisation of the roadmap, as well as the topics for cross-city learning

Roadmap sharing & cross learning objectives
2-day meeting in Newcastle to share the roadmaps of the different cities, as well as the current projects, and to identify cross-learning objectives

New projects
each city identifies the desired new projects to ensure the timely realisation of its roadmap ambition

EINDHOVEN | Murcia | Newcastle City Council (domestic, non-domestic) | Ajuntament de SantCugat | Tallinn

Joint portfolio meeting
3-day meeting in Forlì to share the portfolios of the different cities, as well as to prepare for joint projects that support the achievement of common ambitions

Financing opportunities
identifying different opportunities for financing of the city specific and the joint projects

Organising for learning
organising for continued cross city learning

WP8. Communication & dissemination

Strategy & visuals — developing a communication & dissemination strategy, logo's and graphic charter

Event — Palermo

Regular communication activities — electronic project newsletters, other newsletters and information services, project and partner websites, press releases and other media releases, social media

Event — Tallinn

Regular communication activities

Final event — conference in Murcia

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ROADMAPS FOR ENERGY®

Version 4 September 2015

R4E - ROADMAPS FOR ENERGY

Introduction

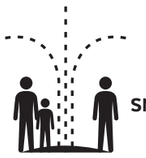
In the Roadmaps for Energy (R4E) project, the partners will work together to develop a new energy strategy: their Energy Roadmap. The difference between the regular energy strategies and action plans and these new Energy Roadmaps is the much earlier and more developed involvement of local stakeholders. These include not only those who will benefit from the new strategy, such as the citizens, but also relevant research and industry partners. They offer a much clearer view of the future potential of the city in terms of measures and technologies, as well as of the challenges presented by today's situations in the cities. The aim is to create a shared vision, containing the desired, city-specific scenarios and the dedicated roadmaps to be embedded in each city's specific context. These will take into account the diversity in the geography, ecology, climate, society and culture of the eight partner cities in the project: Eindhoven, Forli, Istanbul, Newcastle, Murcia, Palermo, Sant Cugat and Tallinn.

The R4E project focuses on the vision creation and roadmapping capacities of the municipalities. This includes initiating joint activities to drive the development and implementation of innovative energy solutions in cities. In this way the partners in R4E will learn the process and the roadmap structure. And they will gain the skills they need to work independently on their future roadmaps.

The ultimate aim is to create a process that will allow the partners to work together in developing the Energy Roadmap to achieve their 'Smart Cities' ambition. But energy and Smart Cities are too broad to cover in one project, so R4E focuses on three key areas of sustainable energy. These are closely linked to the main responsibilities of the municipalities:

SMART BUILDINGS

SMART MOBILITY



SMART URBAN SPACES

Approach

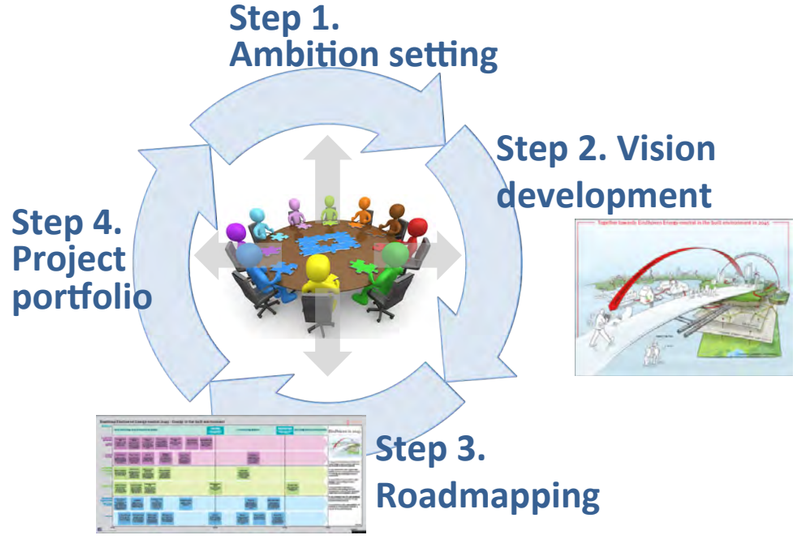
In The R4E project follows a 4-step approach:

1. Set the ambitions of the participating cities on sustainable energy and Smart Cities, as well as their choice of three Smart Energy Saving focus areas: 1. Smart Buildings; 2. Smart Mobility; and 3. Smart Urban Spaces.

2. Develop scenarios for the selected focus areas.

3. Create the roadmap. Identify existing and future technologies and other developments – these will enable the desired future scenarios. Plot the opportunities and developments on a time-line to show the route and milestones towards the desired scenarios. The roadmaps contain common parts for all the partner cities, as well as specific parts for the individual cities.

4. Create a portfolio of new projects and initiatives to achieve the ambitions, visions and roadmaps of the cities. This portfolio shows the shared and individual projects, and includes a cross-city learning plan and a financial plan.



Four step approach of R4E

Step Three: Roadmapping

This report is part of Step 3 of the R4E approach, and describes the second part of Work Package 3 (WP3). The aim of WP3 is to develop the General Roadmap for Smart Buildings. The roadmaps explore the options to achieve the cities' desired future scenarios. To do this, the first step was a desk study to collect the available information on the technology options (see D3.1 - Report Future Options). The desk study was also used to identify all the relevant topics and the most important experts on Smart Buildings.

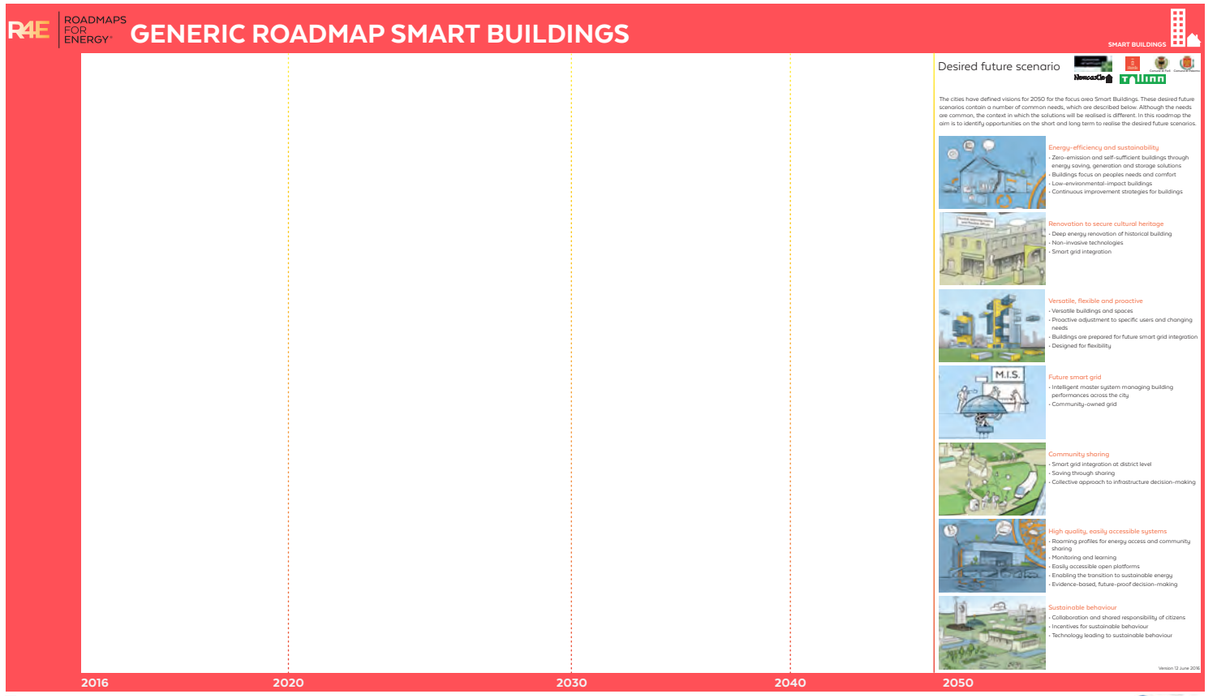
Roadmapping

The results of the desk study and the extensive networks of the R4E partners are used to select international experts and companies from different parts of Europe to collect all the required information. More than 20 experts from industry, knowledge institutes and government were invited to interviews and workshops to share their views on future opportunities. The interviews covered the roles of sustainable technologies, sustainable behaviour and sustainable organisation in achieving the ambitions of the cities as they make the transition to sustainable energy for buildings. . The results of the interviews were used to create a draft roadmap for Smart Buildings. This draft roadmap was aligned with those for Smart Mobility and Smart Urban Spaces to ensure that related topics are well addressed. The resulting Smart Buildings General Roadmap is presented in this report.

The general roadmaps will be used in the next step: co-creating city-specific roadmaps in workshops in the R4E partner cities together with local stakeholders.

How to read this report

This report describes the Smart Buildings General Roadmap, and contains all the relevant information from the Roadmapping research. It starts with an introduction to the Roadmapping research, and the approach to create the general roadmap. Then the experts are introduced, with short descriptions of their contexts, backgrounds and relevant expertise areas for the research. The main part of this report starts with the Smart Buildings joint ambitions of the cities and their shared Smart Buildings needs. The general roadmap is then presented, followed by a more detailed description of the nine topics and their timelines.



