ROADMAPPING
SMART URBAN SPACES

D5.1 Report - Future options for Smart Urban Spaces

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ROADMAPPING

D5.1 Report - Future options for Smart Urban Spaces

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Abstract
This report (D5.1) contains the results of the desk study activities regarding state-of-the-art solutions and future options in the area of sustainable energy for urban spaces from January 2016 to April 2017. The desk study is part of WP5 Roadmapping Smart Urban Spaces of the R4E project.

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Disclaimer: This report presents the views of the authors, and do not necessarily reflect the official European Commission’s view on the subject.

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### WP7. Project management

#### WP1. Ambition setting
- **Ambition workshops**: 3-day workshop in each city to define specific ambitions per focus area.

#### WP2. Vision development
- **Scenario workshops**: 3-day workshop in each city to develop specific desired future scenarios per focus area.

#### WP3, 4 & 5. Roadmapping
- **Roadmap training sessions**: 2-day training session for expert partners on methodology and roadmaps.
- **Scenario workshops**: 3-day workshop in each city to develop specific desired future scenarios per focus area.
- **Roadmap interviews**: Collecting expert insights with 20 experts for each focus area.

#### WP6. Project portfolio
- **Current projects**: Each city identifies projects it has running that will contribute to the realisation of the roadmap, as well as the topics for cross-city learning.
- **New projects**: Each city identifies the desired new projects to ensure the timely realisation of its roadmap ambition.
- **Joint portfolio meeting**: 3-day meeting 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).

#### WP8. Communication & dissemination
- **Strategy & visuals**: Developing a communication & dissemination strategy, topics and graphics.
- **Regular communication activities**: Electronic project newsletters, other newsletters and information services, project and partner websites, press releases and other media releases, social media.

#### Roadmap workshops
- **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.
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**

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.

This report is part of Step 3 of the R4E approach and describes the first part of Workpackage 5 (WP5). The aim of WP5 is to develop the roadmap for Smart Urban Spaces. In this roadmap the options to realise the desired future scenarios of the cities are explored. A desk study provides 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 Urban Spaces and sustainable energy in the urban 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.

The desk study is conceived as a tool to support cities in the definition of their own roadmap. It reflects the inherent complexity of the sustainable processes and synergies which are the enabler mechanisms to arrive to the desired 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.
Approach in WP5 - 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 participants.

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.

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 Solution 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 Solution 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 sit 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 the 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 context 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 Urban Spaces and identified the common aspects. The result was used for a description of the focus area Smart Urban Spaces.

The Smart Urban Spaces theme focuses on sustainable energy solutions for public spaces, where multiple functions and activities physically come together. The ambition of the cities is to create liveable urban spaces by engaged citizens and involvement of all stakeholders. Circular systems contribute to smart use of resources. Sustainable transportation solutions enable the achievement of a healthy living environment.

During the Joint Vision Workshop on 24 and 25 May 2016 in Istanbul the cities presented their desired future scenarios for Smart Urban Spaces 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 Urban Spaces that will be covered by the desk study, as part of the roadmapping step of the R4E project (WP5), are the following.
Flexible and attractive living environment
- Pleasant living environment for everyone
- Adapting while preserving the identity of the city (like history and culture)
- Ecological system connecting the green and blue areas
- Urban space is for people, not for private use (like parking cars)
- Enabling multi-functional use of urban space

Social interaction and healthy behaviour
- Active use of public spaces for sustainable lifestyles
- Well-connected and well-equipped green enhancing social life
- Healthy living environment with extensive ‘green’ and ‘blue’ to support social activities
- Open platforms to encourage citizens to initiate and participate in social events

Climate resilience
- Integrated physical planning to strengthen interdependencies between water, flora, pavement, buildings
- Green areas to help produce and store (renewable) energy, reduce heat stress and recover rainwater
- Private property should be climate resilient as well

Synergy between urban and rural areas
- Open territorial cooperation that encourages innovation and contributes to the local economic development
- Reducing footprint by using circular systems
- Well-designed network of routes to connect urban and rural areas, responding to quality lifestyles and supported by smart technologies

Smart systems and smart grids
- Real-time info to engage people in social activities
- Smart grid to connect public spaces and services
- Centralised ‘brain’ to enable information sharing
- Secure system that ensures privacy by understanding the boundary between public and private information
- Resilient system (optimising resources to conditions)

New business and financing models
- Providing an ideal environment for (local) entrepreneurs with sustainable and healthy services
- Accessible data to develop new apps and services
- Citizens and administration jointly invest in the living environment
- Public space is always freely accessible, but added-value services can be at a charge

Citizens taking the lead and co-creation
- People feel responsible for sustainability and are engaged in urban planning use and maintenance
- People take initiatives, supported by the administration
- Citizens use smart systems to monitor the quality of the environment and contribute to its improvement
- Citizens actively take part in making decisions that influence their living environment
SMART MAIN STRATEGIES
The partners’ desired future scenarios include many different aspects and needs across the list of the seven common needs for Smart Urban Spaces. A clustering from the different needs has been made to explore the options for realizing 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. **Healthy, comfortable and participatory living environment**
   - Cities offer healthy and livable spaces, with highest quality, regarding air quality, green spaces and places for social interaction.
   - Natural Services, for a healthy lifestyle in contact with nature and a biodiversity that assures urban ecosystem resilience; Municipal Services, which favour transparent administration and citizens' engagement due to telematic processes and open data; and Personal Services, as home connected services for assistance, healthcare and security.

2. **Urban Energy Self-sufficiency**
   - Urban metabolism procures energy self-sufficiency at all scales, from building level to urban space and individual city quarters as well as city as a whole.
   - Energy self-sufficiency is based on highest energy efficiency, decentralized renewable energy generation, energy storage at different scales and a centralized smart grid infrastructure.

3. **Optimized Urban Water Cycle**
   - City Water Cycles are optimized regarding water collection, distribution, storage, use, depuration and recycling at different scales, with natural and urban systems benefitting mutually from generated synergies.
   - Rainwater harvesting and ground water wells are added to the urban system reducing grid dependency.
   - Water treatment and reuse in buildings reduces waste water flows and enables alternative urban water treatment systems with less environmental impact.

4. **Optimized Urban Material Flow**
   - Urban metabolisms procure to close material cycles as far as possible in all sectors of the city.
   - Public and private forces promote Life-Cycle Assessment (LCA) creating new business and synergies among urban actors.
   - Waste is understood as nutrient for new processes and products (‘waste to create’) in order to reduce material consumption and waste disposal as much as possible.

5. **Optimized Urban Infrastructures**
   - Cities procure a maximum of synergies between the different urban elements and infrastructures in order to optimize quality of life, mobility, energy efficiency and all kind of urban functions.
   - Multifunctional public spaces, with interactive and flexible uses, are managed in a centralized and participatory way, optimizing the interplay between built environment and urban green spaces.
Smart main strategies - Healthy, comfortable and participatory living environment
Smart main strategies - Urban energy self-sufficiency
Healthy, comfortable and participatory living environment

Optimized Urban Water Cycle

Optimized Urban Infrastructures

Urban Energy Self-sufficiency

Optimized Urban Material Flow

Smart main strategies - Optimized urban water cycle
Smart main strategies - Optimized urban infrastructures

Healthy, comfortable and participatory living environment

Optimized Urban Infrastructures

Optimized Urban Water Cycle

Optimized Urban Material Flow

SMART URBAN SPACES
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.”

**Smart main strategies**

Healthy, comfortable and participatory living environment

Optimized Urban Infrastructures

Optimized Urban Water Cycle

Optimized Urban Material Flow

Healthy, comfortable and participatory living environment
SYSTEMIC SOLUTION MAPS
Cities can be regarded as metabolic systems that require a certain amount of inputs in the form of materials and energy to function. New information processing technologies open the door to the possibility of actually measuring and control the “diet” of a city, which can be useful in decision making when implementing measures to enhance efficiency.

Closing the cycle of materials is a holistic vision of material management aimed to reduce the environmental impacts associated. Soon it will be possible to track the materials moving through the cities and determine which areas of improvement are most relevant. Material accounting systems will be helpful in this task.

**Roadmapping SMART URBAN SPACES**
According to FAO, 20% of greenhouse gas emissions all over the world are produced as a consequence of the food sector alone. And one third of the food produced for humans is wasted before being consumed. The built up of more sustainable urban food systems is thus key to reduce GHG emissions and improve resource efficiency. Sustainable urban food systems include the use of proximity and seasonal products, in which the construction of short supply chains; the reduction of the amount of animal protein and processed foods consumed in citizens’ diet; the use of sustainable and environmental friendly products; the promotion of self-production of vegetables increasing urban farming opportunities; and the prevention of waste production by reducing the amount of packaging used for food delivery.

There is need to implement measures to improve the perception of the general public towards proximity and sustainable food, in particular among those communities less sensitized with this issue. It is essential to promote a progressive transition from current food production and supply actors towards shorter and more sustainable supply chains in which new business opportunities may emerge. This will contribute to create long term local jobs and to strengthen communities.

There are two principal sources of organic resources:
- Public areas
- Individuals also generate a high quantity of organic waste.

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

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.

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, largely (re-)using human and material resources, products, and services found in and around that urban area.

There are two principal sources of organic resources:
- Public areas
- Individuals also generate a high quantity of organic waste.

