RUGGEDISED

Designing smart, resilient cities for all

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Executive summary

In order to "prepare the ground for innovation and implementation of measures in the lighthouse cities", WP 1 of the RUGGEDISED project develops a process to facilitate the lighthouse cities in implementing the smart solutions. This process is based on learning across the cities by exchanging experiences, discussing challenges and articulating the need for support from the supporting partners (TNO for Rotterdam, SP for Umea, and University of Strathclyde for Glasgow). Cross-city learning will take place in Liaison Groups that provide cities with a seamless knowledge brokerage service to transfer and translate state-of-the-art knowledge into practice.

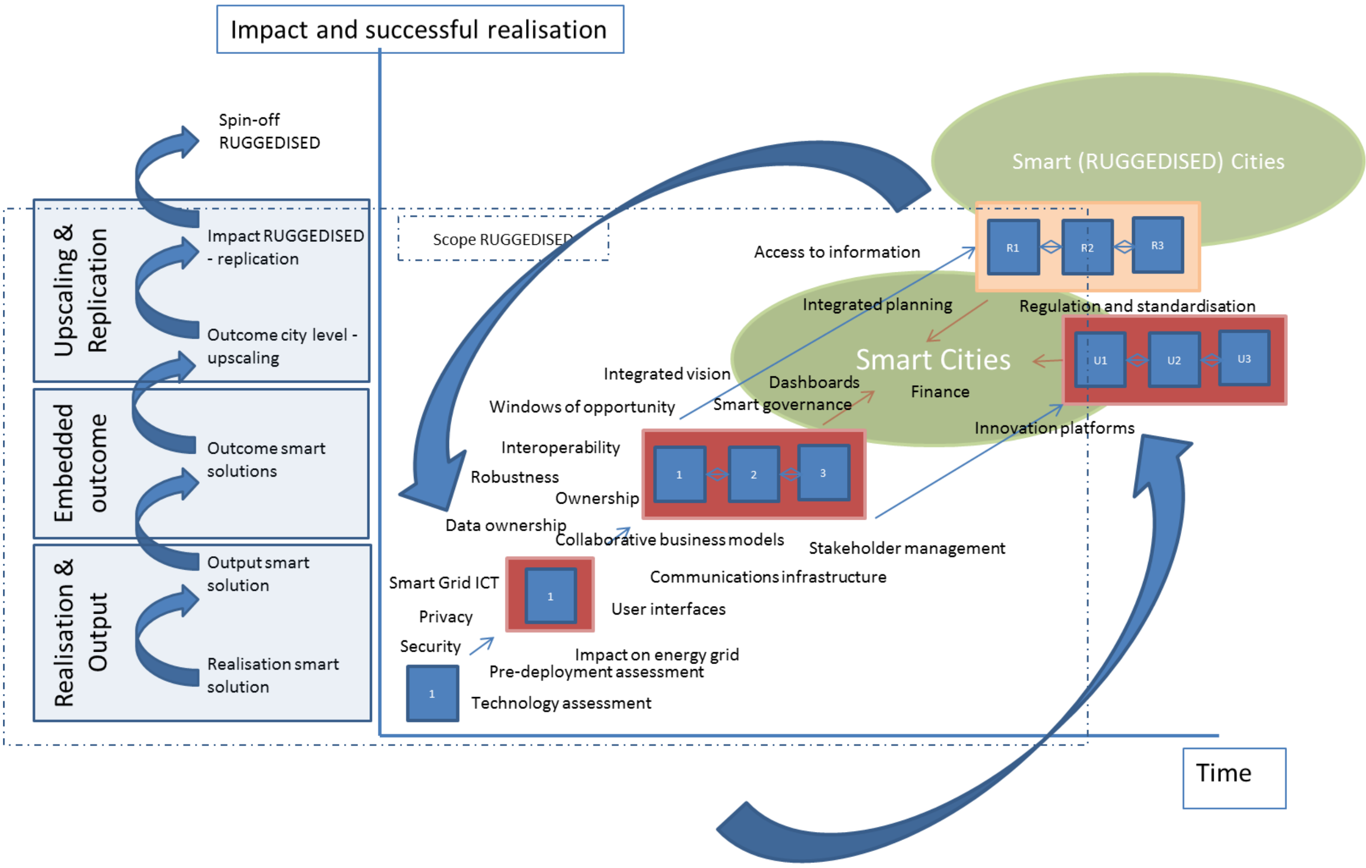
To identify and structure the specific interest areas where the lighthouse cities could require expert support and cross-city knowledge transfer the "overarching innovation and implementation framework" (the framework) for smart cities has been developed. The framework is based on input from practitioners from the lighthouse cities and on relevant theoretical considerations from literature on smart city innovation, implementation and governance. The framework provides a clear definition and operationalisation of smart cities. It addresses the main technical and socio-economic challenges and contextual factors that influence (enhance or suppress) local innovation and the implementation of smart solutions in each of the lighthouse cities.