Roadmap interview template

Example of a Roadmap interview

Clustering all interview results to create the concept generic roadmap

Interlinking and aligning the concept generic roadmaps for Smart Buildings, Smart Mobility and Smart Urban Spaces

Roadmapping

Roadmap research

A (technology) roadmap is a plan that matches the short-term and long-term goals with specific technology solutions to help meet those goals. Developing a roadmap has three major uses:

- It helps to reach a consensus on a set of needs and the technologies required to meet them;
- It provides a mechanism to help predict technology developments;
- It provides a framework to help plan and coordinate innovation and the implementation of innovative solutions.

Roadmapping represents a powerful technique to manage and plan supporting technology, especially to explore and communicate the dynamic links between technological resources, organisational goals and the changing environment.

The most common format for a roadmap is a time-based chart, with a number of layers that typically include both the business and technological perspectives. The roadmap facilitates and supports the evolution of the markets, products and technologies to be explored, together with the links and gaps between the various perspectives. The Roadmapping technique also draws together the key themes from the technology strategy and transitions literature, by the use of its layered structure together with the time dimension.

In the R4E project, the Roadmapping research method is used to develop timelines for relevant topics in sustainable solutions for Smart Buildings, Smart Mobility and Smart Urban Spaces.

Roadmapping template

The Roadmapping method uses a format with multiple layers covering different aspects, such as technologies, products and markets. The roadmap allows the evolution within each layer to be explored, together with the interlayer dependencies, facilitating the integration of technologies into products, services and systems.

The roadmaps cover different elements of sustainability that need to go hand-in-hand to achieve the desired future scenarios:

I. Sustainable technologies
II. Sustainable behaviour
III. Sustainable organisation

The roadmaps plot a timeline showing the different steps that are needed and possible to achieve the desired scenarios in 2050.

The approach

This research involved 25 interviews with experts holding different views on smart and sustainable energy in cities, covering technological, behavioural and organisational aspects.

Experts

The results of the desk study and the extensive networks of the R4E partners are used to select international experts and companies from different parts of Europe to cover a broad range of perspectives. More than 20 experts from industry, knowledge institutes, consultancies and government were invited to interviews and workshops to share their views on future opportunities. These experts are introduced on the following pages.

Structured interviews

The Roadmap interviews were held with a poster showing a timeline starting in 2016 and running until 2050. The common needs of the R4E partner cities were shown at the end of the timeline. The interviewees were asked to identify relevant future options, and to indicate on the timeline when they thought these options would regularly be available. They were also invited to create a storyline showing the expected developments over time, to gain understanding of the prerequisites for specific developments to take place. All the input was collected on Post-it notes to allow easy reconfiguring of the storyline during the interview. The common needs were used to trigger the thinking of the interviewees and to inspired them to reflect on a wider range of technologies and options needed to achieve the desired future scenarios by 2050.

For these interviews, the requested expertise areas of the experts were not specifically their own innovation strategies, but rather their knowledge of important developments in their own fields. The Roadmapping method inspired the experts to use their knowledge to indicate the available options in the shorter and longer term, and to describe the potential developments over time.

Creating the general roadmap

The collected information from the desk study (D3.1) and the roadmap interviews was used in an expert meeting to identify the most relevant topics and to create a timeline for each of them showing when relevant options would become available on the path to meet the cities' needs. All the results of the interviews were used to make a rich summary of the steps on the timeline. A maximum of 15 relevant future options was described for each topic, together with a short title and explanation and where possible including an example.

Aligning the general roadmaps of the three focus areas

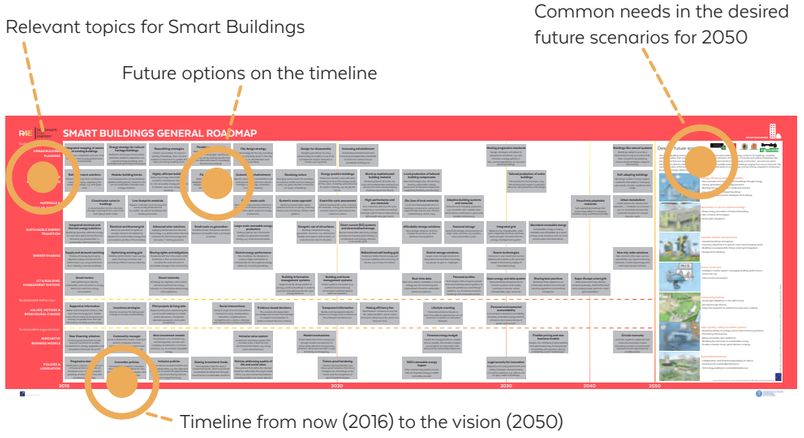
In a cross-theme expert meeting the timelines for Smart Buildings, Smart Mobility and Smart Urban Spaces were aligned to gain understanding of the interlinking areas and potential options across several focus areas.

How to read the general roadmap

The resulting Smart Buildings General Roadmap is presented in this report, together with accompanying information from the desk study and interviews. The roadmap contains four important elements:

- The time axis from now (2016) to the visions for 2050 as described in the desired future scenarios of the cities (see D2.2 — Report Vision Development for the full set of desired future scenarios).
- The eight common needs in the desired future scenarios as described by the cities in the Joint Vision Workshop (see also D2.2) are indicated at the end of the timeline in 2050 as the goal of the roadmap.
- The relevant topics for Smart Buildings on which developments are required to achieve the desired future scenarios. These topics cover sustainable technologies, sustainable behaviour and sustainable organisation.
- The options that will become available in the shorter or longer term for each of the topics. Each topic has a timeline showing the developments that are relevant to that topic.

The image below shows the elements of the general roadmap for Smart Buildings.



Elements of the Smart Buildings General Roadmap

Note: the general roadmap contains the options that were identified in the desk study and the roadmap interviews. However, there will also be future developments; these are not included in the roadmap. The roadmap is not a 'blueprint' towards the desired future scenario – its purpose is to indicate relevant possible future developments that should be taken into account in the development of projects to ensure sufficient flexibility for future-proof cities.

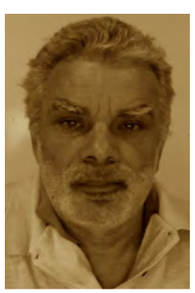
The general roadmaps will be used in the R4E partner cities to co-create city-specific roadmaps together with local stakeholders.

The experts

The experts were selected for their expertise and knowledge on future options. The interviewees work across Europe as members of knowledge institutes, companies, consultancies and profit or non-profit organisations. Their expertise varies from technology oriented to human or social oriented. They are introduced through their expertise and the main criteria for selecting them for the R4E Roadmapping research:

Bauke de Vries is a TU/e Architect at Eindhoven University of Technology, Netherlands and is currently Chair of the Information Systems group in the Built Environment department. His main research topics are: Systems Engineering, Building Information Modelling, City Information Modelling and Process Modelling in the context of Smart Cities development. We invited him especially for his experience as project leader in European research projects regarding architecture and urban planning.

Bill Dunster is a widely recognised ecological architect based in London. As an expert in Sustainable Architecture he founded the architecture practice Zedfactory in 1999, specialising in the field of zero-carbon design and development. Zedfactory's most notable project is bedZED, winner of the 2003 Royal Institute of British Architects (RIBA) Sustainability Award. We invited Mr. Dunster especially for his visionary contributions in the field of sustainable architecture.



Daniel Calatayud is Architect and Urban Planner and professor and researcher at UPC BarcelonaTech. He is a recognised expert in holistic understanding of sustainability in architecture and urban planning, with more than 20 years of experience in the field. We invited him especially for his experience in energetic refurbishment projects within European research programmes, and his outstanding knowledge of the relationships between social, economic and environmental aspects of sustainability, for example in the field of fuel poverty.

Lucienne Krosse is Innovation Officer at KIC InnoEnergy in Eindhoven. With a background in Chemical Engineering, she gained her Masters degree from the University of Twente in the Netherlands. At Delft University of Technology she worked on her PhD in 'compact thermochemical storage'. We invited her especially for her current position as thematic leader 'Intelligent Energy Efficient Buildings and Cities' at KIC InnoEnergy, which provides her with a holistic, research as well as company and market focused vision on energy efficiency at building and city levels.

Christopher Trott is an Environmental Engineer who joined Foster + Partners in 2011 as part of the Creative Engineering team. He has 30 years' experience in master planning, existing and new sustainable building design, low- and zero-carbon site-wide infrastructure design and sustainable building and policy consultancy. Before that he was director of Arup's Sustainable Buildings Team, and has worked on numerous projects including the renewable energy studies and roof building physics at Beijing International Airport. We invited him for his broad experience as the Head of Sustainability at Foster + Partners in London.

Albert Cot is Head of R&D projects in the COMSA EMTE Corporation for activities related to new renewable energy developments, energy efficiency, environmental technologies and transport systems.

We invited Mr. Cot together with his colleague Oscar Aceves, a renowned expert on building integrated photovoltaic applications, for their experience in research and innovation projects regarding renewable energy in buildings and cities.

Albert Cuchí is an Architect and Professor in the Department of Architectural Technology at the Polytechnic University of Catalonia (UPC). He is a founding member of the 'Architecture and Sustainability' group of the Association of Architects of Catalonia and the Sustainable Building Association GBCe – Green Building Council Spain. We invited Prof. Cuchí especially for his experience as an advisor for sustainability issues in the building sector for various institutions, including the Government of Catalonia, the Spanish Government Ministries, the Urban Ecology Agency of Barcelona and the Consortium of the city of Santiago de Compostela.

Peter Loeffler is Head of Innovation and Industry Affairs at Siemens Building Technologies in Switzerland. The company is involved in many front-runner smart buildings and smart city projects such as the Crystal in London. We especially invited him because of his view on the possibilities that future information technologies will provide to buildings and cities.

