Brno's review of practices: Electrical Grid and E-Mobility

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Annotation

The world is facing some profound changes in several areas driven by economic, technological changes, demography, climate, and many others. These changes also bring many new challenges and opportunities. Therefore, new trends such as Smart Cities start to be introduced as a solution for future development and for the challenges, which are brought by the changing world.

There are many different definitions of the Smart City. For example, Gartner defines a smart city as an urbanized area where multiple sectors cooperate to achieve sustainable outcomes through the analysis of contextual, real-time information shared among sector-specific information and operational technology systems. Most of the current definitions have common parts, which including ICT enabling the smart city based on its applications. However, each city is different and the main purpose of the smart city or its definitions should come out of the benefits or improved quality of life for its citizens, which should always be on the first place. The benefits might be in domains such as economic activity, infrastructure efficiency, mobility, energy distribution and consumption, environment, safety, e-government, digital inclusion, healthcare, culture, citizen welfare and many other domains.

The Smart City is divided mostly into several areas: smart energy, smart transport, smart government, smart health, smart health, smart home and others. The Brno city council see three main pillars of the Smart City: (i) Smart Living, (ii) Smart Resources, and (iii) Smart Governance. Together there are also main priorities in the areas of:

- Energy and sustainability,
- Mobility, parking, quality of public transpiration system,
- Open data and information system based on the current needs,
- Efficient city management,
- City development and intelligent urbanization,
- Environmental protection and waste management,
- Services for residents, leisure time, and quality of living,
- Healthcare and social-care,
- Innovation, planning and new technologies,
- Economy and transparency,
- Safety, education and information.

The energy, water, transportation, public health and safety or other key services are the crucial assets, which support smooth operation of critical infrastructure and the whole city ecosystem. However, the energy municipal infrastructure is arguably the most important feature in any city, on which depends many other previously mentioned services. This study is going through the whole issues of electrical grid, smart grid, micro grid, but also e-mobility issue for smart city and introducing the main challenges together with best cases with high replicability protentional for Brno city.

The rest of this publication is divided into following sections: Executive summary, Study specification, Electrical Grid and eMobility in Smart City, Best cases for Spitalka and Brno City, and Conclusion.

Terms and list of abbreviations

For better orientation in the subject there are described the basic definitions of the terms used and the list of abbreviations.
The term “Smart electrical grid” can be described as the power supply network, for other purposes then power supply only. Smart Electrical Grid increase the connectivity, automation and coordination between suppliers, consumers and network by modernizing grid features like demand side management, generation, real-time pricing, and automated meter activation and reading.

The general term “E-Mobility” (Electro Mobility) covers development of electric-powered drivetrains designed to shift vehicle design away from the use of fossil fuels and carbon gas emissions. It includes full electric vehicles, as well as hybrid electric vehicles and those using hydrogen fuel cell technology. This is also related to other related devices such as charging stations and their infrastructure.

The term “Smart City” describes those cities that use Information and Communication Technologies (ICT). The primary purpose is to increase quality and performance of urban services such as energy, transportation and utilities. For the main results are always considered a reduction resource consumptions, wastage and overall costs of services.

ADA	Advanced Distribution Automation
AMI	Advanced Meter Infrastructure
BEMS	Building Energy Management System
BRT	electric Bus Rapid Transit hub
CBA	Cost-Benefit Analysis
DER	Distributed Energy Resources
EV	Electric Vehicles
GLOSA	Green Light Optimised Speed Advisory
ICT	Information and communication Technology
IoT	Internet of Things
IRIS	Integrated and Replicable Solutions for Co-Creation in Sustainable Cities
LED	Light-Emitting Diode
LoRa	Long Range
LPWAN	Low-Power Wide-Area Network
MFD	Macro Fundamental Diagram
NB	Narrow Band
PLC	Power Line Communication
PV	PhotoVoltaic
REMOURBAN	REgeneration MOdel for accelerating the smart URBAN transformation
REPLICATE	REnaissance of PLaces with Innovative Citizenship And TEchnologies
RES	Renewable Energy Sources
SME	Small or Medium size Enterprise
WAN	Wide Area Network

Executive Summary

Discussion and coordination with local utility E.ON – city will be smart only with power supply, the outage scenarios have to be considered:

Increasing of renewable energy sources (RES) share will provide huge problems for industry and energy utility. Only combination of RES and traditional energy sources will provide stability of energy networks. The question of possible combination of RES and traditional energy sources is simple, install and implement RES without public donation. Also, the share of traditional energy sources in necessary. To find the proper combination is based on cost-benefit analysis. For Brno use case, the combination of solar (especially Smartflower) and power supply from utility (for particular areas - local distribution networks without dependency on utility).

Missing topics and solutions in almost every lighthouses:

- Smart garbage solution – Fill-level sensor with prediction and optimization of dustman car way,
- Smart Traffic based on WAZE navigation software,
- Considering drones for mobile base stations for critical situations.

Up-to-date solutions from lighthouse that could be replicable to Brno:

GrowSmarter (http://www.grow-smarter.eu/solutions/)

- Smart street lighting, Big Open Data Platform,
- Energy efficient refurbishment and Energy Quality Assurance,
- Smart waste management, smart traffic signals.

mySMARTLife (https://www.mysmartlife.eu/mysmartlife/)

- In Helsinki, two different storages are considered: one located in the office building Viikki Environmental House and another, a utility scale storage located in Suvilahti.
- New decentralised renewable heat supply.

MatchUp (http://www.matchup-project.eu/solutions/)

- Energy solutions should be considered with gas and water solutions.
- Smart metering systems – information of real-time consumption is benefit based on CBA for Smart metering deployment.
- Intelligent transport systems for garbage.

Replicable solutions which is suitable for Brno:

- Optimal location of charging stations in Smart cities - Lisbon, Portugal.
- Smartflower – The solar panels, which autonomously follow the sun so they're always at the optimal angle to the sun.

Our technical recommendations:

- It is necessary to obtain big data for accuracy planning of charging points positions.
- Prediction of wind speed and sun radiation are essential for microgrids. Also, prediction of power consumption base on deployment of Smart Meters is necessary.
- Energy solutions should be considered with gas and water solutions.

- LoRa and 5G communication technologies are considered. These solutions will have difficulties with replicable to other cities, because of different development of these technologies (for example in some countries the NB-IoT or SigFox are considered for Smart City).

Our recommendation for first deployment of energy micro grid:

First step:

Use the Smart Meter with communication for power consumption prediction and optimization.

Second step:

The communication solution has to be chosen according to particular use case or area. For example, LPWAN sensors for non-critical infrastructure, but suitable for example for parking sensors.

Third step:

The utility already following the process of deployment of Smart energy grids, therefore the automatization of transformer substation or Smart Meters roll-out are in process. The tie cooperation of city council with utility is necessary.

Reasons for connecting a microgrid to a main grid (Point of common coupling (PCC) - it is the point in the electric circuit where a microgrid is connected to a main grid):

Availability:

- Highly available power grids may act as an additional source for micro-grids.

Operations/stability:

- Direct connection of ac microgrids to a large power grid facilitates stable operation but only if the power grid acts as a “stiff” source to the microgrid.
- When using renewable energy sources, a grid connection may allow reducing the need for energy storage in the microgrid.
- If not all loads in a microgrid are critical, a grid connection may allow to reduce the investment in local generation.

Economics:

- Microgrids are typically planned with extra capacity with respect to the local load. This extra power capacity can be injected back into the grid in order to obtain some economic benefit.
- Grid interconnection allows to reduce fuel operational costs by using the grid at night when electricity costs are low.

The communication from all point of microgrid and also from transformer station of main grid is fundamental requirements for connecting a microgrid to a main grid.

Interconnection methods (only the methods without description – it is not the aim of this study):

- Directly through switchgear,
- Power electronic interfaces,
- Static switches.

Our recommendation:

- The dependence of renewable energy output on current climatic conditions, especially for wind and solar power plants. It is therefore necessary to improve the prediction algorithms of electricity generation from renewable energy resources and exploit these algorithms.

- I tis necessary to implement communication to every point (smart meters, smart station) and implement control mechanism.

1 Study specification

1.1 Smart Grid Infrastructure (Smart City Micro-Grid)

Microgrids will be essential for smart cities, because to have a smart city you have to have a strong, robust, reliable power and communication infrastructure.
The main goal of current power infrastructure is providing communications for control and manage the power grids, because if you don't have power you've got nothing.
The use of a micro Smart Grid allows to achieve a high degree of robustness and reliability especially in emergency conditions.

Main reasons for microgrids:

- Microgrids are characterized by their ability to separate or island from the central grid. They can halt their flow of power to the grid, or from the grid at any time. This spares the microgrid and its customers from also becoming victim to a power failure moving along the grid.
- During a power outage, San Diego Gas & Electric contacted customers who had medical conditions and invited them to go to a cool zone, set up at a resort in Borrego Springs, the site of a microgrid that serves 2,800 customers.
    - For example, during extreme hot and cold weather, the central grid sometimes becomes overtaxed. The microgrid can ‘shed load’ during these periods to ease strain on the central grid. This means that the central grid stops transmitting power to certain facilities and the microgrid takes over.
- Microgrids can strengthen community economics several ways — from attracting new businesses to reducing electricity rates. Energy is a main input in pricing of most goods and services. Microgrids offer a means to help keep electricity rates in check through better grid management. This occurs in several ways.
    - Cost-effective energy efficiency improvements for buildings.
    - The microgrid may offer a less costly solution than construction of new substations or transmission and distribution lines.
    - Energy costs.
- Microgrids can help these cities more easily incorporate renewable energy in two ways.
    - First, many microgrids include renewables, in particular solar, which has become increasingly appealing because of its falling costs and low carbon footprint.
    - The microgrid can act as a backup resource on the grid when solar and wind farms do not produce power.

1.1.1 What is a Microgrid?

Microgrid is a small-scale power system that uses a combination of generation, load and storage devices to serve local customers. The power is generated by the community for the community, and any excess is fed directly into the power grid. Size of the Microgrid may range from homes to municipal regions to industrial parks.