The framework allows to:

- Identify areas where the lighthouse cities require expert support and/or cross-city knowledge transfer;
- Create a knowledge base to facilitate the implementation of smart city solutions by describing the state-of-the-art and next steps;
- Embed smart city solutions and knowledge development in the city innovation ecosystem;
- Address the topics that are relevant for implementation of smart solutions and that could be monitored during the implementation phase;
- Implement the smart city solutions in such a way that upscaling and replicability is facilitated;

The framework distinguishes between six steps of realisation that are relevant for the impact of smart city solutions on different levels. These steps of realisation start with a 'simple' and isolated **realisation of a smart solution** in a city. The next step is that a smart solution will produce real **output** if it is well-embedded in the existing urban context. Multiple smart solutions may then successfully produce **outcome** if they are well connected and collaboratively work in an efficient manner. **Outcome at the city level** will be reached if smart solutions go beyond being 'pilot' projects and are successfully up scaled within the same city. Together they constitute a smart urban structure. Real **impact** of the RUGGEDISED project, in terms of the replication of smart solutions, is reached if smart solutions are successfully replicated in the RUGGEDISED follower cities. The **spin-off** of RUGGEDISED is realised when other EU-cities take up the lessons learned and smart solutions.

Through distinguishing different levels of impact we can structure the factors that influence the implementation of smart solutions and their success. For instance, some factors primarily affect the level of implementation and some specifically enhance or suppress that several solutions together produce collaborative smart outcomes. Others are in particular relevant to improve upscaling and replication (see figure).



The framework can be used by city planners and other actors to prepare the implementation process and to assess what aspects need additional consideration. Such assessments stimulate continuous learning of all partners by exploring obstacles that might appear during the process.

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1. Introduction

1.1 RUGGEDISED and Smart Cities; the need for an overarching innovation and implementation framework

In Work Package 1 of the RUGGEDISED project, the first task is to "prepare the ground for innovation and implementation of measures in the lighthouse cities". With this aim WP 1 develops a process to facilitate the lighthouse cities in implementing the smart solutions. This process is based on learning across the cities by exchanging experiences, discussing challenges and articulating the need for support from the supporting partners (TNO for Rotterdam, SP for Umea, and University of Strathclyde for Glasgow). Cross-city learning will take place in Liaison Groups that provide cities with a seamless knowledge brokerage service to transfer and translate state-of-the-art knowledge into practice, see figure 1. Furthermore, the lessons taken from the cross-city learning will also facilitate replication and upscaling of the solutions in the follower cities (Brno, Gdansk and Parma) and other EU-cities.

Figure 1 – Knowledge exchange between RUGGEDISED Cities

In order to identify and structure the specific interest areas where the lighthouse cities require expert support and cross-city knowledge transfer, an overarching innovation and implementation framework has been developed. The framework is based on input from implementation practitioners from the lighthouse cities and on relevant theoretical considerations from literature on innovation, implementation and governance. The framework provides a clear definition and operationalisation of smart cities. It addresses important technical, socio-economic and contextual factors that influence (enhance or suppress) local innovation and the implementation of smart solutions in involved lighthouse and follower cities as well as in the wider community of EU-cities. The overarching smart city innovation and implementation framework provides actors who want to implement local smart solutions in their cities with an overview of relevant aspects, structures and feeds the discussions in the Liaison Groups of the Lighthouse cities, and links smart city solutions with the existing state-of-the-art knowledge, innovation management, policy and smart city governance.