Maria Serrano is a Telecom Engineer and currently Director of Field Marketing for Spain and Portugal at Schneider Electric. Before that she was director of the Smart City Excellence Centre of Schneider Electric. We invited Mrs. Serrano especially for her experience in leading initiatives together with cities in the field of smart technologies.

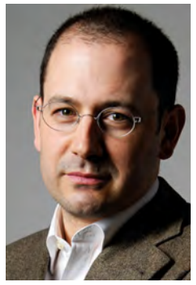
Ursula Eicker is Full Professor at Stuttgart Technology University of Applied Sciences (HFT). As Research Director of Zafh.net (Centre for Sustainable Energy Technology) of HFT, she manages research projects in the field of City Energy Planning, with a special focus on energetic simulation of city environments in relation to energy efficiency of buildings, renewable energy systems and district heating and cooling networks. We invited her especially for her outstanding knowledge in this fields and her wide experience of European Research Projects relating to energy in buildings and cities.

Gallus Cardonau is the Director of the Swiss Solar Energy Agency in Zurich. For more than 25 years he has been an activist for the promotion and implementation of Solar Energy in Switzerland and beyond. He regularly organises corresponding national and European Solar prizes, for example the Norman Foster Plus Energy Buildings Award, and is politically active as consultant to policy-makers. We invited him especially for his experience of the political, legal and social transformation processes in relation to the renewable energy transition.

Joris Voeten is Senior Engineer for Urban Green Spaces at Urban Roofscapes, Amsterdam. He is an expert on green roofs, urban greening and related technological solutions. Before that he was Concept Manager and Urban Green Space Engineer at SHFT. We invited him especially for his rich experience in the transformation of urban environments into green urban landscapes, for example through the Sloterdijk railway station project in Amsterdam.

Karsten Voss is Full Professor of Building Physics at the University of Wuppertal and is a renowned expert on Energy Efficiency in Buildings and Cities. Before that he was responsible for German national research programmes such as ENOB (Energy Optimised Buildings), and has special knowledge in the field of Nearly Zero-Energy Buildings, Energetic Refurbishment and Energy Efficiency strategies for buildings and cities. We invited him for his wide experience in these fields, forming part of the Solar Decathlon Community and European Energy Endeavour Secretariat.

Nuria Pedrals is an Architect and President of AUS – Association Architects and Sustainability at the Architects' Association of Catalonia (COAC), Barcelona. Before that she was General Director of Quality of Buildings and Refurbishment of Housing in the Department of Environment and Housing of the Catalan Government. We invited her especially for her rich experience in the field of legislation on energy efficiency and sustainability in housing.



Jan Cremers is Full Professor for Building Technology and Integrated Architecture in the Faculty of Architecture and Design at Stuttgart Technology University of Applied Sciences (HFT). He conducts research projects in the field of energy efficiency and renewable energy in buildings. We invited him especially for his wide experience in the field of Solar Architecture and renewable energy technologies in relation to buildings.

Werner Lang is Full Professor of Energy Efficient and Sustainable Planning and has been Design at the Technical University of Munich and Director of the Oskar von Miller Forum, Munich, since 2010.
We invited him especially for his expertise in energy-efficient and sustainable design and the use of renewable energy in buildings, as well as his experience in the development of building components and systems.

Georg W. Reinberg is a well-known Solar Architect based in Vienna, Austria. His widely recognised work consists of more than 350 ecologically oriented projects so far, over 100 of which have been implemented. He is an international lecturer and teaches at different universities in Austria and beyond. We invited Georg W. Reinberg especially for his wide experience as a successful practitioner in the field of ecological architecture.

Ignacio Fernandez is Associate Director and Design & Technology leader at ARUP in Spain. He is a building envelope consultant with broad experience in international large-scale projects of renowned architects such as Richard Rogers, Norman Foster, Zaha Hadid and Herzog & de Meuron among others. We invited him for his international experience in Sustainable Building Design.

Josep Puig is Vice president and Head of the Spanish section of EUROSOLAR – European Association for Renewable Energy. He is consultant for energy and environment at Ecoserveis and professor for Energy at the Autonomous University of Barcelona. We invited him for his wide experience in the field of renewable energy implementation, among others as the driving political force, who implemented the Solar thermal energy law for buildings in Barcelona (Ordenaza Solar, 2001).

Jaume Salom is Head of the research group in Thermal Energy and Building Performance at the Catalonia Institute for Energy Research (IREC) in Barcelona. Before that he was co-founder and General Manager at Aiguasol – cooperative company for engineering and energy consulting services. He teaches in different Masters and postgraduate courses. We invited him especially for his brought experience in national and international research and consultancy projects in relation to energy efficiency and renewable energy in buildings.

Florian Lichtblau is a renowned Solar Architect based in Munich, Germany. His projects are based on a holistic approach to sustainability at social, economic and environmental levels. He lectures in seminars at different universities and institutes and is regularly a jury member in competitions. We invited him for his experience in outstanding projects in the field of refurbishment of large housing stocks, which includes a holistic rejuvenation approach for whole living areas.

In an earlier project by TU/e LightHouse on the Roadmap for energy in the built environment “Eindhoven Energy-Neutral 2045” several workshops and interviews were held with experts from the municipality of Eindhoven and invited experts in the field:

- Berend Aanraad, The Natural Step
- Pallas Agterberg, Alliander
- Jan Bekkering, HetEnergiebureau
- Rob Bogaarts, Woonbedrijf
- Sjef Cobben, Eindhoven University of Technology
- Astrid van Deelen, Brainport Development
- Paul van Dillen, Novesco
- Marcel van Dooremalen, Trudo
- Bas van Dun, Brabant Water
- Marc Eggermont, Woonbedrijf
- M. Gibescu,Eindhoven University of Technology
- Aris de Groot, Ecovat Renewable Energy Technologies
- Rick Harwig, Eindhoven University of Technology
- Bjorn Janson, Endinet
- Jarno de Jonge, Waterschap De Dommel
- Paulus Karremans, Endinet
- Wil Kling, Eindhoven University of Technology
- Cees Midden, Eindhoven University of Technology
- Richard Moerman, Waterschap De Dommel
- Jan Roggeband, Brainport Development
- Antoine Stultjens, Ennatuurlijk

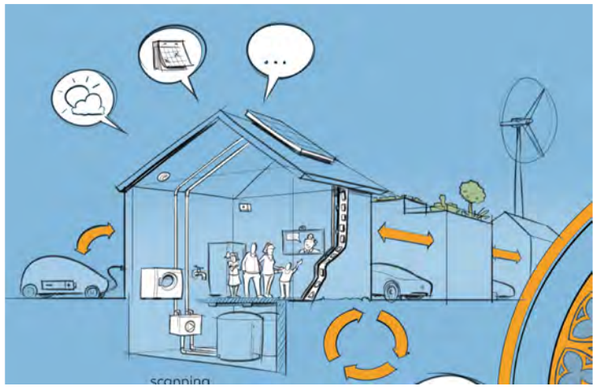
We would like to thank all participants for their contribution to the roadmap research.

COMMON NEEDS IN THE DESIRED FUTURE SCENARIOS

At the Joint Ambition Workshop on 19 October in Palermo, the cities shared and discussed their ambitions for Smart Buildings and identified the common aspects. The result was used for a description of the Smart Buildings focus area.

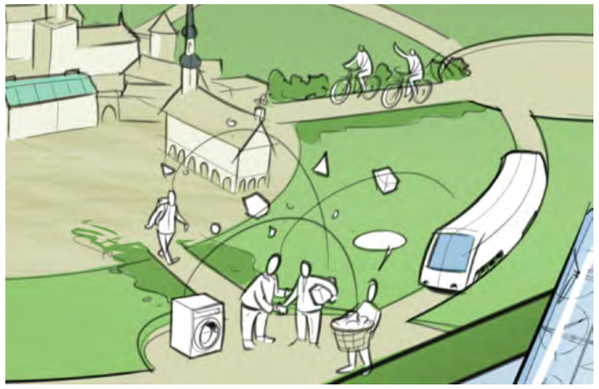
The Smart Buildings theme focuses on the built environment and sustainable energy solutions for buildings, including residential, offices, public and commercial buildings. The ambition of the cities is to create self-sufficient buildings that can generate their own 'green' energy, and have very low environmental impact during construction, renovation and use. Self-sufficient districts and cities are created with a blend of suitable solutions for new as well as historical buildings. The owners and users of the buildings are well-aware and engaged in saving energy and applying energy efficiency measures.

At the Joint Vision Workshop on 24 and 25 May 2016 in Istanbul, the cities presented their desired future scenarios for Smart Buildings to each other and held in-depth discussions to understand each other's needs and contexts (WP2). Seven common needs were identified, as shown on the following page.