Requirements of microgrids:

1) Self-Healing Grids
    - Network with high reliability and inherent security in all levels.

- Decentralized control and wide spread use of sensors and measuring equipment.

2) Economical Grids
   - Optimum use of assets and applying the concepts of demand response and demand side management.
   - Non-hierarchical distribution of electric power production and use of distributed generation driven by the consumers.
   - Extensive use of network automation and reduced human intervention.
3) Low carbon network (environmental considerations)
   - Integration of multiple energy resources.
   - Electrification of transport sector.
   - Management of pollution and carbon dioxide emission.
4) Two-way communication and advance software
   - The smart devices transmit the information over a two-way communications pathway.
   - A key aspect of the smart grid will be its use of the same information technology that enables two-way communication between the consumers and utility.

<u>The components of microgrid are:</u>

- Distributed Generation (solar power generator, wind turbines, natural gas, hydropower).
- Storage cell (diesel generators, batteries, super capacitors).
- Power Management System (building/home Energy Management System).
- Charging station/electric hybrid vehicle park.
- Point of Common Coupling (to traditional grid, Utility Connection).
- Electrical/heat loads.

1.1.2 Microgrid challenges

The increase in penetration of renewable energy sources (RES) into the electric power system is quite appealing. The existing power grid suffers from unpredictable and intermittent supply of the electricity from these sources especially wind and PV solar energies.

These RES are variable with time based on wind speed and sun radiation, therefore power system planning with reliable communication to RES and prediction of wind speed and sun radiation are essential for microgrids.

<u>Design of microgrids</u>

Key design questions:

- How much generating capacity in solar PV panels and wind generation?
- What do I need in diesel generators and batteries or other storage sources for backup?
- What mix will provide the necessary performance at the least cost, or with the lowest possible emissions, or with some mix of the two?

<u>Our recommendation:</u>

- Smartflower are the solar panels, which autonomously follow the sun so they’re always at the optimal angle to the sun have to be consider (generating 40% more energy production than traditional solar), see Figure 1-1 [6].

- Prediction. Prediction of wind speed and sun radiation are essential for microgrids. Also, prediction of power consumption base on deployment of Smart Meters is necessary.

First step: Use the Smart Meter with communication for power consumption prediction and optimization.

Second step: The communication solution has to be chosen according to particular use case or area. For example, LPWAN sensors for non-critical infrastructure, but suitable for example for parking sensors.

Third step: The utility already following the process of deployment of Smart energy grids, therefore the automatization of transformer substation or Smart Meters roll-out are in process. The tie cooperation of city council with utility is necessary.

Figure 1-1: Visual simple example of smart flower design.

1.1.3 Other Smart Grid infrastructure components

From another point of view, the view of people of Smart city, these components are interesting:
Smart Rainwater harvesting. Smart Rainwater harvesting combine rainwater buffering systems, the communication (LPWAN, IoT) and intelligent sensors or metering (reading water consumption). These three concepts ensure real-time decision of limit the waste, prediction or avoid flooding.

- Smart parking.
- Smart lighting.
- Smart bench:
    - Smart benches with charging, wi-fi, environmental sensors powered by solar energy have to be considered. But also Smart living benches with flower panel supporting biodiversity is necessary to considered.
- Smart bus/train stop. Smart stop has free Wi-Fi, charging ports, interactive display maps, a solar panelled roof, and even a swing [8].

1.1.4 Smart Grid Infrastructure in Brno – from the utility (E.ON) point of view

There are two main topologies of structures for defining the layout of a distribution or transmission grid, namely the radial grid topology and the mesh grid topology.
The radial grid is a tree shaped which does not contain closed loops. This means that you start on one bus and deliver power to the next bus without the possibility of finding the original bus, except by turning backwards. This kind of topology is the simplest and cheapest topology for an electrical grid, however, if a line is disconnected for some reason in this topology, all the lines downstream will lose

power as well.
On the other hand, in the mesh grid topology it is possible to find closed loops and power is delivered through multiple lines which are connected to each other forming a mesh. This kind of topology is more reliable, has fewer losses but requires higher investments.

For reliable power supply, the mesh grid topology is the best solution:

- In Brno centre, there is mesh grid topology (3700 supply point, 69 transformer stations). Mesh grid is for power supply of transformer station, in the case of disconnection of one way, the power supply will be assured.
- In Brno-Bohunice (Smart District Bohunice), installation of smart switchboard, implementation of mesh grid, installation of PLWA communication technologies.

1.2 E-charging infrastructure

1.2.1 Charging

The first condition is obvious: a fully charged electric vehicle at a given charging station must be able to reach another station. In other words, the distance between stations must be less than the range of the vehicle.
The second condition relates to the number of electric cars in the area around a charging station, which determines the local demand for charging. This demand has to be satisfied by the capacity of the local charging station and by a certain fraction of the capacity of other stations within range. This fraction represents drivers' willingness to charge up at a station other than their local one. And the smaller this fraction, the higher the density of charging stations must be.
The last condition is that the charging stations must cover the entire city. So, it must be possible to travel from every part of the city to every other part of the city by hopping from charging station to the next. The conditions all together guarantee that the serving areas of the charging stations cover every corner of the city for all possible EVs.

1.2.2 Bus

Ground-level power supply for tram (e.g. Tramway de Bordeaux, Ground-level power supply tram in Jumeirah, Dubai).

1.2.3 Optimal location of charging stations in Smart cities

As a prerequisite for Electric vehicles (EV), an adequate charging infrastructure is needed to supply these vehicles with electrical fuel. The main point of interest is to determine the optimal locations for charging stations. These contributions are necessary for optimal location of charging stations in Smart cities [9]:

- Determining the importance of points of interests, concerning the establishment of a charge point infrastructure.
- Deriving optimal locations for charge points based on actual charging infrastructure usage (daily utilization and number of users).
- Developing an algorithm to calculate an optimal charge point infrastructure, based on urban economics and big data.
- Providing a tool for city planners, i.e. the frequency of visits of individual POIs, it also

determines the charging activity.

2 Electrical Grid and E-mobility trends in Smart City

2.1 European context (The European Smart City Lighthouse Projects)

2.1.1 GrowSmarter (http://www.grow-smarter.eu/)

Lighthouse cities: Stockholm (Sweden), Cologne (Germany), Barcelona (Spain)
Solutions: Low energy districts, integrated Infrastructures, sustainable Urban Mobility.

2.1.1.1 Example 1: Smart street lighting

Smart LED street lighting

- Real time feedback reduces downtime and cuts maintenance costs
- Major energy savings without reduced traffic safety and comfort
- Less light pollution at times or in areas with low traffic-intensity

How it is work?

1) Standalone system with automatic dimming during 6 hours of the night
    - Each individual light fitting records when it is turned on and off and uses those times to calculate the middle point. From that middle point, the effect is lowered to 66% for a duration of 6 hours, or until it is turned off.
2) Adjustable dimming curve set in a Central Management System (CMS)
    - All lamps are connected to a Central Management System where a dimming schedule is run. In the dimming schedule, lighting levels are set according to sunset/sunrise and specific times during the night.
    - The lighting is turned on at sunset to 100%, at 10 PM it is dimmed to 67%, at 1 AM it is dimmed to 50%, at 5 AM it dims up to 67% again, at 6 AM to 100% and it is turned off again at sunrise. Dim steps are equal to changing one lighting class in the road safety standard.
    - This solution requires a constant power feed, which is not custom for a lighting installation that usually breaks the power supply during daylight hours.
    - Also, the CMS communicates with two different technologies; one group of light fittings are connected to a Mesh net while the other group is using powerline communication.
3) Presence detection system which raise the lighting levels for a number of lamps on detection.
    - A bicycle lane or pedestrian street might have several hours without usage. During that time the lighting is dimmed to 40%.
    - When a person is approaching the street, a sensor reacts and dims up the lighting to 100% on the detecting lamp and three luminaries ahead. After a pre-set interval the lighting is dimmed down to 40% again.

Potential for replication

The potential for replication is high. With the support of the system provider, consultants and contractors this investigation would be reasonably easy to replicate.
However, there are several technologies available on the market today and for a test like this to be useful some strategic goals should be set. For example, which communication technologies are feasible in this specific area? Are we considering adding functionality in the future, Internet of Things capabilities for example?

There are a few specific competences which are useful in investigating a system like this: lighting management, software/CMS design, hardware, data communication and security. It is also important to consider the maintenance contractors' capabilities in maintaining a smart system.

Streetlights as Wi-Fi

- Adds sensors to existing fibre-optic network and connects to an Internet of Things open data platform
- Produces real-time information for traffic emissions reduction
- Open data system can be used by all parts of the city administration and innovated by local SMEs

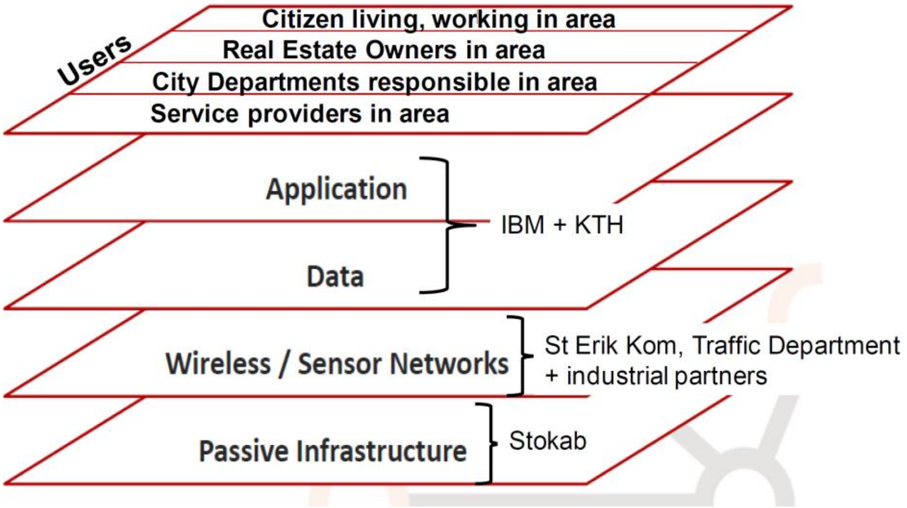

Figure 2-1 Overview of the process

<u>How it is work?</u>

- In Slakthusarea two types of sensors are installed to collect data on people and vehicle flow. (See Figure 2-1).
- The sensors are connected to the existing optical fibre network. When pedestrians and bicyclists pass a sensor a time and IDtag is collected from their mobile phone devices. When the same ID passes another sensor it is possible to, for instance, define the average speed and direction of the person. The other sensor is identifying vehicles' registration plates and checks it against the vehicle register. When there is a match the vehicle information such as type of vehicle, CO_2 emission can be defined.
- This gives very exact information of the transport emissions in the area over a given time. The real-time data in Stockholm is then transferred to IBM: IOT Watson environment, where it can be analysed, visualised, but also used for developing applications for users.