The framework allows to:

- Identify areas where the lighthouse cities require expert support and/or cross-city knowledge transfer (connection to Work Packages 2 - 4)
- Create a knowledge base to facilitate the implementation of smart city solutions by describing the state-of-the-art and next steps (connection to Work Package 8)
- Embed smart city solutions and knowledge development in the city innovation ecosystem
- Address the topics that are relevant for implementation of smart solutions and that could be monitored during the implementation phase (connection to Work Package 5)
- Implement the smart city solutions in such a way that upscaling and replicability is facilitated (connection to Work Packages 6 - 7)

The current Deliverable 1.2 presents the “overarching innovation and implementation framework”.

1.2 Methodology

During the RUGGEDISED kick-off in November 2016 all consortium members (lighthouse cities, implementation partners, knowledge partners, and others) were asked to indicate factors that will potentially enhance or suppress the implementation of the smart city solutions in the lighthouse cities. These ‘enhancers’ and ‘suppressors’ were further elaborated, categorized, and complemented with factors from a literature review after the kick-off meeting. We translated them into a logical draft ‘innovation and implementation framework’. In January 2017 we organised a workshop in the frame of Work Package 1 in Delft, The Netherlands, to further discuss the draft framework and the enhancing and suppressing factors. During this workshop participants from the lighthouse cities and supporting knowledge partners further detailed the framework and discussed the particular challenges regarding the enhancers and suppressors. Moreover, a detailed action list and task division was made to complete this Deliverable 1.2. Each participant to the WP 1 workshop in January 2017 contributed to this deliverable with either input on specific city challenges or input on state-of-the-art knowledge and practice related to the framework, enhancers and suppressors. A literature review was done to complement the suppressing and enhancing factors further.

1.3 Reading guide

The Deliverable is structured as follows. In the next chapter the framework is presented. Chapter 3 describes the concept Liaison Groups and links the framework to the knowledge brokerage service. Chapter 4 explores the lighthouse city challenges related to the different components of smart cities: hardware, software and orgware. Chapters 5 – 7 elaborate on the framework in more detail. For each factor relevant to the implementation of smart city solutions recent scientific insights and practical know-how are provided. In chapter 8 conclusions are drawn and the enhancing and suppressing factors are prioritized. The conclusion analyses how particular challenges faced by the Lighthouse cities can be tackled and, the other way around, what contribution RUGGEDISED can make to increase the scientific and practical knowledge base on the implementation of smart city solutions.

2. Smart cities innovation and implementation framework

2.1 The framework

"A smart city is a place where the traditional networks and services are made more efficient with the use of digital and telecommunication technologies, for the benefit of its inhabitants and businesses. The smart city concept goes beyond the use of ICT for better resource use and less emissions. It means smarter urban transport networks, upgraded water supply and waste disposal facilities, and more efficient ways to light and heat buildings. And it also encompasses a more interactive and responsive city administration, safer public spaces and meeting the needs of an ageing population" [1]. A recent study for the European Parliament (Manville et al., 2014) defines a smart city as 'a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership'. 'Smart City' initiatives are then multi-stakeholder municipally based partnerships aimed at addressing problems of common interest with the aid of ICTs, which underpin 'Smart' classification.

Cities are complex (eco)systems. City developments, such as new housing and infrastructure schemes, influence these systems. They connect and shape places and change daily patterns between various functions of the city. Planning, designing and implementing such city development have always been difficult. Predicting the impact of city developments on the functioning of the city ecosystem is challenging. Moreover, embeddedness in and connection to the existing urban configuration is crucial for new urban development projects to function well. In this regard, implementing smart solutions may be even more challenging than traditional urban developments, since smart city measures by nature have a networked and connected character. This is why successful implementation of smart solutions more than ever relies on embeddedness in the complexity of the existing urban innovation (eco)system.