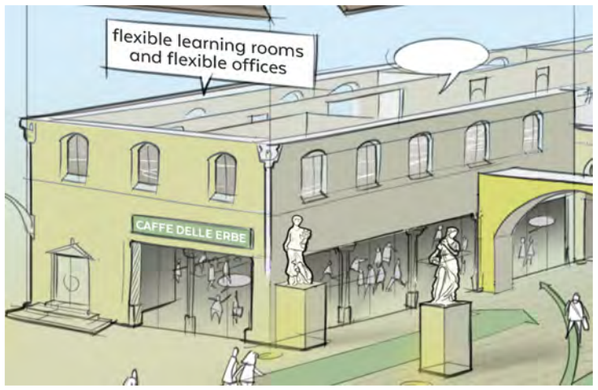
Energy-efficiency and sustainability

- Zero-emission and self-sufficient buildings through energy-saving, generation and storage solutions
- Buildings focus on peoples needs and comfort
- Low-environmental-impact buildings
- Continuous improvement strategies for buildings



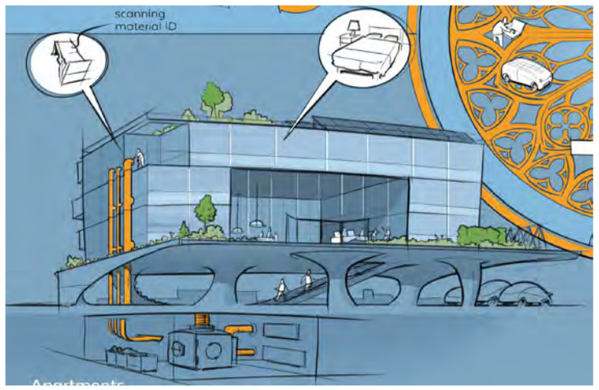
Community sharing

- Smart grid integration at district level
- Saving through sharing
- Collective approach to infrastructure decision-making



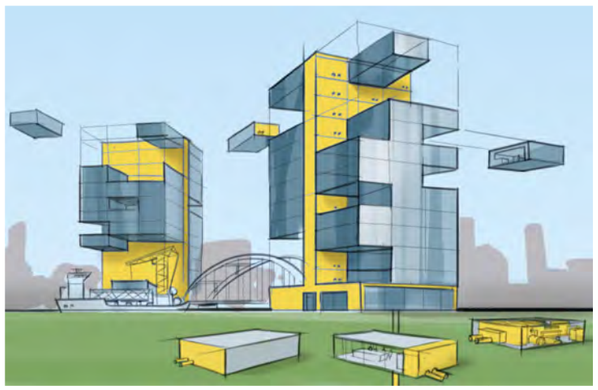
Renovation to secure cultural heritage

- Deep energy renovation of historical building
- Non-invasive technologies
- Smart grid integration



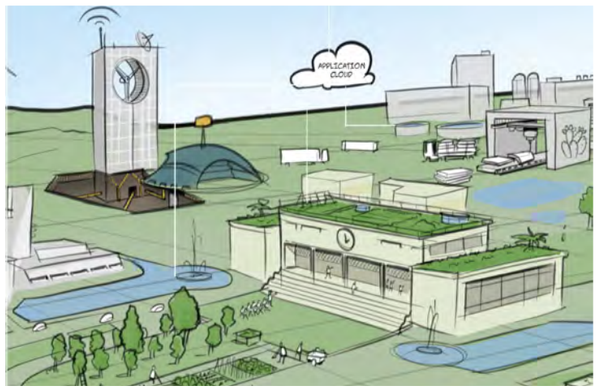
High quality, easily accessible systems

- Roaming profiles for energy access and community sharing
- Monitoring and learning
- Easily accessible open platforms
- Enabling the transition to sustainable energy
- Evidence-based, future-proof decision-making



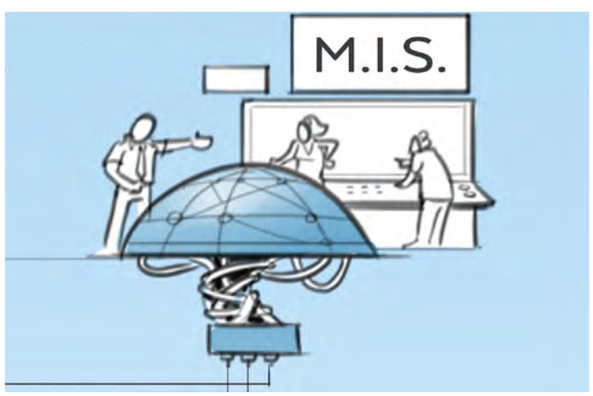
Versatile, flexible and proactive

- Versatile buildings and spaces
- Proactive adjustment to specific users and changing needs
- Buildings are prepared for future smart grid integration
- Designed for flexibility



Sustainable behaviour

- Collaboration and shared responsibility of citizens
- Incentives for sustainable behaviour
- Technology leading to sustainable behaviour



Future smart grid

- Intelligent master system managing building performances across the city
- Community-owned grid

SMART BUILDINGS GENERAL ROADMAP

Roadmap topics Smart Buildings

In the generic roadmap timelines are created for the topics that require developments to achieve the desired future scenario in 2050. The topics selected for the Roadmap Smart Buildings are described briefly.

Sustainable technologies

The first element to achieve the sustainable energy ambitions is the availability of sustainable technologies. There is already a vast amount of sustainable technologies available, and in the meantime new technologies are being developed rapidly. Unfortunately there is not always a consensus on what is the best option for the future. The technology developments included in the Roadmap Smart Buildings are:

URBAN BUILDING PLANNING

Urban Building Planning is about the structured approach to buildings within the overall city planning strategy. This topic refers to the need for integrated mapping of existing assets on a city-wide scale for the development of holistic use and refurbishment strategies. This includes strategies for cultural heritage buildings and the introduction of progressive building standards, as well as developments towards the use of closed-cycle systems.

ENERGY-SAVING BUILDING SOLUTIONS

The topic Energy-Saving Building Solutions refers to materials, systems and strategies that allow reduction of the energy needed for the construction, operation and maintenance over the lifetime of the building. This topic includes strategies for building materials and systems, and for concepts of flexibility and adaptability that allow energy savings. It also refers to the way building and their components will be constructed in the future.

MATERIALS & CIRCULAR SYSTEMS

Materials & Circular Systems is about material, water and waste cycles in buildings and their contribution to energy-efficiency and resource savings. The topic refers to the importance of closing material, water and waste cycles of buildings and the use of low-impact materials. This includes how buildings and their materials can be made increasingly adaptive, contributing to an urban metabolism based on closed resource cycles.

SUSTAINABLE ENERGY TRANSITION

The topic Sustainable Energy Transition refers to the transformation of energy systems on the scale of building and grid towards integrated renewable-energy solutions. It is about the way current energy systems are becoming increasingly smart and integrated, shifting towards solar based, building-integrated renewable-energy solutions. The topic includes future grid developments for electricity and heat, including storage solutions and integrated management.

ENERGY SHARING

Energy Sharing refers to strategies that make individual buildings contributors to efficient city wide solutions. This topic includes the active future role of buildings in the overall energy system, including demand and supply matching and contributions to improved grid stability. More specifically, this topic is about how to optimise the overall district energy performance, based on future energy grids.

ICT & BUILDING MANAGEMENT SYSTEMS

ICT & Building Management Systems is about the increasing generation and use of data for energy optimisation and management in buildings and grids. This refers to smart meters and their evolution towards smart networks supported by building information and home management systems, as well as aspects regarding the increasing availability of real-time data and the interoperability of networks resulting in performance improvement through mutual learning.

Sustainable behaviour

One of the crucial elements of a sustainable city is the behaviour of citizens. Awareness is required to make a collective turn towards more sustainable solutions and energy-saving alternatives. In many cases, available technologies are not sufficiently attractive to gain acceptance in mass markets. The behavioural developments included in the Roadmap Smart Buildings are:

VALUES, MOTIVES & BEHAVIOURAL CHANGE

The topic Values, Motives & Behavioural Change includes personal and institutional ways to incentivise transformations through new approaches to information, experience and personal accountability. This includes instruments like incentives, pilot projects and lifestyle coaching, which could contribute to evidence-based decision-making and lifestyle changes.

Sustainable organisation

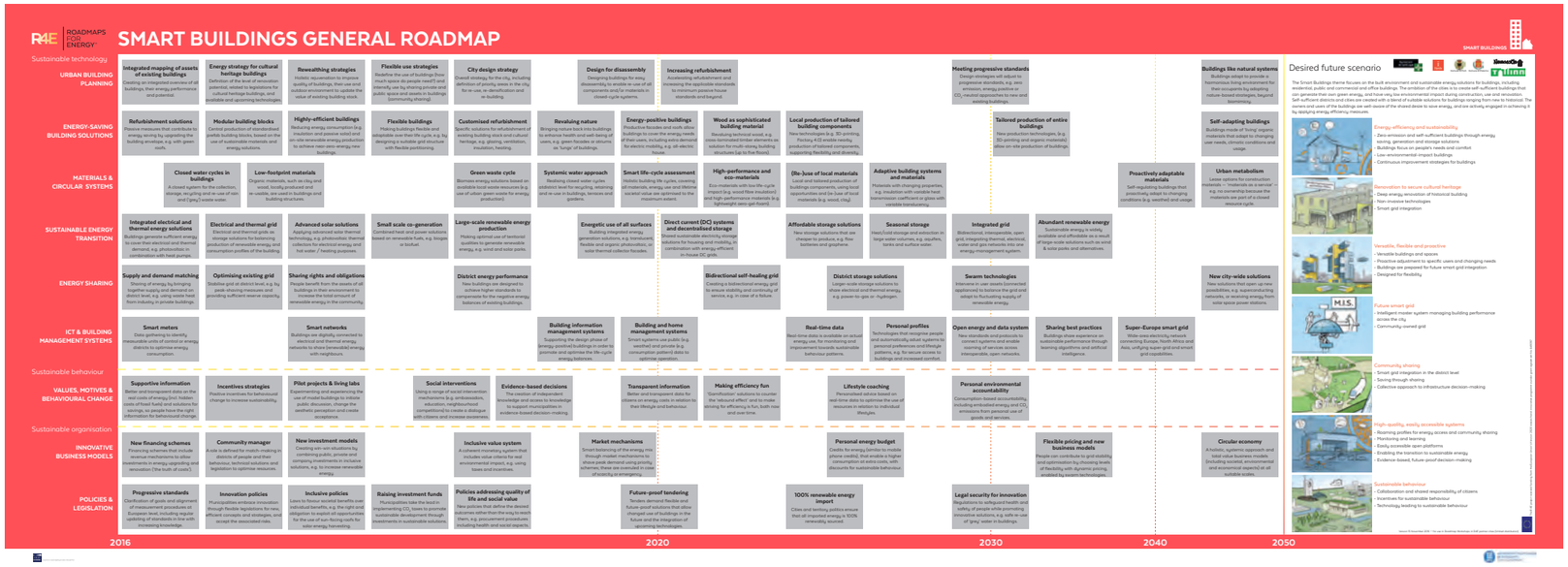
Last but not least, the element of sustainable organisation is addressed. How can we organise the collaboration between relevant parties (public, private, citizens) to achieve the desired future scenarios? Because the technology is not yet mature, new business models are needed to enable learning processes, and that can be adapted when needed. The organisational developments included in the Roadmap Smart Buildings are:

INNOVATIVE BUSINESS MODELS

The topic Innovative Business Models refers to new financial schemes, investment models and market mechanisms that accompany transition processes or that arise as a result of those processes. This also includes new and inclusive value systems, coherent monetary systems and new ways to manage energy at personal and community levels, viewed from societal, environmental and economical perspectives.