The technology for capture, conveyance, filtration, storage and use of rainwater has made significant advances worldwide and will continue to progress moving forward.
- Smart Rainwater Tank System (SRT)
- Web-Based Knowledge Management System (WBKMS)
- Smart Water Grid (SWG)
- Weather-based “Smart” controllers for irrigation

### Technologies

**TO17-Waste management**
- Waste management consists of different processes such as:
  - Collection
  - Transport
  - Processing
  - Disposal
  - Managing
  - Monitoring of waste materials

**TO19-Organic material cycle**
- Organic material, organic matter or natural organic material (NOM) refers to the large pool of carbon-based compounds.
- Carefully separating organic waste is a key opportunity for energy saving. Converting it to compost and fuels reduces the amount of organic material going to a landfill.

**TO20-Urban farming technologies**
- 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, largely (re-)using human and material resources, products, and services found in and around that urban area.
- 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
- Community gardening
- Continuous productive urban landscapes

**TO21-Rainwater management**
- The technology for capture, conveyance, filtration, storage and use of rainwater has made significant advances worldwide and will continue to progress moving forward.
- Smart Rainwater Tank System (SRT)
- Web-Based Knowledge Management System (WBKMS)
- Smart Water Grid (SWG)
- Weather-based “Smart” controllers for irrigation

**TO23-Wastewater treatment systems**
- Wastewater treatment is a process used to convert wastewater into an effluent that can be either returned to the water cycle with minimal environmental losses or reused.
- Some Wastewater treatment technologies are:
  - Smart water meters
  - Smart water quality monitoring
  - Coved sourcing data collection
  - Smart constructed wetlands

**Smart constructed wetlands**
- Water treatment is a process used to convert wastewater into an effluent that can be either returned to the water cycle with minimal environmental losses or reused.
- Some Wastewater treatment technologies are:
  - Smart water meters
  - Smart water quality monitoring
  - Coved sourcing data collection
  - Smart constructed wetlands

**SWeb-based knowledge management system (WBKMS)**
- The technology for capture, conveyance, filtration, storage and use of rainwater has made significant advances worldwide and will continue to progress moving forward.
- Smart Rainwater Tank System (SRT)
- Web-Based Knowledge Management System (WBKMS)
- Smart Water Grid (SWG)
- Weather-based “Smart” controllers for irrigation
The integration of green infrastructure and water management in cities allows for the recreation of a natural water cycle at an urban scale, which contribute to increase the resilience and adaptive capacity of cities in front of climate change and changes in land use and other socio-economic activities. This can be achieved by combining the hydrological and ecological values of the urban landscape, that is, using urban spaces to manage water resources, water demand and the risks of flood and droughts. Blue-Green Cities generate a multitude of environmental, ecological, socio-cultural and economic benefits through integrated planning and management and may be key to future resilience and sustainability of urban environments and processes.

TO01-Microclimate control

The microclimate scale may be at the level of a settlement (urban or rural), neighbourhood, cluster, street or buffer space in between buildings or within the building itself.

Different tools are used to assess the resulting impacts on critical infrastructure and society.
- In situ measurements
- Remote-sensing observations
- Modelling of urban weather
- Climate and atmospheric processes

TO02-Rainwater management

The technology for capture, conveyance, filtration, storage and use of rainwater has made significant advances worldwide and will continue to progress moving forward.
- Smart Rainwater Tank System (SRT)
- Web-Based Knowledge Management System (WBKMS)
- Smart Water Grid (SWG)
- Weather-based “Smart” controllers for irrigation

TO03-Wastewater treatment systems

Wastewater treatment is a process used to convert wastewater 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

Future Challenges

Green and blue spaces take into account quantitative as well as qualitative aspects of the development of open spaces such as: quality assurance, public space, mobility, rainwater management, green space, nature conservation and agriculture as well as housing construction and urban renewal.

The population growth and the subsequent urban densification call for permanent quality improvement. Green and open spaces that play a major role in the revitalisation and further development of the quarters in this respect, parks will remain the most important open space type. Parks are an essential element of the urban development concept in development areas. They have landmark value, ensure the quality of everyday life in the new city quarters and need to be designed according to the high demands on sustainability, robustness and design quality. Multi-functional green links are of special significance for further development of green and blue space infrastructure because they need to be wide enough in order to allow for several non-motorised ways of movement and recreation next to each other, and they also need to provide for the promotion of bio-diverse structure.
Packaging, garden waste, damaged or old-fashioned clothing and furniture, food scraps, newspapers and cardboards, and a wide variety of other everyday articles make up the bulk of municipal solid waste (MSW). It is estimated that 11.2 billion tonnes of solid waste are produced worldwide every year. With the aim to reduce the environmental issues related with such material waste, several cities worldwide are leading the zero-waste effort. Zero waste is a holistic approach aiming for a complete change in the material flow geared towards closed production cycles. This vision includes waste reduction in source (reduction of packaging, reduction of the use of hazardous materials, etc.), reduction through recycling and reuse (boosting up-cycling and leasing strategies) and efficient management (waste segregation, composting, energy production, etc.).
Urban space can integrate elements for energy collection, use and consumption at three different levels: (1) buildings’ rooftops, which can be used for distributed energy production (from micro wind turbines, photovoltaic systems, solar thermal systems, etc.), (2) streets and public spaces, in which energy is consumed and measures for energy efficiency can be implemented (including the design of efficient urban forms or the use of efficient infrastructures such public lighting systems; and (3) the underground level in which energy is stored and distributed. These three levels are integrated in smart grids, which automatically monitor energy flows and adjust to changes in energy supply and demand accordingly. When coupled with smart metering and sensor systems, smart grids provide valuable real-time information, which helps to reduce power consumption during peak hours; enables grid connection of distributed green generation power; allows for the incorporation of grid energy storage for distributed generation load balancing; and prevents system failures.

Future Challenges

Behavioural changes and acceptance by citizens are key factors for transition to urban sustainability. Citizens’ awareness and participation needs to be boosted by municipalities. ICT-enabling solutions can help to reach such objectives and to empower citizens.

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 complexity of the urban system.

Reducing the footprint of urban systems is a major goal to be achieved. Local action requires local capacities and responsibilities in addressing urban energy and environmental problems, including a mediating role among the multiple stakeholders that take part in any decentralized urban decision making process.
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, the maintenance of which represents an important cost for the municipality. Such spaces, properly managed, can play an important role for the building of stronger communities and empower citizens. The integration of ITC technologies can help with the proper management of the use of urban spaces. Sensor technologies would detect when and how a space is being used and translate such information to decision support systems. This may allow, for instance, the urban services (urban lighting, public transport, etc.) to adapt in real-time to the activities taking place in a specific space. Citizens will have access to such information through telematic urban services and smart urban appliances and will be able to propose further activities or to join existing ones.

A fast-growing wave of urban experimentation with telematics is emerging across advanced industrial cities. Increased mobility has generated the need for efficient effective yet simplified systems to achieve objectives such as the following:

- Supply chain management (SCM)
- Decision Support System (DSS)
- Field force automation (FFA).
- Locating fleet at given point in time

In the current and future applications, sensors can be classified into groups as follows:

- CO₂ levels
- Energy consumption
- Temperature
- Wind speed movement
- Heat radiation

The function of monitoring systems is data acquisition and transfer to the management system. Different kind of sensors are used:

- MEMs micro-electromechanical sensors
- Biosensors
- Image Sensors
- Motion Detectors

In the current and future applications, sensors can be classified into groups as follows:

- Microelectromechanical sensor technology
- Biosensors
- Image Sensors
- Motion Detectors

The following smart urban appliances have been developed:

- Citizen Help and Information Virtual Office
- Smart bus stops
- Wi-Fi points
- Reporting services
- Smart traffic lights
- Smart parking
- Interactive informative panels

Manchester
http://www.manchester.gov.uk/downloads/download/5645/digitial_strategy

Umea
http://en.sensesmartregion.se/

Turku
http://pleecproject.eu/downloads/Partner-Sect-ion/WP2/052012%20%20Smart%20City%20Proj/Proj/exp2_d2_1_results_turku_final.pdf

Stockholm
http://www.c40.org/case_studies/stockholn-ocal-seaport

Future Challenges
To promote compact and mixed-use neighborhoods, optimized distribution of space, and prioritization of walking, cycling, and public transportation is key for the building up of flexible urban spaces.
SSM-07 Health and home services

Buildings’ maintenance and citizens’ wellbeing and comfort requires the satisfaction of certain needs. These needs are covered by a wide range of home services, from plumbing, electrical, heating and cooling, connectivity, appliance repair, painting, security, etc. The emergence of the Internet of Things (IoT) has opened up a whole new world of innovation enabling the development of as-a-service models. This represents an opportunity to widen the range of possible services connecting the public and private spheres: health care, education, water and energy supply, sewerage, solid waste services, etc. Citizens can be engaged in monitoring the service levels through simple indicators thus playing an active role in the definition of urban services. The built structures in cities will probably remain similar to current ones, however, smart urban services will change our perception of urban spaces.

Technologies

TO02-Telematic urban services
A fast-growing wave of urban experimentation with telematics is emerging across advanced industrial cities. Increased mobility has generated the need for efficient effective yet simplified systems to achieve objectives such as the following:
- Supply chain management (SCM)
- Decision Support System (DSS)
- Field force automation (FFA)
- Locating fleet at given point in time

TO03-Telematic citizen services
The aim of telematic citizen services is to add value to city solutions for citizens’ needs, through multimedia telematic products that deliver access to local information and services. Some types of telematic citizen services are:
- Telecommuting
- E-democracy
- Telemedicine
- Participatory sensing

TO04-Monitoring systems
The function of monitoring systems is data acquisition and transfer to the management system. Different kind of sensors are used:
- CO₂ levels
- Energy consumption
- Temperature
- Wind speed movement
- Heat radiation

TO05-Open database
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.

