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

ROADMAPPING SMART BUILDINGS

D3.1 Report – Future options for Smart buildings

ROADMAPS FOR ENERGY®

24 April 2017

Torsten MASSECK, UPC

ROADMAPPING

D3.1 Report - Future options for Smart Buildings

Work Package title: WP3, Roadmapping

Task: 3.2, Desk study Smart Buildings

WP coordinator: UPC

Submission due date: April 2017

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Abstract

This report (D3.1) contains the results of the desk study activities regarding state-of-the-art solutions and future options in the area of sustainable energy for buildings from January 2016 to April 2017.

The desk study is part of WP3 Roadmapping Smart Buildings of the R4E project.

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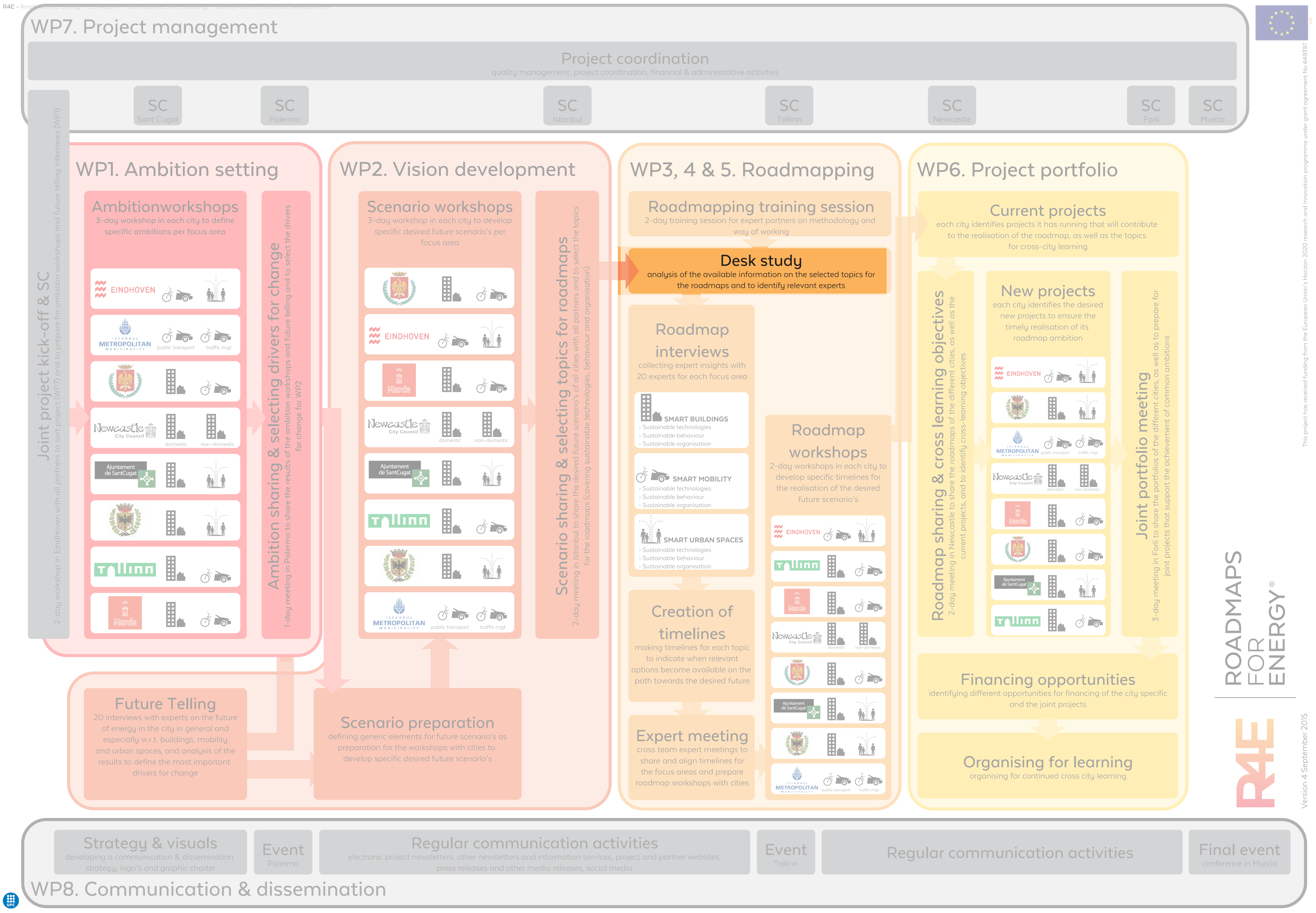
Versions of this report:

21 September 2016	Draft for submission to EU Commission
20 January 2017	Concept for internal check by R4E partners (limited distribution)
24 April 2017	Final version for public distribution

Contents



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
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EINDHOVEN
METROPOLITAN
public transport
traffic mgt
Newcastle City Council
domestic
non-domestic
Ajuntament de SantCugat
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
WP2. Vision development
Scenario workshops
3-day workshop in each city to develop specific desired future scenario's per focus area
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)
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
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Expert meeting
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WP6. Project portfolio
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New projects
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Joint portfolio meeting
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Financing opportunities
identifying different opportunities for financing of the city specific and the joint projects
Organising for learning
organising for continued cross city learning
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
Scenario preparation
defining generic elements for future scenario's as preparation for the workshops with cities to develop specific desired future scenario's
Strategy & visuals
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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
WP8. Communication & dissemination
ROADMAPS FOR ENERGY®
R4E
Version 4 September 2015
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R4E - ROADMAPS FOR ENERGY

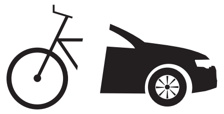
Introduction

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.

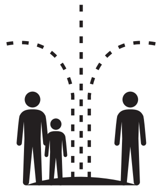
The R4E project focuses on the vision creation and roadmapping capacities of the municipalities. This includes initiating joint activities to drive the development and implementation of innovative energy solutions in cities. In this way the partners in R4E will learn the process and the roadmap structure. 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

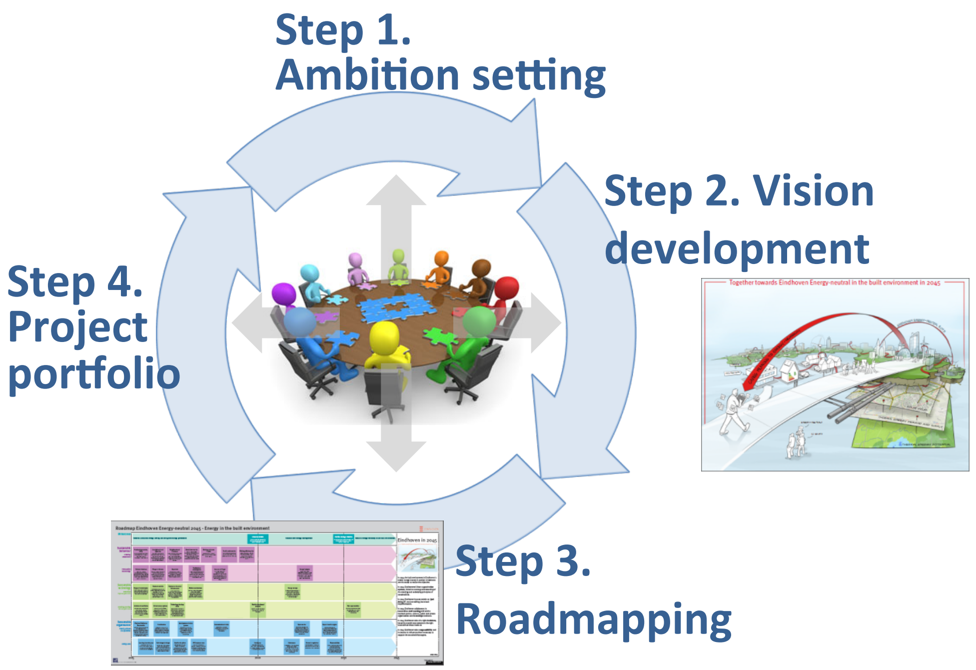
In The R4E project follows a 4-step approach:

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

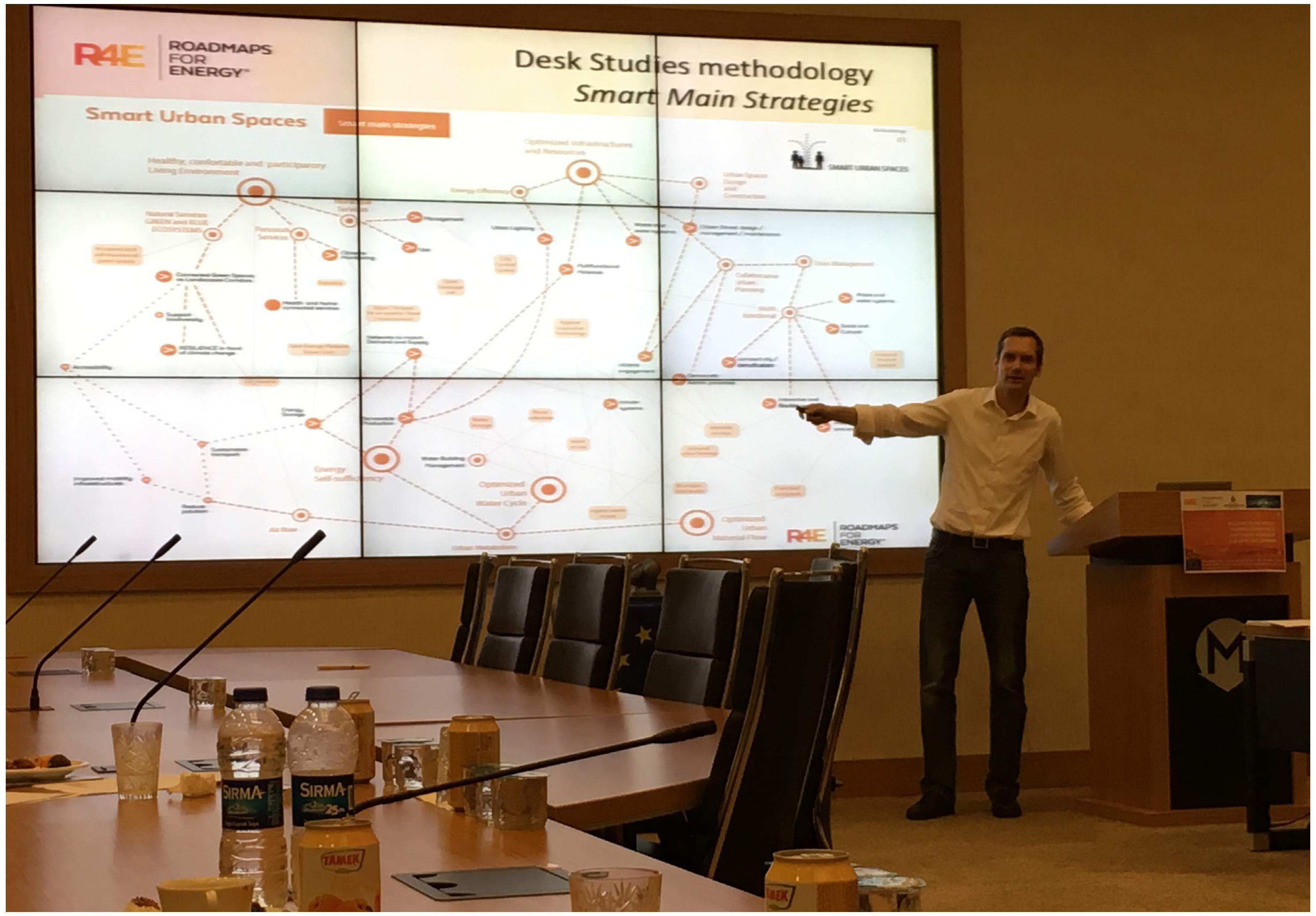
Step Three: Roadmapping

This report is part of Step 3 of the R4E approach and describes the first part of Workpackage 3 (WP3). The aim of WP3 is to develop the roadmap for Smart Buildings. In this roadmap the options to realise the desired future scenarios of the cities are explored. A desk study is done to collect available information on technological options. Experts from industry, knowledge institutes and governments will be invited to workshops to share their views on future possibilities. The extensive networks of the R4E partners is used to select experts with knowledge in this area. In the roadmap process international experts and companies are explicitly invited and workshops in different parts of Europe are held to collect all information. Through the network of the R4E cities also the local companies are invited to co-create the roadmaps. The roadmaps cover sustainable technologies, sustainable behaviour and sustainable organisation in order to realise the ambitions in Smart Buildings and sustainable energy in the built environment.

Desk Study

A desk study is conducted to collect available information on the future options that are relevant for the realisation of the desired future scenarios of the cities. This desk study covers all the topics that have been identified in the Joint Vision Workshop in Istanbul at the end of WP2 (see D2.2 - Report Vision Development). The findings of the desk study contribute to identify the most important experts to be invited for the roadmapping interviews and workshops.

Desk studies are conceived as a useful tool to help the cities to draw their own roadmap. They reflect and transmit the inherent complexity of sustainable processes and synergies wich are the enabler mechanisms to arrive to the desidered scenarios. In that way, it's not only about providing access to the most extensive information in the fields of sustainable technologies, behaviours and organization related to energy, but to give cities the capacity of using this information for developing the most suitable roadmap and corresponding projects.


R4E
ROADMAPS FOR ENERGY
Desk Studies methodology
Smart Main Strategies
Smart Urban Spaces
SIRMA


İSTANBUL
BÜYÜKŞEHİR
BELEDİYESİ
METRO
İSTANBUL
Her Yerde Metro, Her Yere Metro

Approach in WP3 - Roadmapping: Desk Study

City Visions and Scenarios

As a result of the vision development (Step 2) visualisations of the desired future scenarios have been created and during the joint vision workshop in Istanbul (May 2016) common visions of all cities have been described.

The aim of Step 3 is that cities develop their roadmaps in the selected focus areas based on these visions and scenarios.

Desk Study

To support the participatory processes of the R4E project in generating consistent roadmaps for energy and solid implementation plans, desk studies about the state of the art of energy technologies and related sustainability concepts and solutions are facilitated to the participant cities.

The individual city visions as well as the joint city visions have been taken as starting point in order to cluster the main areas of interest of all partners, represented in the desk study as "Smart Main Strategies".

The desk study is based on the following 4-step approach in order to structure knowledge and give consistent future outlooks on technologies related to smart energy strategies of cities.

SMART CASE STUDIES	SMART MAIN STRATEGIES	SYSTEMIC SOLUTION MAPS	TECHNOLOGY OUTLOOK
Reference important Case Studies which are already applying specific smart strategies for a sustainable energy future, e.g. Amsterdam, Stockholm or Freiburg	Cluster main concepts and ideas of stakeholders into basic strategies, e.g. Cooperative Buildings, Productive Buildings, or Urban Energy Self-sufficiency	Describe underlying systemic solutions through mapping the complexity of e.g. Collaborative Urban Planning, Green Energy Production, or Smart Thermal Grids	Resumes the state of the art and future outlook on specific technologies which form part of the systemic solutions, e.g. Urban Lighting, Photovoltaic or Energy Storage devices

General Outline of the desk study

After describing and further defining the Smart Main Strategies of the partner cities, based on the developed visions and scenarios for their energy future with horizon 2050, so called Systemic Solutions Maps are developed in order to represent graphically the complexity of each strategy and its interrelation with diverse concepts and technologies.

A third step consists in specific Technology Outlooks about technologies that have been mapped within the Systemic Solutions Maps, documenting their current state of the art, their specific challenges and their future perspectives.

In a fourth step Case Studies are referenced to the different Systemic Solutions in order to showcase light house projects of urban energy transition, which already apply specific smart strategies or technologies for a sustainable energy future.

This desk study structure allows all partners to generate and improve their knowledge in fields like e.g. the energetic refurbishment of existing buildings, or the establishment of smart energy grids with a high amount of distributed renewable energy sources, gaining a holistic and systemic vision of each strategy.

The specific feature of System Solutions Maps furthermore allows to be used as individual or collective tool for understanding complexity and interrelations among different strategies and technologies.

Systemic Solution Maps

Systemic Solution Maps are introduced as comprehensive representation of the inherent complexity of almost any strategy towards a reduced energy demand and a higher degree of sustainability on building level as well as on urban scale.

Systemic Solution Maps are the connecting elements, which allow to set into the right relation the basic Smart Main Strategies for a sustainable energy future and the existing and developing energy technologies as well as related technological solutions described through the Technology Outlook section.

The systemic approach allows to map visually the interrelation of different parameters for a specific approach, e.g., in the field of material flows, water consumption or renewable energy generation, facilitating the understanding of the complexity of each specific field of action, the interrelation of technical, organizational and social aspects, as well as the corresponding developing technological solutions, which allow to transform this current representation of complexity into a vision of a possible future.

Technology Outlook

Technology Outlooks contain information about identified technologies which are considered significant in the transformation towards a more sustainable energy future.

Technology Outlooks are structured in a description of the State of the Art of a specific technology, near future challenges and opportunities for innovation. Links to further information e.g. technology reports, white papers or research are included to facilitate complementary information to the reader.

Smart Case Studies

Case Studies are considered important element in order to visualize and discuss future options for buildings and cities. Case studies can be selected and included as inspiring examples into individual stakeholder processes of cities.

How to use

The Systemic Solution Maps are the core element of the desk studies in the areas of Smart Buildings and Smart Urban Spaces. Stakeholders may use the generated material in different forms, e.g.:

- read and reflect individually on these System Solution Maps (personal learning material)
- use in discussions and participatory processes (poster format in order to discuss collectively complex approaches and solutions)
- adapt or further develop maps according to each city specific social-economical, climatic, cultural and environmental context, e.g. relating maps and technologies in co-creation processes which allow to discuss and develop collectively local solutions

Roadmapping Workshops

System Solution Maps have been presented to the city partners at the joint Vision Building Workshop in Istanbul in May 2016, obtaining valuable input from city representatives regarding the readability of the maps, their usefulness as tools in participatory processes, and most specially about missing or under represented issues, which should be included within the maps, e.g. stronger references to urban resilience strategies or a stronger focus on the complexity of historic buildings within the city context.

This stakeholder feedback has allowed to introduce changes and to improve the documents for their use as supporting tools in the city specific Roadmapping Workshops.

In the contex of these Roadmapping Workshops Desk studies and the applied methodology of Systemic Solution Maps will then have to proof that they are useful tools for multi stakeholder processes, and that the mapping of complexities and relations among concepts, strategies and technologies will result in a useful identification of potential synergies and innovations.

GENERIC DESIRED FUTURE SCENARIOS

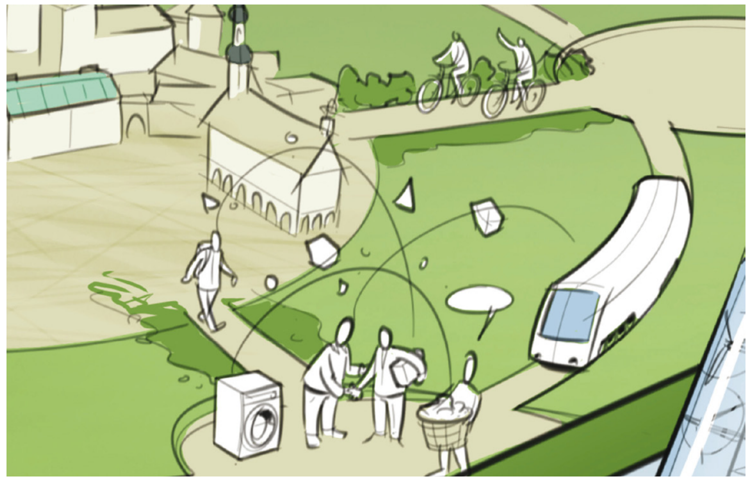
During the Joint Ambition Workshop on 19 October in Palermo the cities shared and discussed their ambitions for Smart Builidngs and identified the common aspects. The result was used for a description of the focus area Smart Buildings.

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.

During 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 had in-depth discussions to understand each other's needs and context (WP2). The seven identified aspects of the future scenarios that are common for all cities will be covered by the desk study in the remainder of this report. Moreover, the desk study provides relevant information on the future options that are relevant for the realization of the cities' generic desired future scenarios. The seven common needs for Smart Buildings that will be covered by the desk study, as part of the roadmapping step of the R4E project (WP3), are the following.

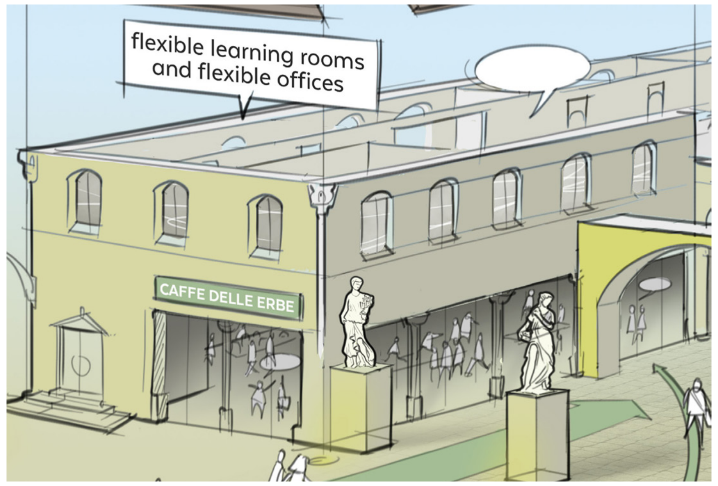
Energy-efficiency and sustainability

- 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



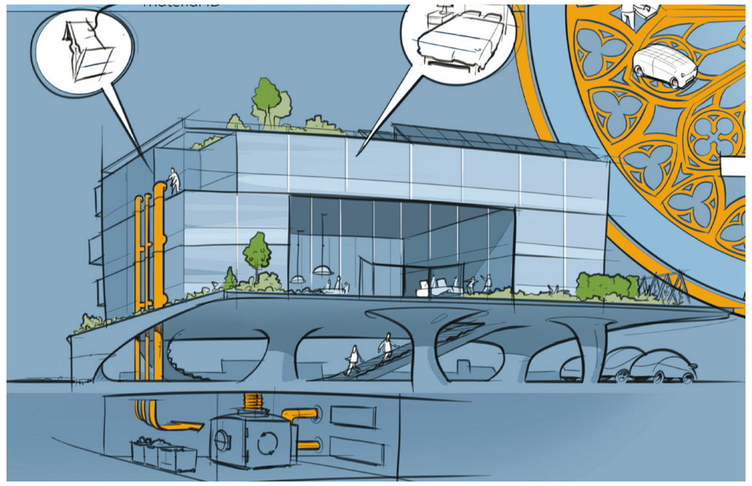
Community sharing

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



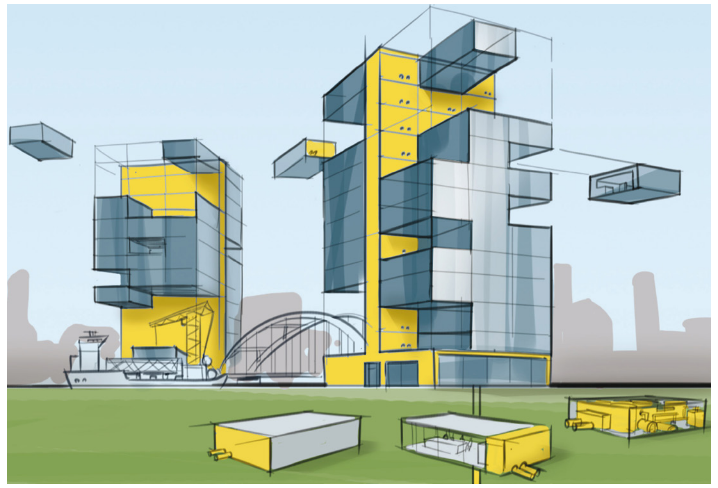
Renovation to secure cultural heritage

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



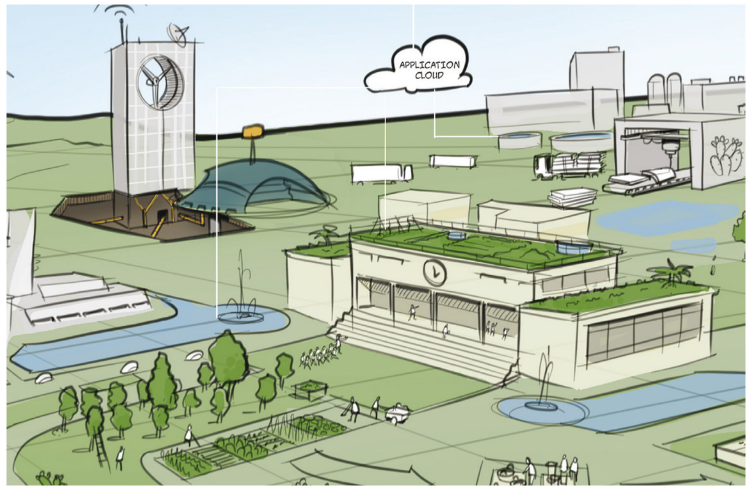
High quality, easily accessible systems

- 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 MAIN STRATEGIES

SMART BUILDINGS

Smart main strategies

The partners' desired future scenarios include many different aspects and needs across the list of the seven common needs for Smart Buildings. A clustering from the different needs has been made to explore the options for realising the desired future scenarios of the cities in a structured approach. The clustering and resulting Smart Main Strategies (SMS) have been jointly discussed with the city experts during the Joint Vision Workshop on 24th and 25th of May 2016 in Istanbul. The Smart Main Strategies are the starting point for the development of Systemic Solution Maps and Technology Outlooks of the Desk Studies.

The following five Smart Main Strategies are derived from the partners' common needs:

1 Energy self-sufficient Buildings

Buildings generate energy in order to cover their own demand and even deliver energy for electro mobility or other consumers nearby. Energy sources are renewable and building or site integrated.

Storage solutions at different scales, mini grids, demand side management and the connection to smart grids allow maximum energy efficiency at 100% renewables.

2 Productive Buildings

Buildings generate resources for urban life, like food through urban farming on roofs, terraces and even façades, energy through renewable energy systems, and water through rainwater harvesting and grey water recycling.

3 Zero Environmental Impact Buildings

Buildings produce low or even no emissions of CO_2 or other greenhouse gases, contributing to a clean and healthy urban environment.

Materials of new buildings and retrofitting solutions use natural materials with low or even no waste production during construction, and a lifecycle concept for materials and systems, which allow closing the material cycle on mid and long term.

4 Adaptable Buildings

Different uses are possible for many public, but also private buildings through adaptable multi functional spaces, which are controlled, maintained and managed through tele management.

Buildings also adapt to weather and even climate change through adaptive and reactive building envelopes, which optimize indoor comfort and energy efficiency of buildings..

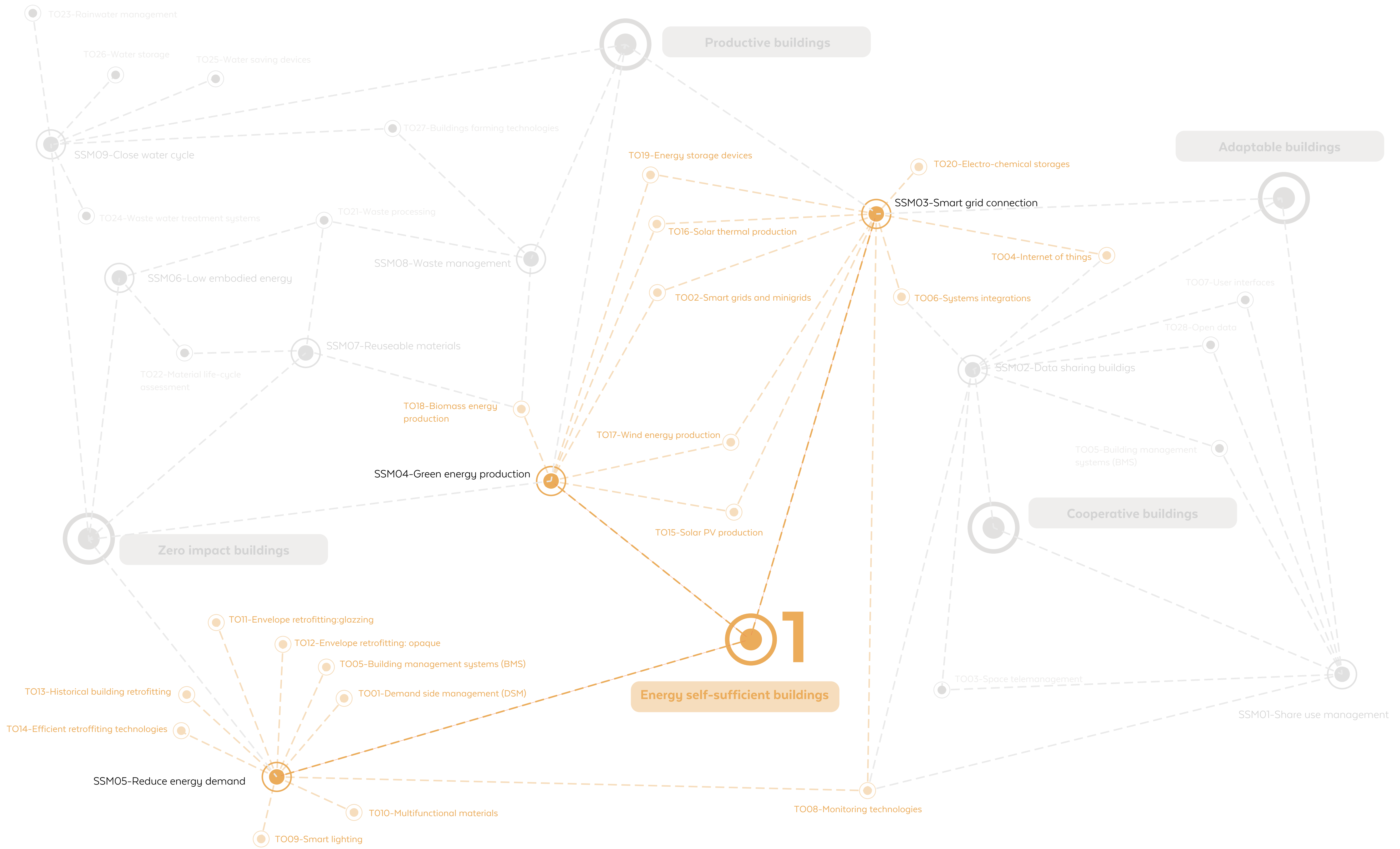
5 Cooperative Buildings

Synergies are fostered among buildings regarding energy generation, storage and consumption, and resource availability in general (space, water, energy, food, social capital).

Buildings are cooperating among each other's to interchange these resources for an overall resilient community.

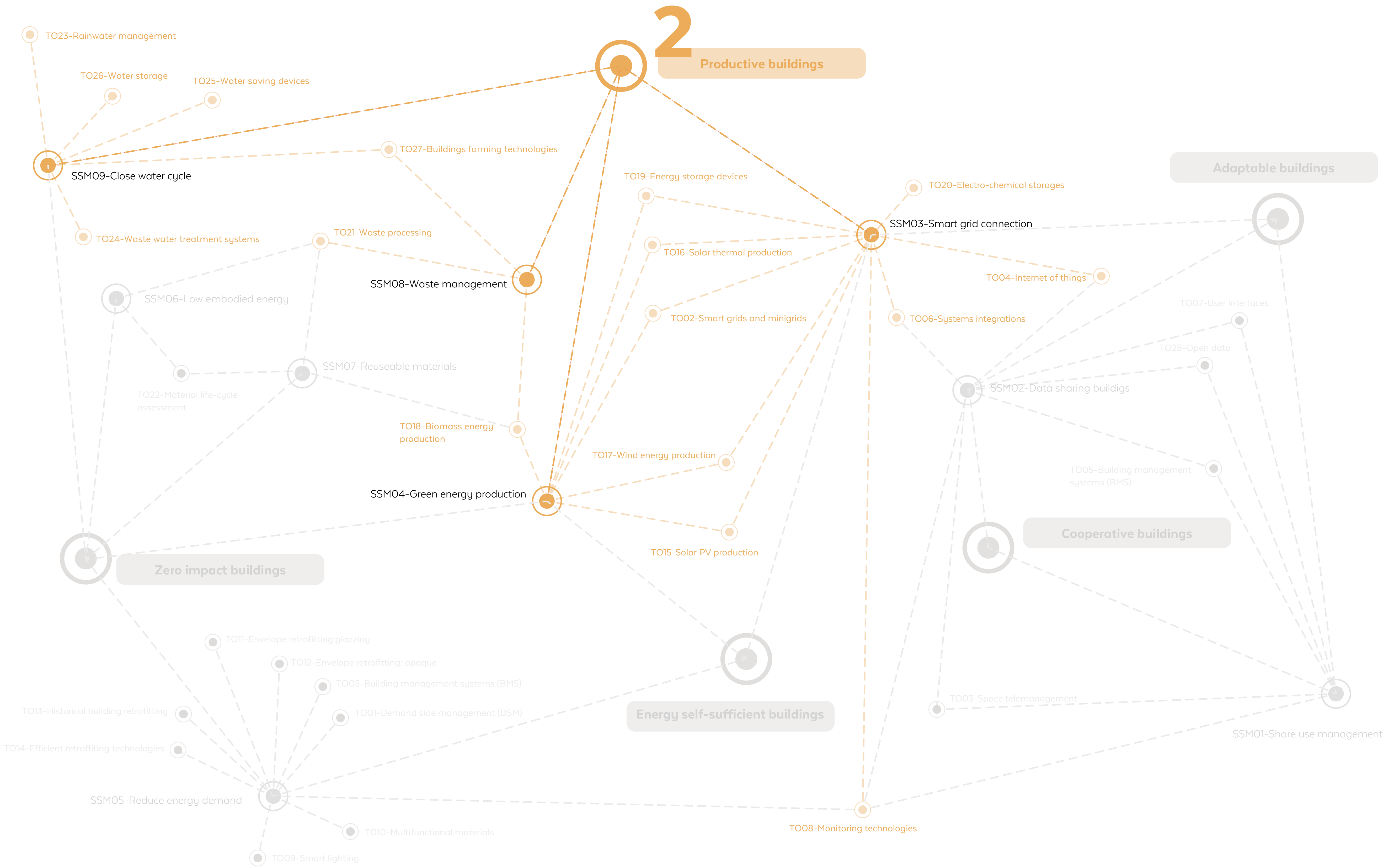
They also generate synergies among habitants and neighbours through specific housing concepts and space design, facilitating social interaction, neighbourhood initiatives and collaborative actions, increasing the "social efficiency" of a place.