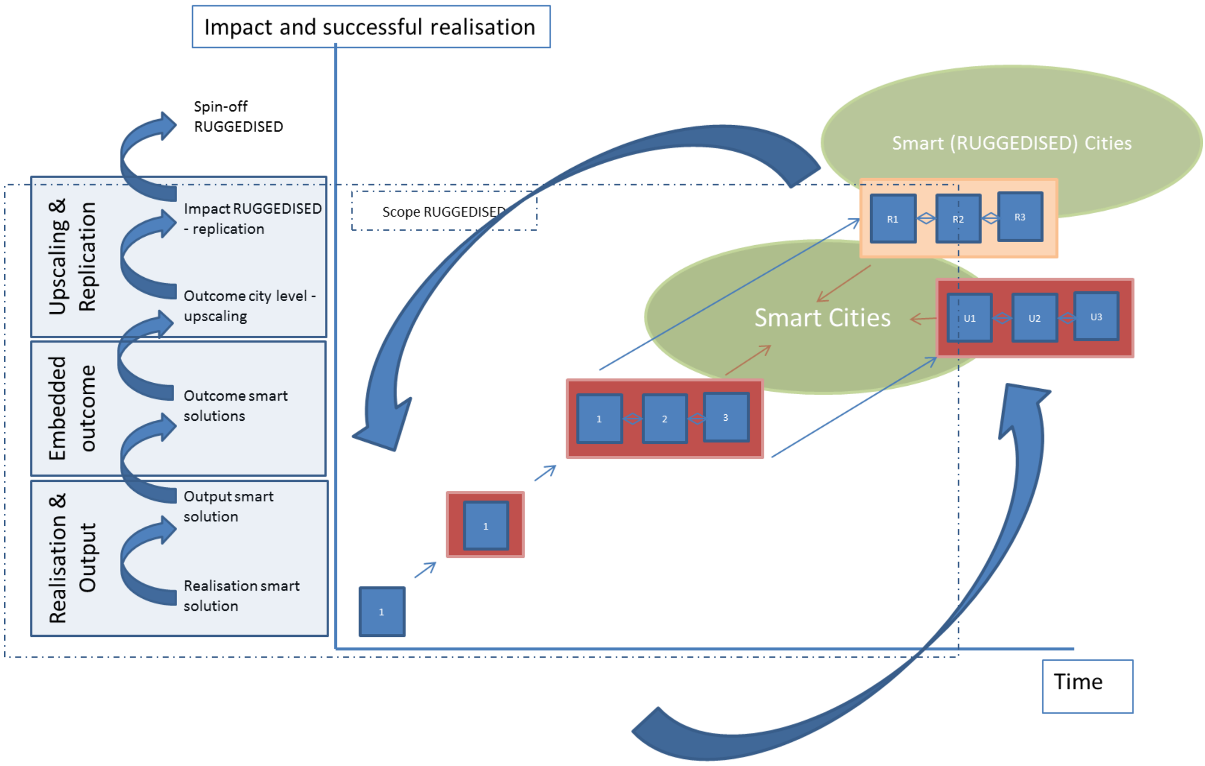


Figure 2 – Overarching Innovation and Implementation Framework

[1] https://ec.europa.eu/digital-single-market/en/smart-cities (20-04-2017)_

Considering this networked character of smart solutions, and in order to get grip on the factors that may influence their implementation, it is important to think beyond implementation and look at the real success or impact a smart solution has. Therefore, the "overarching innovation and implementation framework" (Figure 2) distinguishes between six steps of realisation (vertical axis) that describe three different levels of impact that are interrelated. The first step in this concept is a 'simple' and isolated **realisation of a smart solution** in a city. A smart solution produces real **output** if it is well-embedded in the existing urban context. Multiple smart solutions may successfully produce **outcome** if they are well-connected to each other and collaboratively work in an efficient manner. **Outcome at the city level** will be reached if smart solutions go beyond being 'pilot' projects and are successfully up scaled within the same city. Together they constitute a smart urban structure. Real **impact** of the RUGGEDISED project is reached if smart solutions are successfully replicated in the follower cities, in different contexts. The **spin-off** of RUGGEDISED is realised when other EU-cities take up the RUGGEDISED lessons and smart solutions.

Through distinguishing these steps of realisation we can structure the factors that influence the implementation of smart solutions and their level of impact. For instance, some factors primarily affect **realisation and output** and some specifically enhance or suppress that several solutions together result in **embedded outcomes**. Others factors are in particular relevant for **upscaling and replication**. The framework ideally works in such a way that each RUGGEDISED smart city solution can be assessed on its potential impact on different levels, while analysing in detail how enhancing and suppressing factors play a role for that particular solution. On the basis of such assessments city planners and other actors can design a successful implementation process, assess the potential impact, and select specific aspects that need further consideration for a successful implementation.