<u>Integration with other smart solutions</u>

In Smart Measure 8.1 IBM is implementing an open consolidated big data platform. All data from the sensors installed in Slakthusarea are gathered in the IBM platform called Blue Mix. The connection with the use cases in Smart Measure 8.1 is shown in Figure 2-2 (below).

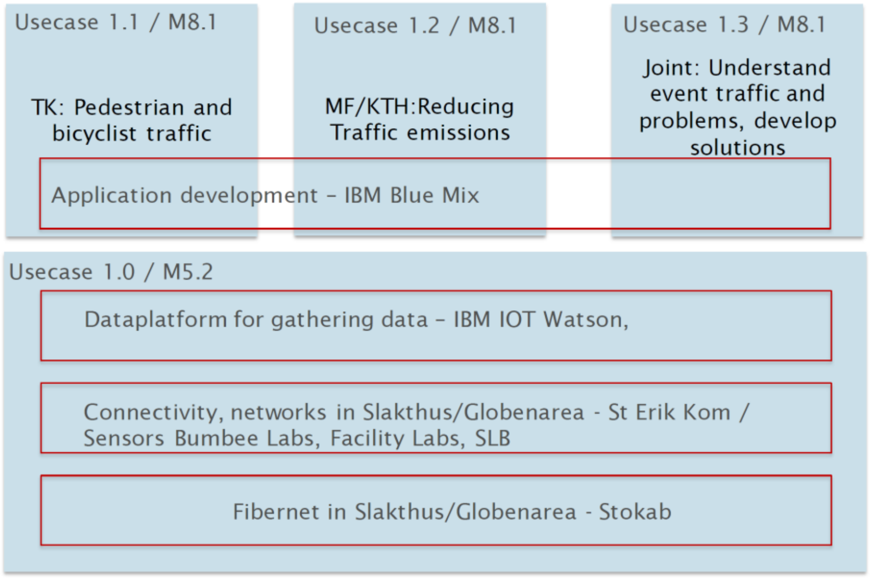

Figure 2-2 Integration with other smart solutions

Potential for replication

- The concept is possible to replicate in other cities even if they do not have an optical fibre network. The sensors can also send data through 3G/4G. The data collecting sensor solutions are selected so that they fulfil the criteria of data security and do not jeopardise the anonymity of individuals. These are currently approved for the Swedish market, but can after approval in other countries, be used for gathering data in street environments. IBM IOT Watson platform is available in all markets, as well as the Blue Mix platform.

Smart meter information analysis

- Efficient infrastructures in public areas integrate different utilities' technologies, such as smart meter infrastructures, and urban and environmental sensors.
- Awareness-raising on energy consumption behaviour aimed at lower energy consumption and a reduction in CO_2 emissions.
- A new communication channel will provide direct access to the energy data through the City Platform (GrowSmarter Platform).

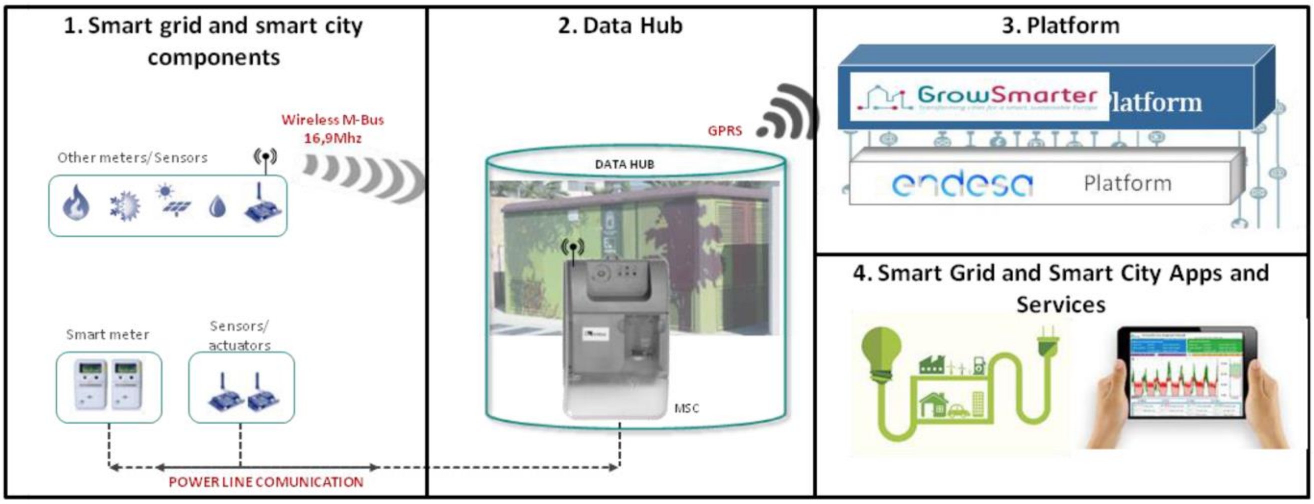

Figure 2-3 Smart meter information analysis and actuators

<u>How it is work?</u>

- Within the GrowSmarter project, the infrastructure's architecture is composed of four main layers:
    - Field Components:
    - Meters (electrical, gas, water, heating, cooling).
    - Urban and environmental sensors.
    - Data Hub, composed of an MSC installed at the secondary substation.
    - Platform.
    - Energy Services and Apps.
- The MSC installed at the secondary substation collects data from the different field components and then transfers it to the GrowSmarter Platform through a central system (Endesa Platform). This data will be managed through the GrowSmarter Platform and will offer some added value energy services.
- The main communications technologies supported are:
    - Radiofrequency (RF) based on wireless MBus protocol, used for communication between the concentrator and gas, water and heating meters.
    - PLC (Power Line Communication), used for communication between the concentrator and electrical meters.

<u>Expected Impact</u>

In Barcelona, Endesa will demonstrate a big step in the evolution of efficient infrastructures installed in public areas thanks to the integration of the infrastructure of different utilities with the capacity to integrate water, gas, heating, and also urban and environment sensors and actuators data.

This measure will contribute to the city's development in energy efficiency thanks to the collection of a variety of high city data, providing greater awareness of energy consumption and enabling tenants to manage their own.

For example, the provision of energy meter data is expected to encourage tenants to optimise their consumption, reducing the cost of energy.

New added value energy services and apps are expected to be developed by third parties, which would benefit from the information collected and managed through the City Platform.

2.1.1.2 Example 2: Big data management

Big Open Data Platform

- Integrates data from a variety of domains to form one single access point for application developers.
- Provides a universal and accessible platform that allows application developers to build uniform services for cities with minimal effort and no redesign.
- Promotes equal access to public data, fostering sustainable and equitable public development

How does it work?

This solution consists of three components:

1) City ontology, together with a browse and query tool:
   The city ontology reflects the meaning (i.e. semantics) of all the urban concepts (entities and relationships) that describe the domains of interest and the connections between them. The browse and query tool allow keyword-based search of concepts, navigation starting from these anchor concepts, and the construction of queries in a graphical fashion.

2) Semi-automatic mapping tool:
   This tool aligns the semantic model and the specific model of the city data platform and will be available via web. Multiple users could participate collaboratively to produce valid alignments.

3) Semantic access layer (SAL):
   Functions as an access point for applications that pose semantic queries to access the data on the city platform. Applications accessing data from different cities can work without modification if a SAL exists for those cities that maps between the city ontology and the actual city schema. SAL acts in behalf of the applications (with their security and privacy credentials defined by Cellnex) to fetch the required data via a REST API and compute the query results for the few most common queries operations (such as join). It calls the mapping tool to know which the resources in the city platform schema are that correspond to the semantic concepts contained in a query.

Data integration solutions traditionally imply a data warehouse approach. While this is based on a well-established and efficient technology, as well as solid formal foundations, several characteristics of data in urban environments are a misfit for this type of data integration.
Firstly, data and schemas evolve; secondly, data is incomplete and no assumptions should be made about non-existing data; thirdly, there are an increasing number of data sources of heterogeneous nature and formats that need to be integrated in an efficient and, as much as possible, automated way; fourthly, data is usually available for consulting but cannot be moved around and stored at the target.
These are scenarios where semantic technologies excel. There are not only a natural fit for the Open World paradigm, but they evolve gracefully and foster semiautomatic mapping techniques for

massive data population and access.
One advantage is that new data can be integrated faster, new semantic relationships can be inferred, and users can query the data without having to learn a query language nor understand the entire data model at a time.

Integration with other smart solutions
Our solution accesses city data via the API offered by Cellnex (GrowSmarter API). Given that this is a REST API, the semantic queries cannot be translated into an SQL query against the city data platform; instead SAL will implement some of the most common operations required by the queries, such as joins. The GrowSmarter API implements secure and private access to resources.