POLICIES & LEGISLATION

Policies & Legislation refers to the role of municipalities and the changes in policies, with a holistic focus on the improvement of quality of life and social value for the community. This includes policies and legislations on environmental and energy standards, as well as innovation, public tender, public investments and taxes to reach overall political goals.



Smart Buildings General Roadmap showing the topics at the start of the timeline.

R4E ROADMAPS FOR ENERGY®

SMART BUILDINGS GENERAL ROADMAP

Sustainable technology

URBAN BUILDING PLANNING

Integrated mapping of assets of existing buildings
Creating an integrated overview of all buildings, their energy performance and potential.

Energy strategy for cultural heritage buildings
Definition of the level of renovation potential, related to legislations for cultural heritage buildings, and available and upcoming technologies.

Rewealthing strategies
Holistic rejuvenation to improve quality of buildings, their use and outdoor environment to update the value of existing building stock.

Flexible use strategies
Redefine the use of buildings (how much space do people need?) and intensify use by sharing private and public space and assets in buildings (community sharing).

City design strategy
Overall strategy for the city, including definition of priority areas in the city for re-use, re-densification and re-building.

Design for disassembly
Designing buildings for easy disassembly to enable re-use of all components and/or materials in closed-cycle systems.

Increasing refurbishment
Accelerating refurbishment and increasing the applicable standards to minimum passive house standards and beyond.

ENERGY-SAVING BUILDING SOLUTIONS

Refurbishment solutions
Passive measures that contribute to energy saving by upgrading the building envelope, e.g. with green roofs.

Modular building blocks
Central production of standardised prefab building blocks, based on the use of sustainable materials and energy solutions.

Highly-efficient buildings
Reducing energy consumption (e.g. insulation and passive solar) and on-site renewable energy production to achieve near-zero-energy new buildings.

Flexible buildings
Making buildings flexible and adaptable over their life cycle, e.g. by designing a suitable grid structure with flexible partitioning.

Customised refurbishment
Specific solutions for refurbishment of existing building stock and cultural heritage, e.g. glazing, ventilation, insulation, heating.

Revaluing nature
Bringing nature back into buildings to enhance health and well-being of users, e.g. green facades or atriums as 'lungs' of buildings.

Energy-positive buildings
Productive facades and roofs allow buildings to cover the energy needs of their users, including extra demand for electric mobility, e.g. all-electric house.

Wood as sophisticated building material
Revaluing technical wood, e.g. cross-laminated timber elements as solution for multi-storey building structures (up to five floors).

MATERIALS & CIRCULAR SYSTEMS

Closed water cycles in buildings
A closed system for the collection, storage, recycling and re-use of rain and ('grey') waste water.

Low-footprint materials
Organic materials, such as clay and wood, locally produced and re-usable, are used in buildings and building structures.

Green waste cycle
Biomass energy solutions based on available local waste resources (e.g. use of urban green waste for energy production).

Systemic water approach
Realising closed water cycles atdistrict level for recycling, retaining and re-use in buildings, terraces and gardens.

Smart life-cycle assessment
Holistic building life cycles, covering all materials, energy use and lifetime societal value are optimised to the maximum extent.

High-performance and eco-materials
Eco-materials with low life-cycle impact (e.g. wood fibre insulation) and high-performance materials (e.g. lightweight aero-gel-foam).

SUSTAINABLE ENERGY TRANSITION

Integrated electrical and thermal energy solutions
Buildings generate sufficient energy to cover their electrical and thermal demand, e.g. photovoltaic in combination with heat pumps.

Electrical and thermal grid
Electrical and thermal grids as storage solutions for balancing production of renewable energy and consumption profiles of the building.

Advanced solar solutions
Applying advanced solar thermal technology, e.g. photovoltaic thermal collectors for electrical energy and hot water / heating purposes.

Small scale co-generation
Combined heat and power solutions based on renewable fuels, e.g. biogas or biofuel.

Large-scale renewable energy production
Making optimal use of territorial qualities to generate renewable energy, e.g. wind and solar parks.

Energetic use of all surfaces
Building integrated energy generation solutions, e.g. translucent, flexible and organic photovoltaic, or solar thermal collector facades.

Direct current (DC) systems and decentralised storage
Shared sustainable electricity storage solutions for housing and mobility, in combination with energy-efficient in-house DC grids.

ENERGY SHARING

Supply and demand matching
Sharing of energy by bringing together supply and demand on district level, e.g. using waste heat from industry in private buildings.

Optimising existing grid
Stabilise grid at district level, e.g. by peak-shaving measures and providing sufficient reserve capacity.

Sharing rights and obligations
People benefit from the assets of all buildings in their environment to increase the total amount of renewable energy in the community.

District energy performance
New buildings are designed to achieve higher standards to compensate for the negative energy balances of existing buildings.

Bidirectional self-healing grid
Creating a bidirectional energy grid to ensure stability and continuity of service, e.g. in case of a failure.

ICT & BUILDING MANAGEMENT SYSTEMS

Smart meters
Data gathering to identify measurable units of control or energy districts to optimise energy consumption.

Smart networks
Buildings are digitally connected to electrical and thermal energy networks to share (renewable) energy with neighbours.

Building information management systems
Supporting the design phase of (energy-positive) buildings in order to promote and optimise the life-cycle energy balances.

Building and home management systems
Smart systems use public (e.g. weather) and private (e.g. consumption pattern) data to optimise operation.

Sustainable behaviour

VALUES, MOTIVES & BEHAVIOURAL CHANGE

Supportive information
Better and transparent data on the real costs of energy (incl. hidden costs of fossil fuels) and solutions for savings, so people have the right information for behavioural change.

Incentives strategies
Positive incentives for behavioural change to increase sustainability.

Pilot projects & living labs
Experimenting and experiencing the use of model buildings to initiate public discussion, change the aesthetic perception and create acceptance.

Social interventions
Using a range of social intervention mechanisms (e.g. ambassadors, education, neighbourhood competitions) to create a dialogue with citizens and increase awareness.

Evidence-based decisions
The creation of independent knowledge and access to knowledge to support municipalities in evidence-based decision-making.

Transparent information
Better and transparent data for citizens on energy costs in relation to their lifestyle and behaviour.

Making efficiency fun
'Gamification' solutions to counter the 'rebound effect' and to make striving for efficiency is fun, both now and over time.

Sustainable organisation

INNOVATIVE BUSINESS MODELS

New financing schemes
Financing schemes that include revenue mechanisms to allow investments in energy upgrading and renovation ('the truth of costs').

Community manager
A role is defined for match-making in districts of people and their behaviour, technical solutions and legislation to optimise resources.

New investment models
Creating win-win situations by combining public, private and company investments in inclusive solutions, e.g. to increase renewable energy.

Inclusive value system
A coherent monetary system that includes value criteria for real environmental impact, e.g. using taxes and incentives.

Market mechanisms
Smart balancing of the energy mix through market mechanisms to shave peak demand using priority schemes; these are overruled in case of scarcity or emergency.

POLICIES & LEGISLATION

Progressive standards
Clarification of goals and alignment of measurement procedures at European level, including regular updating of standards in line with increasing knowledge.

Innovation policies
Municipalities embrace innovation through flexible legislations for new, efficient concepts and strategies, and accept the associated risks.

Inclusive policies
Laws to favour societal benefits over individual benefits, e.g. the right and obligation to exploit all opportunities for the use of sun-facing roofs for solar energy harvesting.

Raising investment funds
Municipalities take the lead in implementing CO_2 taxes to promote sustainable development through investments in sustainable solutions.

Policies addressing quality of life and social value
New policies that define the desired outcomes rather than the way to reach them, e.g. procurement procedures including health and social aspects.

Future-proof tendering
Tenders demand flexible and future-proof solutions that allow changed use of buildings in the future and the integration of upcoming technologies.

2016 — 2020

LIGHT HOUSE

Meeting progressive standards
Design strategies will adjust to progressive standards, e.g. zero emission, energy positive or CO_2-neutral approaches to new and existing buildings.

Buildings like natural systems
Buildings adapt to provide a harmonious living environment for their occupants by adopting nature-based strategies, beyond biomimicry.