TO06-Sensor technologies
In the current and future applications, sensors can be classified as follows:
- Microelectromechanical sensor technology
- Biosensors
- Image Sensors
- Motion Detectors

TO09-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 it is used and its user. There are several types of UI:
- Graphical user interface (GUI)
- Direct manipulation interface
- Gesture recognition interface

Case studies

Hammarby Sjöstad (Stockholm)

Umea

Stockholm
http://international.stockholm.se/city-develop ment/the-smart-city/

Future Challenges

Market structures are in many cases still very similar to how they were fifty years ago. It appears, however, that we are about to witness remarkable changes in the way we live, move, work and shop in cities.
The existence of citizens is perhaps one of the only constants in cities as they evolve in new and yet-unimagined ways. Citizens are also those suffering or engaging the outcomes of the multiple challenges that cities daily face. They are also contributors to urban issues, as their behaviour makes a meaningful difference in the exit of implemented policies. Moreover, citizens offer an immense aggregate power from their behavioural change, education, participation and empowerment. Thus, it is important to develop more participatory environments in which the collective intelligence and creativity is boosted. A smart use of Information and Communication Technologies (ICT) may contribute to this aim. Open data systems, the implementation of tools for e-democracy or of telematic services, can be used to enhance information availability, simplify interactions and allow direct communication between citizens and city governments.

Case studies

**Montpellier**
http://www.invest-in-montpellier.com/node/8995

**Maribor**
http://www.izvestja-marlbo.si/en/Projects/Smart_Economy_and_Cooperation/Participatory_Budget_of_Municipality_of_Maribor/

**Rotterdam**
http://www.invest-in-montpellier.com/node/8995

Future Challenges

Any project aiming to encourage citizen engagement should consider the following principles:
- Simple
- Reciprocal: ‘Give for getting’ to create fair and lasting relationships
- Participative
- Inclusive: Ensure solutions that are representative of the whole population
- Online-Offline balanced
- Conscious of privacy and rights: Build trust from the start
- Conscious of citizens’ emotions
- Change-enabler with city stakeholders: Make the municipality a partner
- Wallet-savvy: Use citizens’ own funds in smart ways that benefit citizens

Technologies

**TO02-Telematic urban services**
A fast-growing wave of urban experimentation with telematics is emerging across advanced industrial cities. Increased mobility has generated the need for efficient effective yet simplified systems to achieve objectives such as the following:
- Supply chain management (SCM)
- Decision Support System (DSS)
- Field force automation (FFA)
- Locating fleet at given point in time

**TO03-Telematic citizen services**
The aim of telematic citizen services is to add value to city solutions for citizens’ needs, through multimedia telematic products that deliver access to local information and services. Some types of telematic citizen services are:
- Telecommuting
- E-democracy
- Telemedicine
- Participatory sensing

**TO05-Open database**
Open data is data that are free to use, reuse, and redistribute. It is considered an important enabling of building smartification contributing to innovation with occupant’s 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.

**TO08-Smart urban appliances**
The following smart urban appliances has been developed:
- Digital labels
- User app interaction
- Graphical User Interface (GUI)
- Gesture recognition
- Health telematic appliances
- Decision support system (DSS)
- Field force automation (FFA)
- Participatory sensing
- Telecommuting
- E-democracy
- Telemedicine
- Participatory sensing

**TO09-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 it is used and its user.
There are several types of UI:
- Graphical user interface (GUI)
- Direct manipulation interface
- Gesture recognition interface
**Case studies**

**Maribor**

**Montpellier**
http://www.invest-in-montpellier.com/node/5095

**Barcelona**

**Future Challenges**

Integrated urban water management (IUWM) is the practice of managing freshwater, wastewater, and storm water as components of a basin-wide management plan. It builds on existing water supply and sanitation considerations within an urban settlement by incorporating urban water management within the scope of the entire river basin. IUWM is a strategy for achieving the goals of Water Sensitive Urban Design. It seeks to change the impact of urban development on the natural water cycle, based on the premise that by managing the urban water cycle as a whole, a more efficient use of resources can be achieved providing not only economic benefits but also improved social and environmental outcomes.

**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. Smart water management allows for a holistic vision of the water urban cycle, monitoring in real-time water supplies and consumption points and balancing the whole water grid in order to improve the efficiency of the system. It mainly includes **rainwater management and harvesting** technologies, **storm water and disaster prevention** technologies, demand monitoring and demand forecast, and **grey- and waste-water treatment** technologies.

**Technologies**

**TO01-Microclimate control**
- The microclimate scale may be at the level of a settlement (urban or rural), neighbourhood, cluster, street or buffer space in between buildings or within the building itself.
- Different tools are used to assess the resulting impacts on critical infrastructure and society.
  - In situ measurements
  - Remote sensing observations
  - Modelling of urban weather
  - Climate and atmospheric processes

**TO21-Rainwater management**
- In the recent years, the technology for capture, conveyance, filtration, storage and use of rainwater has made significant advances worldwide and will continue to progress moving forward.
  - Smart Rainwater Tank System (SRT)
  - Web-Based Knowledge Management System (WBKMS)
  - Smart Water Grid (SWG)
  - Weather-based “Smart” controllers for irrigation

**TO22-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
  - Smart constructed wetlands

**Networks of meteorological sensors**
- Smart water meter
- Smart weather station
- Online weather forecast
- Smart water quality monitoring
- Water sensitive urban design (WSUD)
- Smart rainwater tank system (SRT)
- SWeb-based knowledge management system (WBKMS)
TECHNOLOGY OUTLOOK
TO-01 Microclimate control

Climate is usually defined as the average of the atmospheric conditions over both an extended period of time and a large region. Small scale patterns of climate resulting from the combined influence of topography, urban buildings structure, water courses, vegetation, etc., are known as microclimates, which refers to a specific site or location. The microclimate scale may be at the level of a settlement (urban or rural), neighbourhood, cluster, street or buffer space in between buildings or within the building itself. The accurate detection of atmospheric conditions might be advantageously exploited by public authorities, for instance, to better plan the public and private transportation, to evaluate the impact on people health, control the greenhouse phenomenon or increase resilience in front of the climate change.

Monitoring

In situ measurements; remote sensing observations; and modelling of urban weather, climate, and atmospheric processes are utilized for applications such as assessing the resulting impacts on critical infrastructure and society, examining risk and implementing appropriate adaptation and mitigation techniques, exploring the future impacts of changing climates upon cities, and investigating the role cities play in global climate change.

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.

Control

Active micro-climate control is environmental control using mechanical devices to regulate the case climate. Mechanical controls are more effective and require less maintenance. Mechanical methods include the use of humidifiers, dehumidifiers, air cleaners and more. Active controls can be used in almost any enclosure and have many cost reductions in building energy use.

Passive micro-climate control is environmental control using buffers rather than mechanical devices. Buffers that can be used are saturated salt solutions, inorganic hygroscopic materials, or organic hygroscopic materials, they can even be absorbent materials used in the construction of the case. Making the decision to use a passive micro-climate control requires the consideration of a couple of factors: (1) the primary material the artifact is made of; (2) the ambient conditions outside the micro-climate; (3) the size, design and leakage rate of the case; (4) the appropriate range and level of the humidity desired and; (5) the type and amount of passive buffer needed.

Networks of meteorological sensors are essential to monitor atmospheric processes, and to assess both long-term climate change and short-term weather events. In particular Wireless Sensor Networks (WSNs) represent a key technology for environmental monitoring and, consequently, for decision making. Today, an increasing number of urban meteorological networks of differing size and scales are being implemented in and across cities, which provides unprecedented new opportunities for the high-resolution monitoring of the urban climate, which helps to control energy demand and to reduce disruption on transport networks (see TO-06 Connectivity for more information about Networks).

Smart weather stations: a major field of current research consists in developing intelligent systems capable of integrating environmental data, to improve efficiency in the use of resources and to enable sustainable functioning of man-made utilities. This can be achieved by making an intelligent use of environmental variables forecasts, for applications such as photovoltaic plants, micro-grids, solar-powered sensor networks and energy management in buildings, where predictions of the atmospheric conditions can reduce energy costs and the risks of malfunctioning.

Participatory monitoring has emerged as an alternative or addition to professional scientist-executed monitoring, which can be costly and logistically and technically difficult to implement. Involving local people and their communities in monitoring is often part of the process of sharing the management of land and resources with the local communities. It is connected to the devolution of rights and power to the locals. Aside from potentially providing high-quality information, participatory monitoring can raise local awareness and build the community and local government expertise that is needed for addressing the management of natural resources.

Citizens’ Observatory concept: There is no clear definition of a Citizens’ Observatory available yet. In a broad sense, an CO for supporting community-based environmental governance can be defined as “the citizens” own observations and understanding of environmentally related issues and in particular as reporting and commenting on them within a dedicated ICT platform”. As such, the Citizens’ Observatory promotes communication and supports the sharing of technological solutions (e.g., sensor and sensor platforms, mobile apps, web portals) and community participatory governance methods (e.g., aided by various social media streams) among citizens. This definition shows three core components that underpin some of its objectives, i.e., raising the citizens’ environmental awareness; enabling dialogue among citizens, scientists and policy- and decision-makers; and supporting data exchange among citizens, scientists and other stakeholders.