Urban TRAFFIC

- Provides a fast and easy overview of the current traffic flow within your city
- Data and information can be used to improve traffic management by exploiting historical data to detect unusual situations
- Data can also be provided on open data platforms of cities, so external app developers can use these data as well. All urban data can be included independently of the manufacturer of the data provider

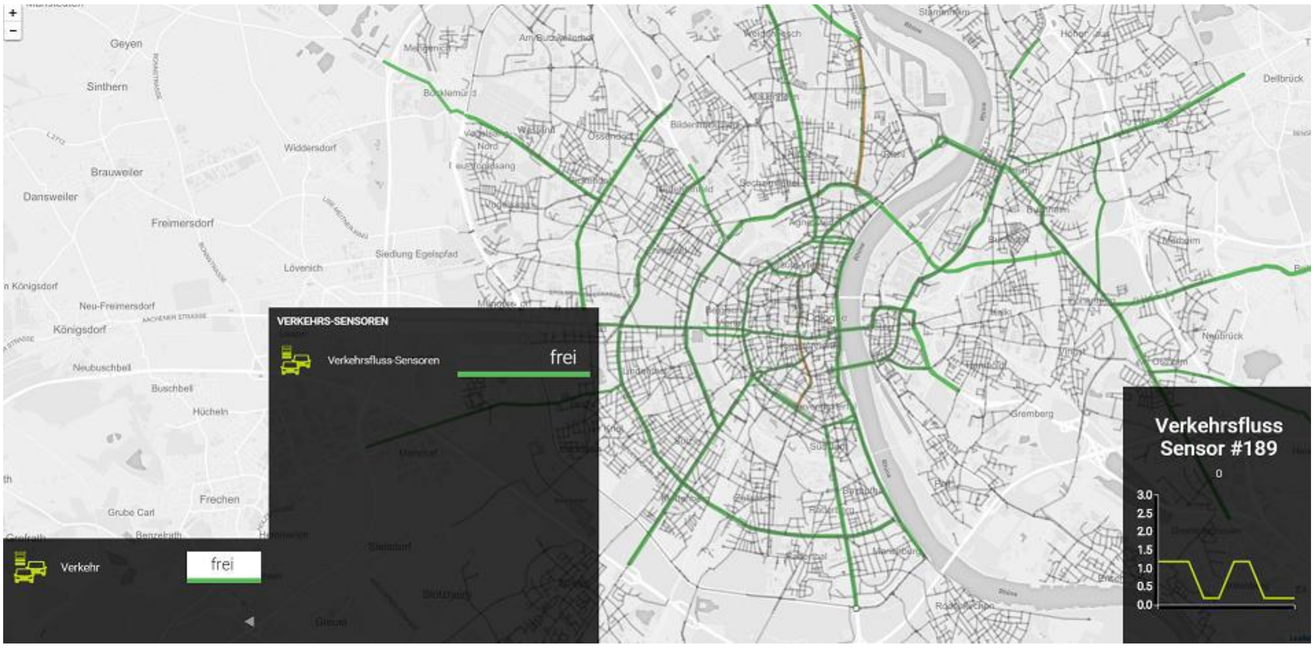

Figure 2-4 Urban Traffic

What is the solution?
The picture above (Figure 2-4) shows the City of cologne's Urban TRAFFIC app. The map provides a view of Cologne's street map, with the different colours indicating current traffic flow in each street. In the current version of the app, 4 different colour indicators are used: green, yellow, red an d grey. Green indicates a good traffic situation with no traffic jams. Yellow is less good and red is bad. Grey indicates a disconnection from the sensor source. In the picture above the traffic situation shown is

good and therefor all supported streets are green. The map gathers its data from the UrbanPulse data backend which is described in the next paragraph. The original data source are traffic sensors installed next to streets, which capture the current traffic flow. Future versions of the app will be enriched with more traffic information such as available parking spaces, and the location of bike sharing and car sharing spots.

<u>How does it work?</u>

The picture below (Figure 2-5) shows an overview of the whole system which is implemented for Cologne in the context of GrowSmarter. The UrbanPulse module in the middle is a multisided big open data platform. This means that it is open to any kind of urban data on the urban data side and can provide data and information via open standards to different data consumers.

Urban data is provided by traffic management systems, from project partners, and from urban companies like energy provider. Additionally, environment data from sensors can be used. The data will be stored to provide historical comparison for the data analytics. Data and information are provided to apps or as Data Services to consumers. In the image above, the Urban TRAFFIC app is the data consumer and depicts the information.

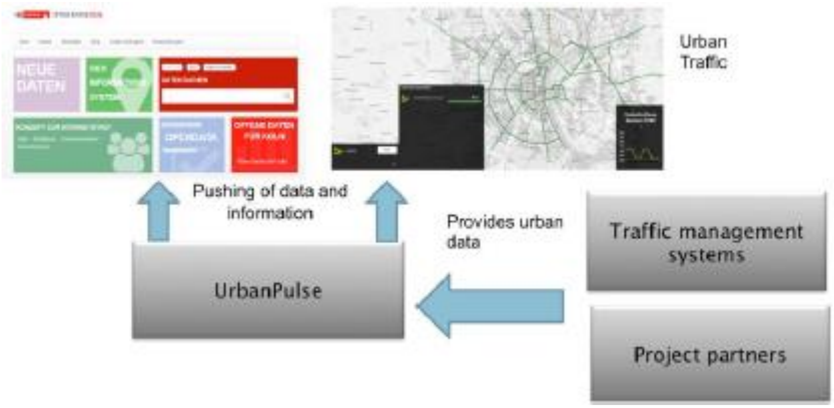

Figure 2-5 UrbanPulse as multisided open big data platform in the backend

<u>Potential for replication</u>

The solution can be replicated in any European cities as it is not dependent on proprietary standards and therefore connectors from the data source to the UrbanPulse can be developed for every sensor / service interface. Connections to the Urban TRAFFIC app and the open data platform are realized by open standards to ensure every app developer can use the data easily.

2.1.1.3 Example 3: Energy Quality Assurance

- Focus on energy savings throughout the building process
- Avoids delay in the building process by appointing an Energy Coordinator
- Avoids energy consumption increases due to staff changes within the project

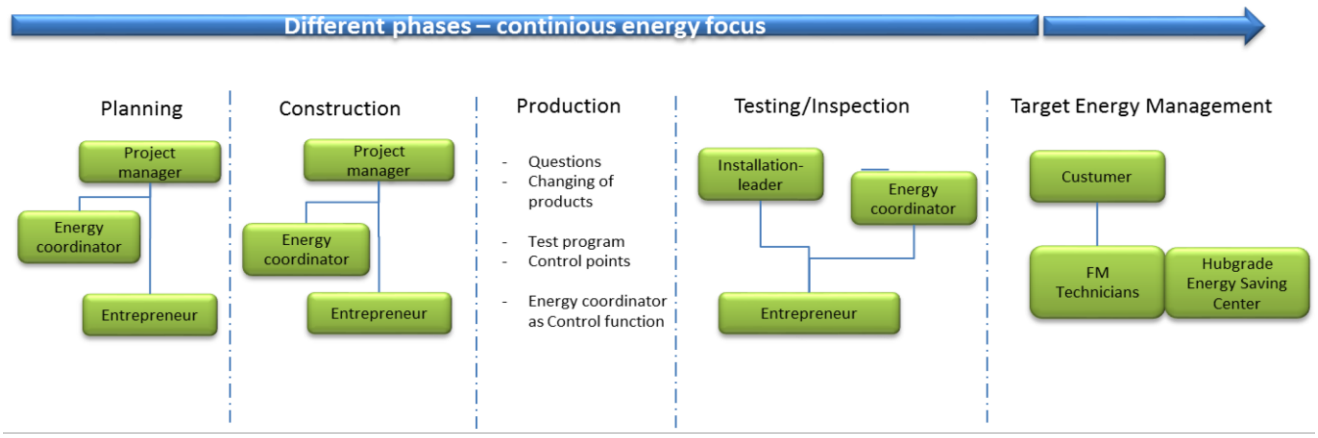

Figure 2-6 Smart building shell refurbishment

What is the solution?

By nominating an exclusive Energy Coordinator to follow the project in the construction/refurbishment phase, delays related to staff transitions are avoided. Based on earlier experiences, errors during planning and construction have been shown to lead to 10-20% extra energy consumption.

Potential for replication

By nominating an exclusive Energy Coordinator to follow the project in the construction/refurbishment phase, delays related to staff transitions are avoided. Based on earlier experiences, errors during planning and construction have been shown to lead to 10-20% extra energy consumption.

2.1.1.4 Example 4: Efficient and Smart Climate Shell and Equipment Refurbishment

- External insulation of the façade, substitution and upgrade of blinds, monitoring of heating, consumption and solar thermal energy generation.
- Increased comfort, reduction in noise pollution and humidity.
- Involvement of residents through a community wide association for the decision-making process before, during and after the works.

What is the solution?

Passive measures including external insulation in all façades and substitution and upgrade of blinds in all windows. Both wool and expanded polystyrene insulation will be employed, the former on ventilated façades and the latter on the rest of façades. Insulation design in each façade has been optimised in order to protect indoor spaces from weather conditions depending on the orientation and irradiation received.

Integration with other smart solutions

The refurbishment of this building will be linked to measure 4.2, in which a platform to visualise the monitored energy data is being developed, and to measures 8.1 and 8.2, which cover the creation of an open data platform and semantic urban model.