Smart main strategies - Energy self-sufficient buildings



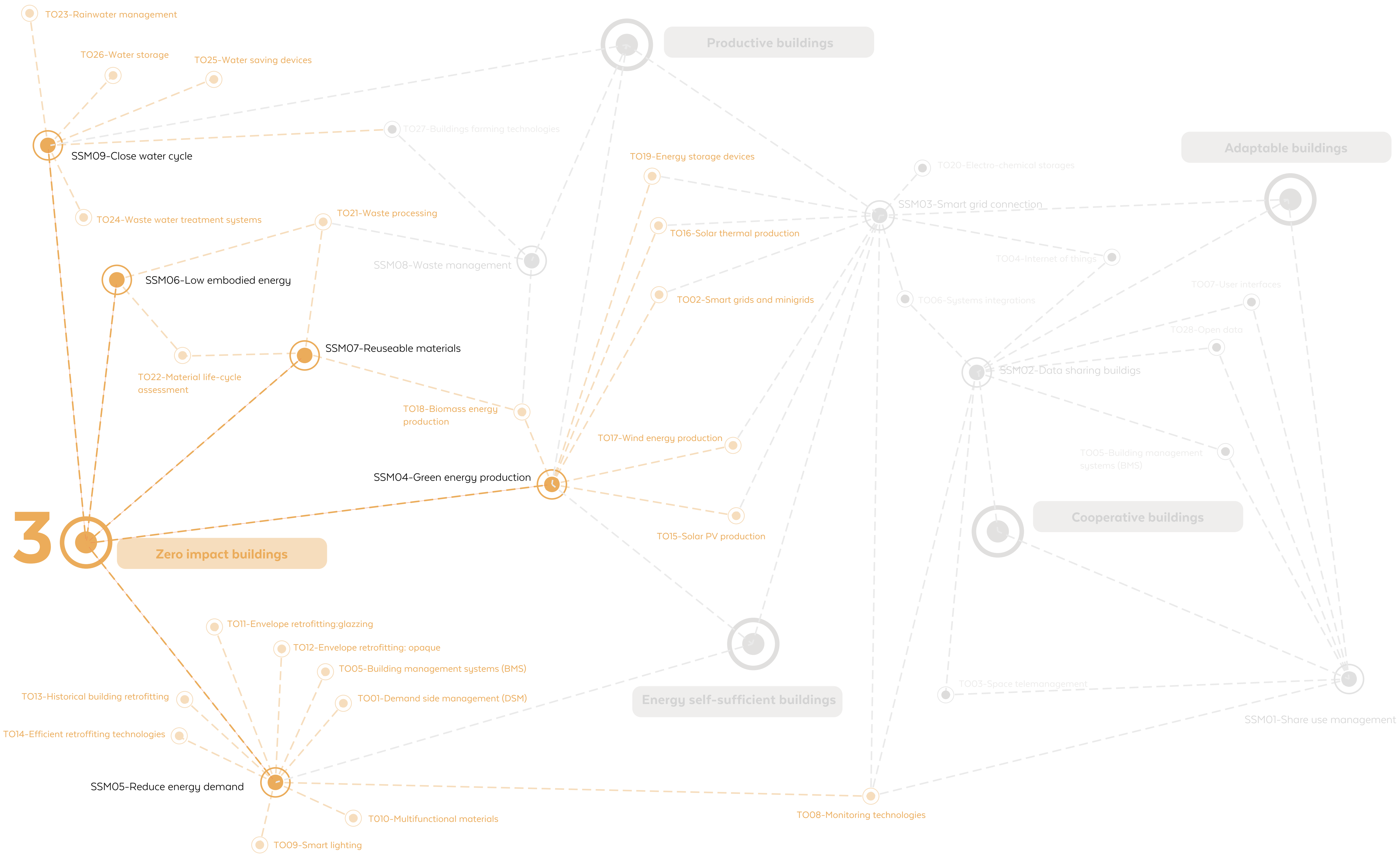
SMART BUILDINGS

Smart main strategies - Productive buildings



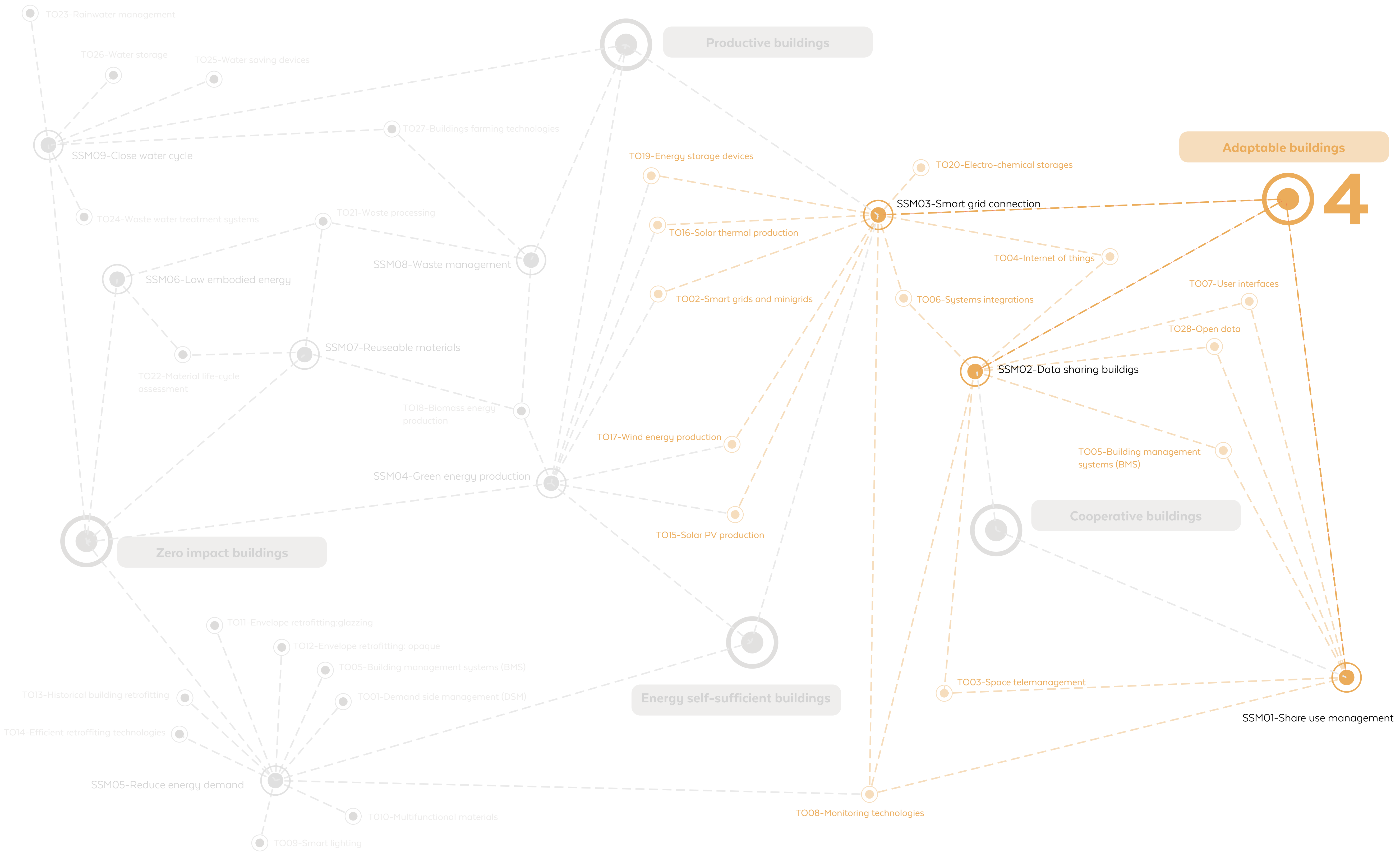
SMART BUILDINGS

Smart main strategies - Zero impact buildings

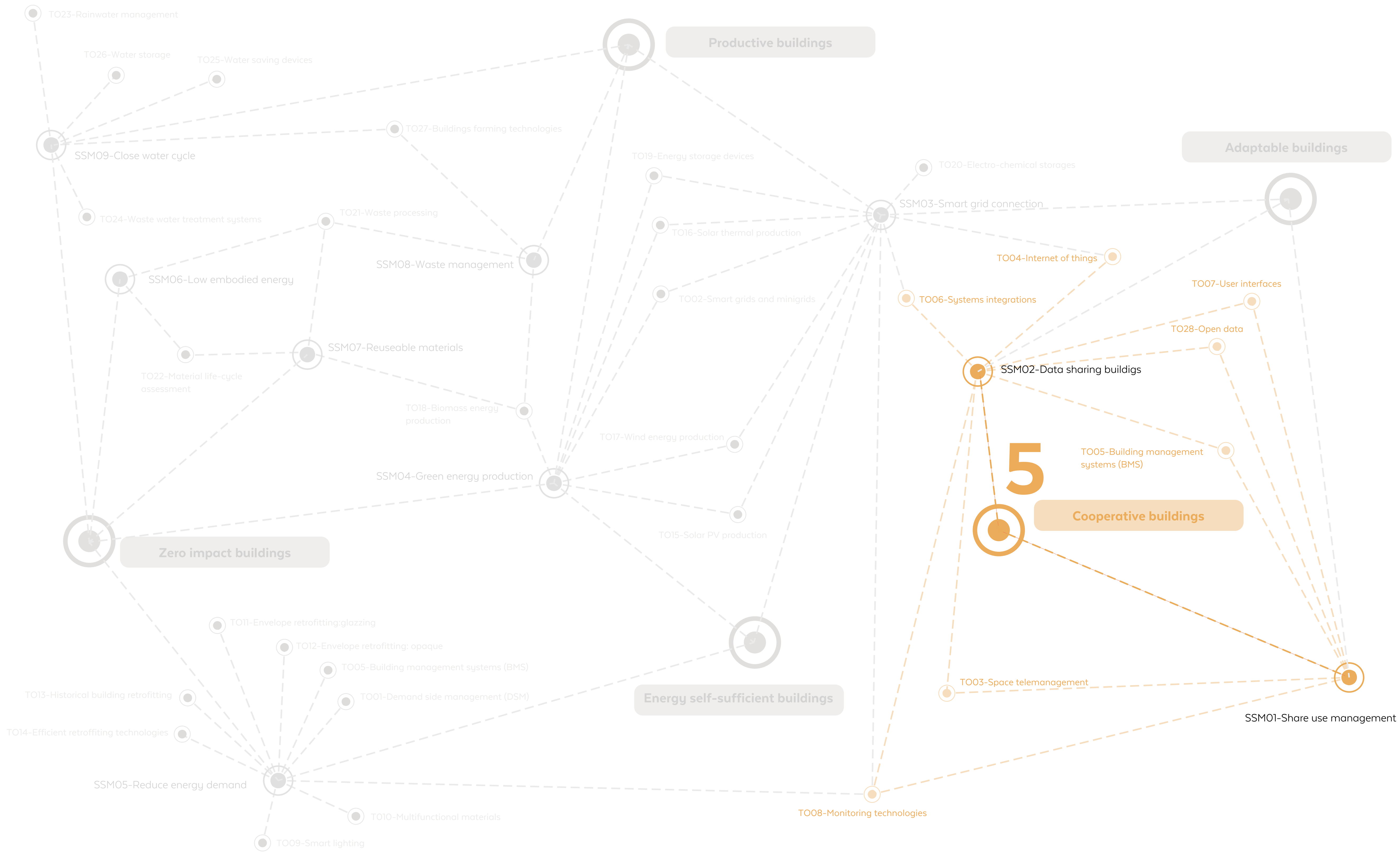


SMART BUILDINGS

Smart main strategies - Adaptable buildings



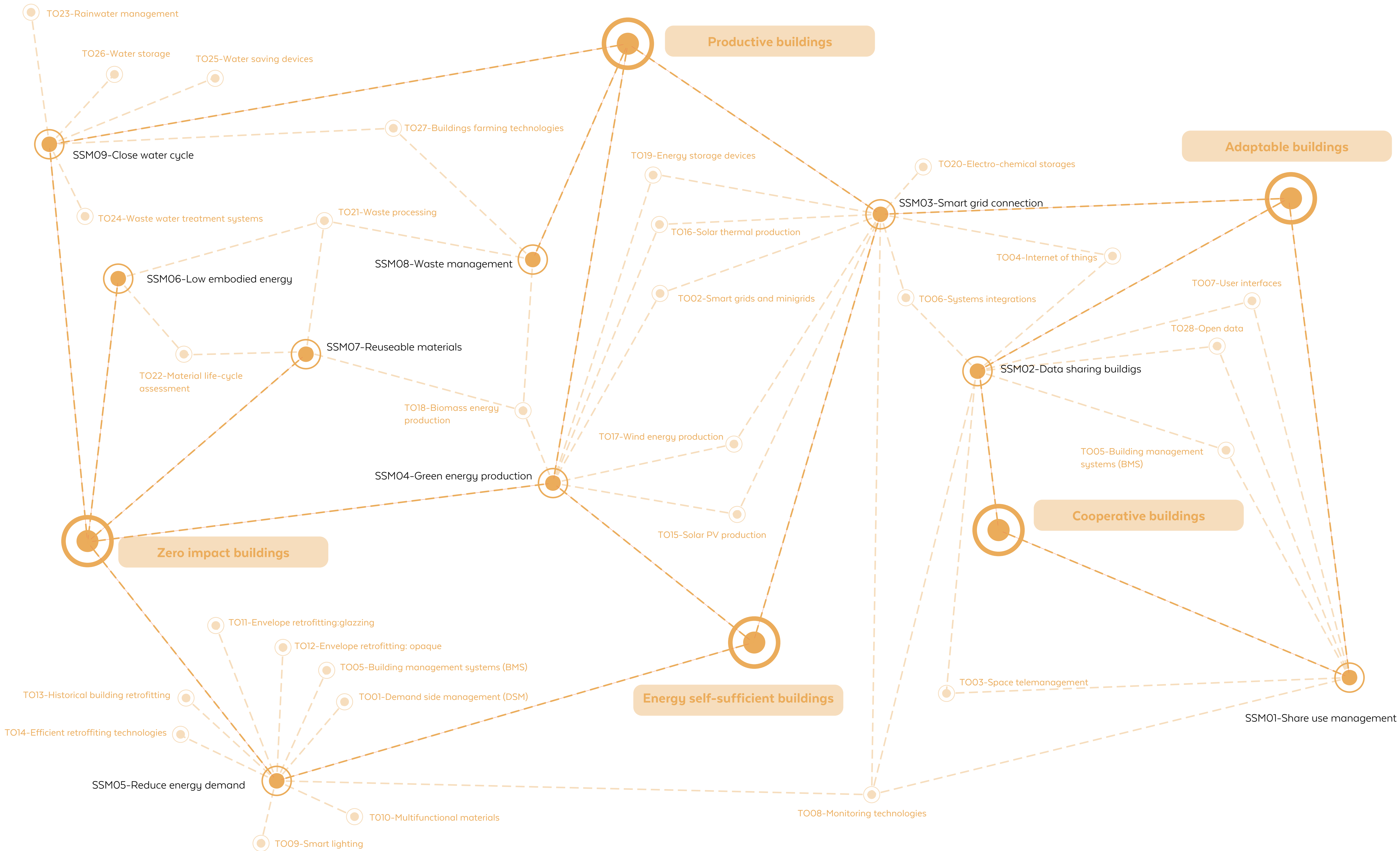
Smart main strategies - Cooperative buildings



SMART BUILDINGS

Smart main strategies

In order to support the participatory processes of the R4E project in generating consistent roadmaps for energy and solid implementation plans, desk studies about the state of the art of energy technologies and related sustainability concepts and solutions are facilitated to the participant cities. The individual city visions as well as the joint city visions have been taken as starting point in order to cluster the main areas of interest of all partners, represented in the desk study as “Smart Main Strategies”



SYSTEMIC SOLUTION MAPS

SMART BUILDINGS

SSM-01 Shared use management

Case studies

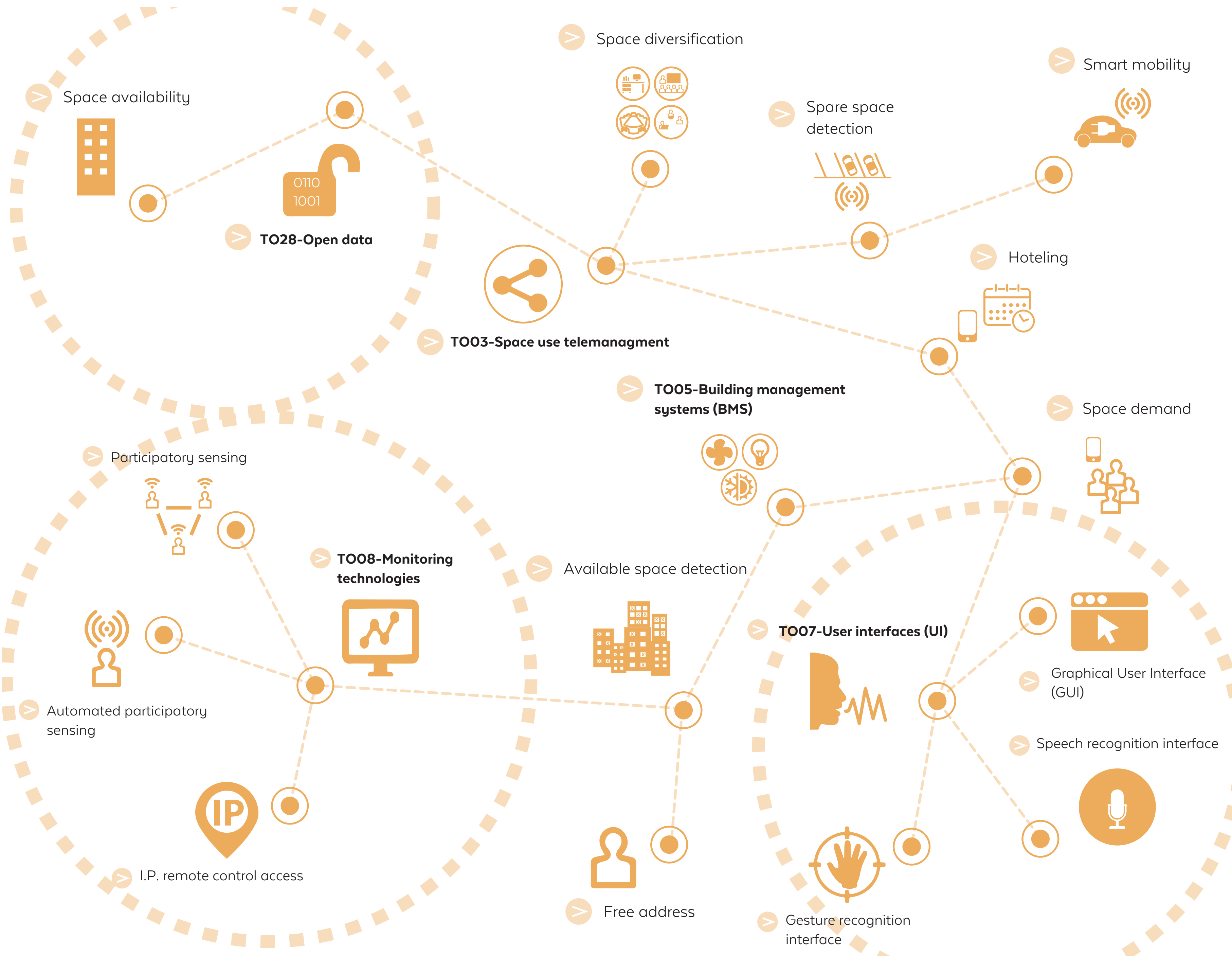
San Francisco

https://liquidspace.com/?looking=no

London

http://neuehouse.com/

Shared spaces reduce costs, improve collaboration, and have social impact by ensuring that non-profit organizations and other social agencies have access to quality spaces for work, the arts, and education. At neighbourhood and community levels, non-profit centres and hubs are important assets, essential to creating inclusive and vibrant communities. A strategy to develop this capacity could be based in administrative platforms to identify and support how shared physical spaces can be used to tackle organizational and community challenges. In a 2011 Harvard Business Review article, Michael Porter proclaimed that the purposes of corporations must be grounded in “shared value” that reconnects “company success with social progress” as a “new way to achieve economic success”. Shared platforms, shared services, shared spaces, and broadly, the sharing economy (with Airbnb as the most notable preacher) are now well rooted and growing exponentially.



Future Challenge

The ability to work remotely is on the rise. And this change is redefining family and community structures. The spending habits of a new generation of millennials are reflecting a focus on efficiency and fulfilling experiences. Communication software companies have to build tools that keep remote teams connected.

As work becomes more flexible and communication more mobile, the office is turning into an increasingly complex and even abstract concept. Will the workplace be on-site at employer's property, or on-demand at a collaborative space? Or will work simply be a mindset independent of place or time of day?

Technologies

TO03-Space use telemanagement

Organizationally, shared spaces reduce costs, improve collaboration, and enhance impact by ensuring that nonprofits and other social agencies have access to quality spaces for work, the arts, and education

- **Coworking**
  It is the sharing of workspace among freelance and other independent workers
- **Community Hub**
  It is place-based, dedicated to serving a specific geographic area, for example, at neighbourhood level or as a hub for rural areas.
- **Multi-tenant non-profit centres (MTNC)**
  (1) they are composed of multiple primarily not-for-profit tenant organizations;
  (2) they exist as a physical site (one or more buildings)
  (3) they typically provide office space, rent rates, and lease terms oriented to the non-profit sector and provide services.

TO07-User interfaces UI)

There is an interface for each technology. It may be a simple, mechanical handle or a complex, digital display, but there needs to be a connection between what is used and its user.

There are several types of UI:

- **Graphical user interface (GUI)**
- **Direct manipulation interface**
- **Gesture recognition interface**

TO05-Building management systems

A building management system (BMS), or building automation system (BAS), is a computer-based control system installed in buildings that controls and monitors:

- **Lighting**
- **Power systems**
- **fire systems**
- **Security systems**

TO08-Monitoring technologies

The function of monitoring systems is data acquisition and transfer to the management system.

In monitoring systems, sensors are responsible of data acquisition. Different kinds of sensors detect different kinds of physical quantities or their change rate:

- **CO_2 levels**
- **Energy consumption**
- **Temperature**
- **Wind speed movement**
- **Heat radiation**

TO28-Open data

Open data is data that are free to use, reuse, and redistribute. It is considered an important enabler of building smartification contributing to innovation with occupants and business value-added applications and services.

The concept of inter-connected collaborative buildings builds on top of the grid-connected buildings idea to further increase energy savings as well as improvements that align with smart grid requirements.

SMART BUILDINGS

SSM-02 Data sharing buildings

Case studies

Montpellier

http://www.invest-in-montpellier.com/entreprendre-grands-projets/smart-city

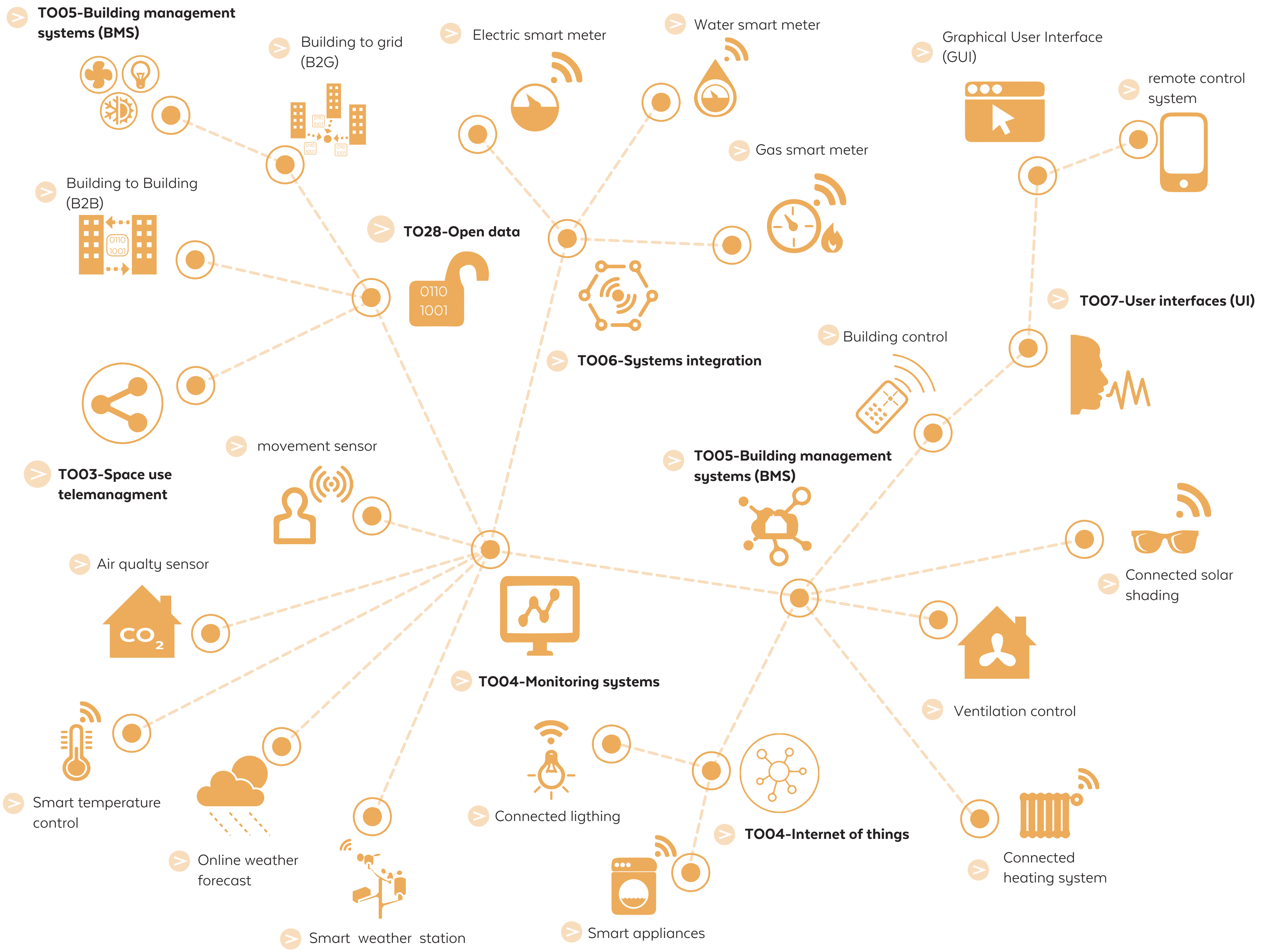
Maribor

http://www.smartcitymaribor.si/en/Projects/Smart_Environment_and_Energy/Smart_neighbourhood_Maribor/

Future Challenge

The power grid will be able to notify buildings when excess energy is available and needs to be dissipated. Because of the collaborative nature of the buildings, this energy will be consumed by multiple buildings to achieve most optimal energy utilization. Multi-objective optimization techniques such as advanced heuristic methods can be used to achieve optimal energy utilization.

While collaborative entities are a basic concept in the overall smart grid design, intra-building collaboration and its advantages are rarely discussed. The concept of inter-connected collaborative buildings builds on top of the grid connected buildings idea to further increase energy savings as well as improvements that align with smart grid requirements. Building to Grid (B2G) interoperability can be viewed as having one of the highest energy efficiency impacts. While experiments with local generation (wind or solar), or local storage (water tanks) exist today, integrated peak-shaving strategy is not yet taking an active role, even in smart cities. Advanced decision supports tools such as fuzzy decision engines that utilize expert knowledge and building/grid requirements can be used in addition to other algorithms to achieve short/long term building prediction and peak-shaving. The algorithms will need to be based on interoperability with utilities and market pricing in order to achieve required improvements of peak-shaving.



Technologies

TO03-Space use telemanagement

Organizationally, shared spaces reduce costs, improve collaboration, and enhance impact by ensuring that non-profits and other social agencies have access to quality spaces for work, the arts, and education. There are different ways to share spaces:

- **Coworking**
- **Community Hub**
- **Multi-tenant non-profit centres (MTNC)**

TO05-Building management systems

A building management system (BMS), or building automation system (BAS), is a computer-based control system installed in buildings that controls and monitors:

- **Ventilation**
- **Lighting**
- **Power systems**
- **fire systems**
- **Security systems**

TO07-User interfaces

There is an interface for each technology. It may be a simple, mechanical handle or a complex, digital display, but there needs to be a connection between what is used and its user.

There are several types of UI:

- **Graphical user interface (GUI)**
- **Direct manipulation interface**
- **Gesture recognition interface**

TO04-Internet of things

The internet of things (IoT) is the internetworking of physical devices, vehicles, buildings and other items—embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data.

TO06-Systems integration

In information technology, systems integration is the process of linking together different computing systems and software applications physically or functionally, to act as a coordinated whole.

TO08-Monitoring technologies

The function of monitoring systems is data acquisition and transfer to the management system.

In monitoring systems, sensors are responsible of data acquisition. Different kinds of sensors detect different kinds of physical quantities or their change rate:

- **CO_2 levels**
- **Energy consumption**
- **Temperature**
- **Wind speed movement**
- **Heat radiation**

TO28-Open data

Open data is data that are free to use, reuse, and redistribute.

The concept of inter-connected collaborative buildings builds on top of the grid connected buildings idea to further increase energy savings as well as improvements that align with smart grid requirements.

SMART BUILDINGS

SSM-03 Smart grid connection

Case studies

Amsterdam

https://amsterdamsmartcity.com/projects/usage-of-smart-cooling-and-heating-systems-for-pharmaceutical-processes-rc01jgzv

Umea

http://www.formas.se/pagefiles/5460/formas_sb11_brochure.pdf

Maribor

http://www.smartcitymaribor.si/en/Projects/Smart_Environment_and_Energy/Smart_neighbourhood_Maribor/

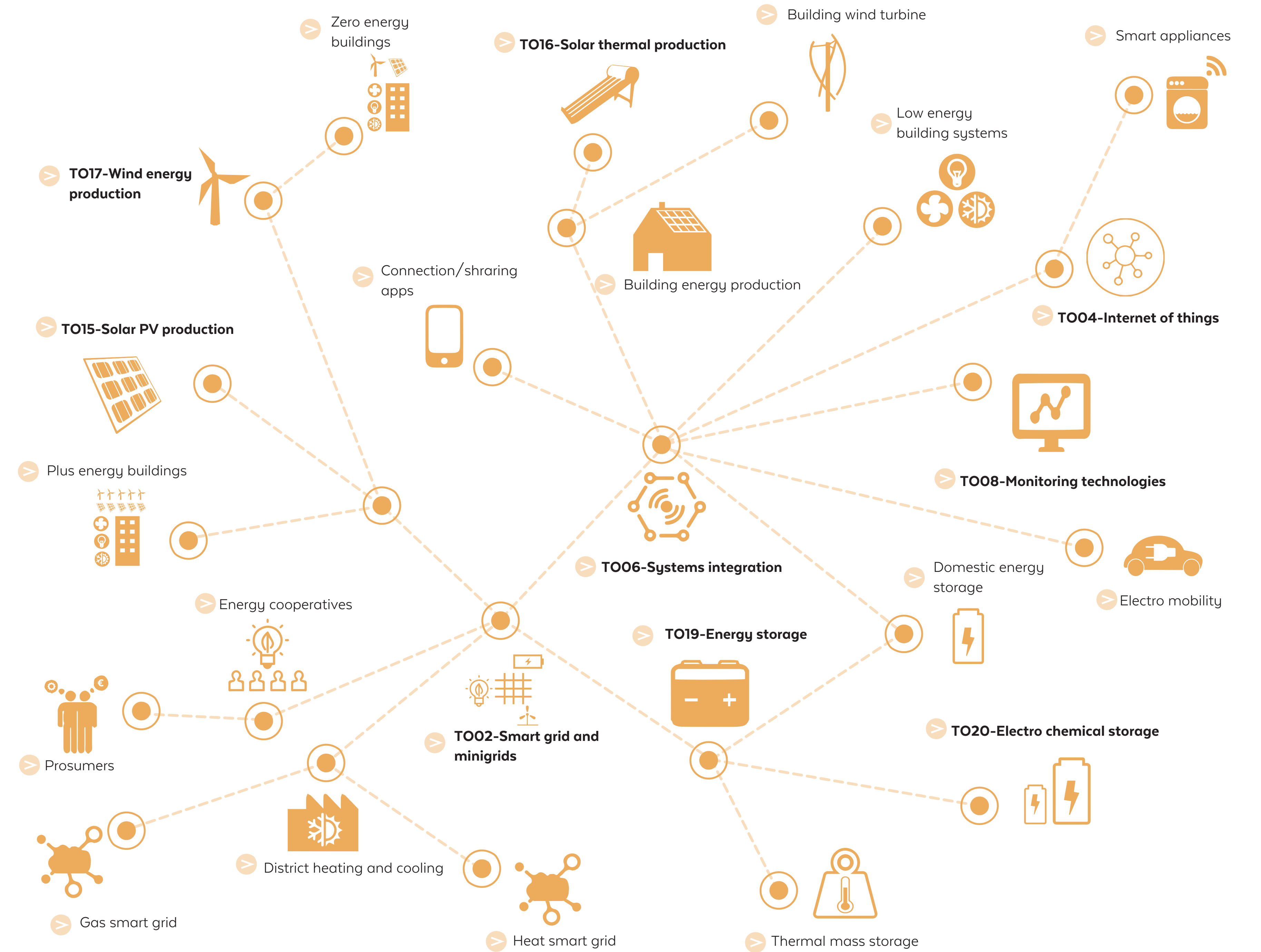
Future Challenge

A smarter electricity grid could fundamentally change the way people pay for and manage their electricity use. In theory, the technology could help reduce demand, save money, and improve reliability and efficiency. But implementing the necessary changes will be difficult.

The smart grid will incorporate new networking technology, including sensors and controls that make it possible to monitor electricity use in real time and make automatic changes that reduce energy waste. Furthermore, grid operators should be able to instantly detect problems that could lead to cascading outages.

For consumers, the smart grid could also mean radical changes in the way they pay for electricity. Instead of a flat rate, they could be charged much more at times of high demand, encouraging them to reduce their energy use during these periods

Smart grids are energy networks that can automatically monitor energy flows and adjust to changes in energy supply and demand accordingly. When coupled with smart metering systems, smart grids reach consumers and suppliers by providing information on real-time consumption. Some of the benefits of such a network include the ability to reduce power consumption at the consumer side during peak hours, called demand side management; enabling grid connection of distributed generation power (with photovoltaic arrays, small wind turbines, micro hydro, or even combined heat power generators in buildings); incorporating grid energy storage for distributed generation load balancing; and eliminating or containing failures such as widespread power grid cascading failures. The increased efficiency and reliability of the smart grid is expected to save consumers money and help reduce CO_2 emissions.



Technologies

TO02-Smart grid and minigrids

A smart grid is an electrical grid which includes a variety of operational and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficiency resources. Associated concepts:

- **Universal access**
- **Hybrid and smart mini-grids**

TO08-Monitoring technologies

The function of monitoring systems is data acquisition and transfer to the management system.

Different kinds of sensors detect different kinds of physical quantities:

- **CO_2 levels**
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- **Wind speed movement**
- **Heat radiation**

TO16-Solar thermal production

Most of the energy we need is heat, which solar panels and wind turbines cannot produce directly. Direct use of solar energy can be the solution.

Solar water heating system are classified by the following types:

- **Active systems**
- **Passive systems**
- **Direct systems**
- **Indirect systems**

TO19-Energy storage

Most of the renewable energy resources, such as solar and wind power, require to store the energy produced in order to ensure its availability independently of the availability of the resource at a specified time. Several technologies have been developed for storage.

TO04-Internet of things (IoT)

IoT is the internetworking of physical devices, vehicles, buildings and other items—embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data.

TO06-Systems integration

Systems integration is the process of linking together different computing systems and software applications physically or functionally, to act as a coordinated whole.

TO15-Solar PV production

Photovoltaic allows for a decentralized energy generation in buildings with a minimum impact on the environment. There are different PV technologies:

- **Crystalline materials**
- **Thin film solar cells**
- **Concentrated solar PV (CPV**

TO17-Wind energy production

Wind energy can take many forms, and there are many different segments in this industry serving different needs. Wind turbines can be classified into:

- **Horizontal axis wind turbines.**
- **Vertical Axis Wind Turbines**

TO20-Electro chemical storage

Electrochemical capacitors (EC) store direct electrical charge in a material. Then, batteries convert the charge into chemical energy, or SMES into magnetic field energy.

SSM-04 Green energy production

Case studies

Vauban

http://www.vauban.de/en/

Amsterdam

https://amsterdamsmartcity.com/projects/city-zen-virtual-power-plant

Hammarby Sjöstad (Stockholm)

http://www.symbiocity.org/en/approach/Cases-undersidor/Hammarby-Sjostad-three-in-one/

Maribor

http://www.smartcitymaribor.si/en/Projects/Smart_Environment_and_Energy/Smart_neighbourhood_Maribor/

Future Challenge

Renewable energy technologies have an enormous potential and that potential can be realized at a reasonable cost. Market research shows that many customers will purchase renewable power even if it costs somewhat more than conventional power.

However, significant market barriers and market failures will limit the development of renewables unless special policy measures are enacted to encourage that development. These hurdles can be grouped into four categories

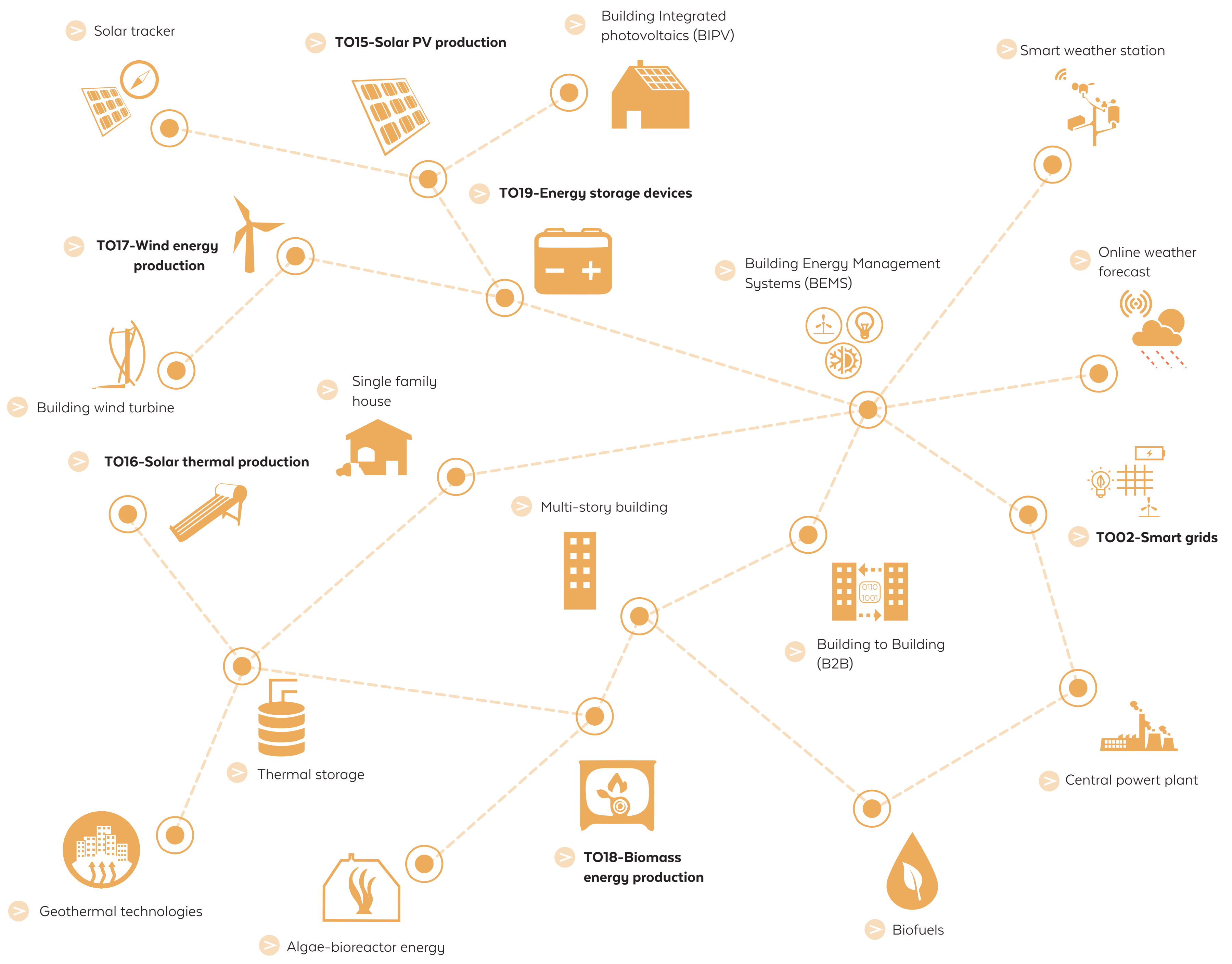
Commercialization barriers faced by new technologies competing with mature technologies

Price distortions from existing subsidies and unequal tax burdens between renewables and other energy sources.