To know more...

2 http://journals.ametsoc.org/doi/full/10.1175/BAMS-D-13-00193.1
4 http://www.engineersgarage.com/articles/sensors
5 Information regaled to sensors:
  - http://www.engineersgarage.com/articles/sensors
6 Smart weather stations: http://www.mtnpide.com/1424-8220/5/5/12/1984/Rem
8 http://www.musecc.com/what-is-passive-micro-climate-control

Fig 1. Researchers at Columbia’s Earth Institute used a thermal map developed by NASA to determine hot spots in New York’s urban heat island. Areas of high temperature appear red, and cool zones, mostly parks, appear white and blue. Source: NASA Landsat

Near future challenges
A fast-growing wave of urban experimentation with telematics is emerging across advanced industrial cities. They have become a natural policy focus as policy-makers everywhere have struggled to reinvigorate city economies, physically regenerate urban areas, market urban spaces as chatter bases for investment, address social polarization, and restructure public services to address funding crises. Three areas where telematics and telecommunications have emerged as key policy focus can be highlighted: i) the ‘global positioning’ approach, where telematics are used to try and ‘reconnect’ the economic, social and cultural fragments that increasingly characterise contemporary cities, and iii) the delivery of public services via telematics and the establishment of new channels of city–citizen communication.

Urban Infrastructure is best defined with reference to superior use of telematics. Increased mobility has generated the need for efficient effective yet simplified systems to achieve objectives such as the following:

**Supply Chain Management (SCM)** is the management of the flow of goods and services. It includes the movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption. Interconnected networks, channel and node businesses are involved in the provision of products and services required by end customers in a supply chain. Objectives are building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand and measuring performance globally.³

**Decision Support System (DSS)** for efficient planning. DSS is a computer-based information system that supports business or organizational decision-making activities. DSS serve the management, operations, and planning levels of an organization (usually mid and higher management) and help people make decisions about problems that may be rapidly changing and not easily specified in advance—i.e. Unstructured and Semi-Structured decision problems. Decision Support systems can be either fully computerised, human-powered or a combination of both.⁴

**Field force automation (FFA)**. It is the capture of field sales or service information in real time using communications technology, typically handheld PDAs, wireless devices, tablet PCs or mobile phones. The captured data is transferred immediately to back-end systems (ERP, CRM or accounting systems) through wireless connectivity (Wi-Fi, 3G, satellite or GSM). This instant capture of information reduces time delays, avoids manual double entry data errors and enhances field force productivity.⁵

**Locating fleet at given point in time.** To do so, a vehicle tracking system is needed that combines the use of automatic vehicle location in individual vehicles with software that collects these fleet data for a comprehensive picture of vehicle locations. Modern vehicle tracking systems commonly use GPS or GLONASS technology for locating the vehicle, but other types of automatic vehicle location technology can also be used. Vehicle information can be viewed on electronic maps via the Internet or specialized software. Urban public transit authorities are an increasingly common user of vehicle tracking systems, particularly in large cities.⁶

**Efficient route planning & resource optimisation.** To do so, a software is needed that enables the city to manage its logistics operations in real-time through a host of powerful features and functionality.

**Connection-sharing apps**

Smart City applications are addressed to city authorities, infrastructure and utilities managers, and city stakeholders wishing to use smart city solutions in order to increase the competitiveness, cohesion, and sustainability of the city.⁶

- **Virtual city tour** informs citizens and visitors about recreation facilities and general Points of interest (POIs) in a city. Each POI is presented through 360° panoramas, images and text. The users can also create new POIs or add content in an existing POI. An interactive community map is enhanced with the superposition of points of interest such as: public buildings, monuments, parks etc.
- **Participation apps** a platform for managing local issues; from reporting, to administration and analysis. Provide direct citizen–government communication & collaboration.
- **Open government apps** provide transparency of government actions, accessibility of government services and information, and responsiveness of government to new ideas, demands and needs.
- **Healthcare apps** allow personal health monitoring and collection of measurements that can be sent to a health centre. They can also alarm the health centre or personal doctor in case of emergency.⁷
- **Environment apps** use mobile phones and other devices as environmental sensors or as carbon footprint-tracking tools.
- **Crowdsourcing apps** for traffic example they use the phone’s GPS signal and user input to gather real-time data about traffic jams, accidents and speed traps. Other related results are city mood maps, pollution perception maps, road maps and safe road maps.
- **Virtual market apps** where local professionals, brands and small businesses present their business on the map and make special offers.
- **Public transport apps** allow the user to know the time of arrival of the next bus or train and also to plan his route using public transport.

**To know more...**

1 Telematics https://en.wikipedia.org/wiki/Telematics
3 Decision support system https://en.wikipedia.org/wiki/Decision_support_system
8 Klip https://amsterdamsmartcity.com/projects/klip
10 Cassandras C.G. (2016) Smart Cities as Cyber-Physical Social Systems. Engineering 2(2) 156–158. 4

**Opportunities for innovation**

Big data can be used for social transportation for example, bringing unprecedented opportunities for resolving transportation problems that traditional approaches are not competent and building the next generation intelligent transportation systems.

Apps can be created to help the elder connect with each other based on their common interests and location. The goal should be to reduce the loneliness and let seniors be active in life again⁸.

Applications could be developed to warn citizens before extreme weather or disaster conditions in order to save citizens lives. Such apps would be even more helpful and useful in areas considered at risk and in poor areas.

**Near future challenges**

Besides the whole debate around privacy, autonomy, control and security as regards to big data, Internet of Things (IoT) - the network of physical devices, vehicles, buildings and other objects embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data⁹ - is already changing the composition of our society. With some 50 billion devices expected to be connected by 2020, IoT is one of the platforms of today’s Smart City, and Smart Energy Management Systems. Although applying semantic technologies to IoT has still several research challenges as IoT and semantics in IoT is in its early days,⁹ the IoT can potentially assist in integration of communications, control, and information processing across various systems. Application of the IoT can extend to all aspects of transportation systems for example (i.e. the vehicle, the infrastructure, and the driver or user). Dynamic interaction between these components of a transport system enhances urban telematics services by enabling inter and intra vehicular communication, smart traffic control, smart parking, electronic toll collection systems, logistic and fleet management, vehicle control, and safety and road assistance.

Finally, “Smart” is not just collecting and disseminating data. Viewing the Cyber-Physical Social System that a Smart City is as a closed-loop system is extremely important and, in some cases, critical. Simply collecting and disseminating data to a user group can in fact be more harmful than helpful. As an example, today’s “smart parking” technology essentially informs drivers where parking spaces are available; as a result, it is often the case that multiple drivers converge to where a few spaces are available, thus creating additional traffic congestion from drivers attracted to the area who cannot find a space¹⁰.
TO-03 Telematic citizen services

During the past years a fast-growing wave of urban experimentation with telematics is emerging across advanced industrial cities. The aim of telematic citizen services is to add value to city solutions for citizens’ needs, through multimedia telematic products and services that deliver access to local information and services.

Types of telematic citizen services

Telecommuting, remote work, telework, or teleworking 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, or communities, telecommuting may offer fuller employment by increasing the employability of circumstance marginalised groups such as work at home parents and caregivers, the disabled, retirees, and people living in remote areas), reducing traffic congestion and traffic accidents, relieving pressure on transportation infrastructure, reducing greenhouse gases, reducing energy use, and improving disaster preparedness.

E-democracy, also known as digital democracy or Internet democracy, incorporates 21st-century information and communications technology to promote democracy. It is a form of government in which all adult citizens are presumed to be eligible to participate equally in the proposal, development, and creation of laws. E-democracy encompasses social, economic and cultural conditions that enable the free and equal practice of political self-determination.

Telemedicine or health telematics applications are presently revolutionising the developments not only in diagnosis, treatment, surveillance and rehabilitation of patients, but also on the side of the more collective aspects of health care and health prevention such as clinical trials, epidemiology, and health education. Health Information Infrastructure (HII) emerges, making reference to telematics networks together with a set of technologies, health telematics applications and services HII is making possible the rapid dissemination and sharing of health information and research results. This is leading to knowledge creation and to promotion of innovative approaches based on evidence collected in medical practice all over the world.

Emergences: the use of telematics and smart devices in emergencies are particularly important, since they empower the automatic detection of emergencies (including situations where human intervention might not be possible or is impaired), while representing the link between citizens and emergency services and the abstraction layers allowing the adoption of the IoT paradigm. Integrated with the emergency call, smart sensors’ data is automatically relayed to emergency services, improving these services’ capability to assess the emergency and respond swiftly and effectively, saving lives.

Participatory sensing: an emerging concept that integrates crowd-sourced data collection and knowledge discovery of collective behavior.

Although technology helps to solve many local problems and facilitates urban services, its ability to gather unprecedented amounts of information could endanger the privacy of citizens. Privacy breaches can appear within the context of smart cities and their services, citizens’ privacy as a model with five dimensions: identity privacy, query privacy, location privacy, footprint privacy and operator privacy.

The fundamental rights of citizens should be guaranteed at all times. Privacy Enhancing Technologies (PET) can be implemented in the smart city scenario. A combination of these techniques — currently used in privacy models for databases and location-based services —, can be applied to build a model for Citizens Privacy incorporating techniques such as statistical disclosure control (SDC), private information retrieval (PIR), privacy-preserving data mining (PPDM), location privacy, anonymity and pseudonyms, privacy in radio frequency identification (RFID) and privacy in video surveillance.