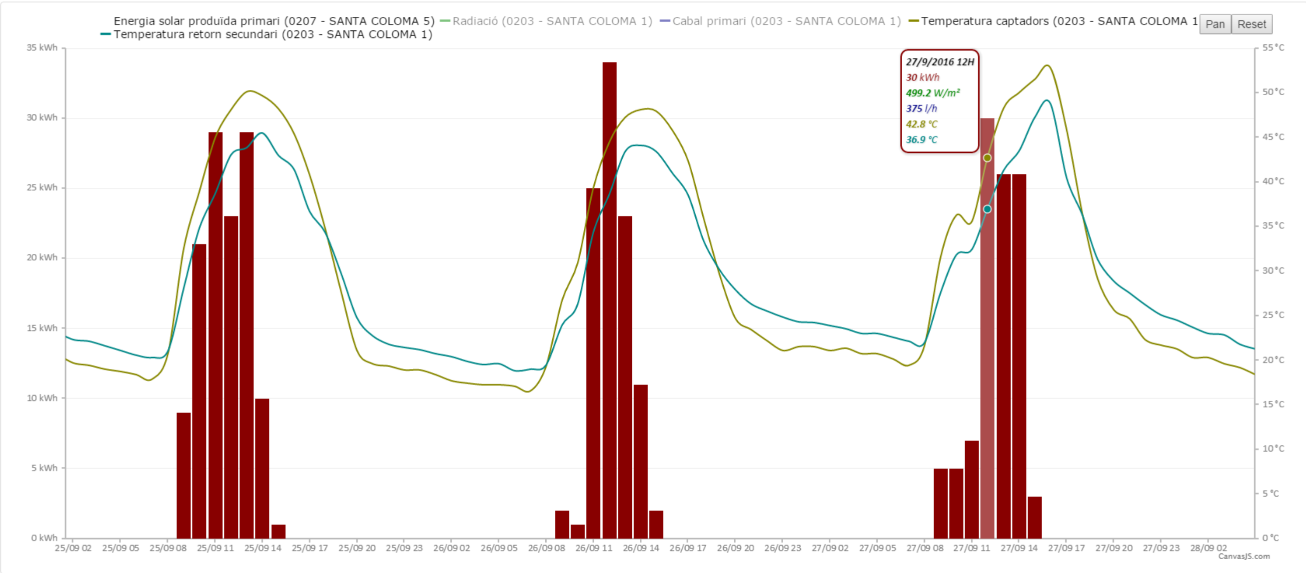

Figure 2-7 Data visualization platform of the monitoring of solar thermal installations.

<u>Potential for replication</u>

Passive measures are strongly dependant on city climate and architectural aspects. The type of wall insulation technique is dependent on the prevailing climate in the city, thus this measure may be replicated in cities with similar climate. However, in general terms the Housing Agency's engagement with social housing tenants regarding energy aspects and refurbishment processes could easily be replicated elsewhere.

2.1.1.5 Example 5: Energy efficient refurbishment

- Decreased energy consumption by 60%
- Lower energy costs and reduced CO_2 emissions
- New installations creating a more balanced extends the lifespan of the buildings.

<u>What is the solution?</u>

This project concerns four fourteen-floor buildings and two four-floor buildings built in 1961. These buildings together host 324 apartments.

Just like most old buildings there are problems with thermal bridges and the fact that the climate shell is not airtight. This in combination with today's standard of desirable indoor temperature leads to high energy consumption, since the warm air leaks out and cold air finds its way in.

A lot of heat and energy is lost in the existing system of installations in our buildings, due to long distances of poorly insulated pipes for heating and water, as well as the absence of heat recovery.

<u>Climate shell refurbishment of Valla Torg:</u>

- Additional insulation by 80 mm to facade and 200 mm to basement walls.
- New type of construction for the roof with added insulation.
- New four glass windows with U-value 0,7 W/(m^{2}K).

<u>New installations of Valla Torg:</u>

- Separate heat exchanger in every building for district- /geothermal heating.

- Heat pumps recovering heat from the exhaust air and transmitting it to produce heat and hot water.
- Wastewater heat exchange system to preheat fresh water.
- Installation of “pipe in pipe” system to reduce hot water circulation losses
- Water-saving tap water fixtures to reduce water consumption
- Electricity saving measures:
    - Low energy lighting fixtures for common spaces
    - Modern and more effective elevators
- Renewable energy: PV cells to produce electricity

<u>How does it work?</u>

In this retrofitting, external insulation is added to the whole building envelope in an ambitious manner and new windows and balcony doors will be installed with the best possible U-values for the project. This way there is control over incoming air. Once finished, the only air intake will be under the windows right behind the radiators to warm the air up before it continues into the apartment. The air exits by exhaust ventilation and the heat is recovered by a heat pump on the roof.

<u>Replication potential</u>

This model of energy renovation can be replicated as a total or by selected parts. The project sets a good example for different locations since it includes systems for district heating for five of the buildings, but also a system for geothermal heating for one of them. These systems can be also used for cooling, which one to use for a follower depends on what the preconditions are on their particular sites.

2.1.1.6 Example 6: Smart waste management

- Handles multiple separate waste streams in one inlet, identifying each user and their waste volumes.
- Increased recycling rates, conversion of food waste to biogas and up to 90% reduction in transport for heavy waste collection. Collected food waste will be processed separately to serve as biogas for public transportation.
- Feedback on individual habits and their environmental impact can be given to system’s users, with the possibility of rewarding ‘good’ behaviours.

<u>What is the solution?</u>

The smart waste collection system combines Envac’s underground waste transportation and optical sorting technologies, integrating smart metering, identification sensors and software. This solution will enable a cost efficient and smarter combined solution, with the possibility of providing feedback to end-users on their waste segregation habits.

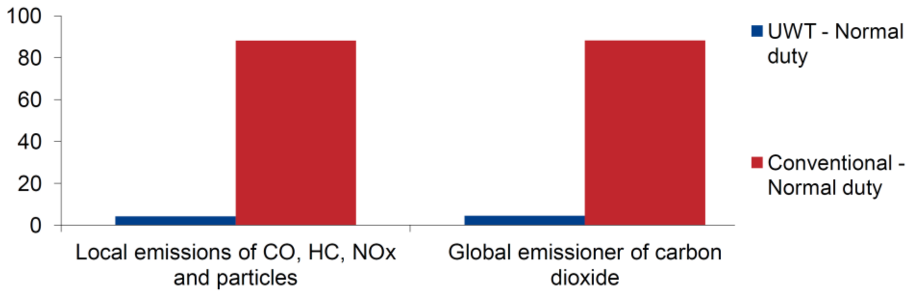

Figure 2-8 Emissions differences

The graph above shows the difference in emissions of CO, HC (hydrocarbons), NOx, particles and SO2in another residential area in Stockholm (Stora Ursvik). UWT stands for underground waste transportation and Conventional stands for bin collection with rear loading lorry.

How does it work?

Residents separate their waste into separate colour-coded bags. When the resident puts his/her waste into the Envac waste inlet, the user is identified alongside the type (by colour of bag) and weight of waste being deposited. The different waste streams are then transported using suction through an underground pipe network to a collection station located outside the central city area.
The system will be able to identify the amount and type of waste thrown away by individual users. This information could be used to provide feedback to the user, for instance, on individual recycling patterns.
Any food waste collected will be processed as biogas, which in turn will be used to fuel public transportation.

Potential for Replication

Many European cities need to increase recycling in multi-family residential housing estates. Typically recycling levels in such areas are around 15% or lower, whereas average national recycling levels often reach 50% and higher. Space and accessibility restrictions for introducing recycling as well as means of providing continuous information and instantaneous feedback on correct behaviours are factors impeding reaching higher recycling levels.
The system can be installed outside the buildings without needing to make any infrastructural changes. This gives it a good replication potential in many housing estates built in the 60s-80s that currently lack possibilities for waste recycling and have difficulty providing individual feedback and rewarding “good” behaviour.

2.1.1.7 Example 7: Smart traffic signals

- Smart management of traffic signal lights can reduce congestion and make traffic flow more smoothly in cities
- Signal priority systems give certain vehicles a green light faster than others, reducing their travel time. This works as an incentive for cleaner vehicles
- Smoother traffic rhythm reduces stops and queuing, which in turn reduces energy consumption, emissions, noise and risk of accidents

What is the solution?

In Barcelona and Stockholm different types of traffic signal light adaptations will be tested to improve traffic flow and decrease congestion.
In Barcelona an improved traffic signal management system will be used to avoid or alleviate congestion in dense urban areas.
In Stockholm a limited number of traffic lights will be equipped with specialised software so that cars with the right equipment can get information and adapt their speed to be able to reach the green lights.
Also, in Stockholm, electric and renewable fuelled delivery trucks operating from a logistics centre will be given traffic signal priority at certain crossings. This is a pilot to see if such an initiative works as an incentive for better vehicles and smarter logistics.

How does it work?
(Barcelona)
The aim of this measure is to provide the city council's traffic managers with an innovative tool to manage traffic in congested areas of the city.
Barcelona will use the information gathered by the tool to test the existence of the theory of the macro fundamental diagram (MFD) of traffic flow in the district of Sant Martí.
The macro fundamental diagram is a diagram which assesses the relationship between the space-mean flow, density and speed of an entire network, with many separate links. This means that all finished trips within the area of study are plotted and saved for analysis.
A macroscopic traffic model considers traffic, flux, traffic density and velocity in the different streets of the district. This forms the basis of the macro fundamental diagram. The MFD represents the capacity of the network in terms of vehicle density.

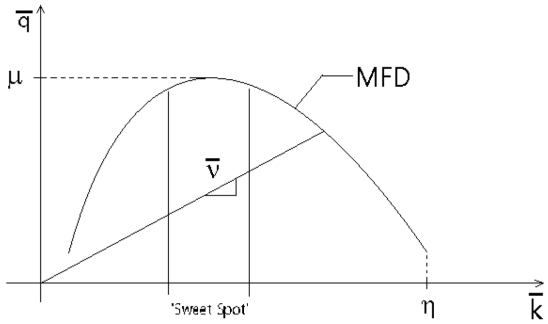

Figure 2-9 Macro Fundamental Diagram (MFD)

By providing the city traffic manager with this information, it will be possible to assess the performance of the traffic light network based on the density of vehicles in the streets. Managers will then be able to see how well each area is performing at different times, enabling them to take the best decisions in terms of traffic light timings.
The MFD model will be built using real data from existing traffic gauges installed in the city. Data from different days and time frames will be gathered and the O/D matrices will be calculated. Using the traffic modelling software Aimsun and traffic demand, it will be possible to estimate the macro fundamental diagram of the area of study.
Recommendations will then be given to the city council in order to help traffic managers improve the traffic light timing for smoother traffic flows.