Failure of the market to value the public benefits of renewables.

Market barriers such as inadequate information, lack of access to capital, "split incentives" between building owners and tenants, and high transaction costs for making small purchases.

Renewable energy is generally defined as energy that is collected from resources which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services. Sun and wind energy are free, but because they are not constant sources of power, renewable energy is considered "variable"—it is affected by location, weather and time of day. Utilities need to deliver reliable and steady energy by balancing supply and demand. While today they can usually handle the fluctuations that solar and wind power present to the grid by adjusting their operations, as the amount of energy supplied by renewables grows, better battery storage is crucial.



Technologies

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- **Horizontal axis wind turbines.**
- **Vertical Axis Wind Turbines**

TO18-Biomass energy production

Biomass is the sole renewable source of energy that provide solid, liquid and gaseous fuels which can be stored and transported.

The term biomass encompasses a large variety of materials as:

- **Wood,**
- **Agricultural residues**
- **Animal and human waste**

Biomass has the advantage of being controllable and available when needed.

SMART BUILDINGS

SSM-05 Reduced energy demand

Case studies

Vauban

http://www.vauban.de/en/

Salzbourg

http://www.smartcities.at/city-projects/smart-cities-en-us/smart-district-gnigl-en-us/

Umea

http://www.formas.se/pagefiles/5460/formas_sb11_brochure.pdf

Maribor

http://www.smartcitymaribor.si/en/Projects/Smart_Environment_and_Energy/Smart_neighbourhood_Maribor/

Rotterdam

http://www.rotterdamclimateinitiative.nl/uk/news/100,000-m2-of-green-roofs-in-rotterdam?news_id=944

Future Challenge

Important investments need to be made in order to achieve meaningful improvements in energy efficiency. Thus, it is crucial to find out where the opportunities are and prioritize the measures of greatest potential. This requires processing great amounts of data resulting from the variety of types of buildings.

Improving energy efficiency and reducing energy demand are widely considered as the most promising, fastest, cheapest and safest means to mitigate climate change. Many opportunities appear to be cost-effective and can deliver additional benefits such as improved energy security, reduced fuel poverty and increased economic productivity. Smart systems may help to reduce energy demand in buildings by controlling energy gains and losses and adapting the building operation to climate changes and users' needs. The control of the ventilation rate, the use of highly efficient appliances that communicate each other in order to avoid or encourage simultaneity and reduce peak demand, the coordination between energy production and consumption are some of the possible strategies.

Technologies

TO01-Demand side management (DSM)

DSM is the modification of energy consumers' demand through various methods as:

- **Financial incentives**
- **Behavioural change through education**

TO09-Smart lighting

Automatic lighting control systems reduce energy consumption by decreasing operating time of lamps based on various factors like occupancy, time of day, availability of daylight, etc.

TO11-Envelope retrofitting: glazing

Different technologies exist to control energy losses.

- **Clear glass and shading**
- **Double skin facades**
- **Automated operation dynamic facades**
- **Advanced solar control glazing**
- **Dynamic glazing**
- **Switchable Liquid Shielding**

TO13-Historical building retrofitting

Using the existing technology it is possible to enhance the sustainability of historic buildings without compromising their unique historic character.

TO14-Efficient retrofitting techs.

It is vital to prioritize and organize the actions to be undertaken. There are different upgrade approaches:

- **Whole-building approach**
- **Fabric first approach**
- **Passivhaus approach**
- **"Insulate then generate" approach.**

TO05-Building management systems

A building management system (BMS) is a computer-based control system installed in buildings that controls and monitors:

- **Ventilation**
- **Lighting**
- **Power systems**
- **fire systems**
- **Security systems**

TO10-Multifunctional materials

Multifunctional materials can react upon external stimulus, simulating, in this way, the behaviour of nature's materials.

It is possible to identify three major families of multifunctional materials:

- **Structural composite materials**
- **Smart or intelligent materials**
- **Nanostructured materials**

TO12-Envelope retrofitting: opaque

New thermal insulation materials are being developed towards higher performance, which allows for the reduction of the thickness needed to reach sufficient levels of thermal insulation.

TO08-Monitoring technologies

The function of monitoring systems is data acquisition and transfer to the management system.

Different kinds of sensors detect different kinds of physical quantities:

- **CO_2 levels**
- **Energy consumption**
- **Temperature**
- **Wind speed movement**
- **Heat radiation**

SMART BUILDINGS

SSM-06 Low embodied energy

Case studies

Helsinki (Viiki)

http://www.hel.fi/static/kanslia/uuttahelsinkia/Pimwag_Ecological%20building%20criteria_report.pdf

Hammarby Sjöstad (Stockholm)

http://www.symbiocity.org/en/approach/Cases-undersidor/Hammarby-Sjostad-three-in-one/

Umea

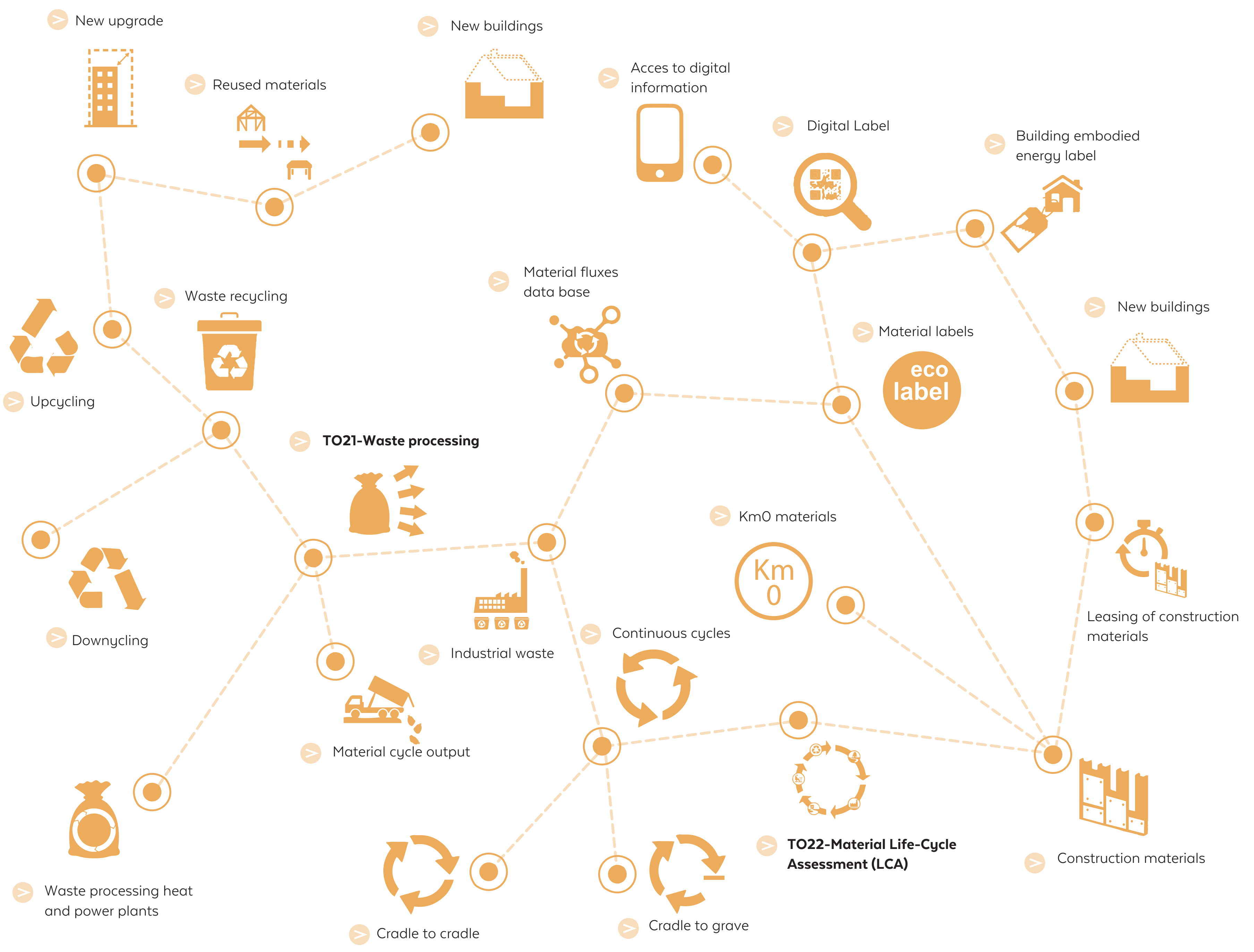
http://www.formas.se/pagefiles/5460/formas_sb11_brochure.pdf

Future Challenge

The materials used in construction need to be carefully considered. Conventional building materials not only represent high levels of embodied energy but also use resources that are finite and are being depleted. Renewable building materials are those materials that can be regenerated quickly enough to remove the threat of depletion and in theory their production could be carbon-neutral.

The commercial availability of renewable materials, however, is a limiting factor and indicate that the industry is not yet well positioned to embrace the strategy to reduce embodied energy of construction. While some conventional building materials could readily be replaced, in many instances a renewable substitute could not be found.

The term “embodied energy” refers to the energy that is used during construction. This includes the energy needed to obtain raw materials; the energy needed to then turn these raw materials into building materials such as timber, concrete, steel, or bricks; the energy used to transport the materials; and finally, the energy needed to power the tools and machinery needed for construction. Another element of embodied energy that you may not think of is how long the materials used in construction will last as each demolishing or renovation will consume more energy and raw materials. therefore, building for quality and durability will actually reduce your building’s embodied energy. The total amount of embodied energy may account for 20% of the building’s energy use, so reducing embodied energy can significantly reduce the overall environmental impact of the building.



Technologies

TO21-Waste processing

It is the management activity that disposes of waste through methods as:

- **Incineration**
- **Landfilling**
- **Reuse**
- **Recycling**
- **Bio-digester**

TO22-Material life-cycle assessment

Life-cycle assessment (LCA, also known as life-cycle analysis or eco-balance) provides a standarised process of examining the environmental impacts of a material, product or service through its entire life-cycle.

Life-cycle stages include:

- **Extraction of raw materials processing**
- **Fabrication**
- **Transportation**
- **Installation**
- **Use**
- **Maintenance,**
- **Reuse/recycling/disposal**

SMART BUILDINGS

SSM-07 Reusable Materials

Case studies

Helsinki (Viiki)

http://figbc.fi/en/building-sector/viikki-environment-house/

London

http://www.recipro-uk.com/

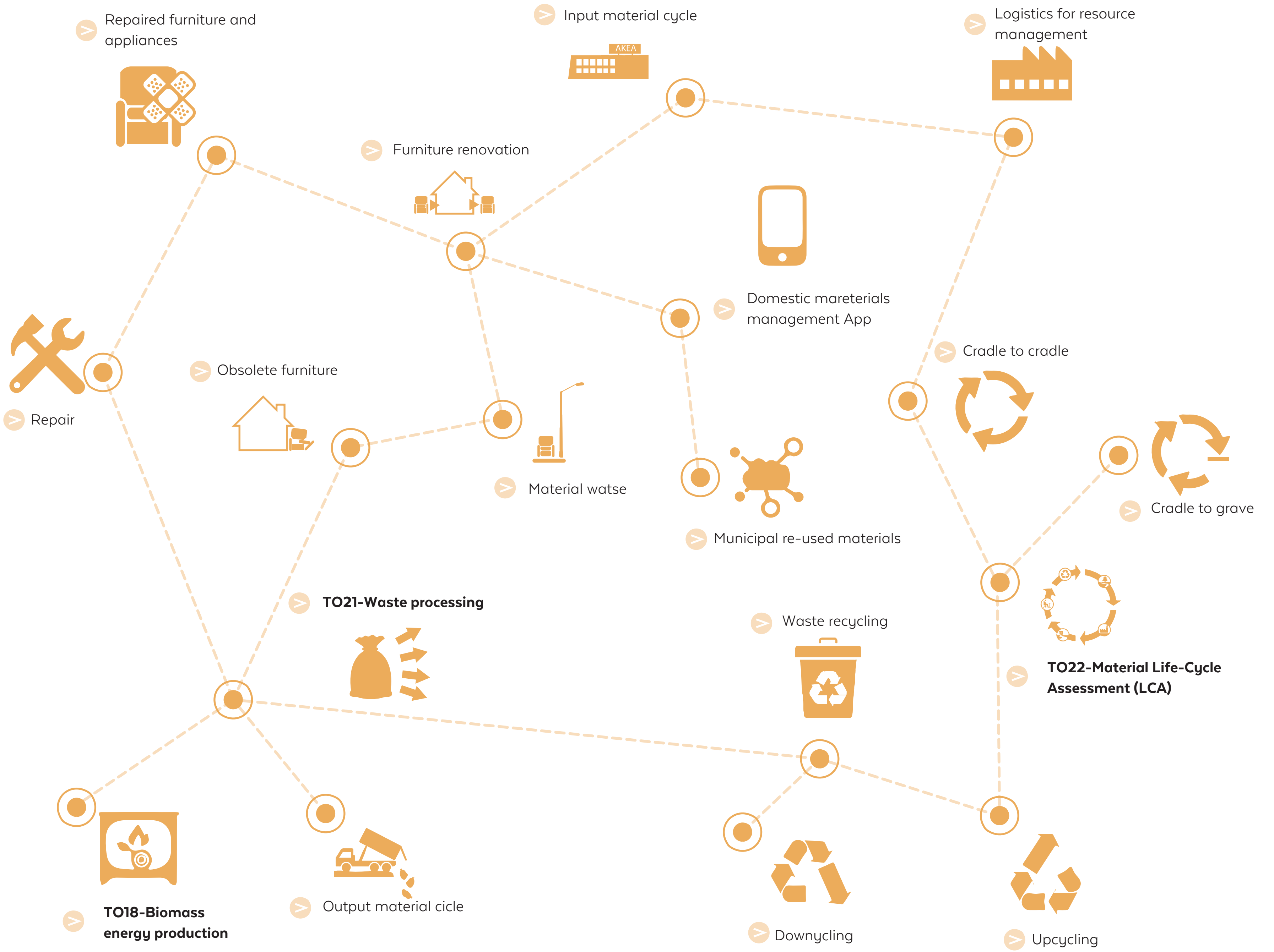
Future Challenge

Current levels of tuse and disposal material generate several environmental problems. For instantece, around 4 per cent of world oil and gas production, a non-renewable resource, is used as feedstock for plastics and a further 3–4% is expended to provide energy for their manufacture.

A major portion of material used each year is used to make disposable items of packaging or other short-lived products that are discarded within a year of manufacture. Our current use of materials is not sustainable. In addition, because of the durability of some materials, substantial quantities of discarded end-of-life products are accumulating as debris in landfills and in natural habitats worldwide

Recycling is one of the most important actions currently available to reduce these impacts and represents one of the most dynamic areas in the waste industry today. Recycling provides opportunities to reduce oil usage, carbon dioxide emissions and the quantities of waste requiring disposal. There is other waste-reduction strategies, namely reduction in material use through downgauging or product reuse, the use of alternative biodegradable materials and energy recovery as fuel.

It is important to recognize that the sustained growth in reuse efforts, as well as the sustained interest of the reuse industry, derives in large measure from the solid waste reduction hierarchy: Reduce, Reuse, then Recycle. It is best to reduce first, reuse as a second option, then to resort to recycling. Reuse is recognized as being distinct from recycling, both in doctrine, and in the handling of the materials this unique industry diverts from the waste stream. Reusers, with little or no processing, keep materials out the waste stream by passing the goods they collect on to others. There are also forms of managing materials that are not quite reuse and not quite recycling, such as repair and remanufacturing. Repair is a method of taking an item, which may appear to have lived its useful life, and fixing it so that it can still be productive. Remanufacturing and refurbishing are ways of taking some used components and some new components to "rebuild" an item. For instance, toner cartridges are often used, then sent to a manufacturer to be broken down and rebuilt using some of the original parts that are reusable, and some new parts.



Technologies

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Biomass is the sole renewable source of energy that provide solid, liquid and gaseous fuels which can be stored and transported.

The term biomass encompasses a large variety of materials as:

- **Wood,**
- **Agricultural residues**
- **Animal and human waste**

Biomass has the advantage of being controllable and available when needed.

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- **Fabrication**
- **Transportation**
- **Installation**
- **Use**
- **Maintenance,**
- **Reuse/recycling/disposal**

SMART BUILDINGS

SSM-08 Waste management

Case studies

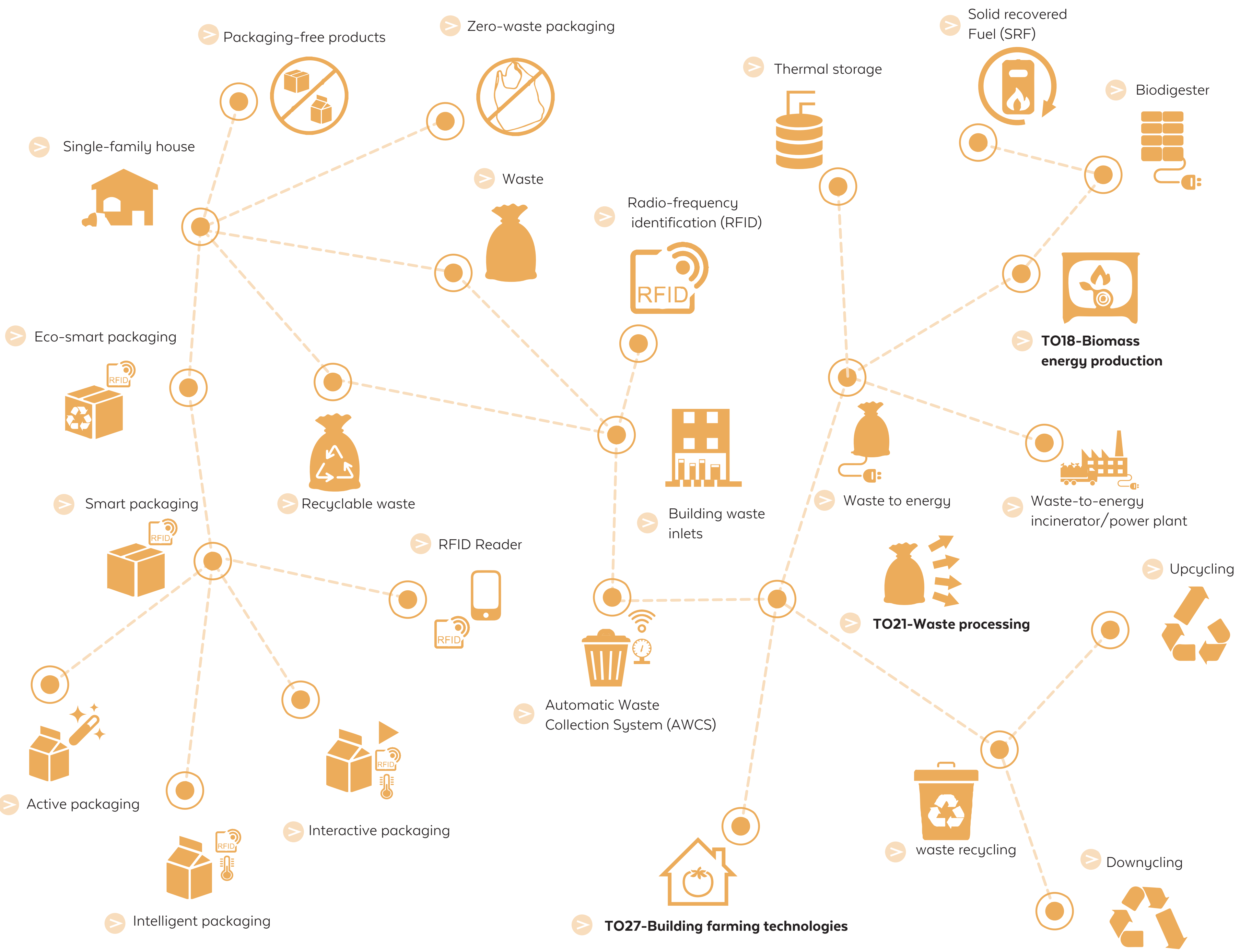
Hammarby Sjöstad (Stockholm)

http://www.symbiocity.org/en/approach/Cases-undersidor/Hammarby-Sjostad-three-in-one/

Rotterdam

http://www.smartbuildingsmagazine.com/news/reducing-waste-in-rotterdam

Waste management strategys are determined by regulation, which establishes a hierarchy where reuse should be given priority over elimination and controlled disposal should rank last. The goal is to reduce the amount of waste that ends up in landfills and to limit the amount of organic waste in landfills. The model has evolved from 100% landfill to zero landfill. Currently, energy efficiency standards have been established, and burning municipal solid waste (MSW) is now classified as waste reuse. But Zero Waste is not only about recycling more and better; it is also about reducing waste generation in the first place. In Zero Waste communities, plastic packaging generation has been radically decreased thanks to the opening of public fountains, bulk liquid dispensers for milk, honey or detergents, bans on bottled water or single-use plastic bags, the implementation of green procurement, policies to stop spillage of food waste and many others.



Future Challenge

Of all the waste streams, waste from electrical and electronic equipment containing new and complex hazardous substances presents the fastest-growing challenge in both developed and developing countries.

Efficient SWM strategies can be implemented only with the active participation of all the stakeholders and citizens. Hence, a stronger civic sense needs to be created among the them and policies need to be implemented for a progressive change of model.

Technologies

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- **Incineration**
- **Landfilling**
- **Reuse**
- **Recycling**
- **Bio-digester**

TO27-Building farming techs

Urban agriculture is an industry located within or on the fringe of a town, which grows or raises, processes, and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products, and services found in and around that urban area.

Intensive cropping technologies have been developed in order to tackle the recurring limiting factors for horticultural production in urban farming

- **Soilless cultures:**
- **Organoponics**

SMART BUILDINGS

SSM-09 Close water cycle

Case studies

Hammarby Sjöstad (Stockholm)

http://www.hammarbysjostad.se/water-and-sewage/?lang=en

Rotterdam

http://www.rotterdamclimateinitiative.nl/uk/news/100,000-m2-of-green-roofs-in-rotterdam?news_id=944

Future Challenge

Cities, as a concept, are not water friendly. Gathering large amounts of humans in a small place throws off nature's built-in balances, which is why man-made water infrastructure is necessary to support a healthy, urban lifestyle, and which allows humans to continue being city-dwellers. But as resources dwindle and cities continue growing, the relationship between water and cities is quickly becoming more taxed. Three biggest water challenges for cities are:

Hitting the Pavement

Pavement and concrete are some of water's biggest challenges. Concrete canyons eliminate rainwater from naturally soaking back into the soil to become groundwater.

This problem can be easily remedied by simply including more greenspace into the urban landscape. Allowing the ground to reabsorb the natural rainfall which then eventually reaches the aquifers seems like an amazingly simply solution

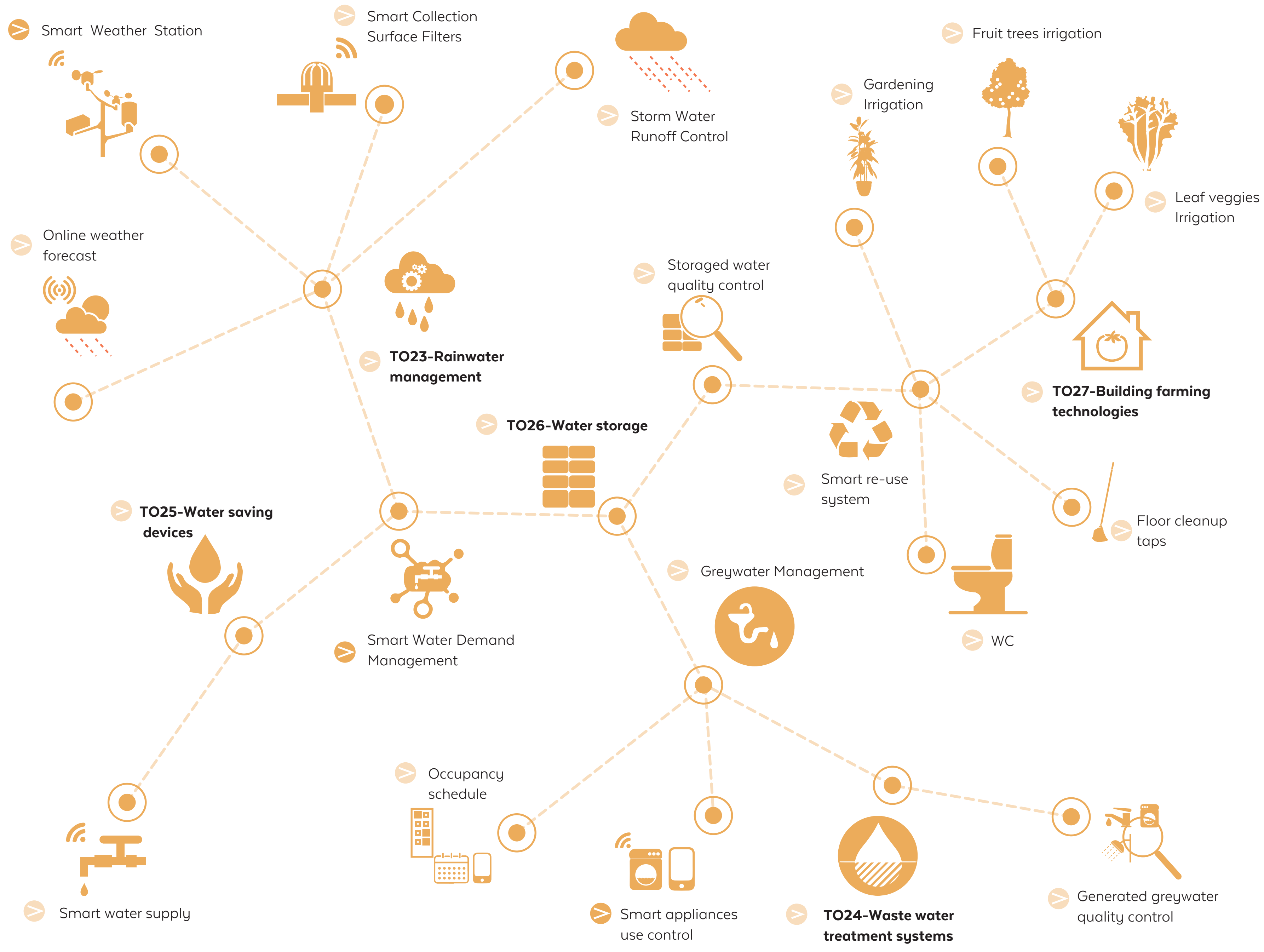
Letting it Slip Through the Pipes

Most water purification sites are kilometers outside of cities. Additionally, most of these pipe networks are decades old. It's means thousands of gallons of cleaned water leak out of the pipes before reaching the end users. Introducing water treatment facilities into the urban fabric eliminates the need for extensive pipe networks, for delivering water to and taking it from the points of use. Decentralized water management systems update water infrastructure to meet modern societal needs by decreasing the opportunities for wasted water.

Keeping it Local

Keeping water close to where it naturally lands is difficult in cities, where it is designed to be drained away and put out of site as quickly as possible. Water reuse on location in a tight feedback loop is the best practice for sustainable water infrastructure. This allows the quickest, most efficient and most economical means of handling water.

Water is the gold of the future. A smart management of this precious resource is a key strategy for any resilient and self-sufficient city of the future. Techniques such as rainwater capture, advanced wastewater treatment, greywater "harvesting", and water-conserving plumbing fixtures are all tools that can be used to reduce the use of potable water. From a smart building perspective, the interest is in how we manage and monitor the water use in buildings. Some of the advantages offered by smart systems are quick detection of water leaks and running fixtures, gathering of usage trends and planning of future demands. Networked water monitoring and management systems consist of water meters, sensor- operator water fixtures such as urinals, water closets, occupancy sensors, etc. Some of these devices can be monitored and managed and others can only be monitored. These types of management systems are also applicable to greywater, wastewater and recycled rainwater systems.



Technologies

TO23-Rainwater management

In recent years, the technology for capture, conveyance, filtration, storage and use of rainwater has made significant advances worldwide and will continue to progress and moving forward.

- **Smart Rainwater Tank System (SRT)**
- **Web-Based Knowledge Management System (WBKMS)**
- **Smart Water Grid (SWG)**
- **Weather-based "Smart" controllers for irrigation**

TO25-Water saving devices

Water saving technologies and strategies are often the most overlooked aspects of a whole-building design strategy. There are a number of strategies that can be employed to reduce the amount of water consumed at a facility. In general terms, these methods include:

- **System optimisation**
- **Water conservation measures**
- **Water reuse/recycling systems**

TO27-Building farming technologies

Urban agriculture is an industry located within or on the fringe of a town, which grows or raises, process and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products and services found in and around that urban area.

Intensive cropping technologies have been developed in order to tackle the recurring limiting factors for horticultural production in urban farming

- **Soilless cultures**
- **Organoponics**

TO24-Wastewater treatment systems

Wastewater treatment is a process used to convert wastewater - which is water no longer needed or suitable for its most recent use - into an effluent that can be either returned to the water cycle with minimal environmental issues or reused.

Some Wastewater treatment technologies are:

- **Smart water meters**
- **Smart water quality monitoring**
- **Crowd sourcing data collection**
- **Smart constructed wetlands**

TO26-Water storage

There are many different options available for water storage. It depends mainly on how much water is going to be used.

- **Brick and Concrete Cisterns**
- **Plastic Tanks**
- **Metal Tanks**
- **Wooden Tanks**
- **Bladders**
- **Ponds and Pools**

TECHNOLOGY OUTLOOK

SMART BUILDINGS

TO-01 Demand side management

Demand Side Management (DSM), also known as Energy Demand Management, is the modification of consumer demand for energy through various methods such as financial incentives and behavioral change through education. Usually, the goal of demand side management is to encourage the consumer to use less energy during peak hours, or to move the time of energy use to off-peak times such as nighttime and weekends. Peak demand management does not necessarily decrease total energy consumption, but could be expected to reduce the need for investments in networks and/or power plants for meeting peak demands. An example is the use of energy storage units to store energy during off-peak hours and discharge them during peak hours. A newer application for DSM is to aid grid operators in balancing intermittent generation from wind and solar units, particularly when the timing and magnitude of energy demand does not coincide with the renewable generation.[1]

Today

The term DSM was coined following the time of the 1973 energy crisis and 1979 energy crisis. Governments of many countries mandated performance of various programs for demand management. An early example is the National Energy Conservation Policy Act of 1978 in the U.S., preceded by similar actions in California and Wisconsin. Demand Side Management was introduced publicly by Electric Power Research Institute (EPRI) in the 1980s. Nowadays, DSM technologies become increasingly feasible due to the integration of information and communications technology and the power system, resulting in a new term: **smart grid**.[1]

DSM types

- **Energy Efficiency**: Using less power to perform the same tasks. This involves a permanent reduction of demand by using more efficient load-intensive appliances such as water heaters, refrigerators, or washing machines.

- **Demand Response**: Any reactive or preventative method to reduce, flatten or shift demand. Historically, demand response programs have focused on peak reduction to defer the high cost of constructing generation capacity. However, demand response programs are now being looked to assist with changing the net load shape as well, load minus solar and wind generation, to help with integration of variable renewable energy. Demand response includes all intentional modifications to consumption patterns of electricity of end user customers that are intended to alter the timing, level of instantaneous demand, or the total electricity consumption. Demand response refers to a wide range of actions which can be taken at the customer side of the electricity meter in response to particular conditions within the electricity system (such as peak period network congestion or high prices).

- **Dynamic Demand**: Advance or delay appliance operating cycles by a few seconds to increase the diversity factor of the set of loads. The concept is that by monitoring the power factor of the power grid, as well as their own control parameters, individual, intermittent loads would switch on or off at optimal moments to balance the overall system load with generation, reducing critical power mismatches. As this switching would only advance or delay the appliance operating cycle by a few seconds, it would be unnoticeable to the end user. This type of dynamic demand control is frequently used for air-conditioners.[1]

These efforts may:

- Promote high efficiency building practices
- Promote the purchase of energy-efficient products
- Encourage the transition from incandescent lighting to more efficient lighting technologies
- Encourage customers to shift non-critical usage of electricity from high-use periods to after 7 p.m. or before 11 a.m.
- Consist of programs providing limited utility control of customer equipment such as air conditioners
- Promote energy awareness and education.

Integrated resource planning

A very important part of the DSM process involves the consistent evaluation of demand side to supply side alternatives and vice versa. This approach is referred to as integrated resource planning. For DSM to be a viable resource option, it has to compete with traditional supply side options.[2]

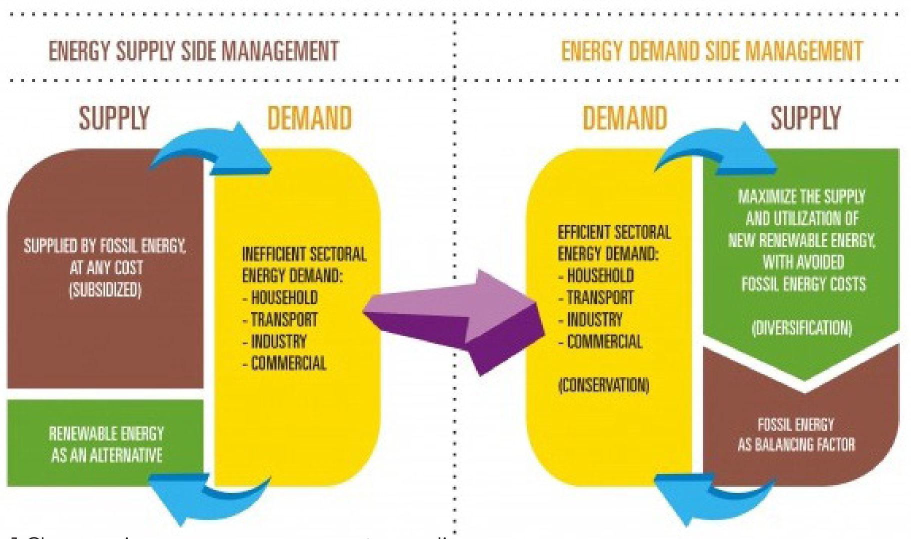


Fig. 1 Changes in energy management paradigm

To know more...

[1] Energy demand management https://en.wikipedia.org/wiki/Energy_demand_management

[2] Gellings, C. W., & Parmenter, K. E. (2016). Demand-Side Management. In D. Y. Goswami & F. Kreith (Eds.), Energy Efficiency and Renewable Energy Handbook (2nd ed., pp. 289–310). New York: CRC Press.

[3] Saad, W., Han, Z., Poor, H., & Basar, T. (2012). Game-Theoretic Methods for the Smart Grid: An Overview of Microgrid Systems, Demand-Side Management, and Smart Grid Communications. IEEE Signal Processing Magazine, 29(5), 86–105. doi:10.1109/MSP.2012.2186410

[4] Sheikhi, A., Rayati, M., Bahrami, S., Ranjbar, A. M., & Sattari, S. (2015). A cloud computing framework on demand side management game in smart energy hubs. International Journal of Electrical Power & Energy Systems, 64, 1007–1016. doi:10.1016/j.ijepes.2014.08.020

Opportunities for innovation

DSM helps to reduce greenhouse gas emissions.

Apart from the energy sector, this technology can also have an appication on water and gas demand management.

The proliferation of advanced technlogies and services implies that disciplines such as game theory will naturally become a prominent tool in DSM. Some main related applications are scheduling of appliances and storage management.[3]

In the future smart grid, energy storage is expected to be a key components in smart homes, and, thus, it has a strong impact on DSM.

Near future challenges

Main challenges:

- Privacy: The consumers have to provide some information about their usage of electricity to their electricity company. This is less of a problem now as people are used to suppliers noting purchasing patterns through mechanisms such as “loyalty cards”.

- To be able to charge the consumer based on the true price of the utilities at that time.[1]

Main areas of research:

- Energy hubs: The presence of energy hubs in the future vision of energy networks creates an opportunity for electrical engineers to move toward more efficient energy systems. Different methodologies such as game theory can be applied to model the demand side management among the smart energy hubs.[4]

SMART BUILDINGS

TO-02 Smart grid

A smart grid is an electrical grid which includes a variety of operational and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficiency resources. Electronic power conditioning and control of the production and distribution of electricity are important aspects of the smart grid. Thus, smart grid refers to a set of related technologies on which a specification is generally agreed, rather than to a specific technology. A smart grid enables the delivery of power from generation sources to end-uses to be monitored and managed in real time.

Today

Some of the benefits of smart grids include the ability to reduce power consumption at the consumer side during peak hours, called demand side management; enabling grid connection of distributed generation power (with photovoltaic arrays, small wind turbines, micro hydro, or even combined heat power generators in buildings); incorporating grid energy storage for distributed generation load balancing; and eliminating or containing failures such as widespread power grid cascading failures. The increased efficiency and reliability of the smart grid is expected to save consumers money and help reduce CO_2 emissions.

Some typical components of a smart grid include[1]:

Intelligent appliances capable of deciding when to consume power based on preset customer preferences. This can go a long way toward reducing peak loads which has a major impact on electricity generation costs -alleviating the need for new power plants and cutting down on damaging greenhouse emissions. Early tests with smart grids have shown that consuers can save up to 25% on their energy usage by simply providing them with information on that usage and the tools to manage it.

Smart power meters featuring two-way communications between consumers and power providers to automate billing data collection, detect outages and dispatch repair crews to the correct location faster.