Finally, we should always keep in mind the importance of the role of humans in Smart Cities. Technology alone cannot transform a city or a community; necessary mechanisms must be included to create incentives for using the technology and for accommodating the “human in the loop.” When it comes to the efficient management of sharable resources, there is a fundamental conflict between the individual and social optima. While technology offers the means to achieve a social (or global) optimum, one cannot impose it in a vacuum. Understanding and respecting human behaviour is a key component of a Cyber-Physical System (CPS), especially related to telematic citizen services; in fact, a CPS should be more accurately referred to as a Cyber-Physical Social System. This wording also implies the importance of municipal governments in developing and implementing the policies necessary to provide incentives and deliver the ultimate value of CPS technologies to smart cities.
TO-04 Monitoring systems

Monitoring is a type of evaluation performed while a project is being implemented, with the aim of improving the project design and functioning while in action, an internal project activity designed to provide constant feedback on the progress of a project, the problems it is facing, and the efficiency with which it is being implemented. From an urban point of view it concerns a smartly monitored city (governed, orchestrated, urbanised, built and environmentally protected) to use it’s urban energy in order to generate a synergy, characterised solutions.1

Monitoring systems can be an effective way to:
- Provide constant feedback on the extent to which the projects are achieving their goals.
- Identify potential problems at an early stage and propose possible solutions.
- Monitor the accessibility of the project to all sectors of the target population.
- Monitor the efficiency with which the different components of the project are being implemented and suggest improvements.
- Evaluate the extent to which the project is able to achieve its general objectives.
- Provide guidelines for the planning of future projects.
- Influence sector assistance strategy. Relevant analysis from project and policy monitoring and evaluation can highlight the outcomes of previous interventions, and the strengths and weaknesses of their implementation.
- Improve project design. Use of project design tools such as the logframe (logical framework) results in systematic selection of indicators for monitoring project performance. The process of selecting indicators for monitoring is a test of the soundness of project objectives and how they can lead to improvements in project design.
- Incorporate views of stakeholders. Awareness is growing that participation by project beneficiaries in design and implementation brings greater “ownership” of project objectives and encourages the sustainability of project benefits. Ownership brings accountability. Objectives should be set and indicators selected in consultation with stakeholders, so that objectives and targets are jointly “owned.” The emergence of recorded benefits early on helps reinforce ownership, and early warning of emerging problems allows action to be taken before costs rise.
- Show need for mid-course corrections. A reliable flow of information during implementation enables managers to keep track of progress and adjust operations to take account of experience (OED).

MONITORING SYSTEM TECHNOLOGIES:
Closed Circuit Television (CCTV) has been an important element in crime prevention strategies in many cities around the world. The information and communication technologies used in smart cities can be used to create CCTV networks that can operate across corporate networks spanning a whole city and even across public networks to enable the use of CCTV anywhere on earth where smart city infrastructure has been installed. This provides economies of scale never before experienced by the designers of physical security and surveillance systems.

Urban data centres: centers were the constantly generated city’s data are being transferred and stored. City control centres: the central place of data control and management.

Participatory sensing2 is a powerful paradigm in which users participate in the sensing campaign by collecting and crowdsourcing fine-grained information and opinions about events of interest (such as weather or environment monitoring, traffic conditions or accidents, crime scenes, emergency response, healthcare and wellness monitoring), thus leading to actionable inferences and decisions. Based on the nature of user involvement, participatory sensing applications can be of two types—automated and user manipulated. The first type of applications automatically collects data samples from smartphone sensors and sends them to the server. The second type of applications depends on the users to manually collect data samples and upload them at their convenience.

Social media monitoring. Social media are successfully used to detect meaningful events exploiting users as human sensors. Examples include the detection of earthquakes, floods, or even crimes. The most used media for this purpose is Twitter.

Today

To know more...
2 Smart Cities: Implications for physical security http://www.securitysolutionsmagazine.biz/2014/05/01/smart-cities-implications-for-physical-security/
5 Bring data centres in from the cold http://thoughts.arup.com/post/details/292/bring-data-centres-in-from-the-cold
7 Urban Emotions http://www.geog.uni-heidelberg.de/gis/urbanemotions_en.html

Opportunities for innovation
Real time information enables cities to take more sustainable, efficient and citizen-centric decisions, smoothly transforming decisions into actions by means of technological solutions.

A combination of physical and non-physical variables during monitoring gives a more holistic view of the urban reality.

Such is the scale of data processing that it has a significant impact on global energy consumption and carbon emissions. And yet, opportunities to improve data centres’ green credentials are often overlooked. For instance, making use of the waste heat they produce could generate a host of benefits.

A solution for the continuous demand for space for data storage could be vacant former commercial, warehouse or factory buildings in the city grid.

Near future challenges
Because of the high density of smartphone users in urban population and ease of participation, the automated participatory sensing paradigm can be effectively applied to continuous monitoring of various phenomena in urban scenarios (e.g., fine-grained temperature monitoring, noise or air pollution), leading to what is called participatory urban sensing.

However, to create a fine-grained and real-time map of the monitored area, the data samples need to be collected continuously (at a high frequency) which poses several research challenges, such as:

i) how to ensure coverage of the collected data that reflects how well the targeted area is monitored?
ii) how to localise the smartphones since continuous usage of the location sensor (e.g., GPS) can drain the battery in few hours?
iii) how to provide energy efficiency in the data collection process by collecting necessary data samples in each data collection round?

Another important challenge affecting urban safety are the cyber attacks. There is a rich literature about cyber-security and the challenges of protecting information that can be obtained by people, organisations and nations with the intent and capability to steal information, and even identities, by exploiting weaknesses and vulnerabilities in data communication internet works.

With regards to the smart city, cyber attacks play a major role and are a main contribu-utor which can affect and paralyse the entire system
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.

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. In smart urban spaces these can be related to topics such as:

- **Business**: Businesses are using data to drive better decisions, create new services, and reach new customers.
- **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.
- **Ecosystems**: Data resources on ecosystems and biodiversity, including ecosystem components, functions, and services.
- **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. It helps to increase transparency in government.

To know more...

2. https://www.data.gov/
5. Open Data Research Network Bibliography http://bibliography.opendataresearch.org/

Near future challenges

The following example illustrates how open databases’ can be used in the near future:

By linking data on i) aggregate water meter readings for different areas in a city with ii) a registry of large companies with their location, the user learns the water consumption in the area where the company is located. Assuming that the company is large and uses large amounts of water as part of its daily manufacturing process, the user can obtain a reasonable estimate on the production of the company and learn, for example, that its production has recently dropped as its water consumption has been significantly reduced. This is an indication of losses. To verify this evidence, the user links iii) open street maps with iv) vehicle axle counts dataset, which collects counts from various locations in the city, to identify the number of vehicles that pass near the entrance of the company. Then, the user compares current readings on axle counts with previous months’ readings and observes a significant reduction in commercial vehicles entering or leaving the company. This observation reinforces the assumption of the user that the company experiences losses, and, thus, the user obtains an early warning that his shares may lose value.

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. 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.

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.

Fig. 1 Diagram of the concepts related with Open Data.
TO-06 Sensor technologies

The function of monitoring systems is data acquisition and transfer to the management system. In monitoring systems, sensors are responsible for data acquisition. Different kind of sensors detect different kinds of physical quantities or their change rate (CO 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.

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. Strictly speaking, a sensor is a device that receives a signal or stimulus and responds with an electrical signal, while a transducer is a converter of one type of energy into another. In practice, however, the terms are often used interchangeably.

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. Sensors do not operate by themselves. They are generally part of a larger system consisting of signal conditioners and various analog or digital signal processing circuits. The system can be a measurement system, data acquisition system, or process control system, for example.

The full-scale outputs of most sensors (passive or active) are relatively small voltages, currents, or resistance changes, and therefore their outputs must be properly conditioned before further analog or digital processing can occur. Because of this, an entire class of circuits have evolved, generally referred to as signal-conditioning circuits. Amplification, level translation, galvanic isolation, impedance transformation, linearization, and filtering are fundamental signal-conditioning functions that may be required.

New technology developments allow for a more accurate and efficient processing of the input data sensed, avoiding, for instance, the need of manual calibration of the sensors. Transducers: 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...

2. Sensors: different types of sensors: http://www.engineersgarage.com/articles/sensors

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

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.

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: chip-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), CitI-Sense, 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 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.

Microelectromechanical sensors (MEMS): 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.
Lighting is responsible for 19% of global use of electrical energy, and accounts for about 6% of the total emissions of greenhouse gases. Regarding to cities, street lights are one of the most important assets to provide safe roads and inviting public areas, and to enhance security in homes, businesses, and city centers. However, it is very costly to operate, with a share of about 40% of the total amount of electricity spent in a city. This factor, together with the continuous rising of electricity costs, is becoming more and more crucial day by day for the budget of a city.

Smart lighting. The concept of smart lighting involves maximizing energy efficiency by strategies such utilizing natural light from the sun to reduce the use of man-made lighting or the simple concept of turning off lighting when not needed. In order to improve the overall efficiency of the system, each component of the lighting equipment (lamps, lighting fixtures, control systems and a control gear) has to be optimized.