Integration with other smart solutions:
In Stockholm the signal priority for trucks is connected to the construction consolidation centre operated by Carrier. Environmentally sound trucks from Carrier will be given priority at traffic lights between the consolidation centre and the GrowSmarter building sites in Valla Torg and Slakthusområdet.

2.1.2 STARDUST (https://stardustproject.eu/)

STARDUST (2017-2022) is an EU Horizon 2020 Smart Cities project, which brings together advanced European cities (Pamplona, Tampere, Trento, Cluj-Napoca, Derry, Kozani and Litomerice). Technical solutions and innovative non-technical solutions will be implemented and validated, enabling them to be bankable and replicable for other cities. The STARDUST main impact targets are carbon emission reduction, higher RES share, energy savings and payback time.

Main actions in three main lighthouse cities Pamplona, Tampere and Trento are:
- New renewable energy sources (RES)
- novel combined heating and cooling energy systems with advanced ICT scheme
- electric vehicles and charging stations

New action in comparison with other projects and lighthouse:
- Green Light Optimised Speed Advisory (GLOSA) will be established to advise the drivers the correct speed needed to pass through the traffic lights. They will promote better mobility within the city while reducing the carbon emissions.

Interesting specific actions:
- Platform for mobile apps for the Young Athletics World Championships in Tampere 2018
- Concept for pedestrian and cyclist guidance in the Ratina arena area
- A guidance whole plan for the train station, the bus station and the airport
- A model for guidance in special situations (like road works)

Our technical recommendations:
- It is necessary to obtain big data for accuracy planning of charging points positions.
- Increasing RES share will provide huge problems for industry and energy utility. Only combination of RES and traditional energy sources will provide stability of energy networks.
- There are missing of technical specification, because on first year’s solution.

2.1.3 MAtchUP (http://www.matchup-project.eu/)

MAtchUP (2017-2022) is EU-funded Smart City project involving three lighthouse cities (Valencia, Dresden and Antalya) and four follower cities.

Main activities:
- Energy solutions: Smart controller for building, electrical storage, urban renewables, smart metering systems, public lighting, district heating.
- Mobility solutions:

- charging infrastructure (including measurement and simulations),
- electric vehicles,
- intelligent transport systems.
- ICT solutions
- non-technical actions
- An increased penetration of renewable energy into the buildings' energy mix
    - Solutions integrating several technologies based on one or more renewable energy sources (and their combination with energy storage systems where necessary) will be developed to achieve the highest possible share of renewable energy. Photovoltaic systems, biomass plants and solar thermal collectors will be integrated into the buildings to produce renewable electricity to reduce the greenhouse gas emissions.

<u>Our technical recommendations:</u>

- Energy solutions should be considered with gas and water solutions
- Smart metering systems - information on real-time consumption is benefit based on CBA analysis for Smart metering deployment.
- Water storage should be considered.
- Intelligent transport systems for garbage should be considered.
- There are missing of technical specification, because on first year's solution.

2.1.4 RUGGEDISED (http://www.ruggedised.eu)

RUGGEDISED is a next smart city project funded under the European Union's Horizon 2020 research and innovation programme. It brings together three lighthouse cities: Rotterdam, Glasgow and Umeå and three follower cities: Brno, Gdansk and Parma to test, implement and accelerate the smart city model across Europe.

Working in partnership with businesses and research centres these six cities will demonstrate how to combine ICT, e-mobility and energy solutions to design smart, resilient cities for all. This means improving the quality of life of citizens, reducing the environmental impact of activities and creating a stimulating environment for sustainable economic development.

Towards to other cities evolving with RUGGEDISED, there are some examples of compatible solutions with Brno (Spitalka):

2.1.4.1 Peak load variation management and peak power control (Umeå)

Using buildings as thermal energy storage, an automated peak load management system will be developed and tested in Umeå University's campus to assess and exploit heat variations in the different buildings e.g. offices and teaching facilities alongside more energy-intensive laboratories and computer rooms to potentially reduce energy use on campus by up to 15%.

2.1.4.2 Energy-efficient land use through flexible green parking (Umeå)

A new business model for energy efficient land use in Umeå will be developed. It will aim at the reduction of demand for car parking spaces and directing developer investments away from parking, towards sustainable mobility solutions (car sharing, e-buses, cycling etc), thus reducing the climate impact and overall energy use.

2.1.4.3 RES generation and storage for mobility (Rotterdam)

New renewable energy sources (RES) will be developed to boost the electricity grid and meet the energy demand of the growing electric-bus fleet in Rotterdam. This includes installation of solar panels on roof space close to the bus station to deliver energy off-grid to battery storage at the bus station via a DC-cable, and the installation of wind turbines at the Ahoy exhibition centre.

2.1.4.4 Energy optimized electric BRT-station (Umeå)

A new electric-bus-rapid-transit-hub (BRT-station) will be developed within the Umeå university campus area to tackle the problem of the heat and energy loss during passenger boarding, which currently reduces the range of e-buses during winter. Stops will be provided with shelters, heating systems, an intelligent ticket system using smart-phones and an insulation structure to minimise energy loss during boarding of passengers.

2.1.4.5 Smart charging parking lots (Rotterdam)

Up to 25 smart-charging points for electric vehicles (EV) will be installed in parking lots in the Heart of South project area to enable a two-way energy flow in which vehicles not only draw from the grid, but also store and feed energy back to it. In this way, power can flow from the grid to electric vehicles (EVs) and from EVs to the grid, with utilities effectively harnessing EV batteries as a robust source of distributed generation.

2.1.5 REPLICATE (https://replicate-project.eu)

REPLICATE – REnaissance of PLaces with Innovative Citizenship And TEchnologies – is a European research and development project that aims to deploy integrated energy, mobility and ICT solutions in city districts. Lighthouse cities: San Sebastian (Spain) Florence (Italy), Bristol (Great Britain)

<u>Energy efficiency</u>

- Saving energy consumption
- Up to 56% in relation to existing situation in building retrofitting.
- Up to 35% in District Heating.

<u>Sustainable mobility</u>

- Integrating sustainable EVs, recharging systems and Information Mobility System
- More than 200 EV units.
- 228 charging points.

<u>Integrated ICT infrastructure</u>

- Developing new sustainable and cost-effective services to citizens providing integrated infrastructures that improve efficiencies in the use of local public resources and the delivery of Public Services:
    - New ICT model based on FI-WARE and Open Data Management.
    - New intelligent lighting system based on new LED technology.

- High speed mobile wireless network based on post WIMAX technology.

2.1.6 SmartEnCity (https://smartencity.eu)

Lighthouse cities: Vitoria-Gasteiz (Spain), Tartu (Estonia), Sonderborg (Denmark). The underlying concept is the Smart Zero Carbon City concept, where city carbon footprint and energy demand are kept to a minimum by using demand-controlled technologies that save energy and promote raised awareness. At the same time, the energy supply is entirely renewable and clean and local energy resources are intelligently managed by aware citizens, as well as coordinated public and private stakeholders.

LED Lights with smart controllers

The street light network of the demo area will be supplied with the following sensors and detectors:

- PIR movement detector – capable of detecting people and vehicles and computing the overall human presence and traffic flow level.
- Movement detector with cameras – detects people and vehicles using picture analytics and can differentiate between vehicle types (passenger cars, buses, trucks etc.).
- Light reflection sensor – measures the rate of reflected light from road surface for analysing road conditions (dry, wet, snowy etc.).
- Noise sensor – capable of detecting noise level and source (human speech, traffic etc.).
- Environmental sensor – measures pollution (CO_2, NOx), air temperature, humidity etc.

Benefits:

- Easy adoption by both luminaire manufacturers and end users
- No need for engineering personnel for deployment and maintenance
- Dynamic control of luminaires based on real-time local information
- High reliability and accurate power consumption measurements
- Future proof (i.e. easy to add other devices providing smart city services to the same network)
- Increased resource and energy efficiency
- Smaller carbon footprint and light pollution
- More efficient delivery of city services
- Increased comfort and better living environment
- Better (evidence-based) planning (e.g. traffic)

2.1.7 SMARTER TOGETHER (https://www.smarter-together.eu/)

Lighthouse cities: Vienna, Munich, Lyon will implement the main demonstration activities in specific districts, monitor the results and upscale solutions at city level.

Munich:

- District Heating and Renewables
- Photovoltaic (PV) system
- Battery storage
- Geothermal district heating
- Innovative heat substations

Lyon:

- Data management platform & smart services
- Community Management System connected to the city data platform

2.1.8 IRIS (http://irissmartcities.eu/)

IRIS is a HORIZON 2020 EU beginning in 2017 for a duration of five years. The project has been developed around three lighthouse cities – Utrecht, Nice and Gothenburg. Main activities are:

Smart Renewables and closed-loop energy positive districts
Integrating:

- High share of locally produced and consumed renewable energy at district level,
- energy savings at building level reducing the citizens' energy bills,
- energy savings at district level.

Smart Energy Management and Storage for Grid Flexibility
Integrating smart energy management and renewable energy storage for:

- maximum profits of renewables power/heat/gas
- maximum self-consumption reducing grid stress and curtailment
- unlocking the financial value of grid flexibility

Smart e-Mobility Sector

- Local zero-emission mobility,
- lower household mobility costs,
- smart energy storage in V2G car batteries.

Digital transformation and services - City Innovation Platform (CIP)
Cutting edge information technology and data framework enabling:

- The above-mentioned solutions maximizing cost-effectiveness of the integrated infrastructure.

Next, the City Innovation Platform with open, standards-based application program interfaces (APIs) provides meaningful data and information services for households, municipality and other stakeholders, allowing for a Data Market with new business models.

Citizen Engagement and Co-creation
Design and demonstration of feedback mechanisms and inclusive services for citizens to achieve that they are intrinsically motivated to:

- Save energy,
- shift their energy consumption to periods with redundant renewables,
- use electric vehicles,
- change the vehicle ownership culture towards a use or common mobility assets culture.