Smart substations that include monitoring and control of critical and non-critical operational data such as power factor performance, breaker, transformer and battery status, security, etc.

Smart distribution that is self-healing, self-balancing and self-optimizing including super-conducting cables for long distance transmission, and automated monitoring and analysis tools capable of detecting or even predicting cable and failures based on real-time data about weather, outage history, etc.

Smart generation capable of "learning" the unique behavior of power generation resources to optimize energy production, and to automatically maintain voltage, frequency and power factor standards based on feedback from multiple points in the grid.

To know more...

[1] IEEE, emerging technologies for smart grids: https://www.ieee.org/about/technologies/emerging/emerging_tech_smart_grids.pdf

[2] Strategic research agenda for Europe's electricity networks of the future – SRA 2035 http://www.smartgrids.eu/documents/sra2035.pdf

[3] Interim Project Report: http://www.energy.ca.gov/2012publications/CEC-500-2012-047/CEC-500-2012-047.pdf

European technology platform for the electricity networks of the future: http://www.smartgrids.eu

Euroepan Comission, Smart Grids: http://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters

Smart grids initiatives in Europe: http://www.smartgrids.eu/documents/ETP%20SG%20National%20Platforms%20Catalogue%202016%20edition.pdf

Universal access to affordable, low-carbon electrical power generation (e.g., wind turbines, concentrating solar power systems, photovoltaic panels) and storage (e.g., in batteries, fly-wheels or super-capacitors or in plug-in hybrid electric vehicles).

Hybrid and smart mini-grids

The term mini-grid refers to relatively small electric networks that are used to distribute alternate electric current within a town or neighbourhood. Mini-grids are usually supplied by a single power generation station, although the combination of two or more generation technologies (hybrid power systems) attracts greater interest, as this is an option to improve the reliability of the electricity supply. The application of mini-grids makes no direct contribution to climate change mitigation. However, in combination with electric power generation based on renewable sources, mini-grids can be key to reducing (or even avoiding) greenhouse gas emissions.

The main role of mini-grids in the global energy supply is to enable access to electricity in areas that are not covered by central networks and have no option to be connected to a grid in the future. Mini-grids can lead to a more widespread dissemination and faster deployment of renewable energy technologies. These are more flexible and can be implemented more easily using mini-grids rather than conventional energy technologies. The systems can be managed and owned by local entrepreneurs or organisations, which in turn can boost local development.

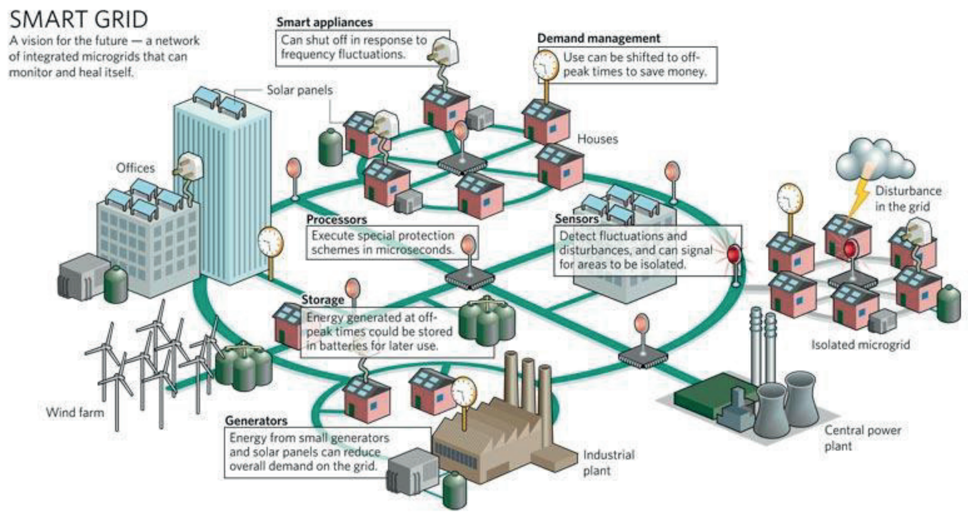


Fig. 1 Smart Grid, a vision for the future. Schematic design showing the different components of a smart grid[3].

Opportunities for innovation

Through smart grids citizens are able to adopt an active role as consumer as well as producer of energy within their local energy network.

New business models arise for optimized concepts of energy generation, distribution and consumption.

Near future challenges

New game rules

Smart grids can help to better integrate renewable energy. While the sun doesn't shine all the time and the wind doesn't always blow, combining information on energy demand with weather forecasts can allow grid operators to better plan the integration of renewable energy into the grid and balance their networks. Smart grids open up the possibility for consumers who produce their own energy to respond to prices and sell excess to the grid.

According to the European Technology Platform Smartgrids[2], one central issue for which development for 2035 must go beyond research for 2020 is the nature of the interactions between the transmission and distribution networks. To deal with the resulting fluctuations, future grids will also require massive amounts of storaege.

Main challenges for smart grids[2]:

-Institutional barriers may produce insufficient incentives to invest in these 'no-regrets' technologies.

-Electric utilities might lack motivation to improve grid efficiency because it results in less electricity consumption while requiring large upfront investments.

-Grid regulators lack capacities to deal with constant new technologies and possible threats they pose to reliability and affordability.

Main areas of research are[2]:

-Small -to medium- scale distributed storage systems.

-Real-time energy use metering and system state monitoring systems.

-Grid modeling technologies by demonstrating and improving long distance transmission systems, monitoring real-time ageing for maintenance purposes and being able to predict in ahead of delivery the generation output.

-Communication technologies, to exchange information among the stakeholders, helping to improve the efficiency of electicity products and services and to form small-scale islanded systems able to securely connect to and disconnect from the synchronizen European power system.

SMART BUILDINGS

TO-03 Space use telemanagement

There is a wealth of civic assets – from charitably-owned recreation centres to publicly owned post offices – that offer possibilities to become revitalized community infrastructure and offer continued civic purpose. Changing demographics and new ways of delivering public services are leaving churches, schools, hospitals, and myriads of other assets vulnerable to deferred maintenance or sale to the highest bidder. There is an opportunity to support communities to identify and map existing publicly- and non-profit held assets as an input into community infrastructure planning.[1]

Today

Space is an important asset in urban environments and, however, little attention is put on how efficiently this resource is managed. There is a long list of public spaces that are being misused most of the time. Classrooms, and school playground courts out of school hours, public office spaces, meeting rooms, representative buildings, parking spaces, etc. are examples of spaces that are empty sometime during the day and the maintenance of which represents an important cost. Such spaces, properly managed, have the potential to be an important source of revenue for the city government both due to the reduction of maintenance costs and to the creation of new services such as leasing or temporal renting of such spaces. Most of the existing strategies of space use management are developed firstly for the working sphere. Some examples are[2]:

Coworking is the sharing of workspace among freelancers and other independent workers, co-working spaces provide workspace and community to people who are often working on their own. As new spaces open and work to recruit members and users, coworking as a concept can fall on a spectrum from theory of change to branding. For example, the coworking wiki distinguishes their community as those committed to 'open coworking' based on the inherent link to open source philosophy.

Community hubs are place-based, dedicated to serving a specific geographic area, for example, at neighborhood level or as a hub for rural areas. Community hubs often active programming and access for residents, not just those with dedicated space in the building or site, for three functions:

(1) services that respond to the needs of the local community and involve providers of social, health employment, and/or business;

(2) space, as public and common areas are available for both formal and unstructured programming;

Fig. 1 Example of a coworking space.

(3) synergy, if multiple tenants/service providers are co-located.

Multi-tenant non-profit centres (MTNC) share three basic features:

(1) they are composed of multiple primarily not-for-profit tenant organizations;

(2) they exist as a physical site (one or more buildings)

(3) they typically provide office space, rent rates, and lease terms oriented to the nonprofit sector and provide services, meeting space and community venues, and opportunities for collaboration and cost sharing that support the missions of tenant organizations. Unlike office buildings where organizations might cluster because of low rents and like-minded tenants, MTNCs are intentional, with missions that guide their development, design, operations, governance, and collaboration.

Flex Location, remote work, telecommuting or telework is a work arrangement in which employees do not commute to a central place of work. Many telecommuters work from home, while others, sometimes called nomad workers use mobile telecommunications technology to work from coffee shops or other locations. Approximately one in five workers around the globe, telecommute frequently and nearly 10 % work from home every day. Communication and an intentional atmosphere of open, transparent dialogue and access to information is considered already as one of the most important aspects in the value proposition of these kinds of organization.

Space sharing can offer benefits to **retail entrepreneurs**, too. The retailers can save money by sharing the cost of a single contractor, and their complementary products help maximize store hours. Point-of-sale software programs allow the different business sharing the space to ring up products in one transaction, then later reconcile which party logged which sales.

To know more...

[1] Girvan, LA (2014). Building capacity, sharing values: shared spaces and social purpose real estate. A scan and discussion paper of what is happening and could happen in Canada. Available at: http://tidescanada.org/wp-content/uploads/2015/04/Building-Capacity-Sharing-Values-Shared-Spaces-and-Social-Purpose-Real-Estate-Final.pdf

[2] Web site with general information on teleworking: https://thelivinglabiesd.wordpress.com/2012/11/06/sustainable-transport-the-impacts-of-transports-on-the-environment-in-the-uk/

[3] Article from Forbes "The death of the office": http://www.forbes.com/sites/jeannemeister/2013/11/06/the-death-of-the-office-what-happens-when-the-workspace-is-mobile-on-demand-and-all-about-networking/#392d5baf2911

Opportunities for innovation

New business opportunities begin to take off, such as shared office providers and online portals that connect landlords who have extra space to rent with on-the-go professionals who need work space quickly.

Access to spaces in buildings can be regarded as a urban service, similarly to public transport.

Near future challenges

Workplace flexibility will turn the office into an increasingly complex and even abstract concept. In the future, the workplace may not be on-site at our employer's property, but on-demand at a collaborative space. Working may not be related to an office-like space anymore, neither to a specific time of day, but to the possibility to access a certain data-cloud in which a spread community will share information and communicate[3].

Indeed, a virtual work station is composed basically by (1) a computer; (2) high-speed internet; (3) a smart phone, with long distance phone plan; (4) a multifunctional scanner/printer/fax. It is probable that in the near future, the virtualization of the work stations will continue with the development of new technologies and especially, of new user-machine interfaces (**see TO07-User interfaces**).

The implementation of an **smart space use management** of existing spaces spread around the city will allow for the citizens and the city government to use publicly accessible building spaces when, where and how they want and to take advantage of the "sharing economy, where it is easier to access an asset than to own it. Wire-less communication, open data, and real-time acces, management and coordination of different kinds of databases will be of crucial importance.

Traditionally slow to change, the commercial real estate industry is gradually shifting from being a space provider to creating experience and community for the next generation.

Shared office spaces are also converging with **residential real estate** aimed at meeting new combined needs for social/work hubs, affordable housing and amenities that enhance their well-being. Examples of this are **lifestyle hotels** or **microapartments** that allow for an affordable housing in the city. Such apartments are flexible, plug-and-play spaces, supplied with all the furniture in the room, TVs, a sound system, a little kitchenette and linked to community spaces.

SMART BUILDINGS

TO-04 Internet of Things

The internet of things (IoT) is the internetworking of physical devices, vehicles, buildings and other items—embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data. The IoT allows objects to be sensed and/or controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit[1].

Today[2]

While there is no universal definition for the IoT, the core concept is that everyday objects can be equipped with identifying, sensing, networking and processing capabilities that will allow them to communicate with one another and with other devices and services over the Internet to achieve some useful objective.

The core concepts underlying the IoT are not new. For years, technologies such as RFID and sensor networks have been used in industrial and manufacturing contexts. The idea of direct machine-to-machine communication is also not new. What the IoT represents is an evolution of the use of these existing technologies in terms of the number and kinds of devices as well as the interconnection of networks of these devices across the Internet[2].

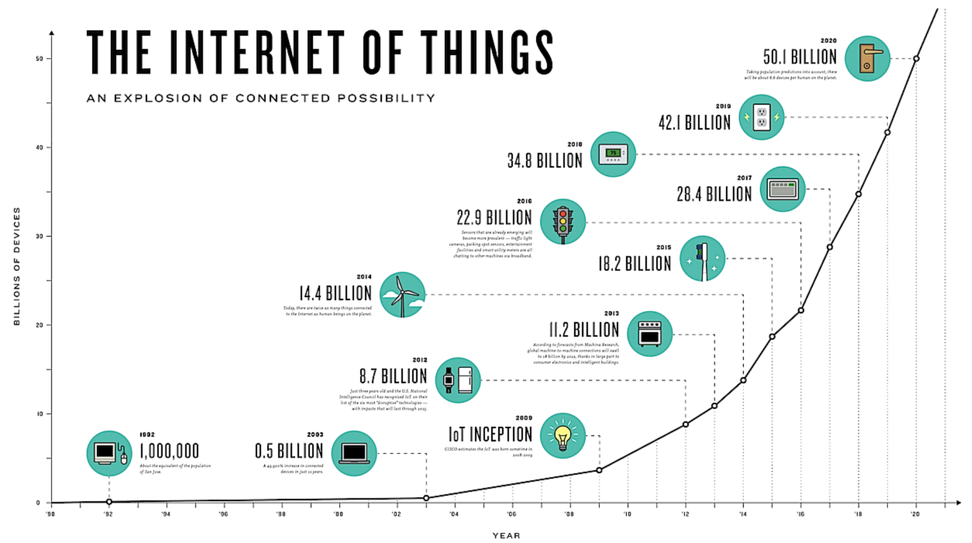


Fig. 1 The potential growth in the IoT market over the next few years[3]. Source: http://efergy.com/blog/the-interent-of-things-in-the-home/#

To know more...

[1] General information about IoT: https://en.wikipedia.org/wiki/Internet_of_things

[2] Scientific paper reviewing IoT: Whitmore, A., Agarwal, A., & Da Xu, L. (2015). The Internet of Things—A survey of topics and trends. Information Systems Frontiers, 17(2), 261-274.

Report *Enabling the Internet of Things*: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.698.6666&rep=rep1&type=pdf

Rerum European Project: https://ict-rerum.eu/cientific paper reviewing IoT: Want, R., Schilit, B. N., and Jenson, S. (2015). Enabling the Internet of Things. IEEE Computer, 48(1), 28-35.

Much of the hardware upon which the IoT is being built already exists and is currently in widespread use:

Radio-Frequency Identification (RFID) is a short range communication technology where an RFID tag communicates with an RFID reader via radio-frequency electromagnetic fields. Tags may contain different forms of data, but the data form most commonly used is the Electronic Product Code, or EPC. a universally unique identifier for an object. These unique identifiers ensure that objects tracked with RFID tags have individual identities in the IoT.

Near Field Communication (NFC) is a short-range communication standard where devices are able to engage in radio communication with one another when touched together or brought into close proximity to one another.

Sensor networks (see TO-08 Monitoring technologies)

However, new software is written to support the interoperability between the numerous and heterogeneous devices of the IoT and searching the data generated by them:

IoT middleware: helps bring together a multitude of devices and data in a way that enables developers to create and deploy new IoT services without having to write different code for each kind of device or data format.

Searching/Browsing: objects in the IoT will be mobile, dynamic, and will generate massive amounts of frequently changing information. Thus, there is the need for an IoT browser that is capable of identifying smart objects, discovering their services and interacting with those objects as well as an IoT search engine that is capable of searching the rapidly changing information generated by IoT-enabled objects.

Moreover, architectures are needed to represent, organize and structure the IoT in a way that enables it to function effectively. There is no agreement on a single architecture that best fits the IoT.

Hardware architecture: several hardware/network architectures exist adapted to the distributed computing environments specific of the IoT. These architectures include peer-to-peer, EPCglobal and autonomic.

Software architectures are necessary to provide access to and enable the sharing of services offered by IoT devices. Service oriented architectures (SOA) and the representational state transfer (REST) model are the most common ones.

Process architectures structure the business processes that will incorporate the IoT. In particular, researchers have looked at how to structure workflows to support the pervasive computing environments.

Opportunities for innovation

The IoT is a big opportunity to improve how we design and build products.

The IoT offers a great market opportunity for equipment manufacturers, Internet service providers and application developers: 212 billion smart objects will be deployed globally by the end of 2020.

Economic growth of IoT-based services is also considerable for businesses. Healthcare and manufacturing applications are projected to form the biggest economic impact.

Near future challenges[2]

The IoT holds the promise of creating a global network supporting ubiquitous computing and context-awareness among devices which are key requirements of ambient intelligence. Ambient intelligence would allow everyday objects to understand their environments, interact with people and make decisions. A world full of smart objects holds enormous promise for improving business processes and people's lives, but it also comes with serious threats and technical challenges that must be overcome.

Privacy: IoT offers immense potential for empowering citizens, making government transparent, and broadening information access. However, privacy threats are enormous, as is the potential for social control and political manipulation.

Security: IoT is being developed rapidly, which increases the risk of an inappropriate consideration of the profound security challenges involved and the regulatory changes that might be necessary.

Design: successful execution of the IoT requires consideration of the interface's usability as well as the technology itself. These interfaces need to be not only more user-friendly but also better integrated.

Sustainability: Modern electronics are replete with a wide variety of heavy metals and rare-earth metals, as well as highly toxic synthetic chemicals.

Intentional obsolescence of devices: companies can use the technologies necessary to support connected devices to intentionally disable their customers' devices via a remote software update or by disabling a service necessary to the operation of the device.

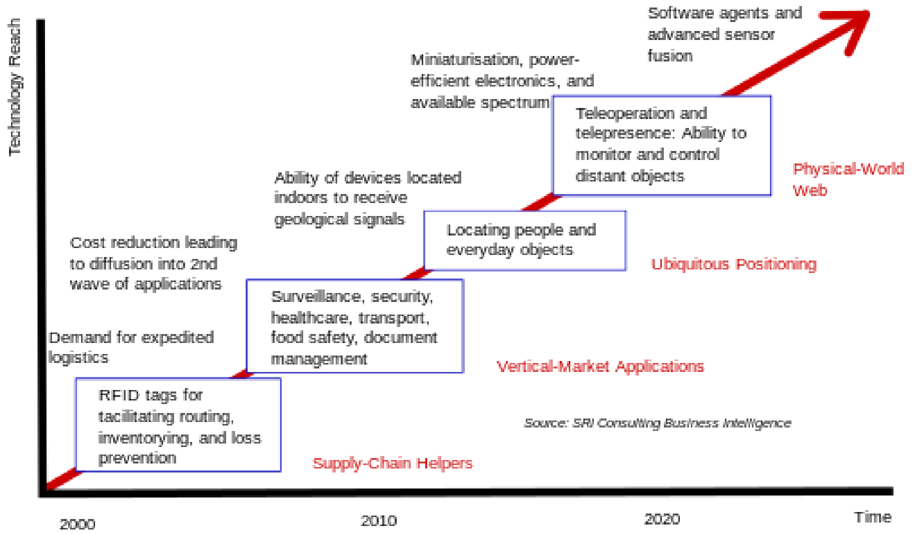


Fig. 2 Technology roadmap Internet of Things[1].

SMART BUILDINGS

TO-05 Building management systems

A building management system (BMS), otherwise known as a building automation system (BAS), is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. The objectives of BMS are improved occupant comfort, efficient operation of building systems, and reduction in energy consumption and operating costs, and improve life cycle of utilities. A building controlled by a BMS is often referred to as an intelligent building, smart building, or (if a residence) a smart home.[1]

Today

Components[2]

A BAS/BMS incorporates sensors (see TO-08), actuators, communications network and information management system. Moreover, building automation interfaces man and machine to attain safe and comfortable living/working environment (see TO-07), energy saving, and efficient operation at reduced time and costs. Almost all applications in this system are based on common functionality, which is depicted in Fig. 1

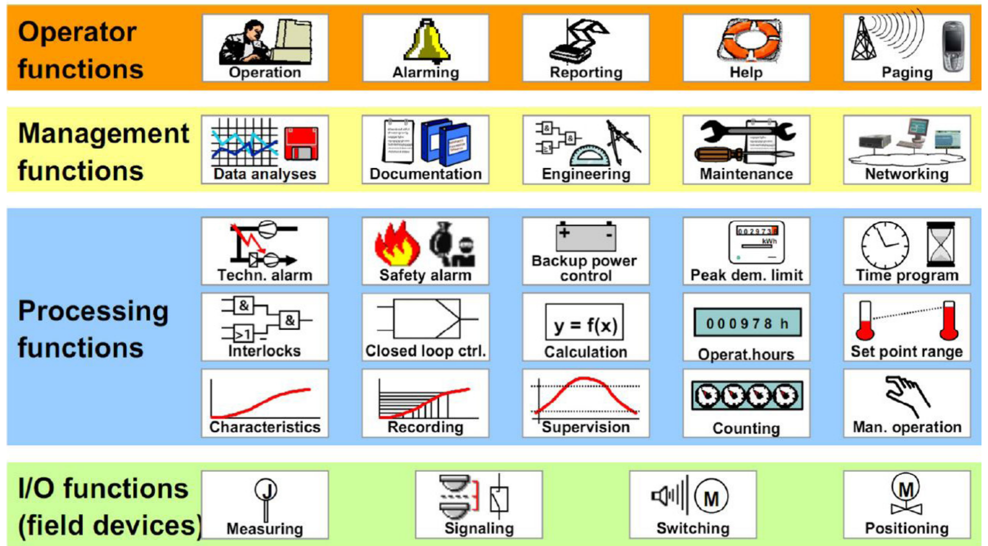


Fig 1. Drawing showing the range of common functionalitites accessible in Building Management Systems [2].

Being able to actuate different building subsystems, both for energy efficiency and comfort of the occupants, is of critical importance in the design of smart building. Actuation comprises two components: the mechanisms to control various building subsystems and the policies that determine when, and in what way, the control should be performed. In order to actuate effectively, it is critical to know the operational status of the building at fine temporal and spatial granularities. This task essentially boils down to sensing various physical attributes –occupancy, internal and external environmental conditions, and energy usage– using either existing sensors or by augmenting the building with additional sensors.

Advantages and disadvantages

Advantages:

- Important energy savings can be acquired
- The possibility to have full control of the buildings infrastructure from one easy to use system, without having to run around the building to turn things on/off or to check status.
- The reduction of operating and maintenance costs: the system can alert to an impending problem before it becomes an irreversible expensive repair.

Disadvantages:

- The initial cost of an installed system can be high, especially if not correctly specified and reviewed. It is important to understand the operation of the systems and the end users to identify the level of automation.
- Once installed, depending on the system brand, the user is generally "locked in" to a long term service contract. The maintenance of the systems requires highly qualified experts on which the user must delegate the regular revision of the system.
- Serviceability – Generally, users are at the mercy of whomever the contractor sends to them when things don't go according to plan.

To know more...

[1] Definition of building automation: https://en.wikipedia.org/wiki/Building_automation

[2] Scientific article on building automation: Jablonski I (2015). Integrated living environment: Measurements in modern energy efficient smart building with implemented the functionality of telemedicine. Measurement.

[3] Definitions and basic concepts related to building automation: http://www.airah.org.au/iMIS15_Prod/Content_Files/Divisionmeetingpresentations/QLD/PPQLD_11-07-2012-TM.pdf

Guide to BAS: http://controlyourbuilding.com/media/files/default/CON1114_BA_InfoGraph_Shortened_E.pdf

Opportunities for innovation

A building with a building automation system (BAS) has up to 30% lower energy and maintenance costs.

The development of building energy management systems (BEMS) will be crucial for the future development of smart grids.

Controls will tend to desapear and integration will be the key. Integrated systems that share information will learn from each other and make desisions by themselves.

Near future challenges

Integration and flexibility (through standardization) are two issues for technological improvement. Modern BAS can control, apart from air conditioning systems, indoor and outdoor lighting, security, fire alarms, and basically everything that is electrical in the building.

Managing building automation systems is complex, especially when the automation moves from user control to some form of rule based behaviour, because the rules might insufficiently reflect what the resident actually wants. In this circumstances, reframing design strategies, given the coevolution of human and building intelligence, can put the area of building beyond the typical smart home conception. Systems capable to learn and evolve by time are to be fully developed in the near future in order to improve users' satisfaction.

Building management has no sense without taking into account occupant behaviour. With the incorporation of new technologies, occupants are faced with complex systems that are difficult to operate, which can lead to an increase on energy use and reduction in overall satisfaction. Further post-occupancy or in-use building evaluations are needed to fully understand and control such effects.

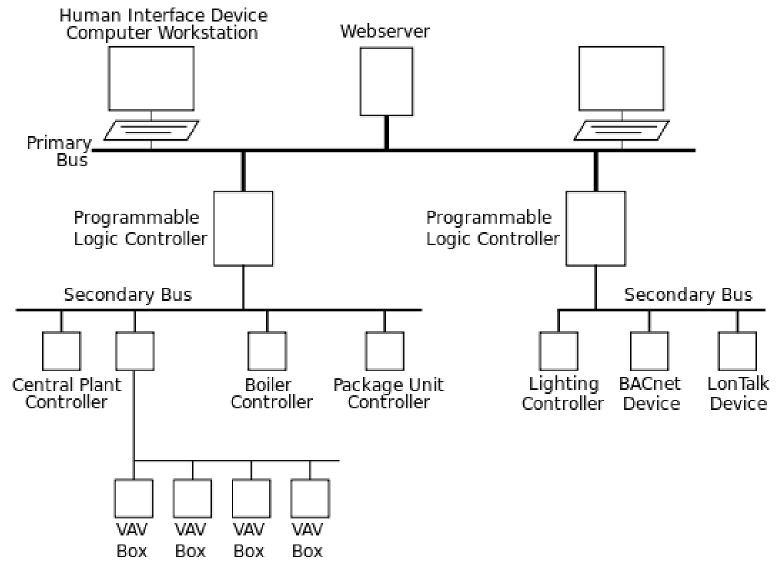


Fig 2. Schema of the components of a Building Management System[1].

SMART BUILDINGS

TO-06 Systems integration

In information technology, systems integration is the process of linking together different computing systems and software applications physically or functionally, to act as a coordinated whole. The system integrator brings together discrete systems utilizing a variety of techniques such as computer networking, enterprise application integration, business process management or manual programming. There are different methods of integration such as vertical star and horizontal integration. Each presenting inherent advantages and disadvantages[1].

Today

CLOSED vs OPEN TECHNOLOGY[2]

Full proprietary (closed) system do not allow interoperability with other manufacturers and uses a specific protocol and bus for its communications layer.

With this style of system, the client is tied to that manufacturer for hardware costs, software costs and upgrades, as well as service and maintenance for the life-cycle of the equipment. However, although many systems use proprietary communications, not all systems that use proprietary protocols are "closed" systems.

"Open Technology" is a term used to ensure the proposed system is capable of interoperability between vendors/manufacturers to allow the client to select any vendor at any time. Two kinds of Interoperable solutions can be distinguished: native systems and proprietary systems with interoperable capabilities.

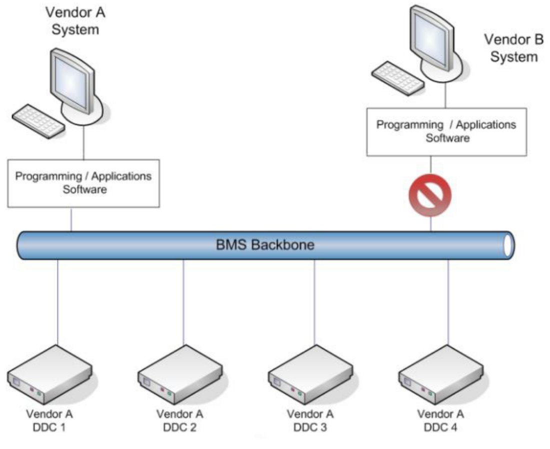


Fig 1. Schema of a full proprietary - closed system[2]

To know more...

[1] Definition of system integration: https://en.wikipedia.org/wiki/System_integration

[2] Presentation on integration systems: Jhttp://www.airah.org.au/iMIS15_Prod/Content_Files/Divisionmeetingpresentations/QLD/PPQLD_11-07-2012-TM.pdf

[3] Five steps for successful system integration: http://www.singlemindconsulting.com/2013/01/13/custom-systems-integration-how-to-overcome-the-5-key-challenges-to-successful-systems-integration/

In **Native Systems** all vendors communicate via a common protocol and on a common bus, and standards ensure an ease of integration between devices & manufacturers. Some use proprietary programming software, protocols and communications for lower level devices, utilising the native primary controller as a gateway/translator.

One advantage is the initial cost of infrastructure as only the one communications bus is required. Another benefit is maintenance, as there is generally less hardware or software required to integrate with the other systems of the same protocol.

A disadvantage is the lack of leadership or master of the BMS network. A single incorrectly addressed device, or device with faulty communications, can bring down the entire network. Locating the offending device or computer can take time and be difficult.

"Native" and "Open" are not the same. Many specifications request "Native" protocols and "Open Technology", and expect that by only allowing products of this nature will achieve the "Open" result. However, this is not allways true. If Native systems use proprietary software for programming, which is not available in the open forum, they are not open anymore.

Proprietary System with Interoperability Capabilities generally use a single bus for the proprietary controller network, and another bus for the other protocols used and gateways devices or software for other protocol integration may be used.

A positive for this solution is that there is a line of segregation between the different protocols. Therefore, the proprietary controller network is less likely to be impacted by other vendors' equipment or computers being added.

A negative for this solution is the initial outlay for infrastructure to support the system. More hardware is generally required also to perform the integration/translation between protocols.

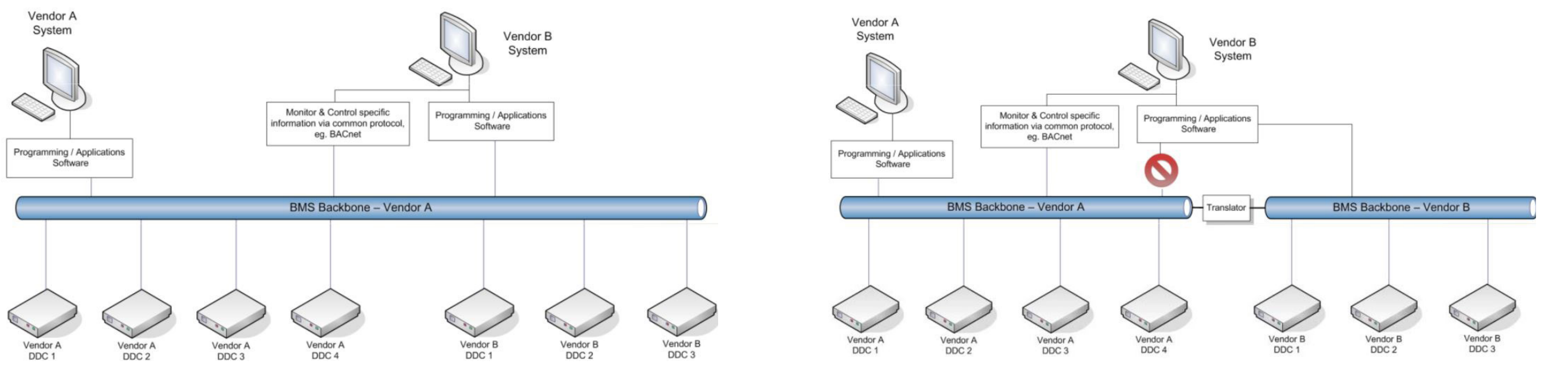


Fig 2. Schemas of two different open systems: a native protocol (left) and a proprietary system fully interoperable (right)[2]

Opportunities for innovation

Systems integration is key ito allow the progressive growth of the smart networks. The integration of different kinds of inputs into the same management system enables for new uses of the existing data. New relationships between the different urban processes may be discobered.

Systems integration is also key for the resilience of the whole information network as it helps for the integration of newly developed technologies into the existing IT infrastructure.

Near future challenges

Cloud computing will define future IT industry. Cloud computing will be a key driver behind the systems integration field. IT vendors that can help customers successfully and securely integrate cloud computing into their infrastructures will be highly sought after.

Plan for emerging technologies. The longevity of any custom systems integration is dependent on its ability to adapt to emerging technology. Keeping the system modular and flexible enhances the shelf life of an integration. This equates to better ROI and a happier team over the long term. Looking beyond immediate needs, and plan for change are key strategies for a successful system integration project[3].

Process agility is key. That is, a structure capable to quickly react to changes in needs and to maintain real-time communications.

Technology convergence is a trend in system integration. Corporate divisions such as security, fire, facility & IT management are most and most merged to be managed by a single platform.

SMART BUILDINGS

TO-07 User interfaces

If technology is essential to our future success and goals, then the means by which we interact with it must be critical. User interfaces (UI), like language, are a technology that enables the communication of ideas. For every technology, there is an interface. It may be a simple, mechanical handle or a complex, digital display, but there needs to be a connection between what is used and its user[1].

Today

In the past decade, research on smart homes has been moving towards applying the principles of ubiquitous computing. The smart home adjusts its functions to the inhabitants' needs according to the information it collects from the inhabitants, the computational system, and the context. In this kind of intelligent environment, information processing and networking technology is hidden away, and interaction between the home and its devices takes places via advanced, "natural" user interaction techniques, such as speech[2].

There are several types of UI some of which are described below[3]:

Command-Line Interface (CLI): the user provides the input by typing a command string with the computer keyboard and the system provides output by printing text on the computer monitor.

Graphical user interfaces (GUI): accepts input via devices such as a computer keyboard and mouse and provide articulated graphical output on the computer monitor. There are at least two different principles widely used in GUI design: Object-oriented user interfaces (OOUIs) and application oriented interfaces.

Direct manipulation interface: is the name of a general class of user interfaces that allow users to manipulate objects presented to them, using actions that correspond at least loosely to the physical world. Multi-touch is a main technology related with this kind of interfaces, which enables the interaction of the user through a touchscreen.

Adaptive user interface (AUI): is a UI which adapts its layout and elements to the needs of the user or context and is similarly alterable by each user.

Brain-computer interface (BCI): Sometimes called a mind-machine interface (MMI), direct neural interface (DNI), or brain–machine interface (BMI), is a direct communication pathway between an enhanced or wired brain and an external device. BCIs are often directed at researching, mapping, assisting, augmenting, or repairing human cognitive or sensory-motor functions.

Speech recognition interface: words or phrases spoken by humans are converted into electrical signals, and these signals are transformed into coding patterns to which meaning has been assigned. This UI is useful in virtual reality because it provides a fairly natural and intuitive way of controlling the simulation while allowing the user's hands to remain free.

Gesture recognition interface: similarly to speech recognition, human body expressions (such as waving or pupil movement when reading) are interpreted as input signals for specific pre-programmed machine responses.

Example of GUI using multi-touch screen technology.

Example of BCI. Muse is a lightweight, wireless haedband that can engage with computers and smarphones[4].

To know more...

[1]General information about User Interfaces: https://uxmag.com/articles/what-do-user-interfaces-want

[2]Koskela T and Vaananen-Vainio-Mattila K. (2004). Evolution towards smart home environments: empirical evaluation of three user interfaces. Pers Ubiquit Comput, 8:234–240. DOI 10.1007/s00779-004-0283-x

[3]Description of different types of user interfaces: ttps://en.wikibooks.org/wiki/A-level_Computing/CIE/Computer_systems,_communications_and_software/System_software/User_interfaces

[4]http://bits.blogs.nytimes.com/2013/04/28/disruptions-no-words-no-gestures-just-your-brain-as-a-control-pad/

Timeline of User Interfaces: https://timeline.knightlab.com/examples/user-interface/

Opportunities for innovation

User interface design education will expand analogously to engineering, which not only has several major disciplines (chemical, civil, electrical, mechanical, etc.), but multiple sub-disciplines and cross-disciplinary fields.

Near future challenges[1]

Complexity: Contemporary interface design is focused on limiting the end-user's exposure to complexity, but effective design should really be about managing complexity. This added complexity means developing new tools and processes for creating interfaces, building more expertise into UIs, and understanding user needs at a deeper level.

Diversity: We should expect to see the trend of diversified interfaces grow, with a multitude of potential solutions for interacting with any given technology, such as device-specific versions of interfaces.

Ubiquity: The spread of mobile devices and the emergence of the Internet of Things (IoT) have begun to formalize the need to "UI for everywhere."

Hundreds of years from now, will technology even need user interfaces? In a lifetime we have seen the process of interacting with a computer go from mechanical, to text-based, to graphical, to voice- and gesture- activated. These rapid advances are not just technological changes—they have shaped our interactions with and expectations of all technology. User interfaces have made the complex accessible, even personal.

The current trend of "invisible interfaces" speaks to the emergence of interaction technologies that lack the traditional keyboard/mouse/touchscreen controls, and that we may even interact with unknowingly. Ultimately, it's likely that external systems will gain a level of self-sufficiency that requires minimum human interaction. But when we get to that point, we can turn inward. Like language, interfaces are not just about connecting us with others, but providing a framework for amplifying our own thinking. Instead of thinking as user interfaces as a means to connect us with external technologies, we will use technology as a way to better interface with ourselves.

SMART BUILDINGS

TO-08 Monitoring technologies

The function of monitoring systems is data acquisition and transfer to the management system. In monitoring systems, sensors are responsible of data acquisition. Different kind of sensors detect different kinds of physical quantities or their change rate (CO_2 levels, energy consumption, temperature, wind speed, movement, heat radiation, etc.). Transducers are in turn responsible of transforming such diverse types of physical quantities into their corresponding electrical signal, which will be later interpreted by the management system. Thus, monitoring is the interface between the physical world and the information domain.