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 control systems and gears, different schemes can be implemented depending on the nature of the inputs that the control unit uses to activate the switch/relay to turn equipment on or off. These are namely (1) occupancy-based control schemes, (2) daylight-linked lighting controls and (3) lighting control by time scheduling. The two first need the use of different kinds of sensors:

(1) Occupancy sensing: Smart lighting that utilizes occupancy sensors can work in unison with other lighting connected to the same network to adjust lighting per various conditions. There are different kinds of occupancy sensors available, such as ultrasonic sensors (which are sensitive to all types of motion and are able to detect movements not within the line of sight); motion-detecting microwave sensors; heat-sensing infrared sensors; and sound-sensing; optical cameras, infrared motion, optical trip wires, door contact sensors, thermal cameras, micro radars, etc.

(2) Daylight sensing: daylight-linked automated response systems have been developed to further reduce energy consumption. Nevertheless, many times, rapid and frequent switching of the lights on and off can occur, particularly during unstable weather conditions or when daylight levels are changing around the switching illuminance. This can also reduce lamp life. A variation of this technology is the "differential switching" or "dead-band" photoelectric control.

Integration of the solar power systems with public lighting systems: photovoltaic panels can be mounted on the lighting structure or integrated in the pole itself and used to charge Ta rechargeable battery, which powers the lamp during the night. This results in a higher independency of the utility grid and reduced operation costs.

Remote control of street lighting lamps: assigning IP addresses to light bulbs enables the monitoring, management and control of every light bulb from any Internet-enabled device to save energy as well as electricity costs.

Near future challenges

In the coming days, we will see the introduction of a multipurpose, smart lighting grid, combining ICT (IP, energy and lighting functions). This will create new possibilities (and with them new design opportunities) in the ways the social and urban space can be used. Lighting Systems will suffer an important evolution with the introduction of LED lighting capabilities allowing new strategies of energy savings, incorporation of renewable energy sources and optionally a bidirectional interconnection with the mains.

Standardisation will take place within IEDs and lenses, which thereby become exchangeable modules. Standard modules will become available as building blocks, enabling flexible configuration of lighting and control systems.

Other kinds of lamps might be developed. Bioluminescent trees or algae street lamps are just two examples. By merging bioluminescent jellyfish’ and bacteria’s light producing compounds with plants, illuminating city streets with trees that glow at night can be envisioned. Smart lighting and urban systems will be integrated, leading to systems that manage energy, waste, mobility, care, lighting etc. at overall city level based on an integrated, holistic approach.

Interaction with real-time information will make adaptive systems possible. Lower energy requirements of the light sources and controls will make small, self-sufficient lighting systems achievable. This will represent a first step towards ‘invisible’ systems that disappear in the context of their environments.

To know more...

6. Integrate ICT infrastructure in the public lighting systems in order to provide new services to citizens while reducing the energy consumption of public lighting. This action includes a new facility of lamp post, which contains different type of sensors, such as traffic, pollution, temperature and humidity sensors.

Public lighting plays a prominent role in reflecting and reproducing inequalities. It can be used to focus value, care and creativity on public spaces, estates and future mixed-use housing. It can help build social inclusion and civic life across urban spaces, working to produce light as a socio-technical infrastructure that is cost-effective socially sustainable, and creates spaces that are engaging, accessible and comfortable for the diverse citizens who share them.
Smart appliances or devices play an essential role in our lives, aiding navigation and solving other problems in both urban and non-urban environments. Through interactive representations of complex and temporally extended patterns of data to amplify not only human perception but also cognition, these smart devices are opening new possibilities for design innovation and business opportunities.

Thanks to the advances that brought the internet of things (IoT), i.e. 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 following smart urban appliances were developed.

- **Citizen Help and Information Virtual Office**: allows users to carry out a range of basic procedures with the assistance of the municipal help and information staff.
- **Smart bus stops**: with the use of QR codes or an application it can advice the citizen on how much time they must wait for the next bus to come.
- **Wi-Fi points**: free Internet-connection service that allow internet access and information on the city such as events guide and municipal procedures among others.
- **NFC or QR codes**: that one can access through his mobile, tablet, PDA or any other device with an internet connection. They provide specific and accurate information on somebody's current location in the city as well as the activities going on there at that precise moment.
- **Reporting services**: to report damage, dirt or danger. They may work through an app, a QR code, or reporting points in the city.
- **Smart traffic lights**: emit sound for blind people and provide green corridors for Fire Brigade vehicles.
- **Smart parking**: Real time parking information to easily locate garages, lots and free parking in the city.
- **Interactive informative panels**: may provide information on weather conditions, traffic conditions based on crowdsourcing, augmented reality and interactive maps. It also offers real-time public information specific to the neighborhood, such as historical places to visit, current cultural activities, messages from the Town Hall or information about associations.

**To know more...**


**Fig. 1 Example of an interactive information panel.**
TO-09 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.

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.

There are several types of UI some of which are described below:

**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.

**To know more...**
1. General information about User Interfaces: https://uxmag.com/articles/what-do-user-interfaces-want
5. 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**

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

Today

Global In 2016, global solar installations reached 64.7 GW, led 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.

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.

Solar cells

Different 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 polycrystalline 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 lowered and integration is easier. Amorphous silicon based solar cells have higher efficiency than other materials such as, Copper-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 (QD0 and “hot carrier” (HC) based solar cells are some examples.

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

Inverters

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.

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 (LCOE) for PV generation. By 2050, solar PV will provide 16% of global electricity and renewables 79%. Solar PV will equal wind power in cutting CO₂ 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.

To know more...


Fig. 2 Overview of different conversion technologies2.

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

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**To know more...**


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**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 maintenance and can be implemented at a higher density.

Collaboration among domestic and international producers, researchers, and stakeholders 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.

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**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 generation 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.

Utilization of wind forecasting in operational practice of power systems and advanced controls 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.

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.
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. 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.

**TO-12 Biomass**

Biomass can be converted into electric power through several methods. Most bio-power plants use direct-fire combustion systems. They burn biomass directly to produce high-pressure steam that drives a turbine generator to make electricity. In some biomass industries, the exhaust or spent steam from the power plant is also used for manufacturing processes or to heat buildings. These combined heat and power (CHP) systems greatly increase overall energy efficiency to approximately 80%, from the standard biomass electricity-only systems with efficiencies of approximately 20%. Other options include gasification, pyrolysis (yields bio-oil by rapidly heating the biomass in the absence of oxygen), and anaerobic digestion (which produces gas when organic matter is decomposed by bacteria in the absence of oxygen). Different methods work best with different types of biomass.

**BIOGAS**. Biogas is the gas produced by the biological breakdown of organic materials. There are two primary methods of recovering biogas for use as energy: anaerobic digestion of waste (most commonly manure or other wet biomass), and recovering of the biogas formed in existing landfills.

**Anaerobic digestion.** Batch digesters and continuous digesters are the two basic types of anaerobic digesters. Batch-type digesters are the simplest to build. Their operation consists of loading the digester with organic materials and allowing it to digest. The retention time depends on temperature and other factors. Once the digestion is complete, the effluent is removed and the process is repeated. In a continuous digester, organic material is constantly (or regularly) fed into the digester. The material moves through the digester producing biogas without the interruption of loading material and unloading effluent. There are three types of continuous digesters: vertical tank systems, horizontal tank or plug-flow systems, and multiple tank systems. Proper design, operation, and maintenance of continuous digesters produce a steady and predictable supply of usable biogas, which is better suited for large-scale operations.

**Landfill gas recovery.** Anaerobic digestion occurs naturally underground in landfills, producing about 40% to 60% methane, and carbon dioxide. The rate of production is affected by waste composition and landfill geometry. Gas extraction can be made using a series of wells and a blowers/flare system. The collected gas is then directed to a central point where it can be processed and treated depending upon the ultimate use for the gas. The most efficient use of gas is heating, which is appropriate for applications with constant heating demand throughout the year.

**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 biomass 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 high 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.

**Smart Urban Spaces**

**TO-12 Biomass**

Biomass energy production at a district scale can help to reduce urban waste to be managed at city scale.

**Opportunities for innovation**

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 CO₂ as raw materials either in engineered photosynthetic microorganisms or in completely synthetic living factories. Biofuels will be produced by:

- Photosynthetic microorganisms (photobiological solar fuels)
- Microbial electrosynthesis (MES), combining photovoltaics and microbial fuel production (electrobiomass). 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.

**To know more...**

Whole Building Design Guide website:
- [https://www.wbdg.org/resources/biogas.php](https://www.wbdg.org/resources/biogas.php)
- [https://www.wbdg.org/resources/biomasselectric.php](https://www.wbdg.org/resources/biomasselectric.php)
- [https://www.wbdg.org/resources/biomassheat.php](https://www.wbdg.org/resources/biomassheat.php)

1Hall, DO and Scrase JI. Will biomass be the environmentally friendly fuel of the future? Biomass and Bioenergy Vol. 15, Nos 4/5, pp. 357±367, 19
4es2014264
Geothermal technologies allow for the use of the Earth’s heat, a renewable energy source originating from the Earth’s nucleus. The term “geothermal energy” might bring to mind hot springs and billows of steam rising from the soil, but other technologies exist that allow for the use of the Earth’s heat at virtually any location. Indeed, geothermal energy refers to any energy recovered from below the ground. This includes geothermal heating, in which hot underground water is used to heat a building, geothermal power, in which steam from very hot underground rock (more than 150 °C) is used to drive an electric generator and geothermal heat pumps (sometimes called a ground source heat pump), which can work anywhere. In smart cities, the use of geothermal energy may contribute to balance energy supply and demand on the smart grid or to deliver the energy needed to operate heat pump systems.