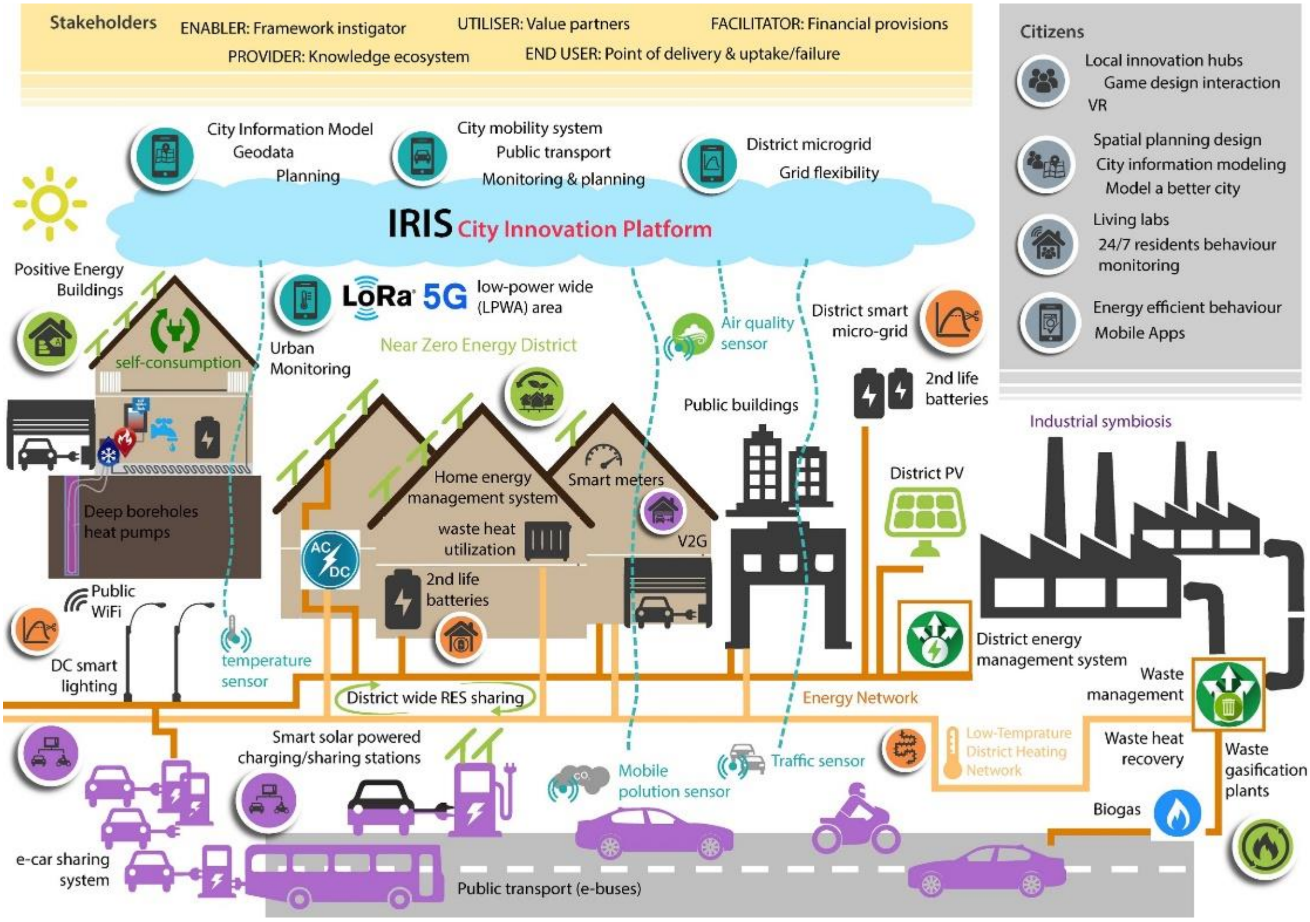

Figure 2-10 Concept of the IRIS City Innovation Platform

<u>Our technical recommendations:</u>

LoRa and 5G communication technologies are considered. These solutions will have difficulties with replicable to other cities, because of different development of these technologies (for example in some countries the NB-IoT or SigFox are considered for Smart City). Energy elements (e.g. DC smart lamping, waste heat generation, near zero and positive energy buildings) along with storage solutions (deep boreholes, PCM, 2nd life batteries) for increasing grid flexibility and promotion of RES, integrated with mobility aspects (e.g. solar powered V2G) in a district level will in the very near future allow the EU citizens to be autarchies, without experiencing any grid stress problems.

2.1.9 Sharing Cities (http://www.sharingcities.eu/)

The Sharing Cities 'lighthouse' programme in EU funding and starts in 2016. Lighthouse cities are Lisbon - London – Milan. Because of start in 2016, there are many results, which is interesting for Brno:

- current developments on smart lighting (the 'Humble Lamppost')
- Urban Sharing Platform (USP) development

2.1.10 Triangulum (https://www.triangulum-project.eu/)

The three-point project Triangulum is one of currently twelve European Smart Cities and

Communities Lighthouse Projects, set to demonstrate, disseminate and replicate solutions and frameworks for Europe's future smart cites. The Lighthouse Cities Manchester (UK), Eindhoven (NL) and Stavanger (NO) serve as testbeds for innovative projects focusing on sustainable mobility, energy, ICT and business opportunities. The project consortium combines interdisciplinary experience and expertise of 22 partners from industry, research and municipalities who share the same objective and commitment to develop and implement smart solutions in order to replicate them in the three follower cities Leipzig (D), Prague (CZ) and Sabadell (ES) as well as in the Observer City Tianjin (CHN).

2.1.11 REMOURBAN (http://www.remourban.eu)

REgeneration MOdel for accelerating the smart URBAN transformation: The main objective of REMOURBAN project is to deliver a replicable urban regeneration model based on innovative combination of technologies and methodologies demonstrated in the three lighthouse cities1 of the project. This main targeted output of the project is aimed at showing the pathway, or in other words the 'right direction' as a lighthouse does, to cities of Europe (and beyond) towards becoming more sustainable, more attractive and more liveable places upgraded through the deployment of smart solutions and services. The main objective of REMOURBAN project is to deliver a replicable urban regeneration model based on innovative combination of technologies and methodologies demonstrated in the three lighthouse cities1 of the project. Lighthouse cities: Valladolid (Spain), Nottingham (England), Tepebasi (Turkey) The REMOURBAN sustainable urban regeneration model will be designed to offer holistic integrated approaches, jointly in the energy and mobility sectors, plus the ICT potentiality, in which all aspects of sustainability are considered.

<u>Example targets - Low energy districts</u>

- Monitoring tools for energy - Develop and deploy monitoring tools to achieve performances related to energy efficiency and financial viability - Energy efficiency and financial viability progress
- District scale retrofitting - Addition of new technologies of features to old districts. Users comfort improvement - Efficiency and environmental progress
- Renewable heating and cooling - Use of heating and cooling from renewable energy sources - Greenhouse gas emissions reduction. Shift to a new and more sustainable energy scenario
- Electricity disturbed generation - Electricity generation from small scale energy sources located close to where the electric energy is being used - Efficiency improvement because electricity is not transmitted over long distances
- Advanced BEMS - Building energy management system - Electricity generation from small scale energy sources located close to where the electric energy is being used - Efficiency improvement because electricity is not transmitted over long distances.

2.1.12 mySMARTLife (https://www.mysmartlife.eu/)

The mySMARTLife project funded by EU H2020 aims at making the three lighthouse cities of Nantes, Hamburg and Helsinki more environmentally friendly by reducing the CO_2 emissions of cities and increasing the use of renewable energy sources.

Interesting results, which are already deployed:

- In Helsinki, two different storages are considered: one located in the office building Viikki Environmental House and another, a utility scale storage located in Suvilahti. Suvilahti storage can supplement the flexibility from electric vehicles. With smart control of the battery, it can increase the amount and improve the predictability of the charging load flexibly and thus its value in reserve markets.
- new decentralised renewable heat supply in an existing district heating system: Find out more about the research and conclusion in the following publication: Miika Rämä, Mikko Wahlroos, Introduction of new decentralised renewable heat supply in an existing district heating system, Energy, Volume 154, 2018, Elsevier, 1 July 2018, pp. 68-79.
- solar panel benches to be installed in Helsinki
- Self-driving bus in Helsinki

2.2 Worldwide context

2.2.1 Microgrids

The Smart City Malaga Project was launched by Endesa and covers 4 square km around the Playa de la Misericordia and includes 11,000 domestic customers and 1,200 industrial and service customers. The main lines of the Smart City focus on the development of efficiency measures, energy saving and the active management of the demand of individuals consumers, integrating the generation of renewable energy into the grid, storage, electric mobility (charging points for electric vehicles, electric buses and V2G infrastructures), remote management services or information security. Smart City Malaga Project involves also the use of new smart meters in the context of the remote management system enables a much more sustainable electricity consumption, as well as the installation of advanced telecommunications systems and remote controls. Smart city Malaga is based on Smart Grid key components: communications to the end nodes. Communications are based on real-time IP networks for:

- AMI (Advanced Meter Infrastructure)
    - Smart meters (electricity, water and gas)
    - Demand response
    - Smart buildings and homes
    - Smart and informed customers
- ADA (Advanced Distribution Automation)
    - Real-time monitoring
    - Network failure and recovery
    - Network automation
- DER (Distributed Energy Resources)
    - Electric vehicles
    - Energy storage
    - Distributed generation of renewable sources

Remarks to Smart City Malaga Project:

- Real-time communication with PLC communication is not possible.
- The advantages of smart meters deployment in the context of Smart City are not clear.

Japan's First Microgrid System (see Figure 2-11)**.** The microgrid system power a total of 117 homes. A solar power generator (4.6kW), storage cell (11.2kWh) and Home Energy Management System has been installed in each of the homes in this project. Within the housing district, each home's storage cell is connected by private power distribution lines. The storage cell control unit makes it possible to reverse the power flow current and mutually share electric power between homes.