Today

Sensors[1]: In the broadest definition, a sensor is a device whose purpose is to detect events or changes in its environment, and then provide a corresponding output, typically in the form of electrical or optical signals. In the current and future applications, sensors can be classified into groups as follows:

- **MEMS:** based on the Microelectromechanical sensor technology. They are used for patient monitoring which includes pace makers and vehicle dynamic systems.
- **Biosensors:** based on the electrochemical technology. They are used for food testing, medical care device, water testing, and biological warfare agent detection.
- **Image Sensors:** based on the CMOS technology. They are used in consumer electronics, biometrics, traffic and security surveillance and PC imaging.
- **Motion Detectors:** based on the Infra Red, Ultrasonic, and Microwave / radar technology. They are used in videogames and simulations, light activation and security detection.

Significant improvements in measurement and modelling techniques are now occurring, including a new generation of low-cost sensors of comparable quality to research-grade instrumentation. Such equipment is often designed to communicate via the Internet of Things (IoT) and transmit data in near-real-time ideal for use in high-density networks.

The combination of computational techniques (including data from sensors) with experimental techniques (such as observation) makes the evaluation of a person's interaction with the environment more accessible and realistic. In this sense, context-specific field studies, such as studies of thermal preferences in areas of a particular city, are an example that can be employed directly in design decision-making.

Transducers[2]: selection of a transducer is one of the most important factors which help in obtaining accurate results. There are many types of transducers, that can be classified based on quantity to be measured (temperature, pressure, displacement, etc.), based on the principle of operation, that is, the principle behind the process of conversion (photovoltaic, piezoelectric, chemical, electromagnetic, etc.) and based on whether an external power source is required or not (passive and active transducers respectively).

To know more...

[1] Chapman, L., Muller, C. L., Young, D. T., Warren, E. L., Grimmond, C. S. B., Cai, X. M., & Ferranti, E. J. (2015). The Birmingham urban climate laboratory: An open meteorological test bed and challenges of the smart city. Bulletin of the American Meteorological Society, 96(9), 1545-1560. Available on: http://journals.ametsoc.org/doi/full/10.1175/BAMS-D-13-00193.1

[2] General information about transducers: http://www.electrical4u.com/transducer-types-of-transducer/

[3] Information reglated to sensors:
- http://www.engineersgarage.com/articles/sensors
- http://www.iupac.org/publications/pac/2004/pdf/7604x0723.pdf
- Castell, N., Kobernus, M., Liu, H. Y., Schneider, P., Lahoz, W., Berre, A. J., & Noll, J. (2015). Mobile technologies and services for environmental monitoring: The Citi-Sense-MOB approach. Urban climate, 14, 370-382.

Near future challenges

The state of the technology will continue to push towards miniaturized, commoditized, low cost sensors with higher sensitive and efficiency. Nanotechnology and the development of microelectromechanical sensors (MEMS) will play an important role in this regard. Some examples already exist: biochip-based algal biosensors for the detection of volatile toxic compounds (vapours of formaldehyde and methanol); graphene-based sensors that can detect harmful air pollution with very low power consumption, etc. An important advantage of miniaturising is portability: sensors can be integrated in bicycles, smartphones and other devices. This is being tested in projects such as MESSAGE (2006-2009), CitiSense, CommonSense and Citi-Sense-MOB. However, significant challenges remain with respect to often variable data quality and to the difficulty of deriving meaningful information from the collected data.

Smart sensors: are the combination of both sensor and actuator that are capable to compute the harvested data and to make decisions based on it. Smart sensors can perform self-calibration and can broadcast information about its own status. Moreover, they can be multisensing, which means that a single device can measure multiple factors (i.e. pressure, temperature, humidity, etc.).

Biosensors[3] provide fast, reliable, and sensitive measurements with lower cost; many of them aimed at on-site analysis. They incorporate a biological material intimately associated with a physicochemical transducer. For environmental control and monitoring, biosensors can provide fast and specific data of contaminated sites. They offer other advantages such as the ability of measuring pollutants in complex matrices or the possibility of determining not only specific chemicals, but also their biological effects, such as toxicity or endocrine-disrupting effects.

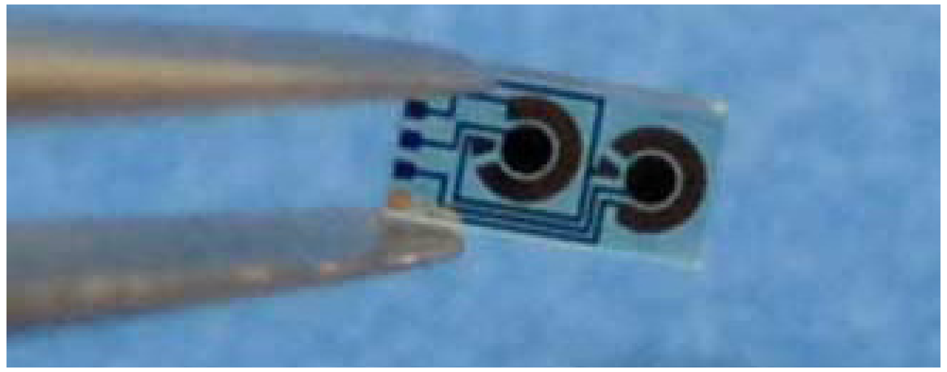


Fig 1. Miniaturised biosensors are being developped for medicine, but in the future might be also used for other applications.

Microelectromechanical sensors (MEMS)[3]: Over the past several decades MEMS researchers and developers have demonstrated an extremely large number of microsensors for almost every possible sensing modality including temperature, pressure, inertial forces, chemical species, magnetic fields, radiation, etc. Remarkably, many of these micromachined sensors have demonstrated performances exceeding those of their macroscale counterparts.

Monitoring will not only focus on the building environment but also on occupants behaviour. The interconnection of these two kinds of data will allow the buildings and the users to learn from each other and adapt their behaviour to achieve a common objective (for instance, reduce energy consumption).

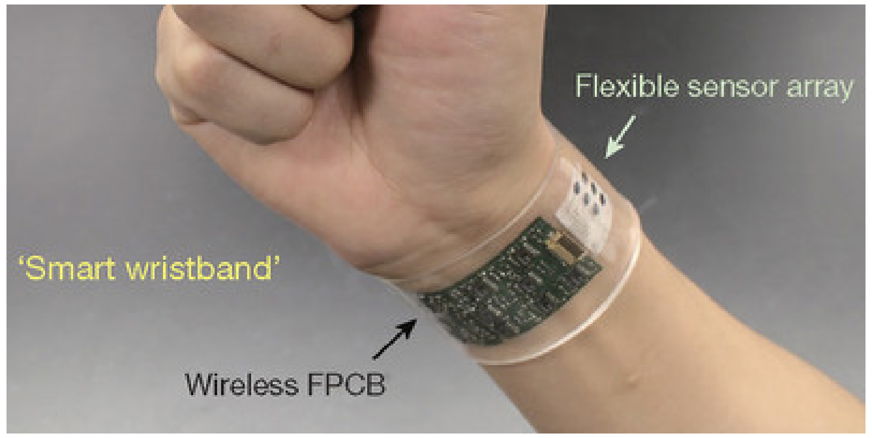


Fig 2. Wearable sensors will be mainstream in the near future.

Opportunities for innovation

The number of physical quantities that are massively monitored is increasing: from body constants to human behaviours such as users' preferences or towards a specific service, the acquisition of all this information will open the door for new business opportunities and improve awareness on specific issues.

Miniaturized monitoring systems will allow for the integration of such systems in portable devices such as mobile phones. This will allow for real time, ubiquitous and high resolution data acquisition.

SMART BUILDINGS

TO-09 Smart lighting

Lighting constitutes a significant portion of building energy consumption. Automatic lighting control systems reduce energy consumption by decreasing operating time of lamps based on various factors like occupancy, time of day, availability of daylight. Various technologies exist that perform lighting control. These technologies differ in their input parameters, their control method, control algorithm, cost of installation, complexity of commissioning, etc. Each of the control schemes has a unique set of factors that affect their performance in terms of energy savings as well as user acceptance.

Today

Energy efficiency is one of the main focuses of research in electrical engineering at the present time. Lighting equipment consist of a lamp, a lighting fixture, a control system and a control gear, each contributing to the overall efficiency of the system.

Lamps have shown dramatic increases in energy efficiency in recent years. Compact fluorescent lamps (CFLs) and light emitting diodes (LEDs) require about 80% and 85% less electricity compared to incandescent lamps (ILs) and last 6 and 26 times longer, respectively. New lighting fixtures reflect light in such a way that more light can be used where needed and less light gets lost in the light fixture itself. Regarding the control systems and gears, the available technologies are described below.

1. Occupancy-based control schemes

These are the most common control systems, and are indicated for spaces where the occupancy is infrequent and/or irregular. They use of a motion sensing technique to detect the presence of occupants in a space so the lights switch on and off (motion-based switching) or dim (motion-based dimming) in a pre-fixed delay period. Switching is more efficient, while dimming is generally more satisfying to users, but demands higher installation cost.

The efficacy of the system depends mainly on two key aspects: the definition of the delay period and the technology of the sensor. To define a proper delay period, the occupancy behaviour pattern of the room or area must be studied well in order to get the optimum balance between energy savings and user satisfaction. Regarding the sensors, there are different technologies available:

- **Passive infrared (PIR):** a pyroelectric detector detects a change in the temperature pattern of the space. Accuracy is reduced with distance. A common complaint is false-off errors.
- **Ultrasonic sensors:** sensors emit ultrasonic sound waves and compare that with reflected signals. When the emitted waves are reflected off a moving object, the wavelength of the reflected signal changes. These systems do not require a field of vision as PIR does, and are much more sensitive. However, this can also cause problems as movements coming from other spaces can trigger the sensor giving "false-on" errors. Accuracy is reduced with distance.

To know more...

[1]Asif M, Yusri M, Abdullah H et al. A review on lighting control technologies in commercial buildings their performance and affecting factors. Renewable and Sustainable Energy Reviews 33 (2014) 268-279

Dubois MC and Blomsterberg A. Energy saving potential and strategies for electric lighting in future North European, low energy office buildings: A literature review. Energy and Buildings 43 (2011) 2572-2582

Mills B and Schleigh J. Household transitions to energy efficient lighting. Energy Economics 46 (2014) 151-160

Article about lighting automation systems: http://www.digikey.com/en/articles/techzone/2012/jan/smart-lighting-enters-the-workplace

2. Daylight-linked lighting controls

These systems provide a maximum amount of savings in rooms with provision to receive daylight. The implementing cost is higher than occupancy based controls but have higher energy saving potential, provided that all the factors affecting performance are well controlled, which demands a higher effort and expertise than in the case of occupancy based controls.

Based on the how the control of the lighting system is made, they can be classified as switching systems, which are more adequate for outdoor/common spaces, or dimmable systems, which are more suitable for indoor spaces.

Based on the algorithm of control, it is possible to distinguish between closed loop and open loop systems. Closed loop systems detect lux levels, which includes light from both daylight source and lamps. Open loop systems only detect available daylight levels.

3. Lighting control by time scheduling

These systems operate on a very simple principle based on fixing an operating time of the light fixtures. This is useful in areas where the occupancy pattern is accurately predictable, such as classrooms, etc. Control devices (time switches) are simple and inexpensive. They can be manual or digital, which can be programmed remotely. An override capability is usually provided for the users in case of out of pattern usage of lights. In this case, the time switch automatically returns to scheduled mode after a certain time.

TheSE systems can stand alone or be integrated in a lighting control panel which control lighting of multiple rooms. Control panels can be particularly useful in maintaining different schedules for different areas of the building that follow the same routine. Scheduling systems are commonly used in combination with other control systems like occupancy sensors and photocells as well.

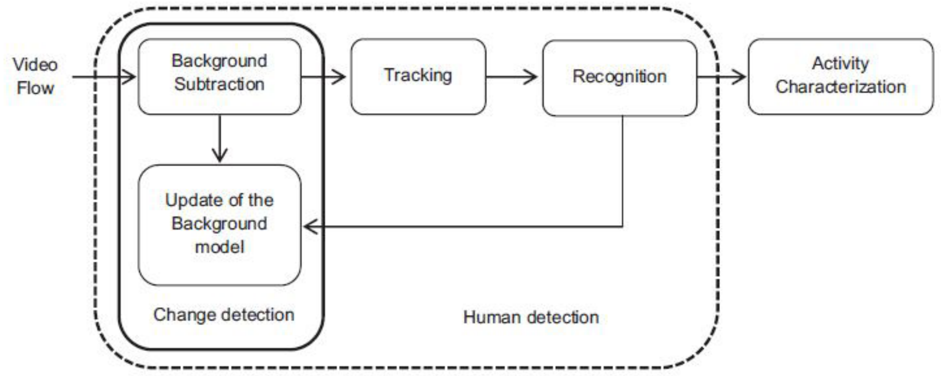


Fig. 1 Occupancy detection algorithm using video imaging[1].

Opportunities for innovation

An algorithm may be developed capable to take into account various parameters of a given area (room type, number of occupants, floor space, window area, orientation, ...) and provide multiple control options using single or multiple control systems and rate them, for instance, in terms of energy saving potential. From the suggestions, the users will be able to make an informed decision. Development of such an algorithm will reduce the frequency of inappropriate application and tunings of control systems i.e. improve the effectivity of commissioning and lead to better user satisfaction.

Near future challenges

Current research in the field of lighting controls is further pushing the possibilities of energy savings and user comfort.

In terms of development of the technologies, researchers are focusing on improving detection using imaging systems and RFID.

Radio Frequency Identification (RFID): RFID tags are installed inside ID cards for tracking entrance and exit times of office employees, students, etc. Using this existing technology in combination with other sensor systems, can help to reduce errors. As RFID tags are person-specific, the system would provide occupant profiling. RFID can be passive or active depending if the tags have their own miniature power source or not.

Digital Imaging: using cameras as sensors would be more accurate than existing presence sensors. This can be done by using existing surveillance cameras and training the system to detect human heads or by developing a background model from which tracking and recognition of occupants can be performed. The use of cameras that can provide luminance information can provide more flexibility of usage, like providing information for proper daylight harvesting and shading control, fire detection... a single camera will combine the applications of multiple separate sensors effectively.

Apart from development of individual technologies, researchers are putting emphasis on developing **networks of sensors** to overcome the faults associated with individual sensors. Wireless sensor networks are gaining focus in lighting control strategies.

Hybridization of control systems also seem to be a promising field. Examples of hybrid systems are systems that control both the internal lighting level and level of daylight penetration using automated window blinds or larger scale wireless network systems that use integrate the sensing of environmental parameters, which are used to detect occupancy status and quantity.

These strategies are becoming easier to achieve with the growing eminence of **Building Automation Systems (BAS)**. BAS provide higher control by the user: brightness level and other parameter in lighting systems can be adjusted from a computer or over internet communication using smartphone apps. Automatic control varies a lot in technology and complexity.

SMART URBAN SPACES

TO-10 Multifunctional materials

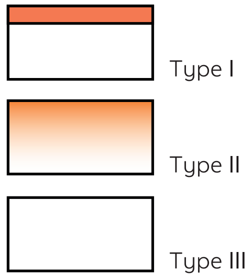
Smart materials are multifunctional materials that have the ability to react upon an external stimulus, simulating, in this way, the behaviour of nature's materials. The introduction of biomemetics in the material science, allows the designing of materials with similar processes as nature does: building from molecules to complete structures.

Today

Today, engineers can imagine designing comfort-tailored performance, such as active structural vibration and noise suppression or temperature compensation, from louvered or pore-based "smart skins"; energy-efficient structures, adaptive structures that can compensate for distortion or heal themselves; and structures reconfigured to satisfy style preferences. Imagine, for example, being able to commute to work in a stately professional car that can be reconfigured into a sportier car for the weekend.

Multifunctionality can be integrated into several dimensional scales with increasing interconnectivity between phases which results in different types of materials:

- Type I: materials comprised of phases in which one function is simply mounted, coated, or laminated to another, usually a structural component.
- Type II: materials comprised of distinct phases in which one function is embedded in another, usually a structural component.
- Type III: materials are truly integrated; the phases are intermeshed, blurring the physical distinctions between them.



It is possible to identify three major families of multifunctional materials:

Structural composite materials. Although composite materials exist since ancient Greeks, they have evolved into composites which can perform functions such as sensing strain, stress, damage or temperature, damage prevention, thermoelectric energy generation, self-healing or active noise and vibration control.

Some examples are composites with embedded optical cabling which can serve as a local area network, shuttling data between systems; metal-intermetallic laminate composites which incorporate functions such as crack propagation prevention, self-healing, improved strength, etc.; thermal energy storage composites which have applications in diverse areas, such as building heating/cooling systems, solar energy collectors, power, and industrial waste heat recovery or self-healing structures which have the ability to maintain their structural integrity by an internal repair system.

Smart or intelligent materials. During the last decade, a lot or research has been focused on designing materials that will be able to adapt to external changes. These materials respond to environmental stimuli with particular changes in some of their variables.

The state-of-the-art smart materials are able to change their properties (mechanical, electrical, and appearance), their structure or composition, or their functions depending on the stimuli received. Some examples are piezoelectric materials, which can bend, expand, or contract when a voltage is applied; shape memory alloys, which have the ability to return to their original shape after they have undergone large deformations; pH sensitive polymers that respond to the changes of the pH of the surrounding medium by varying their dimensions or polychromic, chromogenic, and halochromic materials that change colour due to external influences (for instance, alterations in pH, temperature, light, or electricity).

Smart materials have advanced a lot since that initial attempt in the 1990s, many new materials have been developed, the trend now being to combine materials, instead of using only one type of smart material.

Nanostructured materials. Nanostructured materials are among the major outcomes of the nanotechnology research undertaken during the last decade. These materials can be designed to imitate nature mechanisms of self-replication and self-assembling.

Nanocoatings are super-thin coatings with enhanced properties which are useful for a wide range of applications, such as abrasion and corrosion protection, antifingerprint, photocatalysis, lotus-effect (hydrophobicity), etc. (Fig. 1).

Nanoparticles present highly distinct properties in comparison with the bulk material. For instance, inert metals may become highly effective catalysts when manufactured as nanoparticles; opaque particles may become transparent, conductors may become insulators and vice versa. Nanoparticles can comprise a range of different morphologies including nanotubes, nanowires, nano whiskers, nanofibers, etc.

To know more...

[1]General features:

- https://www.grc.org/programs.aspx?id=17252

-http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.131.6441&rep=rep1&type=pdf

[2] Furutre trends:

-https://www.nae.edu/File.aspx?id=7294

-http://www2.mse.vt.edu/inamm/MultifunctionalMaterials/tabid/863/Default.aspx

-http://www.compositesworld.com/blog/post/multifunctional-composites-past-present-and-future

Scientific article focuse on processing challenges: http://link.springer.com/article/10.1007%2Fs00170-009-2428-6#/page-1

Opportunities for innovation

In the future, the design of a new car, airplane, or satellite will truly begin on the atomic scale. Truly smart materials systems, analogous to biological systems, will require a combination of three or more functions, including logic, sensing, energy storage, structure, and actuation. Visionary contexts for multifunctional systems include1:

-Autonomic Systems — a sensing material that can diagnose and adjust its properties by itself in response to its environment.

-Adaptive Systems — allowing reconfiguration or readjustment of functionality, shape and mechanical properties on demand.

-Self-sustaining Systems — with structurally integrated power harvest/storage/transmission capabilities.

Near future challenges

In the future, new functional and reduced-scale materials that are currently in the forefront of technology will be hybridized into designer materials in large engineered systems2. These performance-tailored structures will have the ability to change or adapt the performance or style of a structure on demand.

The key issues underpinning the advancement of these systems are:

- Translation of model biological functions to synthetic materials
- Accelerating transport or dynamic chemical changes in strong, stiff materials
- Optimizing interfaces between hard and soft materials
- Multi-physics modelling of multi-component system
- Reducing the cost and duration of the processing and achieving mass production
- Design using eco-efficient and environmental friendly principles.

The effort is focused on learning how to fabricate largescale materials from nanoscale elements. Although self-assembly and biological processing techniques look promising, they are not yet mature enough for the fabrication of multicomponent systems.

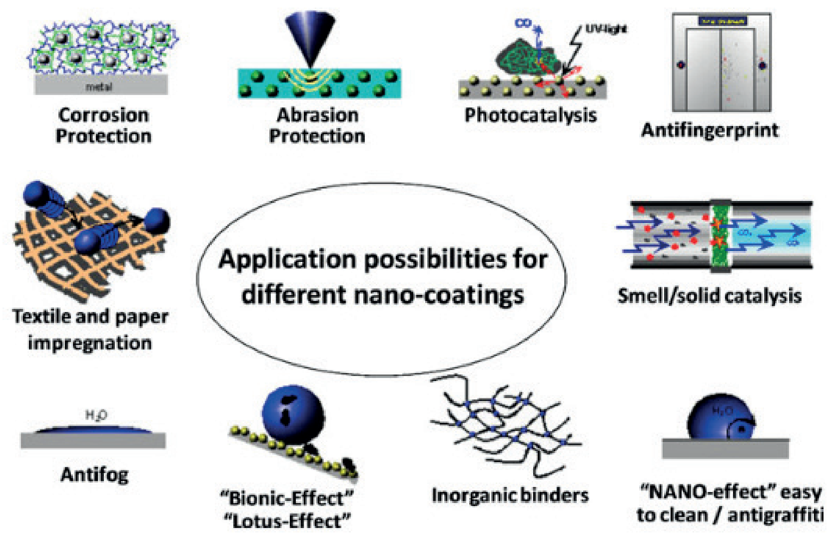


Fig. 1. Potential applications of nanocoatings.

SMART BUILDINGS

TO-11 Envelope retrofitting: glazing

The design of the glazing parts of the building envelope has an important impact on its overall energy performance. Glasses allow for the entrance of direct sun radiation and the high level of energy associated with it. A smart control of solar radiation will help to reduce artificial lighting needs and heating needs in winter and prevent overheating in summer. Glasses are also the weakest part of the envelope in terms of thermal insulation, which may result in important energy loses. Over the last fifty years glass technologies for buildings have undergone radical changes and extended the functions and applications of glazing in modern architecture.

Today

The glazed facade area of buildings is the part that produces the greatest energy losses and energy gains. Different technologies exist and are being developed to control such losses.

Clear glass, combined with automated exterior shading, provides the best viable technology today to improve occupant comfort and save energy by modulating the solar energy that is hitting the glass.

Double skin facades are building envelopes comprising two glazed surfaces enclosing an air cavity. They can be classified into passive non-ventilated facades and active mechanically ventilated and PV integrated facades[1]. **Ventilated facades** protect the building from intensive weather phenomena and noise, and reduce heat demand and cooling loads. Special attention is devoted to studying shading devices inside the ventilation cavity with the aim of solar gain reduction. Semi-transparent building-integrated photovoltaic systems (BIPV) provide the added benefit of electricity generation apart from daylight and heat. However, this technology requires significant additional costs.

Automated operation dynamic facades are systems capable to feature dynamic reaction to environmental data input as well as web based user interaction for the optimization of energy, visual comfort and thermal comfort by means of motorized rotating louver slats that effect changes to the degree of shading and to the opening and closing of ventilation dampers. These systems have been proven to reduce energy consumption in buildings while maintaining indoor environmental quality at a high standard. However, they are controversial due to concerns for risk of occupant distraction and discomfort. It is demonstrated that users must be given the ability to manually override the automated facade control, as the inability to intervene is the greatest source of discomfort.

To know more...

[1]http://www.sciencedirect.com/science/article/pii/S0378778804001641

[2]https://sites.google.com/a/lbl.gov/green-clean-mean/key-strategies/envelope-lighting

Solar concrete, example of new facade materials developments: https://www.youtube.com/watch?v=JUM2LrucRdk

Some examples of smart facades: http://gizmodo.com/5-smart-building-skins-that-breathe-farm-energy-and-g-1254091559

Document on responsive building envelopes: http://www.rvtr.com/files/HPH.pdf

Articles on bio facades: http://www.arcc-arch.org/wp-content/uploads/2015/10/Bio-Facades_KKim.pdf

Near future challenges

New glazing systems will continue to be developed. Improvements are aimed to achieve new methods of modulating solar heat and light transmission, better thermal insulation performance, higher resistance and versatility. Some of the possible technologies are:

Advanced solar control glazings are glasses tuned to reject as much heat as possible, while transmitting high levels of visible light. Combined with exterior shading systems, such systems offer an improved solution that is being deployed in many markets. However, they are still expensive from an energy efficiency perspective for many parts of the world.

Dynamic glazings offer the potential to modulate solar heat through the glazing while maintaining a full view to the outdoors. An example are electrochromic glazings, which change opacity in response to voltage and thus allows control over the amount of light and heat passing through. Pilot projects have demonstrated that these systems can potentially reduce lighting costs, cooling loads and peak electricity demand. More R&D and economies of scale are needed to improve dynamic solar control so that it can become cost-effective for mainstream markets.

Switchable Liquid Shielding: in order to control the amount of solar energy passing through the facade, a thin layer of liquid is pumped through a gap in the exterior double window pane, that reduces the infrared radiation penetrating the glass, without impairing visibility. The technology is claimed to function similarly to low emissivity coatings, the benefit in this case being that it can be administered when useful and removed when larger solar infiltration is desired.

Further configurations for smart windows will be tested. For instance, windows might incorporate water cooled tracking solar cells, thus being capable to generate electricity, reduce cooling loads, improve visual comfort thanks to diffuse radiation and produce domestic hot water. Other possibilities might be the incorporation of new technologies such as photoelectrochromic devices based on dye-sensitized TiO_2 solar cells in PV integrated electrochromic windows.

Fig 1. Integration of multiple functions is a major trend in the development of glazing enveloppes.

Opportunities for innovation

Productive facades that provide shadow when needed and profit solar radiation, adaptable to climate. High performance energy systems will adapt to the façade performance so energy will be used when it is harvest by the façade. The façade and the HVAC systems will cooperate in maintaining indoor comfort.

Building envelope retrofitting will include the use of high performant materials so the improvement of hygrothermal performance will be made with the simple addition of a coating material.

The façades will be multifunctional: they will harvest energy, heat ACS, clean polluted air, perform as street screens... Active systems will be more and more substituted by active facades. Distribution systems will gain importance: from façade to the rest of the building.

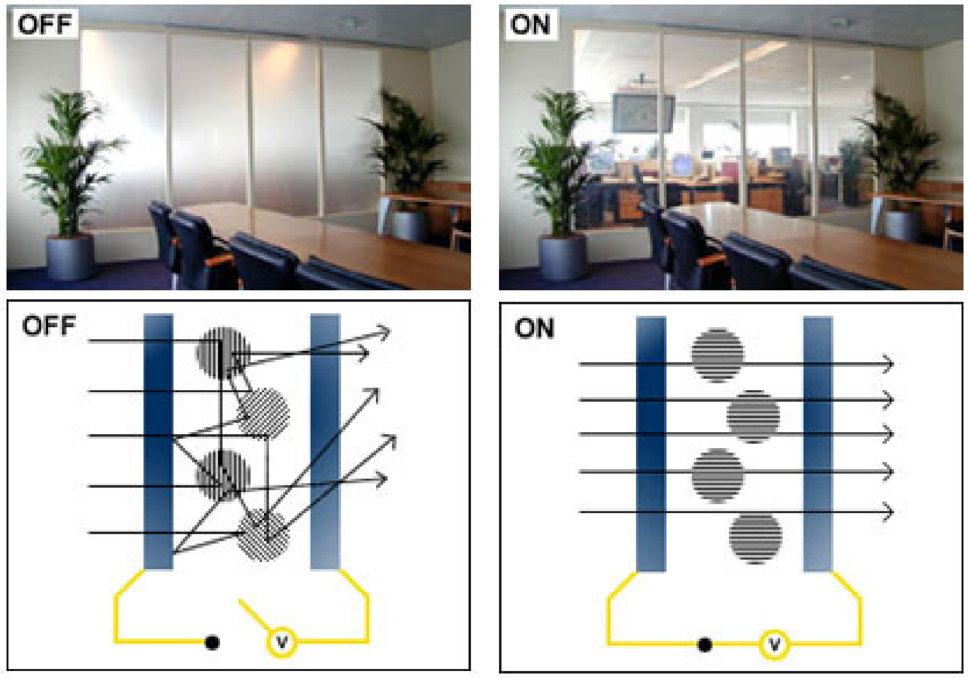


Fig 2. Example of a switchable window. When the glass is switched on, the particles polarise and the glass becomes transparent.

SMART BUILDINGS

TO-12 Envelope retrofitting: opaque

Many studies have been carried on during the last decades showing how the energy performance of buildings can improve with a properly insulated building envelope. The heating loads of buildings depend on the thermal transmittance of envelope components, and the lower the latter, the lower the former. This means that the implementation of thermal insulation materials on existing façades is essential to improve the energy efficiency of existing buildings. New thermal insulation materials are being developed towards higher performance, which allows for the reduction of the thickness needed to reach sufficient levels of thermal insulation.

Today

Insulation materials form the major tool for the improvement of a building's energy behaviour. The use of insulation materials has increased, both in terms of buildings being insulated and in the minimum values of insulation required by the national regulations. Appart from the traditional materials (mineral wools, organic foams and natural fibres), other currently available materials are:

Vacuum insulation panels (VIP) consist of an open porous core of fumed silica enveloped of several metallized polymer laminate layers, with thermal conductivities 10 times lower than conventional materials. High cost, increase of thermal conductivity with ageing and the fact that VIPs cannot be perforated or cut for adjustment at the building site without losing part of their thermal insulation performance, represent the major drawbacks of VIPs.

Gas-filled panels (GFP) hold the same principle as VIPs with the difference that a low-conductance gas is used instead of vacuum. Current GFPs have a thermal conductivity similar to traditional materials, although much lower values can be achieved. The GFPs hold many of the VIPs advantages and disadvantages. Their future development is doubtful, as VIPs seem to be a better choice in comparison.

Aerogels can be produced as either opaque, translucent or transparent materials, thus enabling a wide range of possible building applications. Current aerogels have a thermal conductivity of four times lower than traditional materials, although conductivities similar to VIPs can be achieved. Main drawbacks are high production costs and low tensile strength.

Phase change materials (PCM) are not thermal insulation materials, but materials that change phase from solid state to liquid when heated, thus absorbing energy in the endothermic reversible process. Such a phase change cycle stabilizes the indoor building temperature and decreases the heating and cooling loads.

Near future challenges

Limited progress can be expected in the field of the conductivity values of traditional insulation materials. However, improvements can be made regarding fire behaviour, durability, health and environmental properties, applicability or cost. Possible future thermal building insulation materials and solutions are:

Vacuum and Gas insulation materials (VIM and GIM), homogeneous materials with a closed small pore structure filled with vacuum or a low-conductance gas with a thermal conductivity 10 times lower than traditional insulators. They can be cut, perforated and adapted at the building site with no loss of low thermal conductivity.

Nano insulation materials (NIM), homogeneous materials with a closed or open small nano-pore structure with a thermal conductivity similar to VIMs. Unlike VIMs and GIMs, NIMs do not need to prevent air and moisture penetration into their pore structure to maintain their insulation properties.

Dynamic insulation materials (DIM) are materials where the thermal conductivity can be controlled within a desirable range. This may be achieved by changing in a controlled manner the inner pore gas content or concentration, the emissivity of the inner surfaces of the pores or the solid state thermal conductivity of the lattice.

FAÇADE SYSTEMS.

The development of the whole facade systems will evolve towards the integration of different technologies, such as PV systems and smart materials, which will contribute to turn facades into active systems having the ability to sense and respond to external stimulus in a predetermined and controllable manner. Bio façades or algae integrated building envelopes are an example of this.

New solutions will be developed for the load-bearing elements. Load bearing insulation materials such as nanocons will be developed, which will be essentially NIMs with construction properties matching or surpassing those of concrete.

To know more...

[1] http://www.sciencedirect.com/science/article/pii/S0378778804001641

[2] https://sites.google.com/a/lbl.gov/green-clean-mean/key-strategies/envelope-lighting

Solar concrete, example of new facade materials developments: https://www.youtube.com/watch?v=JUM2LrucRdk

Some examples of smart facades: http://gizmodo.com/5-smart-building-skins-that-breathe-farm-energy-and-g-1254091559

Document on responsive building envelopes: http://www.rvtr.com/files/HPH.pdf

Articles on bio facades: http://www.arcc-arch.org/wp-content/uploads/2015/10/Bio-Facades_KKim.pdf

Opportunities for innovation

Productive facades that provide shadow when needed and profit solar radiation, adaptable to climate. High performance energy systems will adapt to the façade performance so energy will be used when it is harvest by the façade. The façade and the HVAC systems will cooperate in maintaining indoor comfort.

Building envelope retrofitting will include the use of high performant materials so the improvement of hygrothermal performance will be made with the simple addition of a coating material.

The façades will be multifunctional: they will harvest energy, heat ACS, clean polluted air, perform as street screens... Active systems will be more and more substituted by active facades. Distribution systems will gain importance: from façade to the rest of the building.

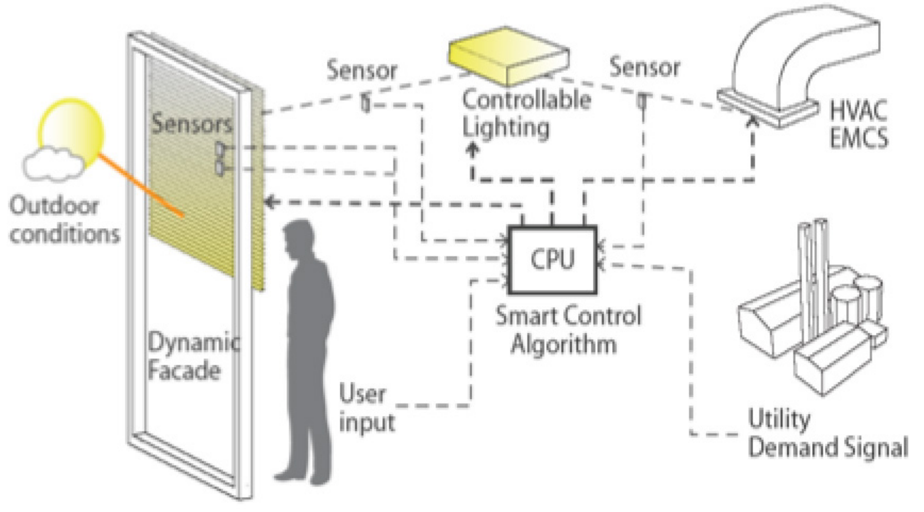


Fig 1. Schematic of "future proof" integrated solutions. Concept integrates: 1) Operable façade components: Motors or actuators for shading devices, light-redirecting elements, operable windows, or switchable glass coatings; 2) Responsive lighting systems with dimmable output to match daylight, task needs and occupancy; 3) Occupant and sensor driven input for all systems control; 4) BMS controls integration that optimizes for comfort, owner cost, utility DR/price signals[2].

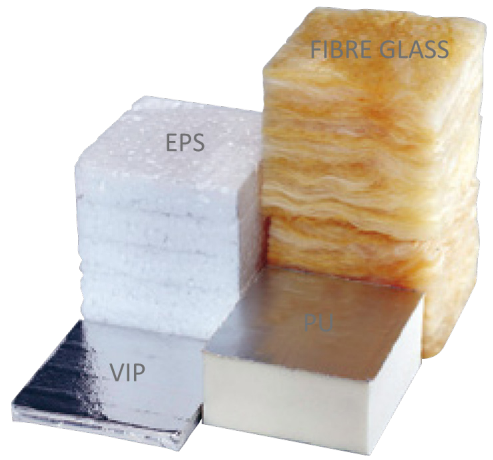


Fig 2. Comparison of the thickness needed to reach the same thermal insualtion with different materials

SMART BUILDINGS

TO-13 Historical building retrofitting

The retrofitting actions in historical or singular buildings is limited. However, some measures such as the implementation of operational measures, the improvement of the hygrothermal performance of envelope[1], the improvement the efficiency of systems or the addition of renewable energy production (when possible) are still possible. A deep analysis of what the existing situation is, is necessary before the stablishment of the retrofiting measures to implement. Decision support tools are useful for the rapid identification and design of the optimal retrofit measures and their priority. Historical buildings are part of a wider building stock in cities and energy balancing measures between buildings are strategies that should also be taken into account.

Today

The **energy-efficient upgrade of historic buildings** is a pluridisciplimary enterprise. As for non-historical buildings, a whole retrofitting strategy should impact on energy demand, energy efficiency and energy management. To achieve the maximum energy savings, the flow of the retrofitting actions implemented shoud be as follows:

1. OPERATIONAL AND MANAGEMENT MEASURES [2]

Energy Standard Operating Procedures are valuable because they promote consistency and gradual learning in building management, while also providing a context for adaptive management[1]. **Performance Specifications** describe how a building system should perform in terms of energy efficiency, capacity, or some other functional criteria.

Energy Audits and Simulations can be used to evaluate nearly every building system, including heating ventilation & cooling systems, hot water heating, electricity and potable water use; before planning of any retrofit project or energy management program. **Energy Information Systems** allow for the monitoring of lighting, HVAC, elevators, and other mechanical systems, and **Energy Management and Control Systems** are able to remotely communicate with the equipment being monitored.

2. IMPROVEMENT OF THE HYGROTHERMAL PERFORMANCE OF THE BUILDING ENVELOPE

Interior insulation systems require the integration of moisture management into the planning phase, as well as the careful design of details such as window reveals and internal wall connections. Two distinct systems are possible:

- **Vapour-impermeable systems** prevent the water vapour flux into the wall with vapour-retardant foils, dense interior plaster, or vapour-resistant insulating layers.
- **Vapour-permeable, capillary-active systems** allow vapour to diffuse into walls; they buffer the resulting moisture and remove the liquefied water from the condensation zone back towards the room.