Three main types of geothermal technologies take advantage of Earth as a heat source.

Direct use geothermal systems use groundwater that is heated by natural geological processes below the Earth’s surface to 100°C or more. Bodies of hot groundwater can be found in many areas with volcanic or tectonic activity. In some locations these groundwater reservoirs can reach the surface, creating geysers and hot springs. Hot water is pump from the surface or from underground for a wide range of useful applications, including large-scale pool heating; space heating, cooling, and on-demand hot water for buildings of most sizes; district heating; heating roads and sidewalks to melt snow; and some industrial and agricultural processes.

Direct use takes advantage of hot water that may be just a few meter below the surface, and usually less than 1.5 km deep. This means that capital costs are relatively small compared with deeper geothermal systems, but also that the technology is limited to regions with natural sources of hot groundwater at or near the surface.

Deep and enhanced geothermal systems: use steam from far below the Earth’s surface for applications that require temperatures of several hundred degrees. These systems typically inject water into the ground through one well and bring water or steam to the surface through another. Other variations can capture steam directly from underground (“dry steam”). They can involve drilling a 1.5 km or more below the Earth’s surface. At these depths, high pressure keeps the water in a liquid state even at temperatures of several hundred degrees. They provide efficient, clean heat for large-scale uses such as industrial processes and some commercial and agricultural uses. In addition, steam can be used to spin a turbine and generate electricity.

Although geothermal steam requires no fuel and low operational costs, the initial capital costs—especially drilling test wells and production wells—can be financially challenging. Steam resources that are economical to tap into are currently limited to regions with high geothermal activity, but research is underway to develop enhanced geothermal systems with much deeper wells that take advantage of the Earth’s natural temperature gradient and can potentially be constructed anywhere.

Ground source heat pumps: shallow or geothermal: take advantage of the naturally occurring difference between the above-ground air temperature and the subsurface soil temperature to move heat in support of end uses such as space heating, space cooling (air conditioning), and even water heating.

It consists of a heat pump connected to a series of buried pipes that can be installed either in horizontal trenches just below the ground surface or in vertical boreholes that go several hundred feet below ground. The heat pump circulates a heat-conveying fluid, sometimes water, through the pipes to move heat from point to point. If the ground temperature is warmer than the ambient air temperature, the heat pump can move heat from the ground to the building. The heat pump can also operate in reverse, moving heat from the ambient air in a building into the ground, in effect cooling the building. GHP require a small amount of electricity to drive the heating/cooling process. For every unit of electricity used in operating the system, the heat pump can deliver as much as five times the energy from the ground, resulting in a net energy benefit. The biggest drawback is that their initial cost can be several times that of traditional heating and cooling systems, with underground installation of ground loops (piping) accounting for most of the system’s cost.

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Today

Geothermal energy has the potential to play a significant role in moving many regions of the world toward a cleaner, more sustainable energy system. It is one of the few renewable energy technologies that can supply continuous, base-load power. Additionally, unlike coal and nuclear plants, binary geothermal plants can be used as a flexible source of energy to balance the variable supply of renewable resources such as wind and solar.

Advances in the use of innovative architectures for GHP technologies can help to improve efficiency. For example, the “one-pipe” configuration for large buildings, which utilizes a single pipe for distribution instead of two, provides energy savings when operating at part load, and saves on piping costs.

Additionally, advances in innovative heat sinks/sources, such as the use of municipal wastewater infrastructure, can provide cost savings by eliminating a traditional bore-field altogether.

Energy savings could also come in the form of component advances. Many compressors and heat exchangers used in today’s GHP systems are not purpose-built for GHP. To-date, the rate of GHP sales has not been sufficient for compressor manufacturers to build specific units that they optimize for GHP operating conditions. Use of optimized components could provide additional energy savings without any impact on other parts of the industry and no need for educating customers or GHP professionals.

Innovative materials and designs for long-life high-temperature geothermal wells: Developing reliable, cost effective and environmentally safe technologies for design, completion and monitoring of high-temperature geothermal wells.

Energy storage will be a key factor in the future geothermal systems
SMART URBAN SPACES

TO-14 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 is an important aspect 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-users to be monitored and managed in real time.

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 CO2 emissions.

Some typical components of a smart grid include:

- **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 consumers 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 superconducting 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.

Universal access to affordable, low-carbon electrical power generation (e.g., wind turbines, concentrating solar power systems, photovoltaics panels) and storage (e.g., in batteries, flywheels 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 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.

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 Smartgrids1, 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 storage.

Main challenges for smart grids2:

- 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 research3:

- 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 advance of delivery the generation output.
- Communication technologies, to exchange information among the stakeholders, helping to improve the efficiency of electricity products and services and to form small-scale islanded systems able to securely connect to and disconnect from the synchronize European power system.

To know more...

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

Fig. 1 Smart Grid, a vision for the future. Schematic design showing the different components of a smart grid4.
District heating (also known as heat networks or teleheating) is a system for distributing heat generated in a centralized location for residential and commercial heating requirements such as space heating and water heating. District heating plants can provide higher efficiencies and better pollution control than localized boilers.

A typical HD system includes:
- **Heat carrier**: pressurised hot water often below 100 ºC
- **Pipes**: prefabricated pre-insulated steel pipes, directly buried into the ground
- **Circulation systems**: central pumps
- **Substations heat exchanger**: without or with plate heat exchangers.
- **Buildings**: Dwellings + service 100-200 kWh/m²
- **Metering**: Heat meters + additional flow metering to compensate for high return temperatures. Wireless readings introduced for more frequent readings.
- **Radiators**: Medium-temperature radiators (70 ºC) using district heating water directly or indirectly. Floor heating.
- **Hot water**: Heat exchanger. Domestic hot tank heated to 60 ºC. Circulation at 55 ºC when needed.

For cooling, the 3rd technology generation constitutes a more diversified cold supply based on absorption chillers, mechanical chillers with or without heat recovery, natural cooling from lakes, excess cold streams, and cold storages. The distribution fluid is still cold water. Many of these third generation installations were established in the 1990s, when CFC refrigerants were banned according to the Montreal protocol.

Since 1970’s we are in the 3rd DH technology generation so called “Scandinavian DH technology”. This model was implemented to increase security of supply in relation to the two oil crises leading to a focus on energy efficiency related to combined heat and power (CHP) production and replacing oil with various local and/or cheaper fuels such as coal, biomass and waste. Solar and geothermal heat has been used as a supplement in a few places.

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**To know more...**

- [https://smartgridtech.files.wordpress.com/2012/05/sg-nature.jpg](https://smartgridtech.files.wordpress.com/2012/05/sg-nature.jpg)

**Opportunities for innovation**

District heating system based only on heat from renewable sources.

All heating demands in housing/services are covered by district heating systems. Most heat is recovered from industry. Electricity is reserved for other uses which need higher energy qualities.

Heat storage allow for the reduction of gas/oil energy.

**Near future challenges**

In 2020-2050 a 4th Generation DH is integrated into a “Smart energy system” which clusters different smart grids (electricity, heat and cooling, gas and others).

**Distribution temperatures are lower** (50 ºC supplypipe; 20 ºC return pipe), both for space heating and hot water supply. This allows:
- Higher heat recovery from flue gas condensation
- Higher performance of heat pumps
- Higher use of geothermal and recycled heat

**Grid losses are reduced** due to:
- Lower distribution temperatures
- Smaller pipe dimensions
- Twin pipes with improved insulation

**More flexible pipe materials** are used which contribute to:
- Reduce risk of scaling at water leakages
- Reduce thermal expansion and cycle fatigue of pipes
- Reduce risk of boiling in the distribution pipes

**Heat is recycled from low-temperature production units** such as industry and commercial buildings (e.g. cooling systems of supermarkets).

**Renewable heat sources are optimally integrated** (central or local solar heating plants with seasonal storage and geothermal heating plants)

A typical 4thG DH system includes:
- **Heat carrier**: low-temperature water 30-70 ºC
- **Pipes**: pre-insulated flexible (possible twin) pipes
- **Circulation systems**: central and decentralised pumps
- **Substations heat exchanger**: mostly plate heat exchangers. Introduction of flat-stations (decentralised supply of hot water in new buildings)
- **Buildings**: reduced demand. New <25 kWh/m²; Existing 50-150 kWh/m².
- **Metering**: continuous reading used for continuous commissioning of customer heating system
- **Radiators**: floor-heating; low-temperature radiators (50ºC); indirect systems
- **Hot water**: highly efficient local heat exchanger
Meanwhile many of the traditional technologies for electricity generation, such as hydro, thermal, nuclear, etc., can deliver the power when required; 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. 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

The different energy storage systems have different performance characteristics that make them optimal for certain grid applications and sizes. Technologies development changes 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](image)

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 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.

**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 limited. 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 grid. An electronic control unit is needed to manage the charge and discharge cycles. A battery 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 minimize friction and thus, enhance 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.

**Near future challenges**

Flow batteries potential advantages over traditional ones are a longer unit life and full charge utilization: due to liquid separation 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.

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.
Municipal solid waste (MSW) management has a direct impact on cities. It is one of the toughest challenges that modern cities have to deal with. Waste management consists of different processes such as collection, transport, processing, disposal, managing and monitoring of waste materials. These processes cost a significant amount of money, time, and labour. Optimising waste management processes help to save money that can be used to address other challenges that smart cities need to deal with.