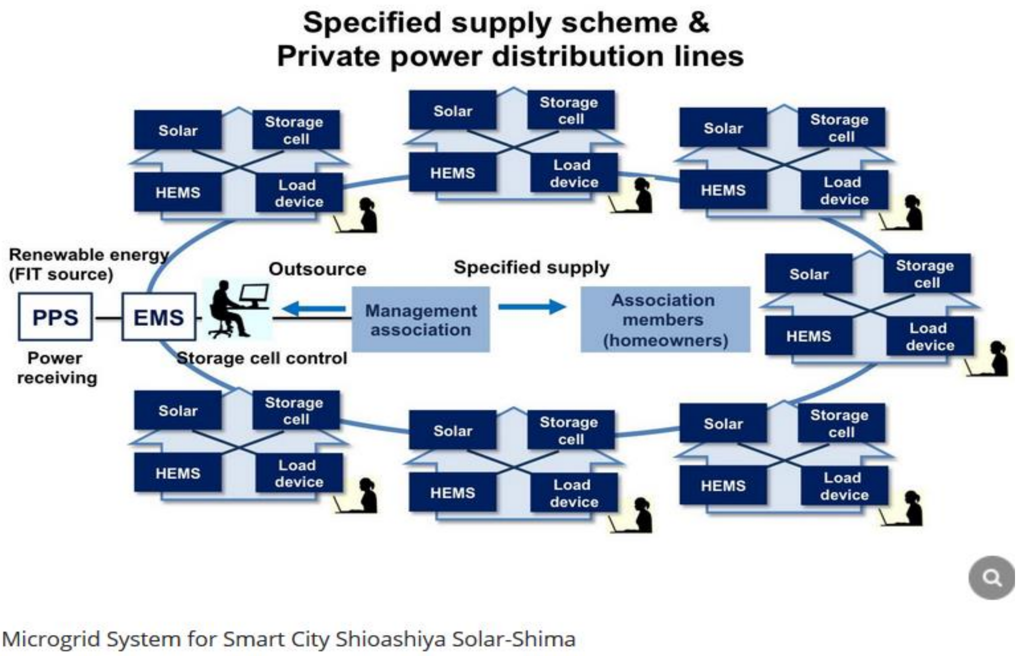

Figure 2-11: Block diagram for Japan's first microgrid system.

2.2.2 Smart parking

Smart parking solutions system optimise parking space usage, improve the efficiency of parking operations and help traffic flow more freely in real time on the housing estate, in malls, airports and so on. The development around Smart parking is driven for example by Nwave or Smart Parking companies from UK United Kingdom [2] [3].

SmartPark solution in UK

In October 2014 Westminster City Council went live with Smart Parking's SmartPark solution, an integrated package of leading-edge technology that provides drivers with real-time information on unoccupied car parking spaces. The deployment includes a network of over 3,400 RFID equipped in-ground vehicle detection sensors which register whether each parking bay is occupied or vacant. This information is relayed live to SmartRep, Smart Parking's powerful car parking management software tool, which collates and analyses the data. The information is fed instantaneously to the council's ParkRight, a simple to use app which drivers can install on their smartphone. The driver then uses ParkRight to identify the best available space and receive clear, precise, GPS-based directions to get them to it. SmartRep software data can also be used for vital future planning to make further improvements to Westminster's parking systems.

Our possible contribution in Smart parking:

- Network based on LPWAN technology
- Evaluation of vendors conclusion - according to our measurements of LPWAN technologies we can evaluated the results of vendors. In Fig. XX are comparison of LPWAN technologies with Nware, these results are not based on real measurements, simulation or evaluation.
- The other technologies from LPWAN, e.g. NB-IoT, must be considered for deployment.

2.2.3 Smart-flooring solution

http://www.pavegen.com/; http://www.birdstldn.com/

The goal of Smart-flooring solution is generating electricity from footsteps. The technology from Pavegen company has evolved from a singular tile, which generates electricity from footsteps, to an entire array with three multi-functional component parts. They to use energy from a footstep to rotate a flywheel [4], [5]. Smart pavement was already deployed in UK or USA in public areas or inside buildings (schools, airports, etc.)

2.2.4 Smart bench

Smart benches powered by solar energy help pedestrians stay connected on the move with mobile charging and wi-fi. The environmental sensors for current environmental conditions, such as noise level and CO_2 were implemented. Five solar benches which can charge mobile devices have been placed in London [7]. Smart living benches with flower panel supporting biodiversity.

2.2.5 Real-Time Traffic Feedback

This affects use of public transit, such as a new project in Kansas [11], [12] that has a free streetcar carrying up to 6,200 passengers a day in a major business district. The success of the program is largely contributed to all the real-time traffic feedback — not just for where exactly the streetcar is always but also the traffic around the downtown area, kiosks that show available parking spaces, etc. (It also helps with ridership that the streetcar has free Wi-Fi.) This 2.2-mile “smart district” corridor even has street lights that dim when there are no pedestrians walking beneath.
Real-time traffic feedback also makes concepts like “congestion pricing” a little easier to sell to consumers who're used to using roads for free. Instead of the typical toll for express lanes, this would change the pricing structure based on peak traffic times and for high-occupancy or exempt vehicles, with the goal of discouraging single-passenger drivers to be on the road at peak travel times.

2.2.6 Replacing Vehicles with Drones

There are some tasks done by city governments like checking water meters and utility lines that don't necessarily need to be done by vehicle. With the emergence of drone technology, more and more utilities and public energy authorities are using drones to do these regular tasks instead of sending out field workers in a bucket truck. Los Angeles is even looking into drone technology to do things like firefighting.
And of course, companies are looking at drone technology to do inner-city tasks too, such as

Amazon's drone pilot program for short-distance deliveries. President Donald Trump just signed an executive memorandum to make it a little easier for these types of companies to test drones in cities.

2.2.7 Interesting documents

1) https://www.tecnalia.com/images/stories/Catalogos/catalogo_FutureCities-SmartCities-EN.pdf
2) https://smartcities-infosystem.eu/sites/default/files/concerto_files/concerto_publications/2014-01_concerto_premium_recommendations_for_policy_makers_final.pdf
3) https://www.iea.org/publications/insights/insightpublications/MarketBased_Instruments_for_Energy_Efficiency.pdf

3 Best cases for Spitalka street and Brno city

There are many interesting projects dealing with Electrical Grid or e-Mobility. However, we need to be careful and take in to the account the replicability of these projects as they are mostly focused on the show-case strategy than the replicability. There are several very interesting ideas, which might apply to the Spitalka project.

- **Include the E.ON distributor** into the process of Spitalka Electrical grid and e-Mobility. The main issue for the smart cities is insufficient discussion over the smart grid or micro grid solution with power distributors. Without enough distribution network, there can't be build reliable infrastructure of the Smart City or reliable services.

- **Follow the ideas in GrowSmarter**. The Smart LED street light, which might also offer the Wi-Fi for the citizens is a very interesting approach, which might bring the smart technologies closer to the citizens. Enough show-case ability and easy-to-replicate put this project as one of the most suitable.

- **Follow the light-city Lisbon in eMobility.** In the case, the Spitalka street will be sufficiently supported project, there might be 1-3 charging stations for e-cars. Therefore, following cities with already build-in charging infrastructure is the right approach, which each city should take.¨

- **The charging stations for e-cars** must be solved and planed in general perspective, it is necessary consider large area, not only Spitalka. This very complicated topics, which is necessary to solve together with utility (they must know the point and predict the charging).

- **Smartflower.** The solar panels, which autonomously follow the sun so they're always at the optimal angle to the sun. Using the renewable energies is one of the most important topics in the energy. Highly efficient solutions, which uses most of the solar power might be the right solution to test in the case of Spitalka street to see its efficiency and suitability for Brno city or bigger cases.

- **Connect with GAS and WATER**. The energy is not alone there as a crucial city asset. There are also water, gas, and others. Connecting the solution for energy with other critical sources is, in our opinion, the right approach. Solving just one part of the solution without thinking about others was never good approach, which mostly end in high-expensive non-interoperable systems, which is very dangerou for sustainability of the city.

- **Focus on own ICT infrastructure**. The ICT infrastructure offers high usability for many different services, analytical data harvesting, sensing, high-modern city management. The ICT infrastructure also help in the case of micro-grid, smart grid and other service-sensor-based solutions. In case of Spitalka, testing own MESH networks such as IQRF, LPWAN networks such as LoRaWAN or even testing comercial solutions such as SigFox or NB-IoT also as prepering for the 5G era is the right approach, which should be considered for selected use-case Spitalka.

3.1 Evaluation of solution for Brno

Overall, Brno is a city with space for realization in most of the mentioned areas of the Light House city solution. The highest potential has in the areas of public transport, automobile transport, energy saving, creating RES and more.

Specifically, these solutions with high potential and benefits can be considered for Brno:

- Smart LED street lighting – already installed in many cities in CZ.
- Smart meter information analysis – one of important thing for future smart grids – information of consumption, power quality in real time (also benefits for customers).
- Big Open Data Platform – important for future research, analysis (especially for universities)
- Urban TRAFFIC – everything connecting to traffic is urgent.
- Smart waste management – Increased recycling rates, conversion of food waste to biogas and up to 90% reduction in transport for heavy waste collection.

Solution which is necessary consider based on CBA analysis:

- New renewable energy sources (RES) – it necessary to consider the number a location, chose the right mix – CBA is necessary.
- Peak load variation management and peak power control – especially for industry buildings or bigger infrastructures.
- RES generation and storage for mobility.

Solution which are necessary consider from the point of view of all Brno city:

- E-charging infrastructure.
- Smart parking lots or BRT-stations.
- Energy-efficient land use through flexible green parking.
- Smart traffic signals.

Solution which is not recommended for implementation according to our best practise:

- Streetlights as Wi-Fi – small benefits.
- Efficient and Smart Climate Shell and Equipment Refurbishment – small potential.

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