Increasement of the airtightness[2] of the construction systems is an efficient strategy to improve energy efficiency in historical buildings. Penetrations usually occur at the end of old and cracked wood beams, in the roof area, particularly at the roof/wall connection to the eaves, at the connection of the collar beam to rafters and where posts giving support to roof beams stand on the insulated top floor ceiling. Such intervention must be carefully analysed to prevent condensation problems.

To know more...

[1] Casini, M (2014). Smart materials and nanotechnology for energy retrofit of historic buildings in International Journal of Civil and Structural Engineering- IJCSE, 2014, volume 1, Issue 3, pag. 28 - 37.

[2] Melorose,J; Perroy, R; Careas, S (2015). Energy Efficiency Solutions for Historic Buildings: A Handbook in Statewide Agricultural Land Use Baseline, 2015, volume 1.

[3] Low-e coatings: http://www.efficientwindows.org/lowe.php

[4] 3encoult project. Efficient energy for EU cultural heritage: http://www.3encult.eu/en/project/welcome/default.html

Glazing surfaces: Retrofitting measures can be applied in **original historic windows** to fulfill comfort and energy efficiency today's requirements. Losses through windows can be reduced by using bars attached only to the exterior glazing surface (uninterrupted space between the panes). Historical **window frames** can assimilate diverse glass-improving measures as **low-e coatings**[3] (external or, preferably, internal) or **double-glazing**, even with gas insulation. For **triple-glazing** solutions the frame usually has to be cut in two shells. Another option is to leave the **old window untouched** and **build a second window** as a thermal layer inside it (**two-layer principle, see Fig.1**).

3. IMPROVEMENT OF THE EFFICIENCY OF SYSTEMS

Heat recovery ventilation: replacing original natural ventilation reduces heat losses fand prevents structural damage. For historical buildings, if it is not possible to improve airtightness to a high standard, a small surplus of extract air (10% max) can protect the building structure. The air inlet and outlet can be designed through unused chimneys or building cellars. [2]

Artificial lighting and daylight design should be non-invasive through a reversible installation for instance. Shutters, which are typical shading devices for many European regions, can be transformed into daylight-redirecting devices and maintain their original functions of solar blocking and security.[2]

Regarding **passive heating**, if exterior insulation is not possible, interior insulation is still preferred to no insulation, especially if interior walls also provide inertia. If only interior insulation is possible (due to the conservation restrictions), **passive cooling** trough night ventilation still remains effective if the interior partition walls provide enough thermal mass. [2]

4. IMPLEMENTATION OF RENEWABLE ENERGY PRODUCTION

For **electricity production**, **photovoltaic technologies** can be integrated in the roof ending or window glass or somewhere other than in or on the building itself to maintain the historic appearance or comply the restrictive regulations. **Solar thermal** energy has similar requirements as PV technologies. Space for hot water tank must be reserved and the existing roof structure needs to be surveyed in order to verify that it will resist the additional weight.

For **wind energy**, freestanding mast-mounted turbines are more viable for historic buildings than building-mounted turbines, which need structural survey of the building and are often not permitted. Historic mills can provide suitable locations for new **hydroelectric** installations, although impacts of vibrations, noise, etc. need to be considered.

The use of **biomass** is a common retrofitting strategy in historic buildings due to its low visual impact and its high efficiency, specially in poorly insulated buildings that have a high thermal storage mass. Many old properties have fireplaces and chimneys to accommodate stoves or boilers, a space for fuel storage with adequate ventilation (an existing shed or garage) and adequate access .

Historic building can also benefit from the constant, low-temperature heating offered by **geothermal energy** to protect its fabric or its contents. However, such systems are not useful for heating where the improvement of airtightness and insulation are not possible.

Low temperature radiators may also be an option, but their appearance is potentially more visually intrusive.

Opportunities for innovation

Training building managers on energy auditing, weatherization, standard operating procedures for energy efficiency, commissioning processes, and working with building management systems is key for the development of new business models related with historical building retrofitting.

Near future challenges

Nanotechnologies constitute a new approach to research and development that aims to control structure and fundamental behaviour of matter at the atomic and molecular level. Regarding the construction sector and focusing in historical buildings interventions, nanotechnology applications concern the fields of energy production and storage systems, and materials science.[1]

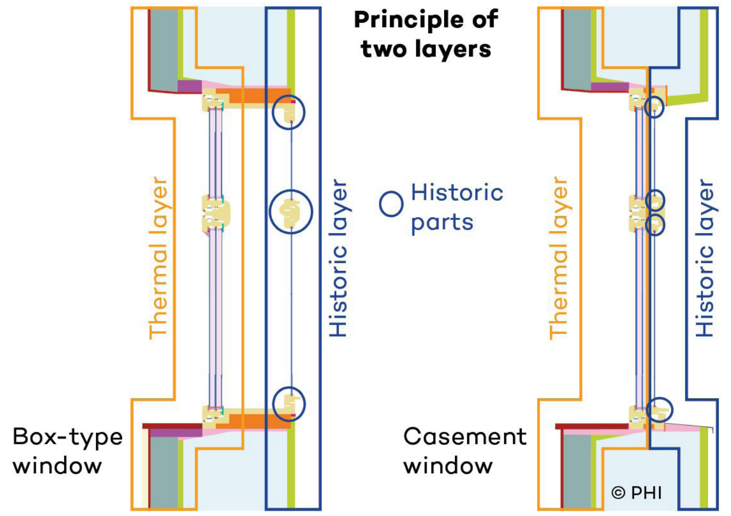


Fig 1. Two-layer principle. Smartwin historic developed by Menuiserie André, Franz Freundorfer, Passive House Institute[4]

SMART BUILDINGS

TO-14 Efficient retrofitting strategies

Given that a significant effort is needed to upgrade existing buildings, it is vital to prioritize and organize the actions to be undertaken with a carefully planned strategy. Depending on the case, the most advantageous strategy may range from prioritise operational measures over the implementation of passive and active solutions to address a higher initial investment in order to achieve energy savings faster and get faster cost returns. Detailed information on what are the key phases in a sustainable building retrofit programme can be found in Ma *et al*[1].

Today

Rather than specific technologies, efficient energy retrofitting has to do with the choice of adequate global strategies. Retrofitting strategies can be aiming to impact on the **demand side management** (improve building insulation, window retrofits, use of natural ventilation, upgrade of equipments and appliances, etc.), on the **supply side management** (integration of green energy production) or on **energy consumption patterns**, that is, human behaviour.

In general, more energy can be saved by using whole building retrofit, as compared to using the typical retrofit approach1. High-level strategies can have different approaches, which are not mutually exclusive[2]:

Whole-building approach: the building is regarded as an energy system with interdependent parts. The interaction between the occupant, building site, climate, and other elements or components of a building is considered. The performance of each component is strongly affected by the rest, and energy performance is considered a result of the whole system.

Fabric first approach: prioritises improvement of the thermal properties of the building fabric through the use of high levels of thermal insulation and airtightness. A range of measures is then employed to increase the efficiency of various systems (e.g. heating and hot water, lighting and electrical appliances). System re-sizing may be desirable as a consequence of reduced energy demand, but oversizing (e.g. of heat distribution systems) can significantly improve overall performance. Finally, renewables are installed to meet the remainder of the CO_2 and energy reduction requirements.

Passivhaus approach: this approach can be considered as a high-specification "fabric first" approach. The aim is to reduce the ecological footprint of a building mainly by reducing the thermal transmittance and the air permeability (<0.6 r/h at 50 Pa) of the envelope. This results in ultra-low-energy buildings with a demand lower than 15 kWh/m² for space heating or cooling and 120 kWh/m² per year in total).

"Insulate then generate" approach: is very similar to the "fabric first" approach. First aims to reduce energy demand from passive design strategies (building fabric, thermal mass and airtightness, ventilation and heat recovery), and then to meet the remaining demand through the use of microgeneration technologies.

To know more...

[1] Scientific paper on state-of-the-art building retrofits: Ma Z, Cooper P, Daly D, Ledo L. Existing building retrofits: Methodology and state-of-the-art. Energy and Buildings 55 (2012) 889-902

[2] Summary of different retrofitting strategies: http://www.instituteforsustainability.co.uk/uploads/File/2236_KeySummary03.pdf

[3] Recommendation from the US National Institue of Building Science: https://www.wbdg.org/resources/retro_sustperf.php

Systematic approaches are useful to identify the strategies to be implemented in a specific building retrofitting.

In general, all systematic approaches include some or all of the following stages[1]:

-Building energy/water auditing

-Building performance assessment and diagnostics

-Quantification of buildings' energy conservation benefits

-Economic analysis

-Risk assessment

-Measurement and verification of energy savings

The US National Institute of Building Sciences give the following recommendations before making a major investment in the energy retrofit of existing buildings[3]:

1. **To determine if the investment is worthwhile** in perspective with other building conditions.
2. To perform a sequence of analysis in order to **determine the best options for energy and sustainability improvements**: (a) energy/water audit; (b) energy consumption audit; (c) building air tightness analysis.
3. **To implement sustainability and energy-efficiency strategies:** (a) upgrade of energy and water systems to minimize consumption; (b) plan the recycling and reuse of demolition debris and construction waste; (c) evaluate occupancy patterns (monitoring); (d) analyse of feasible alternatives to reduce heating and cooling loads (natural ventilation, fresh air intake, etc.); (e) consider solar shading devices for windows and doors, including those that generate electricity by PV devices; (f) investigate renewable energy options; (g) replace existing windows with high-performance windows appropriate for climate and exposure; (h) analyse the benefits of distributed generation if the building is in a campus cluster or can share the on-site energy produced with adjacent buildings; (i) balance the project's sustainable goals with other goals (security, etc.); (j) determine if a cool roof or green roof are cost-effective ways to reduce heat island effect and storm-water runoff; (k) for historic buildings, update systems appropriately to maintain a balance between the need for energy and water savings with the character of the original building fabric; (l) incorporate sustainable operations and maintenance practices (green cleaning products and methods).
4. **To measure the performance of the building** regularly after the intervention.

Opportunities for innovation

Building retrofitting can result in important long-term savings and represent an opportunity for further building upgrade (integration of new uses, new technologies, etc.).

New business models related to energy/water services can be developped. Incentives for savers and cooperation among users to reach common objectives can be boosted.

Near future challenges

Building retrofitting is an important strategy to achieve global CO_2 emissions reductions. However, the investment is important and thus, it must be done to the highest standards. A refurbished building is not expected to undergo a new refurbishment for the next 20 years.

Incomplete refurbishments focused only on the most rentable retrofitting strategies will impede future in-depth interventions as the margin of improvement (and thus investment return) will be reduced. The refurbishment of the existing building stock requires of new business models for long-term returns.

To achieve building resilience due to the effects of climate change, more research on low energy adaptive strategies for building applications is needed[1].

Understanding how best to drive behavioural change is key to understanding how energy efficiency and retrofitting measures can have a real impact.

Ensuring a balanced and secure energy supply 'mix' and a balance in demand side efficiency measures is vital to do not 'scale up failure'.

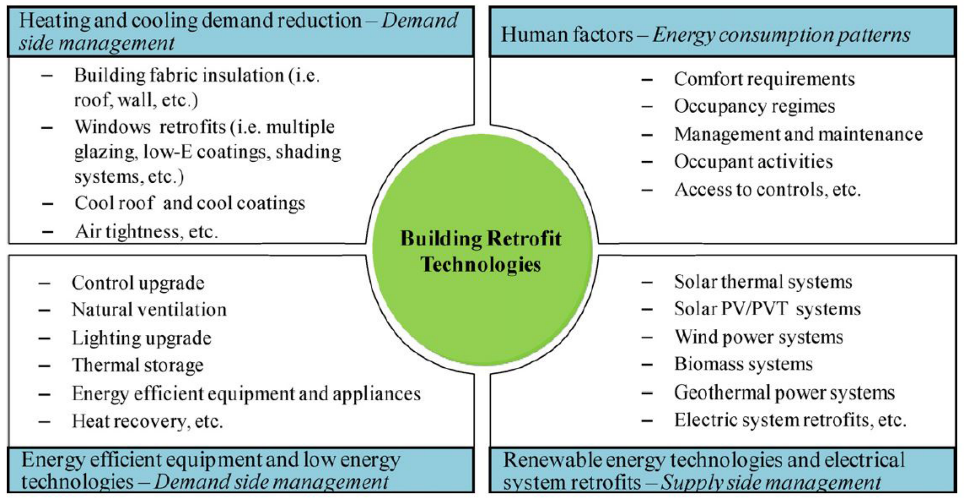


Fig 1. Main categories of building retrofit technologies[1].

SMART URBAN SPACES

TO-15 Solar PV production

Photovoltaic is a rising renewable energy source, which allows a decentralized energy generation in buildings and cities with a minimum impact on its environment.

Distributed PV is evolving slowly in the direction of self-consumption: Prosumers are on the rise. In 2013, more than 50% of distributed PV installations were achieved due to measures allowing or supporting self-consumption. In most cases, such measures were not the main driver for PV installation, but self-consumption of PV electricity is becoming the backbone of distributed PV.

Today

Global In 2016, global solar installations reached 64.7 GW, leaded by China, U.S., and Japan, which account for about two thirds of the global market. In Europe, solar PV is covering today more than 7 % of the electricity demand in Italy, Germany and Greece.

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Solar cells[2]

Dfferent types of PV materials for solar cells are available in the market nowadays, but Silicon based solar cells are leading the market from the beginning. Today, silicon PV cover more than 80% of the global market. However, its conversion efficiency is still a cause of concern among the scientific community. Therefore, the experimental work on different materials such as, amorphous silicon, CdS/CdTe and CIS is going on for efficiency enhancement of the thin film solar PV technology. Also options such as polymer or organic materials for solar cell are being developed which not only enhance the conversion efficiency but also tackle the concern over the environmental problems.

Crystalline materials: based on silicon, which has the advantage of being easy available. Monocrystalline cells are the most common, but polycristaline solutions are also available. GaAs (gallium-arsenic) has high efficiency, low weight and high heat resistance, but also higher cost. These are suitable for concentrated PV modules, hybrid use and space applications.

Thin film solar cells: due to reduced amount of raw materials, costs can be lowed and integration is easier. Amorphous silicon based solar cells have higher efficiency than other materials such as, Cooper-Indium-Gallium-Selenium (CIS/CIGS) and Cadmium-Selenium / Cadmium-Telluride (CdS/CdTe) based.

Concentrated solar PV (CPV): solar energy is concentrated and made fall onto the photovoltaic cells. This enhances the irradiance for improving the conversion efficiency and reduces costs as highly expensive solar cell materials are replaced by less expensive concentrating mirrors or lenses.

Organic and polymer cells (OPV): are becoming favourable presenting advantages such as mechanical flexibility, low fabrication cost, low environmental impact, semi transparency and light weight. However, their efficiency is still very low (around 8%).

Hybrid solar cells: due to combination of high charge-carrier mobility of inorganic semiconductors along with the strong optical absorption of the organic semiconductors, the hybrid organic-inorganic solar cells got much attention recently.

Other technologies: dye-sensitized solar cells are being developed, which exhibit lower cost and simpler manufacturing process than silicon based PV. The use of nanotechnology for enhanced power conversion efficiency (3rd generation PV) is also being investigated. Carbon nanotubes (CNT), quantum dots (QDs) and "hot carrier" (HC) based solar cells are some examples.

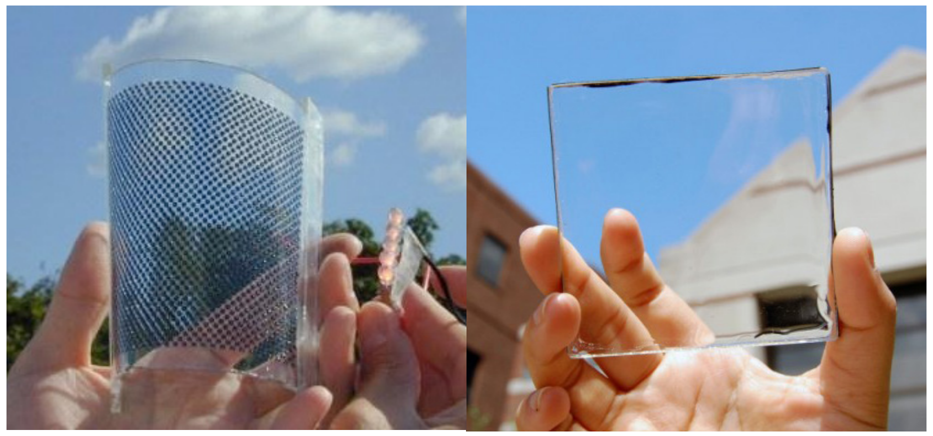

Fig. 1. Flexible and transparent solar photovoltaics are being developed to enhace integration in flexible surfaces, windows etc.

Inverters[3]

The evolution in power converter technology for PV applications has led to the existence of a wide variety of power converter topologies used in practice, which can be classified based on their configuration in **central, string, multistring,** and **ac-module** configurations. String configurations are the most common ones. The main advantages and disadvantages of such technologies are summarised in Fig. xx. Further information on inverters can be found in Kouro S, et al[3].

To know more...

[1]The 2016 global PV outlook: http://www.renewableenergyworld.com/articles/2016/01/the-2016-global-pv-outlook-u-s-and-asian-markets-strengthened-by-policies-to-reduce-co2.html

[2] Scientific paper on PV technologies: Pandey AK, Tyagi VV, et al (2016). Recent advances in solar photovoltaic systems for emerging trends and advanced applications. Renewable and Sustainable Energy Reviews, 53, 859-884.

[3] Scientific paper on inverter technologies: Kouro S, Leon J, et al. (2015). Grid-connected photovoltaic systems: An overview of recent research and emerging PV converter technology. IEEE Industrial Electronics Magazine, 9(1), 47-61.

European Photovoltaic Industry Association (EPIA): http://www.solarpowereurope.org

International Energy Agency (IEA): https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapSolarPhotovoltaicEnergy_2014edition.pdf

Opportunities for innovation

Photovoltaic is a powerful option for decentralized energy generation, e.g. in buildings,, allowing citizens, in combination with smart grids, to adopt an active role as consumer as well as producer of energy within their local energy network.

Large scale deployment of photovoltaic technologies may convert PV in one of the primary energy generation technologies of the 21st century.

Electricity market integration and self-consumption are considered two main drivers of PV redevelopment in Europe within the next years.

Near future challenges

In the near future, solar PV appears as a cost-competitive, reliable and sustainable electricity source in a growing number of countries. System prices below 1 €/Wp (for utility scale PV above 1 mw) will be common in several European countries. This resulting in highly competitive levelised costs of electricity (ICOE) for PV generation. By 2050, solar PV will provide 16% of global electricity and renewables 79%. Solar PV will equal wind power in cutting CO_2 emissions over the next 35 years. Indeed, the carbon footprint of PV electricity will continually decrease through its main drivers:

- Reduction in material used (e.g. thinner silicon wafers, thin-film modules) and recycling of materials
- Higher system efficiencies for converting solar energy into electricity
- Improved manufacturing processes resulting in increased throughput and yield and a reduction in energy usage
- Increased lifetime of PV systems
- Improved Balance Of System (BOS) by lighter structure, improved materials and building integration
- Improvement of logistics through industrial integration over the value chain, distribution network optimizing the transportation.

Main challenges for PV are:

- PV needs to be competitive with other renewables, nuclear and natural gas in times of a changing energy infrastructure
- PV must be smartly integrated in buildings and the urban environment in general
- Grid integration of decentralized renewable energy sources must be solved, avoiding possible threats regarding reliability.

	SMALL SCALE	MEDIUM SCALE		LARGE SCALE
	AC MODULE	STRING	MULTISTRING	CENTRAL
Power range	<350 W	<10 kW	<500 kW	<850 kW (<1.6 MW for dual)
Devices	MOSFET	MOSFET IGBT	MOSFET IGBT	IGBT
MPPT efficiency	Highest (one module–one MPPT)	Good (one large string–one MPPT)	High (one small string–one MPPT)	Good (one array–one MPPT)
Converter efficiency	Lowest (up to 96.5%)	High (up to 97.8%)	High (up to 98%)	Highest (up to 98.6%)
Features	• Flexible/modular • Highest MPPT efficiency • Easy installation • Higher losses • Higher cost per watt • Two stage is mandatory	• Good MPPT efficiency • Reduced dc wiring • Transformerless (very common) • High component count • One string, one inverter	• Flexible/modular • High MPPT efficiency • Low cost for multiple string system • Two stage is mandatory	• Simple structure • Highest converter efficiency • Reliable • Needs blocking diodes (for array) • Poor MPPT performance • Not flexible
Examples	Power One Aurora MICRO-0.3-I and Siemens SMIINV215R60	Danfoss DLX 4.6 and ABB PVS 300	SMA SB5000TL and SATCON Solstice	SMA MV Power Platform and 1.6 Siemens SINVERT PVS630

Green dots indicate positive features, and red dots indicate negative features.

Fig. 2 Overview of different conversion technologies[3].

SMART BUILDINGS

TO-16 Solar thermal production

Most of the talk about renewable energy is aimed at electricity production. However, most of the energy we need is heat, which solar panels and wind turbines cannot produce efficiently. To power industrial processes like the making of chemicals, the smelting of metals or the production of microchips, we need a renewable source of thermal energy. Direct use of solar energy can be the solution, and it creates the possibility to produce renewable energy plants, paving the way for a truly sustainable industrial civilization[1].

Today

SOLAR WATER HEATING[2] systems are most cost effective for building where:

- Water heating load is constant throughout the week and the year (not vacant in summer)
- Cost of fuel used to heat water is high
- Are built in a sunny climate (helpful but not required).

Solar water heating system types are classified by the following types:

- Active systems: require electric power to activate pumps and/or controls.
- Passive systems: Rely on buoyancy (natural convection) rather than electric power to circulate the heated water. Thermosyphon systems locate a storage tank above the solar collector, while integrated-collector-storage collectors place the storage inside the collector.
- Direct system: heat potable water directly in the collector.
- Indirect systems: heat propylene glycol or other heat transfer fluid in the collector and transfer heat to potable water via a heat exchanger.

A solar water heating system is made up of several key components including solar collectors, thermal storage, system controls/controller and a back-up, conventional water heater. Although solar water heating systems all use the same basic method for capturing and transferring solar energy, they do so with three specific technologies that distinguish different collectors and systems.

Low-temperature systems usually operate at low temperature above ambient temperature (up to10°C), and are most often used for heating swimming pools. Collectors are made from polypropylene or other polymers with ultraviolet stabilizers. Hybrid photovoltaic/thermal (PVT) collectors simultaneously convert solar energy into electricity and heat[3]. A typical PVT collector consists of a PV module with peak efficiencies in the range of 5%-20% and an absorber plate (acting as a heat removal device) attached on the back of the PV module. The heat removal plate cools the PV module down to a suitable temperature for better electrical performance, and at the same time, it collects the waste heat, which can then be utilised for low temperature applications.

Mid-temperature systems produce water between 10°C to 50°C above outside temperature, and are most often used for heating domestic hot water. However, it is also possible to use mid-temperature solar water heating collectors for space heating in conjunction with fan-forced convection coils or radiant floors. Collectors are usually insulated copper absorber plates with copper tubes welded to the fins. A cover glass is required to retain heat at higher temperatures, although it reduces the efficiency at low temperature differences.

High-temperature systems use evacuated tubes around the receiver tube to provide high levels of insulation and often use focusing curved mirrors to concentrate sunlight. High-temperature systems are required for absorption cooling or electricity generation, but are used for mid-temperature applications such as commercial or institutional water heating as well. Due to the tracking mechanism required to keep the focusing mirrors facing the sun, high-temperature systems are usually very large and mounted on the ground adjacent to a facility.

These systems can be parabolic trough systems, linear concentrating Fresnel collectors, parabolic dish systems or solar power towers[1]. Almost all of these technologies were developed at the turn of the 20th century. Linear reflectors (parabolic trough systems and linear concentrating Fresnel collectors) are limited to temperatures of about 400 °C, but point concentrators can reach higher temperatures. These include parabolic dish systems, solar power towers, and solar furnaces - which are basically a combination of power towers and parabolic dish systems.

Existing applications in industry[1]: At low and medium temperatures, solar heat can provide warm water for processes like bottle washing or chemical processes, hot air for drying and baking processes, generate steam that can be fed into steam heat distribution networks, etc. In all these applications, the existing industrial machinery and distribution infrastructure remains in place. Only the energy source is replaced.

Thermal storage is generally required to couple the timing of the intermittent solar resource with the timing of the hot water load. Storage can either be potable water or non-potable water if a load side heat exchanger is used. For small systems, storage is most often in the form of glass-lined steel tanks **(see TO-16 Thermal mass storage).**

To know more...

[1]Potential applications of solar thermal: http://www.lowtechmagazine.com/2011/07/solar-powered-factories.html

[2]Whole building design guide. National institute of Building Sciences
- https://www.wbdg.org/resources/swheating.php
- https://www.wbdg.org/resources/svap.php

[3]Tian Y, Zhao CY. A review of solar collectors and thermal energy storage in solar thermal applications. Applied Energy 104 (2013): 538-553.

[4]New technologies: https://www.renewableenergyhub.co.uk/solar-thermal-future-technologies.html

Opportunities for innovation

If we were to use solar thermal plants to generate heat instead of converting this heat into electricity, the technology could deliver energy 3 times cheaper than it does today and become cost-effective also in less sunny regions.

The development of thermal storage technologies can help to achieve seasonal energy, paving the way towards total energy independence from fuels and 100% renewable energy.

Near future challenges

It is often assumed that our energy problems are solved when renewables reach 'grid parity': the point at which they can generate electricity for the same price as fossil fuels. But to truly compete with fossil fuels, renewables must also reach 'thermal parity'.

A lot of potential remains in the use of solar heat for domestic purposes, but the potential for solar heat in industrial processes is even larger than in the domestic market. Though existing solar furnaces prove that anything could be produced using direct solar heat instead of fossil fuels, this is not yet possible in a cost-effective way.

PVT systems will be further developed[4]. Special devices capable to filter and split the Sun's rays (for instance via colour-selective filters), will be incorporated to provide both heat and electricity simultaneously, vastly increasing the efficiency of PVT.

Nanotechnology will also play a role in the development of new technologies. A liquid Filter with Plasmonic Nanoparticles hybrid solar system is being developed by the University of Tulsa that captures non-visible wavelengths of light to heat a fluid containing microscopic light-absorbing nanoparticles. The liquid would also transmit the part of the sun's radiation spectrum most easily converted to electricity to a solar cell and pass waste heat back to the fluid. This heat in the fluid will be stored to provide low-cost solar energy when the sun goes down.

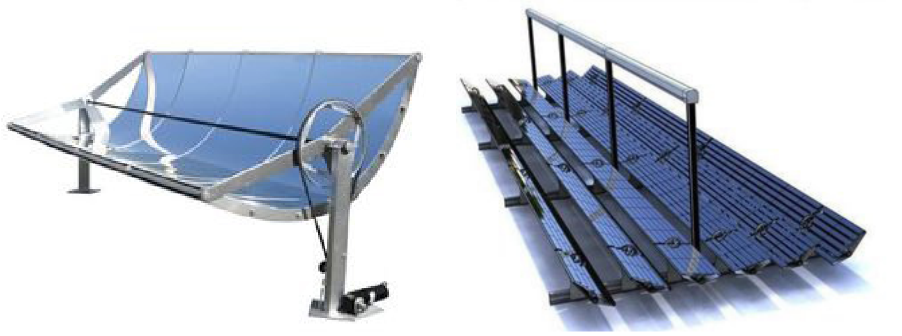

Fig 1. Example of a modular parabolic trough system (left) and a linear concentrating Fresnel collector (right).

SMART BUILDINGS

TO-17 Wind energy production

The concept of wind energy may be simple: wind rotates a rotor, the rotor rotates a shaft, and the shaft powers a generator. But wind energy can take many forms, and there are many different segments of the industry that serve different needs. Wind generation can be produced in utility-scale wind farms, that is, in a group of a multiple wind turbines that has the capacity to reach utility-scale electricity production; in distributed energy wind configurations; or in installations designed to deliver electricity to a facility directly, which typically includes one or two turbines only.

Today

A typical wind turbine is made up of several key components including the nacelle and the rotor[1].

The nacelle houses all of the internal parts of the turbine: the bed plate directs the aerodynamic forces to the tower, but is not associated with the generation of power. The gearbox steps up the revolutions from the low-speed shaft and the hub, which is attached to the high speed shaft of the generator (1,800 revolutions per minute). A generator is used to convert this shaft power to electricity. The wind turbine's controller monitors many system parameters and, depending on the wind turbine design, continually adjusts the wind turbine's blade pitch angle for optimum rotational speed and appropriate lift-to-drag ratios at varying wind speeds.

The rotor includes the elements of the turbine that rotate in the wind, including the hub, the blades, and for pitch-regulated wind turbines, the blade pitch mechanisms and bearings. It is through the rotor that the wind energy is transformed into mechanical energy that turns the main shaft of the wind turbine.

There are a variety of wind turbine designs, most of which use aerodynamic lift principles to convert wind power into a rotational force. The two main types are horizontal axis wind turbines and vertical axis wind turbines. Horizontal axis wind turbines are more sensitive to turbulence, while vertical axis wind turbines suffer from resonant conditions at variable wind speeds. Both types are susceptible to fatigue loads.

Horizontal axis wind turbines.

These are by far the most common type of turbine. They can range in size from 100 W to 5 MW, depending on the type of installation envisaged:

- **Offshore utility-scale wind.** In these configurations, wind turbines of typically more than 3 MW, are installed in large groups in shallow waters, at sites with good wind resources. Several gigawatts (GW) of capacity have been installed in Europe already.
- **Utility-scale wind.** Normally installed in large groups, or wind farms, and at sites with a very good wind resource, these 1 to 3 MW wind turbines inject clean green energy onto the utility grid via transmission lines. Most of the wind industry growth is due to this sector. Turbines used in wind farms for commercial production of electric power are three-bladed and actively directed into the wind.
- **Community-scale wind.** These wind turbines are 100 kilowatts and larger and are installed individually or in small groups. They are connected to the electricity grid on the customer side of the utility meter and are used to reduce the amount of electricity the customer (or community) purchases from the utility. The cost per kilowatt of installed wind energy is higher. Because the projects offset purchases from the utility, they compete with the retail price of electricity, as opposed to the wholesale price of power paid to utility-scale projects.
- **Residential-scale wind.** In these installations wind turbines are 1 to 100 kW in size and are normally installed at a home or small business on the customer side of the utility meter to reduce the amount of electricity purchased from the utility. Significant research and development has been undertaken in the past decade to improve the performance and lower the cost of these smaller turbines.

Vertical Axis Wind Turbines

There are many different design variations of vertical axis turbines. However, all them can be categorized into two basic design types: Savonius rotor and Darrieus blade.

- **Savonius rotor.** This turbine provides a high torque and is more effective at high wind speed locations. Unfortunately, this technology currently lacks a clear track record for mainstream applications. This type of turbine can be more suitable for specific applications such as sign or buoy lighting.
- **Darrieus blade.** The Darrieus rotor utilizes the lift principle and thus is capable of achieving aerodynamic efficiencies similar to that of horizontal axis wind turbines.

The limiting factor of vertical axis wind turbines is that the central rotating shaft must remain rigid and cannot develop a wobble, which may be difficult if the turbine is expected to operate with limited maintenance over its design life. To address this issue, the turbines must either incorporate a very solid lower barring or the top of the unit must be fixed with an upper barring and guy wires. This typically limits the size of the turbine and/or its installation location.

To know more...

[1] US National Institute of Building Sciences: https://www.wbdg.org/resources/wind.php

[2] Scientific paper on PV technologies: Pandey AK, Tyagi VV, et al (2016). Recent advances in solar photovoltaic systems for emerging trends and advanced applications. Renewable and Sustainable Energy Reviews, 53, 859-884.

[3] Scientific paper on inverter technologies: Kouro S, Leon J, et al. (2015). Grid-connected photovoltaic systems: An overview of recent research and emerging PV converter technology. IEEE Industrial Electronics Magazine, 9(1), 47-61.

[4] US vision for wind energy: http://energy.gov/eere/wind/wind-vision

European Photovoltaic Industry Association (EPIA): http://www.solarpowereurope.org

International Energy Agency (IEA): https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapSolarPhotovoltaicEnergy_2014edition.pdf

Opportunities for innovation

New developments will continue to be made aiming for the improvement of systems efficiency. Vortex (bladeless turbines) are an example of this. Vortex wind generators avoid bird killing, noise nuisances, use less materials, need no energy to use and lower maintainance and can be implemented at a higher density.

Collaboration among domestic and international producers, researchers, and stakolders during this time of rapid change facilitates learning about new approaches and technical advances that can lead to increased turbine performance, shorter deployment timelines, and lower overall costs.

Near future challenges

In the near future, wind energy will be the most cost effective source of electrical power. Over the past decade, world wind power capacity grew more than 20 percent a year. China generates more electricity from wind farms than from nuclear plants, and has an easily-reachable wind power goal of 200,000 megawatts by 2020.

Wind plants are expected to meet the same operational reliability as conventional genertion sources. While enormous progress has been made in reliability and availability of systems, significant reductions in overall cost of energy can still be realized through better operations and maintenance (O&M) practices. This is especially true in the offshore environment, where maintenance costs are significantly higher due to more difficult access[4].

Utilization of wind forecasting in operational practice of power systems and advanced cotrols on wind turbines can help operators decide on appropriate reserve levels. In some cases, operators will be able to deploy wind turbine and wind plant response capabilities to help manage the power system[4].

To responsibly expand developable geographic regions and sites there is need to improve the potential of low wind speed locales, offshore regions; and areas requiring careful consideration of wildlife, aviation, telecommunication, or other environmental issues[4].

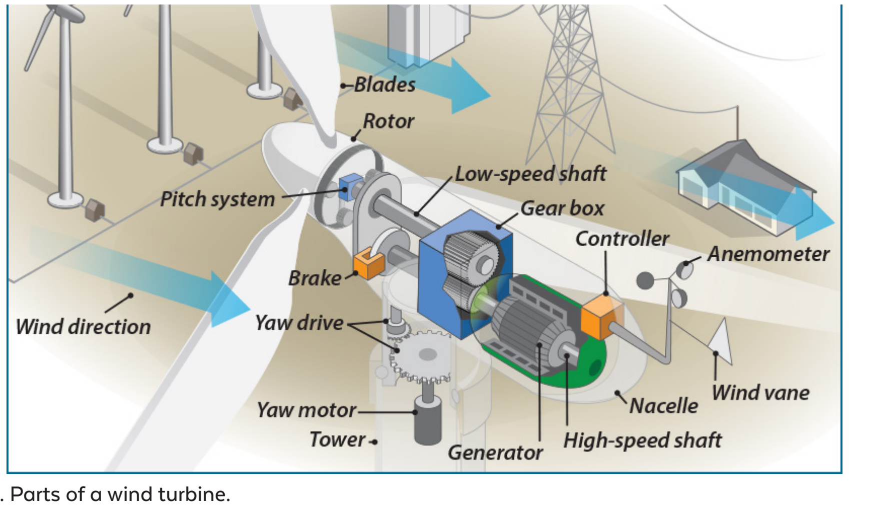

Fig. 1. Parts of a wind turbine.

SMART BUILDINGS

TO-18 Biomass energy production

Biomass is the sole renewable source of energy that provide solid, liquid and gaseous fuels which can be stored and transported. However, the use of biomass as energy source, do not inherently result in environmental and social benefits. In fact, the line between renewable biofuels and non-renewable fossil fuels is sometimes vague[1]. The term biomass encompasses a large variety of materials, including wood, agricultural residues, and animal and human waste. As a source of energy, biomass has the advantage of being controllable and available when needed. The disadvantages are that it requires more space (for fuel storage) and more operator interaction than other renewable energy systems. This includes ordering and delivering fuel, removing ash, and maintaining moving parts. Moreover, biomass combustion produces emissions, which must be correctly monitored and controlled.

Opportunities for innovation

Domestic/district biomass energy production can help to reduce urban waste to be managed at city scale.

Integration of new technologies such as photosynthetic microorganisms in building components for shading or other functions, may open new concepts and business oportunities. SolarLeaf[3] is an example of such new concepts.

Today

HEAT. The production of heat is the main use of biomass as energy source. Larger wood chip systems usually require more integration with the building in which it is housed, particularly if a chip bunker is part of the building structure. Emissions from combustion must be controlled and safely evacuated in order to assure a correct indoor air quality. Different burning technologies are available nowadays:

Fixed-bed systems: fuel is delivered onto a grate where it reacts with oxygen in the air blown through the firebox. This is an exothermic reaction that produces very hot gases and generates steam in the heat exchanger section of the boiler.

Atmospheric fluidized-bed systems: the biomass is burned in a hot bed of suspended, incombustible particles, such as sand. Compared to fixed-bed systems, these systems generally achieve more complete carbon conversion, resulting in reduced emissions and improved system efficiency. In addition, they can use a wider range of feedstocks. However, they have a higher electric load due to increased fan power requirements.

Biomass gasification systems: are similar to combustion systems, except that the quantity of air is limited. This process converts the biomass to a hot gas, which can be combusted in a boiler.

ELECTRICITY. Biomass can be converted into electric power through several methods. The most common is direct combustion of biomass material. Other options include gasification, pyrolysis, and anaerobic digestion. Different methods work best with different types of biomass.

Biomass gasification. Typically, woody biomass such as wood chips, pellets, and sawdust are combusted or gasified to generate electricity.

Pyrolysis. Pyrolysis yields bio-oil by rapidly heating the biomass in the absence of oxygen. Most types of biomass can be used. Bio-oil is then used in boilers and furnaces.

To know more...