MSW management includes different phases, but there is no single approach that can be applied. There is a waste hierarchy, which classifies waste management strategies according to their desirability in terms of waste minimisation (Fig. 1).

**Sensing as a service model**

In a modern smart city, there are several parties who are interested in waste management (e.g. city council, recycling companies, manufacturing plants and authorities related to health and safety). The sensing as a service model allows all the interest groups to share the infrastructure creating a synergistic effect and the related costs collectively. The most important aspect of such a collaboration is the cost reduction. All the interested parties can retrieve and process sensor data in real time in order to achieve their own objective. The cost depends on the data requirement of the interest group. For example:

- A city council may use sensor data to develop optimised garbage collection strategies, so they can save fuel cost related to garbage trucks.

- Recycling companies can use sensor data to predict and track the amount of waste coming into their plants to be processed so they can optimise their internal processes.

- Health and safety authorities can monitor and supervise the waste management process without spending substantial amounts of money for manual monitoring inspections.

- Intelligent waste containers: the use of intelligent waste containers, which detect the level of load and allow for an optimization of the collector truck route, can reduce the cost of waste collection and improve the quality of recycling. To realise such a smart waste management service, the IoT shall connect the end devices, i.e. intelligent waste containers, to a control center where an optimization software processes the data and determines the optimal management of the collector truck fleet.

**Mobile and Web 2.0**

Social networking tools can be used to allow the sharing and exchange of goods and a more optimal recycling and re-use of materials. Both citizens and cities will benefit with options for citizens to recycle.

- Pay as you throw (PAYT): use-based billing for waste management services and to promote incentive-based recycling programs, both of which aim to reduce the amount of trash entering our landfills.

**RFID technology**

The use of RFID (radio frequency identification) and load cell sensor technology can be employed for not only bringing down waste management costs, but also to facilitate automating and streamlining waste (e.g., garbage, recycling, and green) identification and weight measurement processes for designing smart waste management systems.

**Waste handling and treatment**

Different treatment processes can be undertaken in waste management facilities, for its recycling, disposal, and energy recovery.

- Waste sorting in specialized plants that receive, separate and prepares recyclable materials for marketing to end-user manufacturers.

- Mechanical biological treatment: 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 such as incineration or gasification.

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

**Near future challenges**

Transform current waste management practice into a more efficient and sustainable way, the zero waste practice. The concept of the “zero waste city” includes a 100% recycling rate and recovery of all resources from waste materials. However, transforming current over-consuming cities to zero waste cities is challenging. Strategies based on tools, systems, and technologies can assist cities in their transformation into “zero waste cities”; nevertheless, they must also be affordable, practicable, and effective within their local regulatory framework.

**Opportunities for innovation**

Energy from waste can be used as a source of renewable energy for urban services such as support of public transportation, i.e. electrical tramways and metros.

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.

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6 Waste sorting in waste management facilities: https://en.wikipedia.org/wiki/Materials_recycling_facility
7 Mechanical biological treatment: https://en.wikipedia.org/wiki/Mechanical_biological_treatment
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Fig. 1 Sensing as a service model schema.
TO-18 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.

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 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 preferenceability 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:

1. **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.

2. **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.

3. **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 produce wastes that leave it, providing a platform through which to consider sustainability implications.

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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.

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.

The use of smart materials (see TO-XX) 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. 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.
Organic material, organic matter or natural organic matter (NOM) refers to the large pool of carbon-based compounds found within natural and engineered, terrestrial and aquatic environments. It is matter composed of organic compounds that has come from the remains of organisms such as plants and animals and their waste products in the environment. Organic material can migrate through soil, sediment, and water. This movement enables a cycle.

Carefully separating organic waste is a key opportunity for energy saving. Converting it to compost and fuels reduces the amount of organic material going to a landfill. That in turn lowers the production and release of methane and other landfill gases into the atmosphere.

Organic waste generation:
- Public areas: Vegetation in public areas such as parks streets and squares generates organic waste.
- Individuals also generate a high quantity of organic waste.

Technologies for organic waste management:

Online platforms: Online platforms provide options and alternatives to the user to look into reusing old stuff. The existing user is also encouraged to look for options to sell and regain value from the product before discarding the product as waste. Social networking tools can be used to create an exchange and sharing platform for food that can still be consumed. Already processed matter in the form of compost may also be exchanged through these platforms.

Analytics: Accurate projections on total waste generated, waste type and identification of high waste generation areas enable effective planning and management of solid waste management services. Use of analytics during events with large citizen involvement such as festivals and fairs can ensure smooth collection and transport of waste.

Crowd-sourcing: Citizens can be encouraged to report (by using web/mobile/social channels) waste-related activities which need urgent attention from the authorities.

Automated waste collection system: Automated Waste Collection System (ACS) is a long-term solution and can take care of the conventional methods like door-to-door, curb-side, block, community bins collections and transportation via chute system from high rise buildings with waste sucked through pipes and minimal human intervention.

GPS devices and sensors on waste truck: GPS technology to route the waste collection trucks to optimise the collection efficiency and ensure contractors dump waste in designated places. It will also give a clear picture of waste generated per ward.

Sensor-based sorting: Sorting waste material with the use of sensor technology helps in smart sorting. The sensor technology can recognise materials based on their visible spectrum or colour with infrared/ultraviolet spectra or based on their specific and unique spectral properties of reflected light, or atomic density or conductivity/permeability or atomic characteristics.

Intelligent organic waste containers:

The use of intelligent waste containers, which detect the level of load and allow for an optimization of the collector trucks route, can reduce the cost of waste collection and improve the quality of recycling while avoiding odors. To realize such a smart waste management service, the IoT shall connect the end devices, i.e., intelligent waste containers, to a control center where an optimization software processes the data and determines the optimal management of the collector truck fleet.

Temperature and oxygen level sensors:

Those control and management sensors allow to maintain optimal temperatures and oxygen levels necessary to hyper-accelerate the natural aerobic decomposition process and avoid unpleasant odors.

Energy simulation (waste to energy):

Use of energy simulation software and analytics can provide accurate projections of organic waste generation and energy production from organic waste.

Pollution sensors:

Leverage the pollution sensors to gauge pollution levels at landfills.

Analytics-based landfill management:

Accurate waste generation and collection projections along with break-up of type of waste can enable smart landfill management.

To know more...

5 How the biobattery could create recycling innovations for organic waste http://www.wastewiseproductsinc.com/blog/how-the-biobattery-could-create-recycling-innovations-for-organic-waste/

Near future challenges:

Research on batteries capabes of storing energy by the use just about any organic solid waste, including leftover food, lawn clippings, dead leaves, coffee grounds, and even human waste is currently ongoing for large settlements. Those “biobatteries” process these materials and may produce electricity, heat, bio oil, biogas, and/or a plant char that is useful as fertilizer.

Opportunities for innovation:

A cloud based municipal organic waste management system could be explored. The implementation of such an application requires the adoption of IoT and cloud computing for the creation of an ecosystem consisting of the application service provider, community administration, cloud services provider, other utility services providers, mobile services providers in a multi layered system. Composting can help to improve the efficiency of waste management and to close the cycle to organic materials (especially vegetables) locally. Urban farming technologies might contribute to make such environment possible.

Fig. 1 Steps of the organic life cycle.
TO-20 Urban 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.

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/m²/year, vegetable production is the most significant component of urban food production, with at least 100 million people involved worldwide.

Traditional growing systems:

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 food consumption, large-scale commercial farms, community gardens, and even edible landscapes. 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 drivers 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:

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 the most 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.

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.

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

It is clear that in future we will need to consume less meat and change farming practices to become more in harmony with the global ecosystems. Many believe that intensive agriculture has now peaked and that smaller, smarter and ecologically sound organic practice is the future of farming, recognising that good biodiversity is our insurance for food security. Small and organic can easily be produced within the city.

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. 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 are safe and heavier 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 system which would supply the rice roots with a mist enriched with nutrients (Skyfarming), need to be tested yet.

There is now a strong current of thinking that cities need to be ‘biophillic’ i.e. cater to people’s innate need to experience nature and a growing concern for preserving biodiversity. The bio-phillic cities movement, now being galvanised by Professor Tim Beatley of the University of Virginia, is rapidly growing.

To know more...


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

4 Vertical farming: https://www.youtube.com/watch?v=U1h_zJ099iUO and https://www.youtube.com/watch?v=IAcKt9gsGw

Skyfarming
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. 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.

Critical questions one may ask themselves to ensure a proper designed rainwater harvesting system:

- 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.

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

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.

Storm water & 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.

The Early Disaster Warning Systems involve the following elements:

1. Behavior Prediction and Modeling: Modeling the expected behavior 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 the 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 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.

To know more...

TO-22 Wastewater treatment systems

Wastewater or sewage treatment is the process of removing contaminants from wastewater. It includes physical, chemical, and biological processes to remove these contaminants and produce environmentally safe treated wastewater (or treated effluent) [1].

The greatest challenge of the 21st century is to provide new innovative water treatment methods. The conventional treatment processes are becoming incompetent by demands of space, energy, and economy and environment sustainability. The current, rapidly growing considerations have given room for sustainable alternative approaches of being greener, cheaper and energy efficient.

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/labatory 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 like 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 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].

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 favors a decentralized 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].

To know more...


Fig. 1 Scheme of a wetland treatment system.
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