Local production of tailored building components
New technologies (e.g. 3D-printing, Factory 4.0) enable nearby production of tailored components, supporting flexibility and diversity.

Tailored production of entire buildings
New production technologies, (e.g. 3D-printing and organic materials) allow on-site production of buildings.

Self-adapting buildings
Buildings made of 'living' organic materials that adapt to changing user needs, climatic conditions and usage.

(Re-)use of local materials
Local and tailored production of buildings components, using local opportunities and (re-)use of local materials (e.g. wood, clay).

Adaptive building systems and materials
Materials with changing properties, e.g. insulation with variable heat transmission coefficient or glass with variable translucency.

Proactively adaptable materials
Self-regulating buildings that proactively adapt to changing conditions (e.g. weather) and usage.

Urban metabolism
Lease options for construction materials — 'materials as a service' — e.g. no ownership because the materials are part of a closed resource cycle.

Affordable storage solutions
New storage solutions that are cheaper to produce, e.g. flow batteries and graphene.

Seasonal storage
Heat/cold storage and extraction in large water volumes, e.g. aquifers, tanks and surface water.

Integrated grid
Bidirectional, interoperable, open grid, integrating thermal, electrical, water and gas networks into one energy-management system.

Abundant renewable energy
Sustainable energy is widely available and affordable as a result of large-scale solutions such as wind & solar parks and alternatives.

District storage solutions
Larger-scale storage solutions to share electrical and thermal energy, e.g. power-to-gas or -hydrogen.

Swarm technologies
Intervene in user assets (connected appliances) to balance the grid and adapt to fluctuating supply of renewable energy.

New city-wide solutions
New solutions that open up new possibilities, e.g. superconducting networks, or receiving energy from solar space power stations.

Real-time data
Real-time data is available on actual energy use, for monitoring and improvement towards sustainable behaviour patterns.

Personal profiles
Technologies that recognise people and automatically adust systems to personal preferences and lifestyle patterns, e.g. for secure access to buildings and increased comfort.

Open energy and data system
New standards and protocols to connect systems and enable roaming of services across interoperable, open networks.

Sharing best practices
Buildings share experience on sustainable performance through learning algorithms and artificial intelligence.

Super-Europe smart grid
Wide-area electricity network connecting Europe, North Africa and Asia, unifying super-grid and smart grid capabilities.

Lifestyle coaching
Personalised advice based on real-time data to optimise the use of resources in relation to individual lifestyles.

Personal environmental accountability
Consumption-based accountability, including embodied energy and CO_2 emissions from personal use of goods and services.

Personal energy budget
Credits for energy (similar to mobile phone credits), that enable a higher consumption at extra costs, with discounts for sustainable behaviour.

Flexible pricing and new business models
People can contribute to grid stability and optimisation by choosing levels of flexibility with dynamic pricing, enabled by swarm technologies.

Circular economy
A holistic, systemic approach and total value business models (including societal, environmental and economical aspects) at all suitable scales.

100% renewable energy import
Cities and territory politics ensure that all imported energy is 100% renewably sourced.

Legal security for innovation
Regulations to safeguard health and safety of people while promoting innovative solutions, e.g. safe re-use of 'grey' water in buildings.

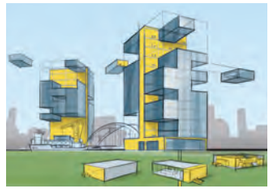
2030 2040 2050

Desired future scenario

The Smart Buildings theme focuses on the built environment and sustainable energy solutions for buildings, including residential, public and commercial and office buildings. The ambition of the cities is to create self-sufficient buildings that can generate their own green energy, and have very low environmental impact during construction, use and renovation. Self-sufficient districts and cities are created with a blend of suitable solutions for buildings ranging from new to historical. The owners and users of the buildings are well-aware of the shared desire to save energy, and are actively engaged in achieving it by applying energy efficiency measures.

Energy-efficiency and sustainability
- Zero-emission and self-sufficient buildings through energy saving, generation and storage solutions
- Buildings focus on people's needs and comfort
- Low-environmental-impact buildings
- Continuous improvement strategies for buildings

Renovation to secure cultural heritage
- Deep energy renovation of historical building
- Non-invasive technologies
- Smart grid integration



Versatile, flexible and proactive
- Versatile buildings and spaces
- Proactive adjustment to specific users and changing needs
- Buildings are prepared for future smart grid integration
- Designed for flexibility

Future smart grid
- Intelligent master system managing building performance across the city
- Community-owned grid

Community sharing
- Smart grid integration in the district level
- Saving through sharing
- Collective approach to infrastructure decision-making

High-quality, easily accessible systems
- Roaming profiles for energy access and community sharing
- Monitoring and learning
- Easily accessible open platforms
- Enabling the transition to sustainable energy
- Evidence-based, future-proof decision-making

Sustainable behaviour
- Collaboration and shared responsibility of citizens
- Incentives for sustainable behaviour
- Technology leading to sustainable behaviour

The R4E project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649397

Urban building planning

Short term developments

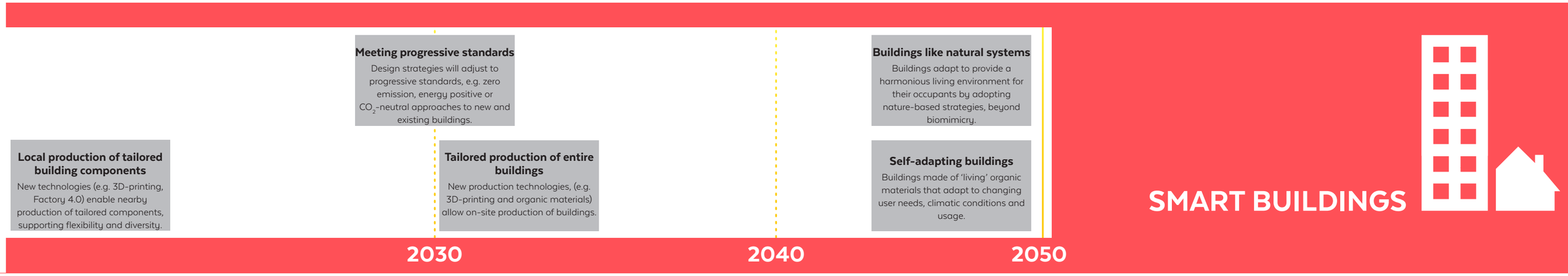
- In the short term, integrated mapping of the existing building stock, including its energy performance and the potential for improvement and use support integrated urban planning processes.
- Specific energy strategies for cultural heritage buildings are developed for the refurbishing of historical buildings, incorporating available and upcoming technologies.
- Rewealthing and rejuvenation strategies focus on the quality of internal and external spaces of the existing building stock. This includes the implementation of new and flexible forms of use, as well as sharing of spaces and infrastructure.
- General city design strategies focus on re-use, re-densification and re-building of the existing buildings and public spaces, defining priority areas for intervention.
- A life-cycle approach for buildings is considered, based on design for disassembly and re-use of materials, using closed cycle systems as far as possible.

Mid term developments

- Once experience has been gained and processes and strategies have been developed, the annual building refurbishment rate will be scaled up to 3 to 5% of the existing building stock, from today's typical rate of 1%. The minimum energy standard for refurbished buildings is the 'passive house' standard. However the standards will develop further, with increasing requirements for higher levels such as zero-emission, energy-positive or CO2-neutral performance over lifetime.

Long term developments

- In the long term buildings increasingly adopt nature-based strategies, and are integrated in and adapting to the surrounding natural systems. In this way they offer harmonious living environments for their occupants.



Energy-saving building solutions

Short term developments

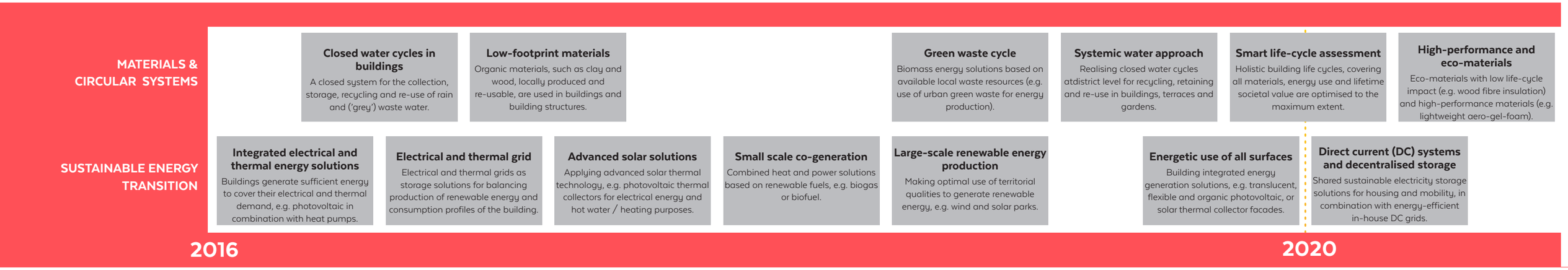
- Refurbishment plays a mayor role, and solutions for the upgrading of building envelopes and installations is gaining importance, including on-site renewable energy generation. The aim is to achieve nearly zero-energy standard in new buildings, and where possible also in existing buildings.
- Modular, prefabricated building blocks allow material and energy savings through centralised productions processes, with increasing flexibility and adaptability of buildings over their life-cycles.
- Customised refurbishment solutions for cultural heritage buildings allow improvement of energy performance while also meeting cultural protection standards. Increased energy performance is achieved through higher standards for both new buildings and those surrounding them.