[1]Hall, DO and Scrase JI. Will biomass be the environmantally friendly fuel of the future? Biomass and Bioenergy Vol. 15, Nos 4/5, pp. 357±367, 19

[2]Aro, EM. From first generation biofuels to advanced solar biofuels. Ambio 2016, 45(Suppl. 1):S24–S31. DOI 10.1007/s13280-015-0730-0

[3] The SolarLeaf concept: http://www.arup.com/projects/solarleaf

Whole Building Design Guide website:

- https://www.wbdg.org/resources/biogas.php
- https://www.wbdg.org/resources/biomasselectric.php
- https://www.wbdg.org/resources/biomassheat.php

Anaerobic digestion produces a renewable natural gas when organic matter is decomposed by bacteria in the absence of oxygen. Corn stover, cereal and very wet wastes, like animal and human wastes are used.

BIOGAS. Biogas is the gas produced by the biological breakdown of organic materials. **Anaerobic digestion**, is the most common production process. Biogas is not a widely used renewable energy technology for buildings since most buildings do not have a large source of organic material. However, if urban farming is going to be integrated or the building is located near a landfill or contained animal feeding operation, this option may be interesting since it can provide low-cost energy.

BIOFUELS. Biomass can be transformed into first, second or third generation biofuels, depending on the production technology and the origin of the raw materials.

First generation biofuels are sourced from sugars, oils and cellulose from crop plants, and have a negative impact on food security while providing little or none GHG reduction. Thus, they are likely to be banned in EU in the near future.

Second generation biofuels are produced from lignocellulosic materials from crop by-products and energy crops which can be grown in marginal lands. Cellulose is broken down into sugars with the help of enzymes which are highly expensive. Research is focused on reducing production costs by different approaches such as using microbes capable to ferment cellulose or designing more digestible cell wall structures.

Third generation biofuels are produced from algal biomass and are nowadays under extensive research. The technology is still not economic and sustainable due to low photon-to-fuel conversion efficiency (PFCE). Combining energy production with the production of high-value chemicals in waste/sea water and with more cost-effective reactors are strategies that might contribute to make the algal biofuel production more profitable.

Several devices are available nowadays that allow the production of energy from biomass in a domestic scale: **Biomass stoves and boilers** are the most known appliances, which burn wood chips or pellets to produce heat for air conditioning and hot water, replacing the conventional natural gas or electric boiler. In automated models, the boiler transports the biomass to the combustion chamber mechanically, as it is needed, and controls the amount of air needed to burn the biomass as efficiently as possible, leaving very little ash. Some devices are designed to produce heat and electricity from wood chips with enhanced efficiency and by avoiding the release of combustion gases. The heat can be used for cooking and the electricity to charge mobile phones and other small devices. Other devices, which are particularly interesting in restaurants, etc., allow the **production of biodiesel from used cooking oil**. Some devices also generate **biogas and fertilizer from organic waste,** that can be used to grow vegetables and cook. With 1 kg of organic waste it is possible to generate biogas to cook for 1 h.

Near future challenges

In the future, the **fourth generation biofuels** (photobiological solar fuels and electrofuels) are expected to bring fundamental breakthroughs in the field of biofuels. Synthetic biology will make engineering of biological systems possible, enabling direct conversion of solar energy to biofuels using only water and CO_2 as raw materials either in engineered photosynthetic microorganisms or in completely synthetic living factories[2]. Biofuels will be produced by:

- Photosynthetic microorganisms (phtotobiological solar fuels)
- Microbial electrosynthesis (MES), combining photovoltaics and microbial fuel production (electrobiofuels). The electricity generated with a renewable source is transformed into a storable liquid fuel thanks to microbial metabolism.
- Synthetic cell factories producing biofuels and other high-value chemicals.

However, this technology is currently at its basic level and only few truly examples have been realised by now. Several issues have to be faced for further development:

- Competition in land use with food production
- Higher photon-to-fuel conversion efficiency (PFCE) and better quality. From current 0.16% to 10%.
- Increase the production of easily processed sugars, carbohydrates and oils by plants, optimise the photosynthesis and their tolerance to stress by using genomic breeding techniques.

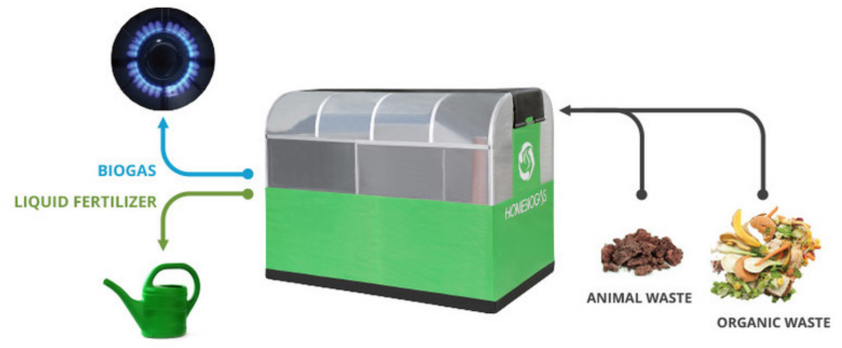

Fig 1. Example of a domestic device for biomass processing.

SMART BUILDINGS

TO-19 Energy storage devices

Meanwhile many of the traditional technologies for electricity generation, as hydro, thermal, nuclear, etc., can deliver the power when required; most of the renewable energy resources, such as of solar and wind power, require to store the energy produced in order to ensure its availability independently of the availability of the resource at a specified time. For this reason, a number of technologies have been developed for storage. The storage system type chosen will depend on the grid's distribution system (DC or AC), the type of electricity, the size of the grid and the characteristics of the consumers, among others[1].

Today

The different energy storage systems have different performance characteristics that make them optimal for certain grid applications and sizes. Technologies development changes quickly over time. In Fig. 1 technologies are grouped based on their **degree of maturity**.

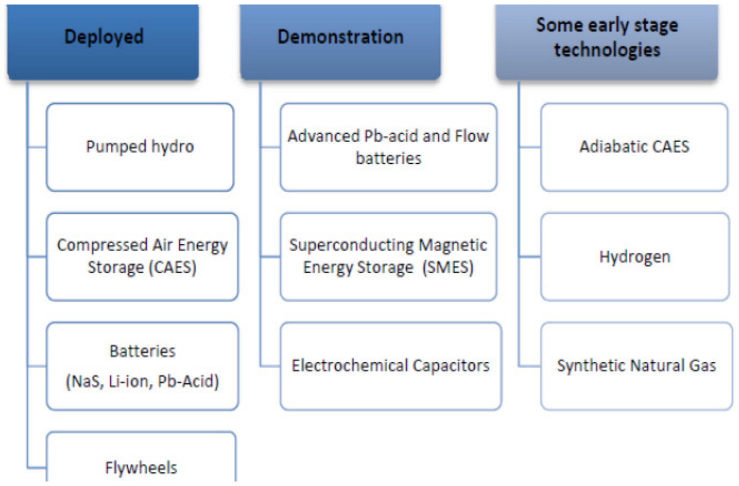

Fig 1. Maturity of electricity storage technologies [2]

For large scales, the two main established technologies, **pumped hydro** and **compressed air energy storage (CAES)**, have long discharge times (tens of hours), and both have very specific geographic requirements making their installation site-dependent[2].

Pumped hydro plants use off-peak electricity to pump water from a reservoir up to a storage basin. When electricity is needed, water is released from the upper reservoir through a hydroelectric turbine into the lower one to generate electricity. These plants take up a lot of space considering that, to produce 10,000 MWh, a reservoir of 1 km in diameter, 25 meters deep, and an average head of 200 meters, is needed. The plants have long lifespans (50-60 years), operate at about 76%-85% efficiency, and may be sized almost up to 4,000 MW, requiring significant investments.

To know more...

[1] Necessity and chacarcteristics of energy storage systems: Dr. Andre Pittet. An overview of technical aspects of mini-grids. Village Electrification through Sustainable use of Renewable Energy (VE-SuRE) avaiable in https://www.eda.admin.ch/content/dam/countries/countries-content/india/en/resource_en_224456.pdf (last update 02/2016)

[2] Governmental report: Jablonski I (2015). Integrated living environment: Measurements in modern energy efficient smart building with implemented the functionality of telemedicine. Measurement.

[3] Flywheel energy storage systems. Beacon power brochure avaiable in http://beacon-power.com

[4] Example of energy storage systems implemented at various scales avaiable in http://energystorage.weebly.com/energy-storage-methods.html

[5] Storage systems in micro-grids: https://www.youtube.com/watch?v=jSMHas5JFzA

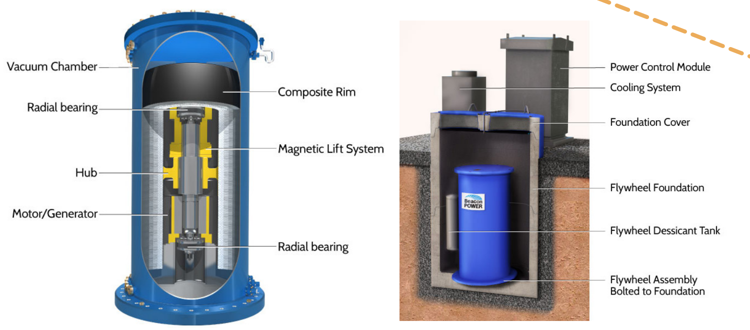

Fig 2. Carbon fiber flywheel diagram (left) and system installation in foundation (right) [3]

Compressed air energy storage (CAES) plants store energy in the form of pressurized air. They are usually located in underground caverns, which cause high environmental impact and are geographically limitated. A CAES plant makes the grid more efficient and provides grid stability during intermittent operations, which allows for the successful integration of several renewable resources.

For lower power and shorter discharge times, storage systems can be designed with **batteries** and **flywheels**.

Battery technologies are the most common storage systems in "non-dispatchable" energy grids: the excess power from the generating unit is diverted into the batteries and, when production is lower than consumption, the required extra power is taken from the batteries to the grid. An **electronic control unit** is needed to manage the charge and discharge cycles. A energy is stored in DC form, **rectifiers** and **inverters** are needed in batteries connected to an AC grid. Battery technologies have different chemistry backgrounds:

- **Lithium-ion (Li-ion).** Good performance in short discharges (under 2 hours), but unable to properly handle deep-discharges. They are suited to power-management operations such as frequency regulation or as an uninterruptible power source (UPS).
- **Sodium sulfur (NaS).** In terms of power, they are somewhat behind Li-ion battery technology, but batteries can maintain longer discharges (4 to 8 hours). Suitable for load levelling and price arbitrage operations.
- **Lead acid batteries.** It's a mature and relatively cheap technology with good battery life. Batteries have low energy density and short cycle time so they are not suitable for large-scale applications nowadays.

Flywheel plants take in electricity and convert it into spinning discs, which can be sped up or slowed down to rapidly shift energy to or from the grid. Flywheels are often designed with magnetic suspension and vacuum to minime friction and thus, enhace efficiency. Flywheel plants may be turned on through an induction machine that acts as a motor during storage and as a generator when returning energy to the grid. They supply steady power (60 Hz) and are mainly used for frequency regulation.

Opportunities for innovation

Storage technology can help contribute to overall system reliability as large quantities of wind, solar, and other renewable energy sources are added to electrical grids.

Energy storage will be an instrumental tool, managing grid reliability and resiliency by regulating variable generation, and improving microgrid and smart-grid functionality

Hydro pumped can contribute with the development of very large wind and PV farms.

In-situ sensors and control technologies to to optimize the energy production, and control the storage as well as thedistribution to the consumers

Near future challenges

Flow batteries. Potential advantages over traditional ones are a longer unit life and full charge utilization: due to liquid suspension and separation of the chemical components, they have a high number of discharge cycles. On the other hand, these technologies have lower energy density and complicated design. They are in demonstration phase.

Superconductive magnetic energy storage (SMES) systems basically consist in a cooling system that chills a superconductive coil below certain temperature, so that electrical currents flow without resistance or loss of energy. Energy is stored inductively in the DC magnetic field of a solenoid, as long as the temperature remains sufficiently low.

A power conditioning system is needed. They are in demonstration phase.

Electrochemical capacitors (EC) technology stores direct electrical charge in the material, while batteries convert the charge to chemical energy, or SMES convert it to magnetic field energy. This makes the storage process reversible, efficient, and fast, but it is still cost prohibitive. (TO18).

Thermochemical energy storage uses reversible chemical reactions to store heating or cooling capacity in chemical compounds. It can achieve high energy densities over conventional storage types: 5 to 20 times greater. It's cost prohibitive.

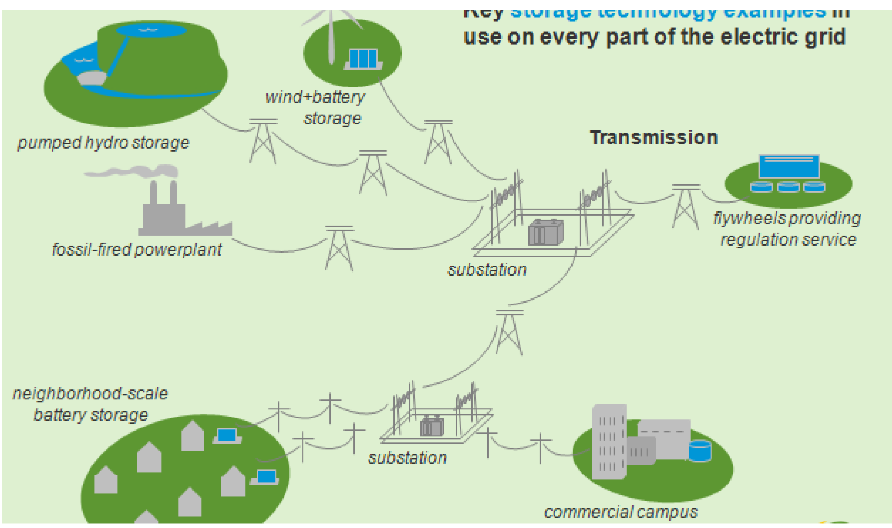

Fig 3. Energy storage technologies implemented at various scales [4]

SMART BUILDINGS

TO-20 Electro-chemical storage

Electrochemical capacitors (EC) store direct electrical charge in a material. Then, batteries convert the charge into chemical energy, or SMES into magnetic field energy. The main family of electrochemical capacitors are called **Supercapacitors**, and can store the energy electrostatically, by polarizing an electrolytic solution, electrochemically or both ways. Sometimes are called **ultracapcitors**, and formerly **electric double-layer capacitors (EDLC)**.

Today

"A **Supercapacitor (SC)** is a high-capacity electrochemical capacitor with capacitance values much higher than other capacitors, but lower voltage limits. It typically stores 10 to 100 times more energy per unit volume or mass than electrolytic capacitors, is able to accept and deliver charge much faster than batteries, and tolerates many more charge and discharge cycles than rechargeable batteries[1].

Electrical energy is stored via **two storage principles**, **static double-layer capacitance** and **electrochemical capacitance**, both contributing to the total capacitance value of a supercapacitor. The distribution of the two types of capacitance depends on the material and structure of the electrodes. Based on the storage principle, supercapacitators can be classified into three types (Fig. 1).

Double-layer capacitors (EDLCs), with activated carbon electrodes or derivatives, have much higher electrostatic double-layer capacitance than electrochemical pseudocapacitance.

- **Activated carbon** is an extremely porous form of carbon with a high specific surface area.Consolidated **amorphous carbon** is the most used electrode material for SC and is produced from activated carbon powder pressed into the desired shape, forming a block with a wide distribution of pore sizes.
- Commercial supercapacitors mostly use powdered activated carbon made from **coconut shells**, which have more micropores than does charcoal made from **wood**.

Pseudocapacitors, with transition metal oxide or conducting polymer electrodes have a high electrochemical pseudocapacitance. They employ Faradaic oxidation/reduction reactions[3], which is fast and reversible, and allow pseudocapacitors to store much more energy than EDLCs [4]

- **Oxides of transition metals** including ruthenium (**RuO_2**), iridium (**IrO_2**), iron (**Fe_3O_4**), manganese (**MnO_2**) or sulphides such as titanium sulphide (**TiS_2**) alone or in combination generate strong faradaic electron-transferring reactions combined with low resistance.
- **Conductive polymers** have high conductivity, low resistance and a relatively high capacitance. Such conducting polymers include polyaniline, polythiophene, polypyrrole and polyacetylene.

To know more...

[1] Definition of Supercapacitor: https://en.wikipedia.org/wiki/Supercapacitor

[2] Supercapacitor family: https://commons.wikimedia.org/wiki/File:Supercaps-family.png

[3] Zhang, J. et al (2012). Electrochemical Technologies for Energy Storage and Conversion, avaiable in https://books.google.es/books?id=AN3B3L5RtqUC&hl=ca&source=gbs_navlinks_s

[4] Abruña, H. et al (2008). Batteries and electrochemical capacitors in Physics Today, vol.61, Issue 12, Pag. 43 - 47, avaiable in http://ecee.colorado.edu/~ecen4555/SourceMaterial/ElectricalEnerStor1208.pdf

[5] New energy storage systems for grid connected renewable installations: Hybrid ultra-capacitor-battery energy storage system. https://news.duke-energy.com/releases/duke-energy-to-put-new-battery-and-ultracapacitor-system-to-the-test-in-n-c

Asymmetric hybrid capacitors, with dissimilar electrodes to exploit the characteristic operating voltages of each material[3].

- Materials with high hydrogen and oxygen evolution over potentials to be applied in **aqueous electrolyte devices**

APPLICATIONS IN ENERGY GRIDS:

- In Energy Harvesting the energy is collected from the ambient or renewable sources, e.g. mechanical movement, light or electromagnetic fields, and converted to electrical energy in an energy storage device. The harvested energy was then used to power an application-specific integrated circuit (ASIC) circuit for over 10 hours.

- Wind and photovoltaic systems exhibit **fluctuating supply** evoked by gusting or clouds that supercapacitors can buffer within milliseconds. This helps **stabilize grid voltage** and frequency, balance supply and demand of power and manage real or reactive power.

- They **provide backup power** for actuators in **wind turbine** pitch systems, so that blade pitch can be adjusted even if the main supply fails.

APPLICATIONS IN STREET LIGHTS:

- Street light combining a **solar cell** power source with **LED lamps** and **supercapacitors** for energy storage, which can last **more than 10 years** and offer stable performance **under various weather conditions**, including temperatures from +40 to below -20 °C

APPLICATIONS IN URBAN MOBILITY:

- In **electric vehicles (EV)** and **hybrid electric vehicles (HEV)** they are used as an interface between the charging station and the grid to solve frequency fluctuation problems

- In **hybrid electric Bus increases acceleration** and reduces energy consumption (Nuremberg)

- Trams that are recharged in 30 seconds by a device positioned between the rails, storing power to run the tram for up to 4 km, more than enough to reach the next stop, where the cycle can be repeated.

- In **light rail vehicles (LRV)** can replace catenary overhead lines in **historical city areas**, so **preserving** the city's **architectural heritage**. Roof mounted supercapacitors are charged at stopover stations when the vehicle is at a scheduled stop. (Mannheim, Heidelberg, Paris, Lyon).

Opportunities for innovation

Lower materials and interfaces costs

Research on new electrodes materials thah must have: good conductivity, high temperature stability, long-term chemical stability (inertness), high corrosion resistance, high surface areas per unit volume and mass

Research on environmentally friendly materials

Research on nanofabrication technology: nanostructured materials with very high surface areas could offer high and reproducible charge-storage capabilities and rapid charge-discharge rates[4]

Near future challenges

New types of carbon materials, such as **carbon nanotubes and nanofibers**, have been studied as possible EC electrode materials. They have larger surface areas than conventional activated carbon and thus offer higher capacitance[3].

Hybrid devices with appropriate dimensional control for ion channels. for increasing the energy and power densities in ECs.

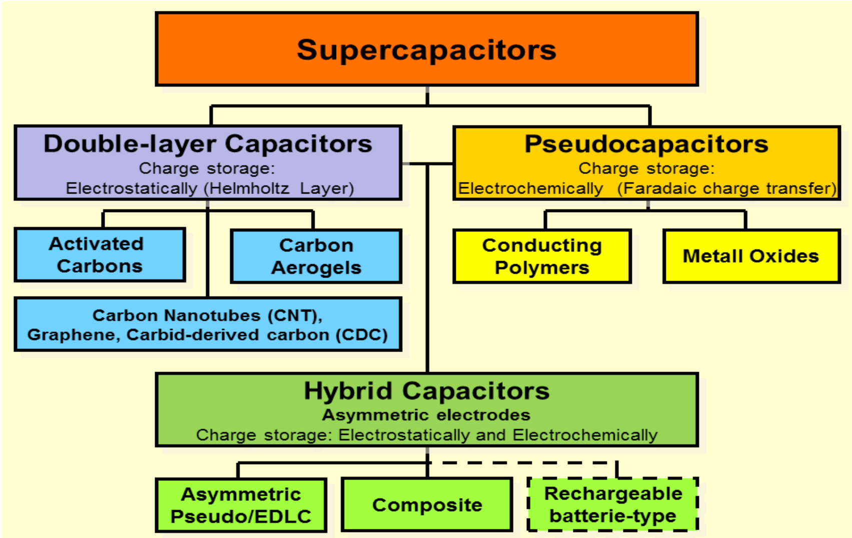

Fig 1. Hierarchical classification of supercapacitors and related types [2]

Fig 2. Hybrid ultracapacitor-battery energy storage system (HESS) [5]

SMART BUILDINGS

TO-21 Waste processing

Municipal solid waste (MSW), commonly known as **trash** or **garbage** (USA) and as **refuse** or **rubbish** (GB), is a waste type consisting of everyday items that are discarded by the public[1].

Today

MSW management includes different phases, but there is not a single approach that can be applied. There is a **waste hierarchy**, which classify waste management strategies according to their desirability in terms of waste minimisation[1] (fig.1).

MSW composition varies greatly from municipality to municipality, changing with time, and it usually does not include industrial, agricultural, medical and radioactive waste or sewage sludge. The list below represents a typical classification [2]:

- Biodegradable waste: food and kitchen waste, green waste, paper
- Recyclable materials: paper, glass, tin cans, metals, certain plastics, fabrics, etc.
- Inert waste: construction and demolition waste, dirt, rocks, debris
- Electrical and electronic waste (WEEE): appliances, light bulbs, screens, smartphones, etc.
- Composite wastes: waste clothing, Tetra Packs, waste plastics such as toys
- Hazardous waste: paints, chemicals, batteries, light bulbs, aerosol spray cans, fertilizers,etc
- Toxic waste: pesticides, herbicides, and fungicides, etc
- Biomedical waste: expired pharmaceutical drugs, etc.

MSW need a specific infrastructure planning and management model due to its strategic importance and its presence in society as a whole: it concerns different social and economic stakeholders throughout the whole process.

Waste prevention and minimisation:

- **Consumption** models: **reduction at source** buying the exact needed amount of fresh and **local products** with less packaging[4]
- **Reuse strategies** as packaging and bottles **recovery systems** or **refurbished products**[4]
- Organic waste treatment at local level, such as **home composting**[5/6]
- Transformation of household waste to **biogas**[7] via chemical and biological processes[8]: household biomass (TO18) or domestic blackwater treatment

Waste collection, local waste **sorting**[9] of recyclable materials and **transport** to waste management facilities:

- **Curbside sorting**: collection at regular intervals by specialised trucks that transport it to specialized facilities
- **"Door to door" systems**: collection every day by specialised trucks that transport it to specialized facilities
- **Dumpster and skips**: collection when they're full and transport by trucks to specialized facilities. They could be superficial or buried
- **Automatic vacuum collection**: waste is transported from the home or commercial premises by vacuum along small bore tubes.

There are diverse processes of **waste handling and treatment** in **waste management facilities**, for its recycling, disposal and energy recovery:

- **Waste sorting** in specialized plants that receives, separate and prepares recyclable materials for marketing to end-user manufacturers[10].
- **Mechanical biological treatment**[11] composed by a mechanical sorting and pre-treatment, and a biological treatment (anaerobic digestion, composting, bio drying) of which biogas and energy could be obtained
- **Final safe treatments** as incineration or gasification

Energy recovery is the conversion of non-recyclable waste materials into usable heat, electricity, or fuel through a variety of processes[1].

- **Anaerobic digestion** of the biodegradable fraction of waste which produces biogas that can be purified and compressed to natural gas quality
- **Incineration** in which solid organic wastes are subjected to combustion so as to convert them into residue (reducing 20 to 30 per cent of the original volume) and gaseous products. That combustion can be placed in a furnace or boiler to generate heat, steam or electricity.
- **Pyrolysis** is a process of thermo-chemical decomposition of organic materials by heat in the absence of oxygen (so is gasification), which produces various hydrocarbon gases.
- **Gasification** and advanced **plasma arc gasification** are used to convert organic materials directly into a synthetic gas (syngas) composed of carbon monoxide and hydrogen.
- **Landfill gas utilization**, is a process of gathering, processing, and treating the methane gas emitted from decomposing garbage to produce electricity, heat, fuels, and various chemical compounds.

To know more...

[1] Waste Management: https://en.wikipedia.org/wiki/Waste_management
[2] Definition of Municipal Solid Waste (MSW): https://en.wikipedia.org/wiki/Municipal_solid_waste
[3] Waste Hierarchy diagram: https://upload.wikimedia.org/wikipedia/commons/thumb/1/18/Waste_hierarchy.svg/1280px-Waste_hierarchy.svg.png
[4] Reduction at source + reuse + recycle: http://www.ewwr.eu/en/ideas/reduce, http://www.ewwr.eu/en/ideas/reuse, http://www.ewwr.eu/en/ideas/recycle
[5] Home composting without worms: http://www.clean-organized-family-home.com/composting-without-worms.html#sthash.VPSCLkUO.dpbs
[6] Vermicompost: https://en.wikipedia.org/wiki/Vermicompost
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[8] Anaerobic digestion: https://en.wikipedia.org/wiki/Anaerobic_digestion
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[11] Mechanical biological treatment: https://en.wikipedia.org/wiki/Mechanical_biological_treatment
[12] Solid Waste Management example: http://www.fukuoka.unhabitat.org/programmes/scp/sri_lanka/detail01_en.html
[13] Waste management in commercial buildings: https://www.epa.gov/smm/managing-and-reducing-wastes-guide-commercial-buildings

Opportunities for innovation

Waste processing is just a part of the whole material cycle. The conception of a city as a metabolic system and an integrated vision of waste and materials fluxes in the city is needed in order to optimise the system. This requires the monitoring and management of a great amount of data.

Waste reduction policies can be implemented in any situation and public event, such as festivals, etc. Plastic bag free cities are examples of policies helping to reduce waste.

Waste processing can be improved with the integration of urban farming strategies, smart grids and district heating.

Near future challenges

It's important to focus in waste prevention and reduction during both buildings construction and buildings operate phase.

Waste construction management is strongly regulated during the construction phase, in every facet of the built environment, from clearing the site for a new development; to reduce and manage the construction wastes.

During operate phase, as well as the household waste management, previously sawed, near future challenges fall on commercial, office and services buildings.

Governmental services buildings introduce and follow strategies and directives to reduce its consumption and waste.

Private buildings owners usually have waste collection and cleaning contracts external to the spaces tenants. Owners or tenants can audit their buildings or business respectively, and found potential particular solutions:

Office buildings can follow strategies, as have various collection systems: they can centralize paper recycling or have a centralised garbage bin and a paper-recycling bin at each desk.

Commercial buildings[13] can create a green team and educate and involve employees to participate. The efforts can go in waste reduction ways before recycling:

- Reduce: modifying their current practices to reduce the amounts of waste generated by changing the design, manufacture, purchase, or use of materials or products.
- Reuse of products and packaging, and prolongs the useful life of these materials, thus delaying final disposal or recycling. Repairing, refurbishing, washing, or just simple recovering used products, appliances, furniture and building materials.
- Donate: Organizations can donate products or materials to others who need and can use the items, saving they storage and disposal costs.

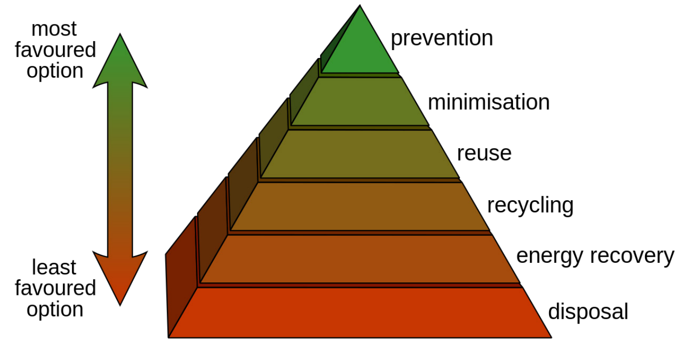

Fig 1. Waste Hierarchy diagram [3]

SMART BUILDINGS

TO-22 Material life cycle assessment

Life-cycle assessment (LCA, also known as life-cycle analysis or ecobalance) provides a formal process of examining the environmental impacts of a material, product, or service through its entire life-cycle. Instead of a single-attribute analysis of a material's environmental impact, such as its recycled content, LCA takes a holistic approach to assess the possible impacts of materials throughout their respective life-cycles. Life stages include extraction of raw materials, processing and fabrication, transportation, installation, use and maintenance, and reuse/recycling/disposal. ISO 14040 defines LCA as the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle[1].

Today

Sustainability assessment standards have been developed across a broad range of product categories to assist manufacturers in identifying strategies and communicating improved performance. The standards often include relevant criteria across the product's life cycle, i.e. from growth phase of renewable materials, raw material extraction, manufacturing, use, and end-of-life management.

These standards are intended to be science based, provide transparency, and offer credibility for manufacturers in making claims of environmental preferability and sustainability, and to harmonize the principles and procedures used to support such claims. Moreover, sustainability assessment standards also provide a means to track incremental changes to the products' sustainability profile.

Certification: once a sustainability assessment standard has been published there are several ways in which products can be certified as meeting the requirements contained in the standard including:

Self-Certification: the manufacturer provide a statement or certificate stating the product meets the standard requirements. The value or strength of this type of certification is solely based on the reputation of the product manufacturer.

2nd Party Certification: an association, to which the product manufacturer belongs, provides the assurance for this certification. It is the responsibility of the association to monitor and assure the quality of the individual members.

3rd Party Certification: a third party provides the certification, which is completely independent from the product manufacturer, contractor, designer, and specifier. Third party certifications are the more trusted form of environmental conformance verification since they require the hiring of an outside auditing firm.

To understanding the flows of energy and materials through cities can be identified three main approaches can be identified:

Production based approaches account for the energy, materials, and emissions produced within a city's boundaries, highlighting the importance of the economic and industrial activities within a city's boundaries. Material flow analysis (MFA) is used to analyse the stocks and flows of materials within a defined system on the basis of mass-balance. This allows for the identification of hidden material stocks and flows accumulations. These studies typically analyse the stocks and flows of specific substances, or analyse important products and materials, thus lacking of a holistic vision.

Consumption-Based Approaches: account for the direct resource use of households and the indirect (upstream) resource use resulting from the purchase of goods and services consumed within a city. This approach highlights the impact of a citizen's lifestyle patterns and behaviour.

Hybrid approaches have emerged that attempt to include both production and consumption perspectives.

All these approaches are related with the concept of urban metabolism. Urban metabolism involves conceptualizing a city as an organism and tracking resources that go into the system and products and wastes that leave it, providing a platform through which to consider sustainability implications.

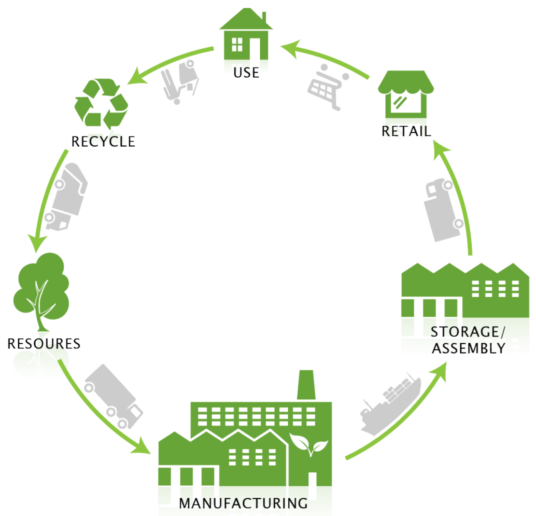

Fig. 1 Closed material cycle cradle-to-cradle. Closed material cycle involves a zero-waste approach, as residues are used as raw materials in the production cycle.

To know more...

[1] US National Institute of Building Sciences: http://wbdg.org/references/mou_lca.php

[2] Li, J. et al., 2015. Big Data in product lifecycle management. The International Journal of Advanced Manufacturing Technology, 81(1-4), pp.667-684.

[3] Smart material https://en.wikipedia.org/wiki/Smart_material

[4] Hosseinijou, S.A., Mansour, S. & Shirazi, M.A., 2014. Social life cycle assessment for material selection: a case study of building materials. The International Journal of Life Cycle Assessment, 19(3), pp.620-645.

[5] Shahrokni, H., Lazarevic, D. & Brandt, N., 2015. Smart Urban Metabolism: Towards a Real-Time Understanding of the Energy and Material Flows of a City and Its Citizens. Journal of Urban Technology, 22(1), pp.65-86.

Opportunities for innovation

A smarter material LCA, may contribute to a better analysis of material flows for the urban space facilitating the studies on urban metabolism and vice versa. Through integrating smart-city technologies, the smart urban metabolism model can provide real-time feedback on energy and material flows, from the level of the household to the urban district.[5]

Living Labs are a fundamental part of urban "smartification," enabling the active participation of citizens in the continuous innovation of urban settings. In the case of materials and their LCA in the urban environment they could contribute a valuable database for the material behaviour in specific urban contexts.

Near future challenges

In the near future materials' cycle should be closed, with the focus being in a **cradle-to-cradle** analysis.

It is generally acknowledged that there is a lack of data on energy and material flows at the urban/city level. This lack of data is an issue for both production- and consumption- based approaches. Periodically available and harmonized datasets provided by statistical institutes are almost exclusively at the national level, and thus, too broad and miss understanding of the urban driving processes.

LCA require for completeness in the description of metabolic flows and need for global system boundaries and consumption-based accounting due to the globalization of production and consumption chains. The consequence is a significant time and resource burden when conducting LCA analysis.

There is a need to consider and understand the agents involved in materials flows, to question their management methods, and to consider the economic and social consequences of these flows. Furthermore, there is a need to know how urban metabolisms change in the short and long-term as a result of changing policy instruments and planning decisions through follow-up studies.

To overcome these problems, future challenges on material LCA are:

The **use of big data**. It is common that some manufacturers either do not store data or know little about how to use these data. This situation makes the different links in the manufacturing chain to not be connected efficiently. The benefits of "Big Data" techniques will permeate the entire manufacturing value chain, which makes manufacturing to reduce the development cycle, optimizing the assembly process, increasing yields, and meet customer needs.[2]

The **use of smart materials (see TO-10 Multifunctional materials).** Smart materials may be used, for instance, to allow a direct monitoring on the material's remaining life span.

There is also a need to **assess social impacts of materials** along the full life cycle, not only to be able to address the "social dimension" in sustainable material selection but also for potentially improving the circumstances of affected stakeholders[4]. A material selection decision should not only capture the functional performance required but should also consider the economical, social, and environmental impacts originated during the product life cycle.

SMART BUILDINGS

TO-23 Rainwater management

The History of rainwater harvesting can be traced back to as early as 4500 BC by the people of the Ur. Ancient Mesopotamia has also left artefacts of rainwater collection and distribution. The constant demand for clean, fresh water has ensured rainwater harvesting practices that have been in use for centuries[1]. In recent years, worldwide the technology for capture, conveyance, filtration, storage and use of rainwater has made significant advances and will continue to make progress moving forward[2].

Today

In order to ensure a proper designed rainwater management systems, it is useful to clarify first some critical questions[2]:

- What is the average annual rainfall for the area?
- For what purpose is the filtered rainwater desired to be re-used? Indoor versus Outdoor use can become a significant cost factor.
- Are there local or regional permitting requirements with regards to storm water runoff or surface discharge from the subject property?
- Does the owner/designer prefer above ground or below ground storage of the rainwater? (Note: above ground storage is typically less expensive than below ground)
- Is there heavy vegetation in the vicinity of the building which would result in heavy leaf and debris loading? Or is the building in an area where there will be minimal leaf and debris during the year?

RAINWATER MANAGEMENT AND HARVESTING TECHNOLOGIES

Smart Rainwater Tank System (SRT): A rainwater tank that is connected to a network and can be monitored and controlled. The system continuously monitors the water level of the tank, stores data and visualises it as a webpage[3].

Web-Based Knowledge Management System (WBKMS): Provides real-time information on how, when and where water is being consumed for the consumer and utility[4].

Smart Water Grid (SWG): A next generation water management scheme, one that integrates information and communication technology (ICT) into the water network structure in order to increase the efficiencies of all elements in the water network[5].

WEATHER-BASED "SMART" CONTROLLERS FOR IRRIGATION

Irrigation demand is the single largest end use of water in the urban sector. Smart controllers —also referred to as **evapotranspiration (ET) controllers**, **weather-based irrigation controllers**, **smart sprinkler controllers**, and **water smart irrigation controllers**— are part of a new generation of irrigation controller products that use prevailing weather conditions, current and historic ET, solar radiation, soil moisture levels, and other relevant factors to adapt water applications to meet the actual needs of plants[6].

STORM WATER AND DISASTER PREVENTION TECHNOLOGIES

Frequent inundation has become a serious problem in urban areas. It is necessary to improve rainwater retention/infiltration in the urban watershed. Smart adaptation to flooding should be a prerequisite for the restoration of a sound hydrologic cycle in the city, and urban biodiversity in the long run[7].

The **Early Disaster Warning Systems** involve the following elements:

(1) **Behaviour Prediction and Modelling:** Modelling the expected behaviour of the water system with multiple degrees of freedom can provide case scenarios for possible disasters and expected impact.

(2) **Risk Assessment:** Risk assessment provides an estimate of the probability of occurrence of an incident along with its expected impact. Priorities can be set to address highest probable events with maximum potential negative impact.

(3) **Warning Service:** Constant monitoring of possible disaster precursors is necessary to generate prompt and reliable warnings on time. Integration of multiple data sources for consistency and fast data fusion is key to undertake a decision.

(4) **Communication and Dissemination:** Clear warnings must reach relevant stakeholders in a fast and reliable way suitable to the incident at hand. Coordinated cross agencies communication and dissemination systems are key.

Clogging Prediction of Permeable Pavement: The clogging progression prediction on the permeable pavement can be predicted by using artificial neural networks (ANNs). Clogging, which is caused primarily by sediment deposition, may result in performance failure of permeable pavement. Measuring the volumetric water content (VWC) by time domain reflectometers (TDRs) is an automated method to track the speed of clogging. Monitoring peak VWC during rain events can be used as an indication of clogging progression over the permeable pavement[8].

To know more...

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[6] Mayer, P.W. & Deoreo, W.B., 2010. Improving urban irrigation efficiency by using weather-based "smart" controllers. American Water Works Association. Journal, 102(2), pp.86–97.

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Opportunities for innovation

Water disaster prevention mesh network - Rainwater Grid (RGS)

It utilises the water storage function of tanks to temporarily store rain water during heavy rainfalls. This will reduce the amount of water flowing into the rivers and the ground and suppress the flood damage. By the use of a smart rainwater tank system, the system continuously monitors the water level of the tank, stores data and visualises it as a webpage. It will be pre-discharge when heavy rainfall is predicted. This prediction will be made by pattern recognition of weather data by Self Organized Map (SOM). Rainwater Grid System to connect the SRTs as a mesh to provide a robust and low-cost rainwater grid. The grid monitors water levels and the water use in real-time, then automatically discharges the tank at an appropriate time (p.e. of a have rain forecast)[3].

Near future challenges

The planning of cities and the planning of their water supplies are intertwined. The future of rainwater harvesting will be widespread adoption of rain collection for various uses everywhere. Some problems to face in complete rainwater systems in the near future are:

i) filtering the water enough to make it potable which can be dealt with by using a combination of micron filters and UV filters with smart technology and

ii) calculating how much water the selected urban area uses per day.

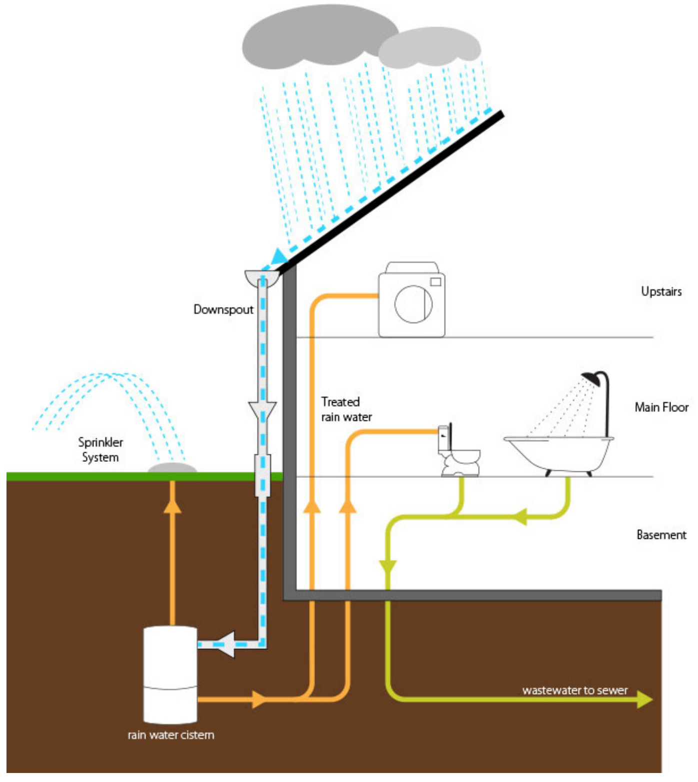

Fig 1. General layout of a rainwater system[4].

SMART BUILDINGS

TO-24 Wastewater treatment systems

Wastewater treatment is a process used to convert wastewater - which is water no longer needed or suitable for its most recent use - into an effluent that can be either returned to the water cycle with minimal environmental issues or reused. The latter is called water reclamation and implies avoidance of disposal by use of treated wastewater effluent for various purposes. Treatment means removing impurities from water being treated; and some methods of treatment are applicable to both water and wastewater[1].

Today

Although disposal or reuse occurs after treatment, it must be considered first, in most of the cases even before the building construction. Since disposal or reuse are the objectives of wastewater treatment, disposal or reuse options are the basis for treatment decisions. Acceptable impurity concentrations may vary with the type of use or location of disposal[1].

Wastewater treatment technologies

Smart water meters: with the traditional water meters, a building's or household's total water consumption is manually read. Customers cannot pinpoint inefficiencies and leaks are difficult to detect. Smart meters allow for continuous, remote monitoring of consumption. As a result we have more comprehensive usage and price signal data and highly accurate leak alarms which lead to less waste water.

Smart water quality monitoring: the traditional water quality monitoring relies on manual, "grab" sampling techniques and field/laboratory analysis. They can be time consuming and costly. On smart water quality monitoring online sensors communicate real-time data to a software platform. As a result, it manages and avoids quality issues before customers are impacted[2].

Crowd sourcing data collection: innovative apps to allow residents to report flooding, social media tools that collect information on water systems. This type of technology makes it possible to automate what had been manual and labor-intensive data collection. The city will be able to monitor and actively control the wastewater collection system. It also helps to cut down on sewer back-ups and overflows[3].

Smart constructed wetlands: They integrate the wastewater treatment with new technologies. Wetlands are transition areas-they have both aquatic and terrestrial features. They are dominated with plants adapted to live in saturated soil conditions. Smart technologies can be used to monitor the temperature, PH and water components in order to ameliorate and optimise the treated water quality.

Smart materials: Smart materials have been used to develop more cost-effective and high-performance water treatment systems as well as instant and continuous ways to monitor water quality. Smart materials in water research have been extensively utilised for the treatment, remediation and pollution prevention. They can maintain the long-term water quality, availability and viability of water resource. Thus, water via smart materials can be reused, recycled and desalinised, and it can detect the biological and chemical contamination as well as whether the source is from municipal, industrial or man-made waste[4].

To know more...

[1] Wastewater treatment https://en.wikipedia.org/wiki/Wastewater_treatment#Wastewater_treatment_plants

[2] Urban Water Resources Management: Smart v. Traditional http://smartcitiescouncil.com/resources/urban-water-resources-management-smart-v-traditional

[3] How smart wastewater management saved an Indiana city millions http://smartcitiescouncil.com/article/how-smart-wastewater-management-saved-indiana-city-millions

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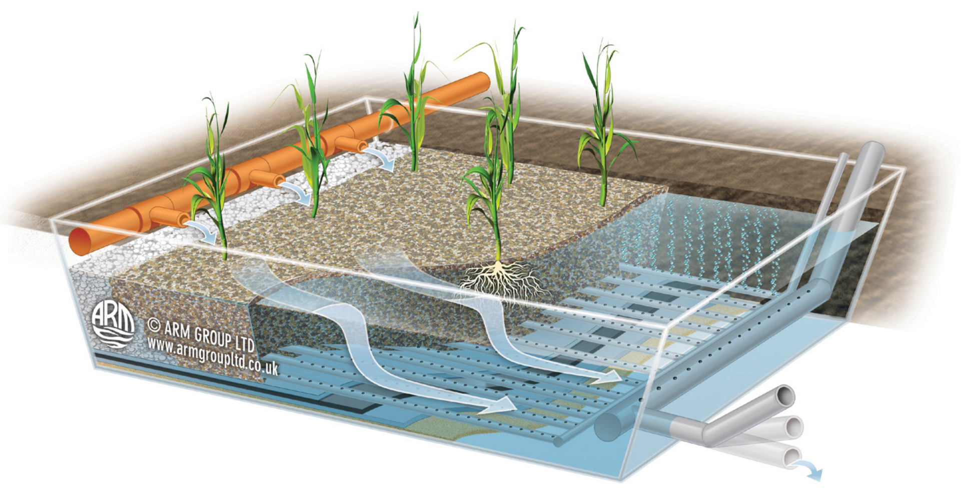

Fig. 1 Schema of a wetland system for water treatment.

Opportunities for innovation

The major consumers of water and consequently producers of wastewater are industrial buildings and touristic establishments. Legislation should obligate the introduction of installations in those buildings from the beginning of their construction that would separate grey water from black water production and disposal. Smart technologies could be then used for the separation of treated grey water for reuse and irrigation and for its quality management and control and possible mixture with other types of water such as rain water. Smart meters could be also used to calculate the volume of the recuperated grey water. Their use would allow the adoption of an adjusted tax system related to the grey water recuperation.

Near future challenges

As urbanisation continues as a global mega-trend, cities must provide healthy and sustainable living places and deliver basic infrastructure services with better efficiency in environmental and economic resource use. Energy-efficient decentralised wastewater treatment facilities can play an integral role as smart cities develop in the coming years. The focus may be in three main points:

- In order to meet growing water demands, the use of wastewater treatment for the recycling and reuse of water streams will increase.
- The need for recycling and reuse at the point of usage strongly favours a decentralised rather than centralized approach to wastewater infrastructure.
- Ecological techniques to wastewater treatment will be required to provide such a service with greater resource efficiency[5].

SMART BUILDINGS

TO-25 Water saving devices

In recent years, there has been a significant emphasis placed on achieving reductions in urban residential water demand through the application of alternative water resources on various housing development scales based on a "fit-for-purpose" concept[1].

Today

Water saving technologies and strategies are often the most overlooked aspects of a whole-building design strategy. It is estimated that implementing smart water network solutions could save global water utilities and their customers up to $12.5 billion per year[2]. There are a number of strategies that can be employed to reduce the amount of water consumed at a facility. In general terms, these methods include:

- System optimisation (i.e., efficient water systems design, leak detection, and repair);
- Water conservation measures; and
- Water reuse/recycling systems.

General technologies:

Smart water meters: With the traditional water meters, a building's or household's total water consumption is manually read. Customers cannot pinpoint inefficiencies and leaks are difficult to detect. Smart meters allow for continuous, remote monitoring of consumption. As a result we have more comprehensive usage and price signal data and highly accurate leak alarms.

Smart water quality monitoring: The traditional water quality monitoring relies on manual, "grab" sampling techniques and field/laboratory analysis. They can be time consuming and costly. On smart water quality monitoring online sensors communicate real-time data to a software platform. As a result, it manages and avoids quality issues before customers are impacted.

Smart leak detention: Traditional leak detention relies on regular sweeps by field teams. It can be time consuming and costly. Smart leak detention depend on fixed sensors or automated software. Those remotely alert system operators in real-time about various network inefficiencies. It prevents water loss and large bursts that interrupt service and cause property damage.

Smart pressure management: In traditional pressure management pressure valves are manually controlled by reactive programmes or field visits. They can be time consuming and costly. In smart pressure management the network water pressure is automatically and remotely controlled based on real-time operating conditions. As a result, it reduces burst frequency and extends infrastructure lifetime.

Smart energy management: Traditional energy management relies on pump station audits or installing pump station controllers. It does not account for water demand or energy tariffs. In smart energy management pump stations are automatically controlled based on real-time optimisation and control applications. As a result, it increases energy efficiency and asset performance while cutting down energy costs[2].

Smart materials: Smart materials have been used to develop more cost-effective and high-performance water treatment systems as well as instant and continuous ways to monitor water quality. They have been extensively utilised for the treatment, remediation and pollution prevention. They can maintain the long-term water quality, availability and viability of water resource. Thus, water via smart materials can be reused, recycled and desalinised, and it can detect the biological and chemical contamination as well as whether the source is from municipal, industrial or man-made waste[3].

Specific technologies

- Smart Showerheads and faucets of low flow and/or automatic with infrared sensor.
- Smart toilets and urinals that control water consumption.
- Multi-pass, closed loop, or air-cooled equipment options instead of single-pass to arrive at the most water- and energy-efficient cooling system with an automatic shut-off valve to the cooling system to eliminate usage when equipment is not running[4].
- Smart, automatic irrigation systems that depend on soil moisture and weather predictions.

Home devices: many Technologies are being developed to save both water and energy at home. Some examples are:

- Showers in which waste water is purified just after use and pumped back to the recycling shower loop, allowing for the saving of 90% of water and 80% of energy. Showers of micro-drops with a consumption as low as 1 l/min. Showers and washbasins in which waste water is recovered for its use at the toilet.
- Devices that can be easily installed in any plumbing system avoiding the waste of water when waiting for the desired temperature for its use.
- Heat exchangers to recover waste water heat.
- Water-free, chemical-free lavatories and toilets.
- Dry wasing machines.

To know more...

[1] Umapathi, S., Chong, M.N. & Sharma, A.K., 2013. Evaluation of plumbed rainwater tanks in households for sustainable water resource management: a real-time monitoring study. Journal of Cleaner Production, 42, pp.204–214.

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[3] Mishra AK (ed.) (2016) Smart Materials for Waste Water Applications. Salem, Massachusetts: Scrivener Publishing.

[4] Water Conservation https://www.wbdg.org/resources/water_conservation.php

[5] Lee, S.W. et al., 2015. Smart water grid: the future water management platform. Desalination and Water Treatment, 55(2), pp.339–346.

[6] Hauser, A. & Roedler, F., 2015. Interoperability: the key for smart water management. Water Science & Technology: Water Supply, 15(1), p.207.

Opportunities for innovation

Smart meters could be used in combination with adjusted tax system to calculate the exact amount of water consuption and tax accordingly. Economic penalties usually reduce the consumption.

In order to increase the efficiencies of all elements in the water network, a smart water grid (SWG) is proposed as a next generation water management scheme, one that integrates information and communication technology (ICT) into the water network structure[5].

Near future challenges

Interoperability: the integration of water processes with information and communication technologies systems offers huge opportunities in terms of efficiency gains, improved security, and overall sustainability. The integration of water processes with ICT systems combines classical water technologies with communication, Information Technology (IT), and advanced software tools. Interoperability in smart water netorks (SWNs) has not been realised yet. Existing literature mainly focuses on specific sub-systems rather than on the whole water distribution network[6].

Despite many devices exist to reduce water consumption in buildings, their adoption is still low. There is need to raise awareness and to promote behavioural changes among users and professionals.

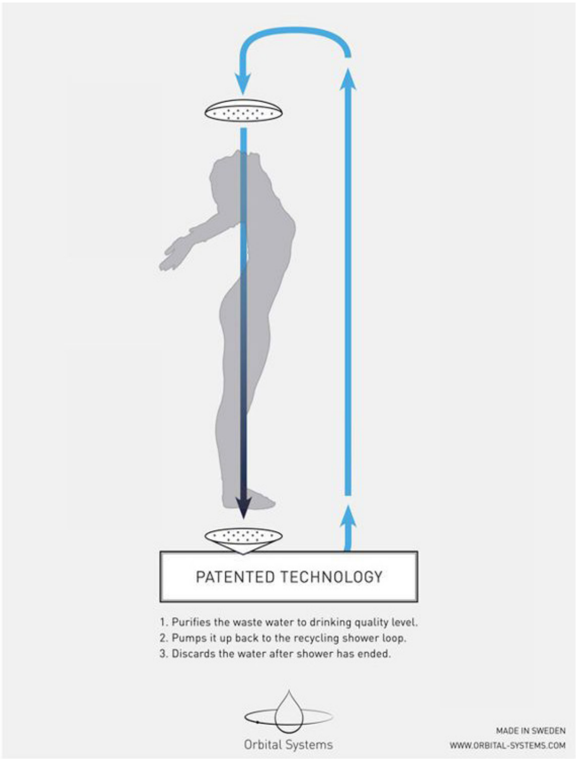

Fig. 1 Schema of the OrbSys shower technology. The heated water is instantly purified and returned to the water loop to be used again.

SMART BUILDINGS

TO-26 Water storage

It is common knowledge that having a supply of water in an emergency is a necessity but most often people do not store water unless they hear of an imminent disaster. Furthermore, water storage is useful for rain water acummulation and also for grey water accumulation for possible reutilisation after treatment.

Today

The need for water use planning

Water conservation technologies and strategies are often the most overlooked aspects of a whole-building design strategy. However, the planning for various water uses within a building is increasingly becoming a high priority. This is due to a number of reasons:

- new and existing water resources are becoming increasingly scarce in a number of regions throughout the country;
- per capita water consumption is increasing annually;
- water and sewer rates have increased dramatically over the last decade (100-400%);
- new water supply options are too costly or altogether unavailable—often resulting in stringent water use requirements in new construction applications.
- the increasing recognition of the water, energy, and O&M savings that can be realised through the implementation of water saving initiatives[1].

Storage systems[2]:

There are many different options available for water storage. It depends mainly on how much water is going to be used.

- Brick and Concrete Cisterns
- Plastic Tanks
- Metal Tanks
- Wooden Tanks
- Bladders
- Ponds and Pools

To know more...

[1] Water Conservation https://www.wbdg.org/resources/water_conservation.php

[2] Rainwater Harvesting http://sustwatermgmt.wikia.com/wiki/Rainwater_Harvesting

[3] Moriyama, T. et al., 2014. Live Demo: Sensor network system for rainwater grid: APCCAS track selection: System and networks for safe and secure life. In 2014 IEEE Asia Pacific Conference on Circuits and Systems (APCCAS). IEEE, pp. 167–168.

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Smart technologies

Water Tank System: A rainwater tank that is connected to a network and can be monitored and controlled. The system continuously monitors the water level of the tank, stores data and visualises it as a webpage[3].

Smart water quality monitoring: The traditional water quality monitoring relies on manual, "grab" sampling techniques and field/laboratory analysis. They can be time consuming and costly. On smart water quality monitoring online sensors communicate real-time data to a software platform. As a result, it manages and avoids quality issues before customers are impacted[4].

Smart leak detention: Traditional leak detention relies on regular sweeps by field teams. It can be time consuming and costly. Smart leak detention depend on fixed sensors or automated software. Those remotely alert system operators in real-time about various network inefficiencies. It prevents water loss and large bursts that interrupt service and cause property damage.

Smart pressure management: In traditional pressure management pressure valves are manually controlled by reactive programmes or field visits. They can be time consuming and costly. In smart pressure management the network water pressure is automatically and remotely controlled based on real-time operating conditions. As a result, it reduces burst frequency and extends infrastructure lifetime.

Smart materials: Smart materials have been used to develop more cost-effective and high-performance water treatment systems as well as instant and continuous ways to monitor water quality. They have been extensively utilised for the treatment, remediation and pollution prevention. They can maintain the long-term water quality, availability and viability of water resource. Thus, water via smart materials can be reused, recycled and desalinised, and it can detect the biological and chemical contamination as well as whether the source is from municipal, industrial or man-made waste[5].

Opportunities for innovation

The use of a stormwater detention tank. Its main function is to prevent the risk of flooding in urban environment due to intense rainfall events. In the moments when the tank is not required to carry out its main function, it can be used as an energy storage system, thanks to the introduction of a pump/turbine group, whose operation will be regulated by electrical market prices[6].

Near future challenges

There are two main challenges for the future regarding the water storage:

- Difficulties on needs prediction. i.e. on the calculation of how much water the average household uses per day.
- Water contamination. An excess of water storage that will not be used in the near future may be easily contaminated.

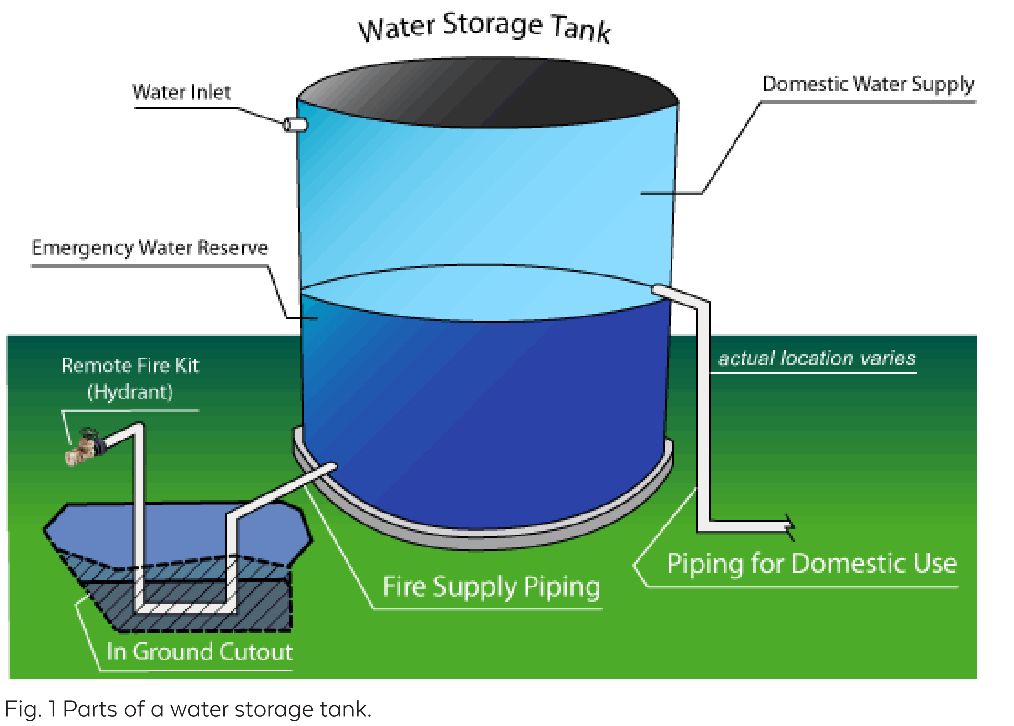

Fig. 1 Parts of a water storage tank.

SMART BUILDINGS

TO-27 Building farming technologies

Urban agriculture is an industry located within or on the fringe of a town, city or metropolis, which grows or raises, processes, and distributes a diversity of food and non-food products, (re-) using largely human and material resources, products, and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area. It has multiple functions and produces a range of non-food and non-market goods that may have positive impacts on the urban setting. It promises environmental benefits resulting from the saving and recycling of resources and reduced food miles. Social advantages include improving community food security, the provision of educational facilities, linking consumers to food production, and serving as a design inspiration. In economic terms it provides potential public benefits and commodity outputs[1].

Today

Driven by global imperatives such as climate change mitigation, more equitable economic models, and health concerns, urban agriculture is, in the past few years, gaining momentum. With potential yields of up to 50 kg/m^2·year, vegetable production is the most significant component of urban food production, with at least 100 million people involved worldwide[2].

Traditional growing systems[2]

Globally, there are various approaches of urban horticulture such as allotments for self-consumption, large-scale commercial farms, community gardens, and even edible landscapes. There are lots of vacant spaces which can be used for urban horticulture such as rooftops, fallow land, and smaller areas like roadsides or private balconies.

Home gardening: this is the most common form of urban agriculture. Vegetables are cultivated in proximity to the home of growers. The production is generally used as a supplement of self-consumption. The benefits include the possibility to practice leisure outdoors activities and some savings on food expenses. However, this practice can have further social implications, such as reducing the risk of obesity and mitigating urban poverty.

Community gardening: in this case, the area for cultivation is shared between various people. Garden organization can be close-knit associations, which act on a larger scale, selling their products in small shops, to loosely organised communities which only share the facilities. The most common limiting factors are limited access to land and infrastructures, soil pollution and lack of tenure on property. Cultivation in mobile containers can help to overcome such limitations. The main benefits are social and educational. Empowerment, the desire for a greener lifestyle and for a strengthened community are the driven factors for engagement.

Continuous productive urban landscapes: this is a holistic approach aiming for the construction of a green infrastructure integrating urban horticulture, green corridors and green urban areas, capable to improve the overall character of the city and to connect it to the rural area. This approach integrates both small-scale gardening with commercial gardening, and can be implemented for instance in paved streets within superblocks.

Innovative cropping systems[2]

Intensive cropping technologies have been developed in order to tackle the recurring limiting factors for horticultural production in urban farming (i.e. low soil quality, water availability and high environmental impact).

Soilless cultures: soilless cultures allow for a better control of pesticides and fertilizers and for the avoidance of agricultural runoff. However, these systems are very intensive and are especially suitable for urban areas with limited cultivation space, as they are characterized by demanding high standards of technology, maintenance, operation, and investment that are necessary in the early stages of development. In hydroponic systems, vegetables are grown in enriched water, which optimises the dosage of nutrients needed. This technology is most suitable for leaf crops, vine crops and culinary herbs, and can be used for instance in rooftop of supermarkets, hotels, hospitals, schools, etc. Aquaponic systems combine hydroponic units with aquaculture units. In this way, vegetable and fish are produced simultaneously and the sustainability of the system is increased by the closing of water and nutrient cycles. The weight of the system is an important limiting factor of this technology.

Organoponics: this is a common cultivation practice in Cuba consisting in the use of raised beds with a mix of soil and organic matter. This system is highly sustainable and cost-effective, as the use of fertilizers is not required.

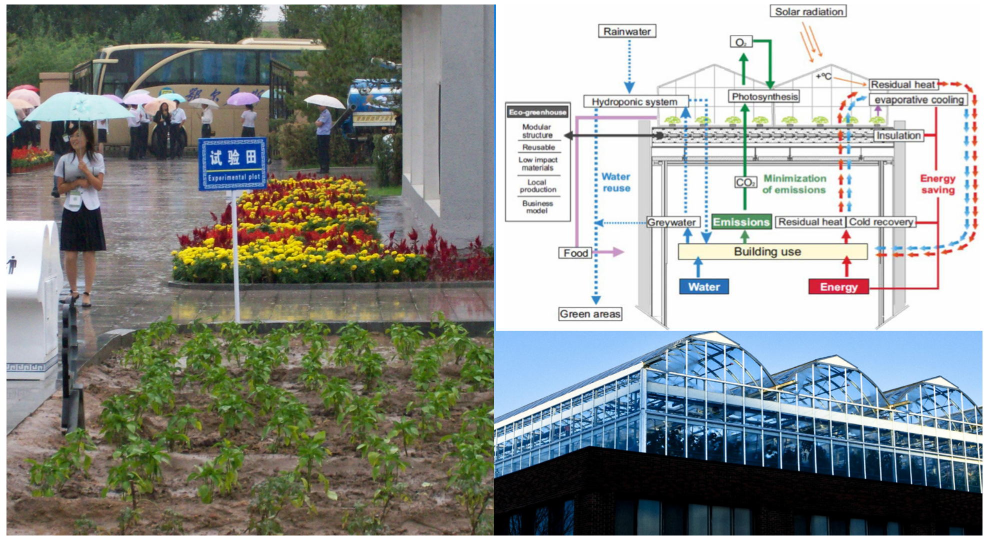

Fig 1. Examples of building farming technologies.

To know more...

[1]Specht, K., Siebert, R., Hartmann, I., Freisinger, U. B., Sawicka, M., Werner, A., ... Dierich, A. (2014). Urban agriculture of the future: An overview of sustainability aspects of food production in and on buildings. Agriculture and Human Values, 31(1), 33–51. http://doi.org/10.1007/s10460-013-9448-4.

[2]Eigenbrod, C., & Gruda, N. (2015). Urban vegetable for food security in cities. A review. Agronomy for Sustainable Development, 35(2), 483–498. http://doi.org/10.1007/s13593-014-0273-y

Organoponics in Cuba: https://www.youtube.com/watch?v=bfnJfpjVmBI&index=4&list=PLB171008D1984A029

Vertical farming: https://www.youtube.com/watch?v=Uh_zJ09jUc0 and https://www.youtube.com/watch?v=ISAKc9gpGjw

Opportunities for innovation

Organoponic and other low-input systems will continue to play an important role for a sustainable and secure food production in the future.

Despite the resource efficiency of indoor farming systems, a revolution in energy production is needed if they have to be environmental friendly and cost-efficient.

Integrating urban horticulture into educational and social programs will improve nutrition and food security. Overlaying these, new technologies in horticultural research need to be adopted for urban horticulture to increase future efficiency and productivity.

To enhance sustainability, urban horticulture has to be integrated into the urban planning process and supported through policies. However, future food production should not be “local at any price”, but rather committed to increase sustainability.

Near future challenges

Innovative forms of green urban architecture aim to combine food, production, and design to produce food on a larger scale in and on buildings in urban areas.

Indoor farming systems use the combined effort of agricultural production and buildings and create an integrated whole within the protected environment of a building. Indoor farms mainly exist as prototypes. Lighting is one of the limiting factors. To overcome this problem, the grow of shade-tolerant species, including edible fungi or invertebrates, can be envisaged[1]. Besides, efficient artificial lighting systems are being developed based on LED technology. LED lamps are lightweight, durable and offer high light intensity levels at a controlled spectral composition and low heat emission. However, the energy costs are still extremelly high, making indoor farming systems very expensive and non-sustainable[2].

Building integrated agriculture (BIA): are systems that exploit the synergies between agriculture and the building environment aiming for a higher efficiency of the ensemble. The principle is to take advantage of the “urban resources”: waste water, waste heat (e.g. from air-conditioning systems and refrigerators), organic waste (e.g. from food industry or households, etc. for on-site production of food. BIA is commonly implemented in roofs. Extensive, drought-tolerant and shallow-rooted crops are generally grown as implementing intensive horticultural plants on roofs is difficult. Greenhouses, when placed in roofs, besides having a good thermal performance, must be light-weight and resistant to wind loads. Installation and maintenance cost are significantly high.

Vertical farming: It is defined as the concept of cultivating plants or animal life within skyscrapers or on vertically inclined surfaces. Vertical production of crops would allow more cultivation area on a relatively small base area, reducing the need for large expanses of arable land. Major advantages are the close proximity of a large-scale crop production to the consumers and the controlled environment throughout the building allowing higher yields. In this way, even cities or sites with contaminated soil or severe weather extremes could grow healthy food sustainably and independently from others. Examples of vertical farming exist in Asian plant factories, in which vegetables are cultivated indoors under fully controlled conditions. Computers and sensors control and measure the main environmental factors that affect vegetable growth, such as lighting, carbon dioxide concentration, relative humidity, and plant surface temperature. Other visions, such as the production of staple crop rice using an aeroponic systm which would supply the rice roots with a mist enriched with nutrients (Skyfarming), need to be tested yet.

SMART BUILDINGS

TO-28 Open database

Open data is data that are free to use, reuse, and redistribute. It is considered an important enabler of urban smartification contributing to innovation with citizen and business value-added applications and services. Healthcare organizations and governments worldwide are increasingly making their data publicly accessible through open data platforms, in an effort to promote accountability, entrepreneurship, and economic growth.

Today

Open data has a great catalysis potential in the Smart Cities' pursuit of innovation. Recent developments towards opening up data in the process of urban "smartification" have demonstrated that making machine-readable information freely available can foster citizen empowerment, enhance public services through participation, leverage new business models, and ultimately change the paradigm on which governments operate.

Open databases topics: in general, open databases can be linked to many domains and be related to many topics such as agriculture, business, ecosystems, education, finance, etc. Its use in smart buildings might be related to:

- **Climate**: Data related to climate change that can help inform and prepare communities, businesses, and citizens. It is possible to find data and resources related to coastal flooding, food resilience, water, ecosystem vulnerability, human health, energy infrastructure and transportation.
- **Consumer**: Data sets and resources that can be used to build apps that help consumers make smarter choices.
- **Education**: Education datasets, apps, resources for the classroom, and details related to schools, institutions and universities that cover education at all levels.
- **Energy**: Data and resources on key energy topics like alternative fuels, green buildings, efficiency, and managing energy at the house level.
- **Health**: Datasets, tools, and applications related to health and health care. Their goal is to improve the health and lives of the citizens.
- **Local Government**: Open data is powering a new civic movement that is changing the way citizens experience our nation's cities, counties, and states.[2]

Open data allows for the exchange of information between different collaborative entities. The concept of **inter-connected collaborative buildings** builds on top of the grid connected buildings idea to further increase energy savings as well as improvements that align with smart grid requirements. This concept present several advantages:

- **"Learning by example"**: new buildings can quickly improve their energy efficiency utilizing other buildings' knowledge base.
- **Information sharing on incoming weather changes.** The constantly evolving knowledge base can be further used for improving building design as well as identifying optimal load patterns for the smart grid.
- **Information sharing on energy/water demand/supply:** Moreover, in an environment where buildings can "talk" to each other, current and predicted demand curves can be shared. Using this information, HVAC system activity can be adjusted to better suit the grid requirements.

Building to Grid (B2G) interoperability can be viewed as having one of the highest energy efficiency impacts. While experiments with local generation (wind or solar), or local storage (water tanks) exist today, integrated peak-shaving strategy is not yet taking an active role, even in smart cities. Advanced decision supports tools such as fuzzy decision engines that utilize expert knowledge and building/grid requirements can be used in addition to other algorithms to achieve short/long term building prediction and peak-shaving. The algorithms will need to be based on interoperability with utilities and market pricing in order to achieve required improvements of peak-shaving.

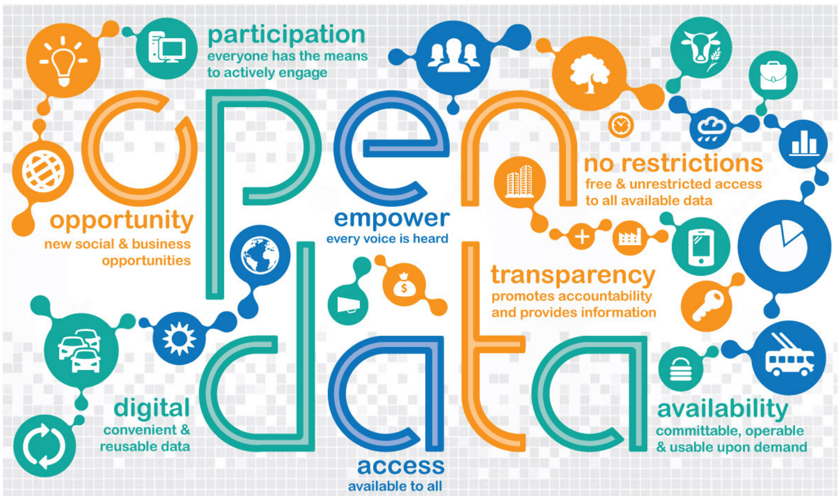

Fig. 1 Diagram of the concepts related with Open Data.

To know more...

[1] Smartly Opening Up City Data http://smartcities.ieee.org/articles-publications/ieee-xplore-readings-on-smart-cities/april-2015.html

[2] https://www.data.gov/

[3] Gkoulalas-Divanis, A., Mac Aonghusa, P. "Privacy protection in open information management platforms." IBM Journal of Research and Development (Volume:58 , Issue: 1), pp.2:1 - 2:11.

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Ojo, A., Curry, E., & Zeleti, F. A. (2015). A Tale of Open Data Innovations in Five Smart Cities. In 2015 48th Hawaii International Conference on System Sciences (pp. 2326-2335). IEEE. doi:10.1109/HICSS.2015.280

Opportunities for innovation

Open data are increasingly generating new business worldwide, providing citizens with a wealth of information that they can combine and aggregate in unprecedented ways.

Open data should be easy to access, analyze, and visualize and could be put to work for communities.

Cities may use data to drive inclusive neighborhood change. The latest analytical tools may be brought together with new and existing data sources to allow public and private actors to anticipate and act upon changes in vulnerable neighborhoods. Relevant data could be collected from multiple sources and integrated at the neighborhood level to develop and implement early warning and response systems.

Near future challenges

While the primary challenge of collaborative buildings is deployment on large scale, currently identifying suitable control techniques and decision systems that will lead to reliable, sustainable and resilient collaborative buildings is the priority. Machine learning techniques coupled with rule-based systems and advanced control strategies may be capable of achieving some requirements of the collaborative buildings concept. Significant research and testing on table-top systems as well as small scale real-world environments is required to identify and improve suitable techniques and technologies.

Many issues still remain to be appropriately addressed so that open data can be explored to its full potential. There are some undesirable side effects of current strategies to open up and effectively use data such as lack of data quality, incompatible data formats and access methods, and various semantic interpretations of data as some of such adverse outcomes, which consequently avoid open-data stakeholders to offer citizens and business value-added applications and services.

To address these issues and make open data actionable, open data should be leveraged on features such as data quality assessment, data homogenization for uniform access, data correlation and semantic adaptation, and secure data access.[4]

Another important characteristic of open data environments is that once published, **it is difficult to anticipate how the data will be used**, and that linking innocuous datasets together may lead to serious privacy violations and powerful analytic tools may reveal sensitive patterns that were unknown at the time that the data were published.

Some **research challenges** that arise in this new landscape are how to pass from single source to linked data, from specific data owner to complex data ownership, from few to frequent data updates, from single- to multi-purpose use and from specific to adaptive adversarial knowledge.[3]

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FUTURE OPTIONS SMART BUILDINGS

D3.1 Report - Future options for Smart buildings

This report (D3.1) contains the results of the desk study activities regarding state-of-the-art solutions and future options in the area of sustainable energy for buildings from January 2016 to April 2017. The desk study is part of WP3 Roadmapping Smart Buildings of the R4E project.

This report is a deliverable of WP3 of the Roadmaps for Energy (R4E) project. The R4E partners work together to develop a new type of energy strategy through visions and roadmaps for the 8 partners cities, in co-creation with local stakeholders. The project supports the development of visioning and roadmapping capacities within the municipalities to spur future development and implementation of innovative energy solutions.

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