Mid term developments

- Buildings are becoming increasingly energy-efficient and energy-producing, with a development towards energy-positive buildings as standard. Energy-producing facades and roofs cover all users' energy needs, including extra demand for electric mobility.
- Wood is increasingly used as a sophisticated building material, even for structural purposes in multi-storey buildings.
- Buildings are based on customised local building components, which are produced by new technologies such as 3D printing or Factory 4.0 solutions, enabling greater flexibility and diversity.

Long term developments

- Entire buildings are produced decentrally and on-site using new production technologies such as 3D printing and with local organic materials.
- Self-adapting buildings based on 'living' organic materials can adapt to changing user needs, climate conditions and usage.



Materials & circular systems

Short term developments

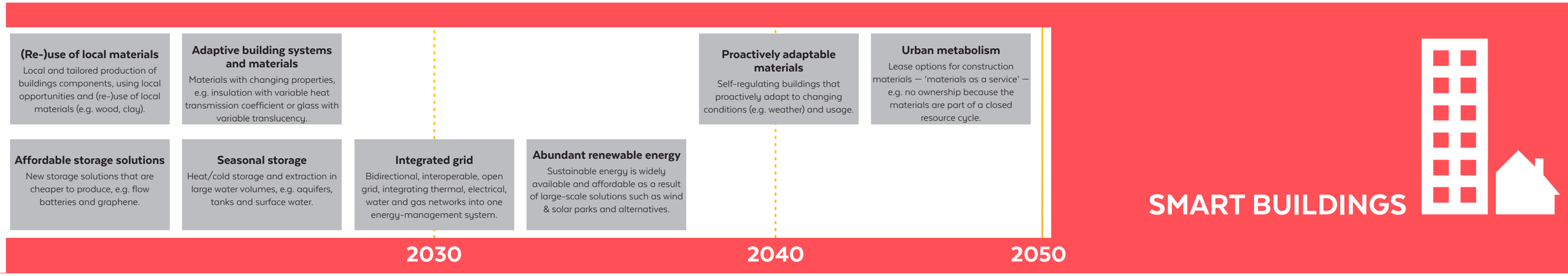
- In the short term water is considered as an increasingly valuable resource, and water cycles in buildings will be closed as far as possible.
- Closed water cycles at district level connect buildings, terraces and gardens to systems for water retention, storage and re-use.
- Building work increasingly uses organic materials such as clay and wood. These are locally produced and re-usable, reducing the overall carbon footprint of constructions.
- Biomass energy solutions use urban green waste for energy production, closing green waste cycles.

Mid term developments

- In the mid-term, smart life-cycle assessment allows calculation, tracking and optimising of material life cycles, energy use and even societal value of buildings over their lifetime.
- High-performance materials and eco-materials with a very low lifecycle impact are standard in buildings.
- Materials and components are locally produced through tailored production processes based on the (re-)use of locally available resources.
- Adaptive building systems and materials with changing properties are available, optimising the thermal performance of building envelopes.

Long term developments

- In the long term buildings are self-regulating, with materials and systems that proactively adapt to different climatic conditions or usage.
- Buildings contribute to an urban metabolism based on closed resource cycles, understanding materials as a service.



Sustainable energy transition

Short term developments

- In the short term, buildings generate enough energy to meet their own energy demand through integrated electrical and thermal energy solutions based on renewable energy.
- Electrical and thermal grids evolve, allowing storage of decentralised renewable energy produced by buildings, as well as balancing of supply and demand.
- Renewable energy technologies evolve towards more efficient and sophisticated integrated systems, e.g. advanced solar solutions such as photovoltaic thermal collectors for building integration or small-scale co-generation power solutions based on renewable fuels such as biogas or biofuel.
- Large-scale renewable energy installations such as wind and solar parks are used widely throughout the territory.
- All available exterior building surfaces are used to harvest solar energy through integrated energy solutions such as flexible and translucent photovoltaic or thermal collector facades.

Mid term developments

- In the mid-term, direct current (DC) systems allow the use of PV electricity through energy-efficient in-house grids, together with increasing amount of shared sustainable electricity storage solutions on all scales for buildings and mobility.
- Energy storage systems are increasingly affordable through the use of new materials and technologies such as flow batteries and graphene-based solutions.
- Affordable seasonal heat/cold storage is shifting the season-to-season availability of harvested thermal energy through large-scale natural or artificial storage options such as aquifers and water storage tanks.

Long term developments

In the long term, bidirectional integrated grids together with affordable storage solutions allow truly sustainable energy systems. Grids are interoperable, creating mixed thermal, electrical, water and gas networks within a single energy-management system.

The growing affordability and availability of sustainable energy solutions, based on a mix of decentralised small-scale and large-scale installations, lead to an abundance of renewable energy in the long term.

Energy sharing

Short term developments

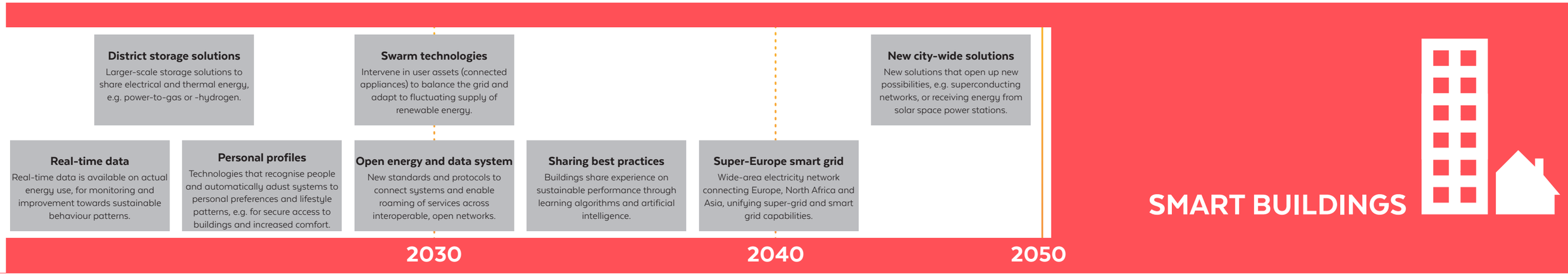
- In the short term, energy resources at city and district level are mapped and managed efficiently, allowing supply and demand matching between producers and consumers of electricity and heat, with individual buildings as contributors to efficient city-wide solutions.
- Existing energy grids with an increasing share of decentralised renewable energy generation are stabilised at district levels by peak shaving measures and by providing sufficient storage and generation capacity.
- Sustainable energy generation and consumption are regarded as community assets, through which people share corresponding rights and obligations, collectively increasing the total amount of renewable energy of a district.
- Energy performance is evaluated at district level. New buildings with higher energy standards and renewable energy production compensate for the older building stock with a negative energy balance.

Mid term developments

- Energy grids are self-healing and bidirectional, with a large number of interconnected decentralised production facilities for renewable energy, and mechanisms to ensure grid stability and continuity of service in case of failure.
- District storage systems are used to balance fluctuations in electrical and thermal energy supply and demand using efficient, large-scale storage solutions such as power to-gas and hydrogen.

Long term developments

- In the long term district energy performance is optimised through innovative approaches such as ‘swarm’ technologies, connecting appliances to self-learning and self-balancing networks and other city-wide solutions such as superconducting networks.



ICT & building management systems

Short term developments

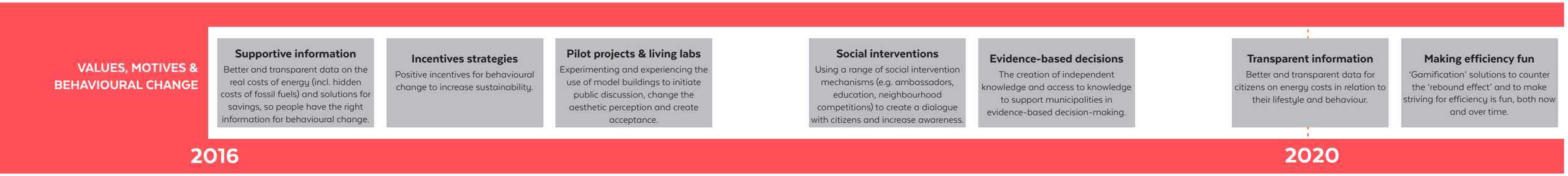
- In the short term ICT & Building Management Systems are evolving. This allows increasing generation and use of data for energy optimisation and management in buildings and grids, based on detailed control through smart meters.
- ICT technologies allow the creation and control of smart networks at local level to share electrical and thermal energy among neighbours.
- Right from the design phase, building information management systems allow simulation of building energy performance. This allows their life-cycle energy balances to be optimised and their contribution at district level to be determined.

Mid term developments

- In the mid-term, building and home management systems allow building energy performance and operation to be optimised using public (e.g. weather forecasts) and private (e.g. individual users consumption pattern) data.
- Detailed real-time data is available on energy use and building performance, as well as on user comfort and behaviour, to improve and optimise building operation. This allows the creation of users' personal profiles, with adaptive systems that can be adjusted to match users' personal preferences.

Long term developments

- In the long term, open energy and data systems allow interoperability of networks resulting in performance improvement through mutual learning. This is based on new standards and protocols to allow connection of systems.
- Buildings are active and self-learning, communicating and sharing experience on sustainable performance through learning algorithms and artificial intelligence.
- ICT contributes to the creation of extended smart grids, e.g. a super-Europe smart grid that connects Europe, North Africa and Asia, unifying super-grid and smart grid capabilities.



Values, motives & behavioural change

Short term developments

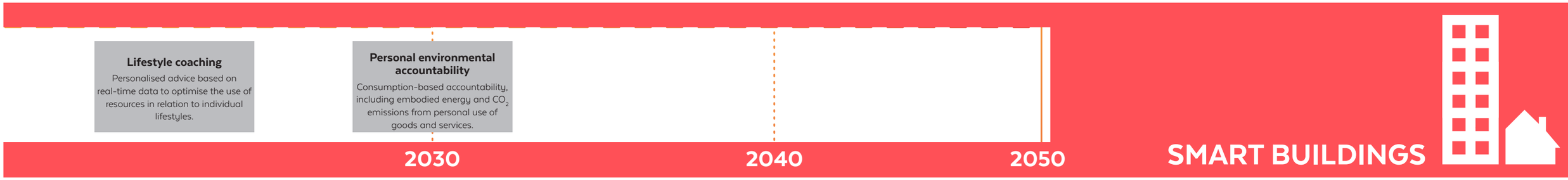
- Behavioural change depends greatly on the availability of reliable data. In the short term the transparency of data is increasing. This makes the real costs of energy visible, including externalised or hidden costs such as those relating to the environmental impact of fossil fuels. This supporting information helps to drive system transformation and behavioural change.
- Incentive strategies encourage people to change their behaviour towards more sustainable lifestyles, motivating through financial and non-financial rewards for individual or collective efforts towards overall societal sustainability.
- Experience and experimentation through pilot projects and living labs promote public discussion and awareness of new building methods and lifestyles. This helps to create acceptance for sustainable buildings, and positively influences the aesthetic perception of sustainable architecture.
- New social intervention mechanisms such as energy ambassadors, specific educational programmes and neighbourhood energy competitions promote dialogue with citizens and increase their awareness of and interest in sustainability.
- Cities can make evidence-based decisions as their access to knowledge increases and changes, with independent entities providing information and supporting municipalities.

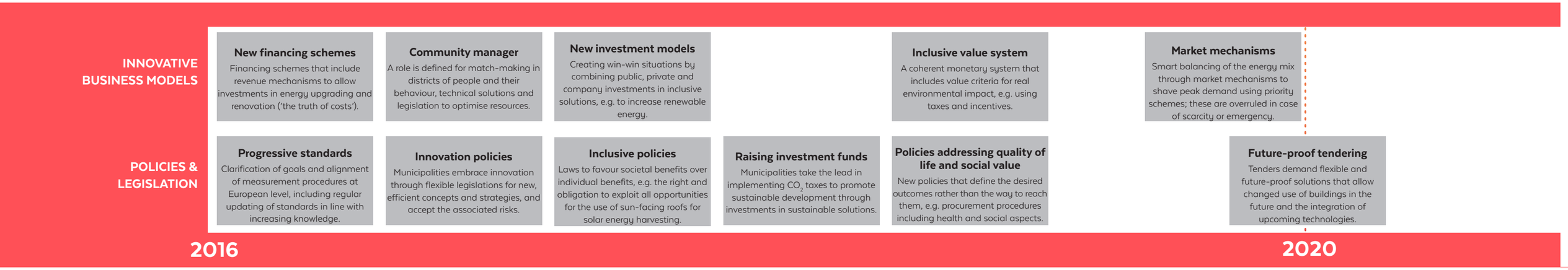
Mid term developments

- In the mid-term information is increasingly transparent, ensuring that citizens have clear and transparent access to data on aspects like energy costs, individual lifestyle and behaviour, and the related environmental impact. This information allows individuals to take evidence-based decisions.
- Strategies like 'Gamification' solutions make energy efficiency and related lifestyle changes fun. For example these use personalised apps and competitions between citizens, allowing comparisons of personal performance and changes towards sustainability.
- Lifestyle coaching by experts helps citizens to optimising their personal use of resource relating to their individual lifestyles. This is based on personalised advice based on the available real-time data.

Long term developments

- In the long term personal environmental accountability drives individual behavioural change, avoiding 'rebound' effects. This personal accountability is based on citizens' individual use of goods and services, and takes into account embodied energy, CO_2 emissions and other indicators of environmental and social impact.


Lifestyle coaching
Personalised advice based on real-time data to optimise the use of resources in relation to individual lifestyles.
Personal environmental accountability
Consumption-based accountability, including embodied energy and CO_2 emissions from personal use of goods and services.
2030
2040
2050
SMART BUILDINGS



Innovative business models

Short term developments

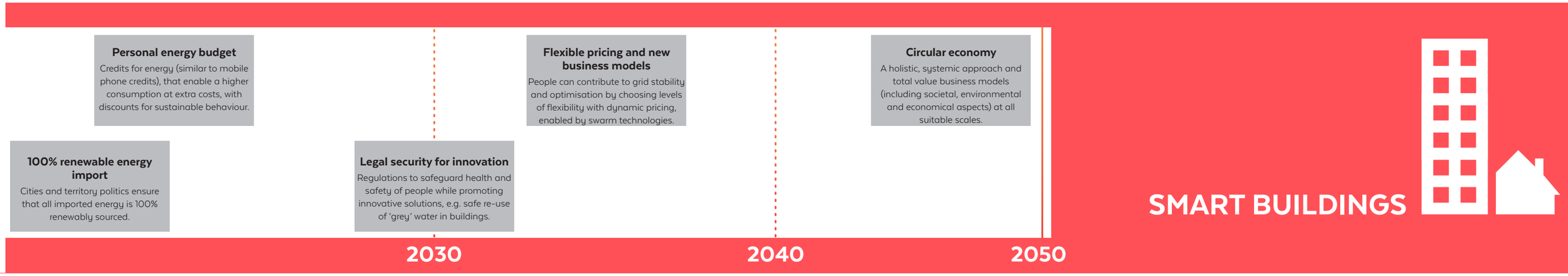
- In the short term new financing schemes promote investments, for example in energy upgrading and renovation of the existing building stock. This includes new revenue mechanisms based on 'truth of costs', a long-term holistic evaluation of costs and benefits for society.
- The 'community manager' emerges to deal with the complexity of communities. This role is defined for match-making in districts. To optimise the use of resources, the community manager matches the energy needs of people - taking into account their behaviour - with the available technical solutions in the district, and legislation.
- New investment models allow the creation of win-win situations based on combined public, private and company investments. These allow inclusive solutions, for example in the field of renewable energy installations.
- An inclusive value system makes existing monetary systems and mechanisms more coherent. Value criteria for the real environmental impact of products and services are included, for example through taxes and incentives.
- Market mechanisms contribute to balancing the energy system, allowing peak shaving and increasing overall energy efficiency.

Mid term developments

- In the mid-term, new mechanisms such as personal energy budgets allow personalised energy consumption. This could be based on energy credits (similar to mobile phone credits), enabling higher consumption at extra cost as well as discounts for sustainable behaviour.

Long term developments

- In the long term, new business models are based on flexible pricing schemes. This encourages people to contribute to overall grid stability and energy efficiency through flexibility in their use of energy in response to dynamic pricing.
- Contributing to the circular economy, business models are based on a holistic and systemic approach. This takes into account the total value of products and services, including their societal, environmental and economic value at different scales.



Policies & legislation

Short term developments

- In the short term, progressive standards are based on clear goals at European level and alignment of national measurement procedures, e.g. for nearly zero-energy buildings. These changes are the result of regular updating of standards based on increasing knowledge.
- Innovation policies of municipalities are based on flexible legislations for new, energy efficient and more sustainable building concepts and strategies. Municipalities accept the associated risks to promote innovation.
- Policies are increasingly inclusive, favouring clear societal benefits over individual benefits. For example this results from citizens' right and obligation to exploit all opportunities to use sun-facing roofs for solar-energy generation. In this was citizens contributing to the energy self-sufficiency of city districts.
- Municipalities use mechanisms like CO2 taxes to raise investment funds and to promote sustainable development by investing in sustainable solutions.
- Municipal policies address quality of life of citizens and social values for society as a whole. Desired outcomes rather than the way to reach them are defined, for example in public procurement procedures, including health and social aspects.

Mid term developments

- In the mid-term, tendering promotes future-proof solutions by including specific demands like flexibility and the ability to change the use of buildings, or easy future upgrading with new technologies.
- City and territory policies ensure 100% renewable energy imports as political and societal goal.

Long term developments

In the long term, the legal security of innovations is assured at different levels. Regulations safeguard the health and safety of people and promote innovative solutions. These contribute to sustainability and resource saving, for example by the safe re-use of grey water in buildings.

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SMART BUILDINGS GENERAL ROADMAP

D3.2 Report - Timelines for the topics in Smart Buildings

This report (D3.2) contains the results of the Roadmapping research conducted between January 2016 and August 2017. The first Roadmapping interviews were held to identify future options for sustainable energy in the area of Smart Buildings.The interview results were analysed In an expert meeting to distil the most relevant topics and to create timelines with future options for those topics. The timeline for Smart Buildings was aligned in a cross-expert meeting, together with the timelines for Smart Mobility (D4.2) and Smart Urban Spaces (D5.2) to ensure that the links between the focus areas were also addressed. The general roadmaps were used in roadmapping sessions held in the R4E partner cities to create city-specific roadmaps (which are reported in D3.3)

The creation of the general roadmap is part of the WP3 Roadmap Smart Buildings within the R4E project. The R4E partners work together to develop a new type of energy strategy through visions and roadmaps for the eight partners cities in co-creation with local stakeholders. The project supports the development of visioning and roadmapping capacities within the municipalities to drive future development and implementation of innovative energy solutions.

R4E ROADMAPS FOR ENERGY®