It also works the other way around. Upscaling and replication is not something that comes after successful implementation. If real impact through upscaling and replicability is pursued, than factors that influence the success of upscaling and replication should be taken into consideration early in the process. It might be problematic if a smart solution is well-implemented, however without taking into consideration the requirements for successful upscaling or replication. From a RUGGEDISED or smart city perspective the impact of successful implementation is then rather limited.

The framework is an analytical tool that helps city planners and smart city practitioners to assess the enhancers and suppressors in the implementation process of their smart solution(s). Such assessments stimulate continuous learning of all partners by identifying obstacles that might appear during the process well in advance. Moreover it explicitly links these implementation challenges to theoretical and practical state-of-the art knowledge on the specific topic that actors need to put extra effort in. The framework thus provides the supporting knowledge partners in RUGGEDISED a structure to build and exchange knowledge in a coherent manner. The different levels of impact are discussed below. Moreover, a list of the RUGGEDISED smart solutions is included in Appendix A.

2.1.1 Elaborating the different levels of impact

The first level of impact is a combination of the realisation and output of a smart solution, the second level of impact relates to the outcome of a combination of several smart solutions that should work together, and the third level of impact refers to both upscaling and replication of the smart solutions. RUGGEDISED spin-off (the fourth level of impact) is beyond the scope of this project. The three levels of impact are elaborated below.

Level of impact 1: <u>Realisation and output</u> of a smart solution
The first level of impact of a single smart solution is its successful implementation and delivering its output.

For instance, the smart electric or thermal grid are developed and ready for use. However, such implementation sometimes occurs, due to several legitimate reasons, in an isolated manner. That is why successful realisation does not automatically mean that the smart solution will produce the intended output. In order to produce real output a smart solution should be used by its stakeholders in the longer term and in a sustainable way. Embeddedness in the existing urban innovation ecosystem is of great importance to guarantee awareness and acceptance. Project development should explicitly address contextual factors, and actors should explicitly seek to connect the smart solution to its physical, social, economic and institutional environment.

Level of impact 2: Embedded outcomes of multiple smart solutions
Several smart solutions in an area are interlinked. Establishing these linkages and effectively exploit them is a challenging task, but will ultimately result in smart districts. Connective project development refers to the aim to explicitly connect several smart city solutions with each other. More than was the case in traditional urban development, smart city development is about integrating infrastructures, communicating systems, connectivity and data exchange. Collaborative business cases, interoperability and openness are important prerequisites to successful connect different smart solutions.

Level of impact 3: Upscaling and replication
If implementation experiences and knowledge of smart solutions are transferred to other parts of the city, this ideally leads to a city-wide smartness. Such upscaling leads to reaching smart city ambitions, however it requires well implemented and successful smart solutions in earlier stages, ongoing innovation and maturity of business cases. The main difference between upscaling and replicability is that the smart solutions will be implemented and embedded in totally different social, economic and institutional contexts. In order to ensure replicability - the smart solutions should be really robust and flexible.

2.1.2 Hardware – Software – Orgware

Apart from the 'level of impact' structure that is introduced in the smart cities innovation and implementation framework, the framework also distinguishes between factors influencing the hardware, software and orgware components of smart solutions. In each of the lighthouse cities measures will be taken on energy and electric mobility, which will require further system integration, infrastructure provision, energy storage, conversion and energy saving, in order to reach the energy and CO_2 reduction targets. These 'hardware' measures will be supported and managed by the 'software' measures, such as ICT applications. Both hardware and software solutions will be facilitated by stakeholder management, institutional and organisational arrangements, innovative business models and local innovation platforms. This is the 'orgware' part of RUGGEDISED. Together they form an integrated mix of measures to reach energy and CO_2 reduction.

The framework should stimulate a smooth knowledge brokerage process, and therefore it is crucial to carefully demarcate the issues that are at stake. A detailed subdivision between levels of impact and different components allows for such knowledge development and – exchange. Table 1 presents the enhancing and suppressing factors that may influence the impact of smart city solutions at each level and for each component. These factors are a composition of the input of factors mentioned by the city actors and complemented with factors from a literature review (see 1.2). The factors will be further analysed in the next chapters.

Table 1 – Enhancing and suppressing factors

Level of impact 1: Realisation and output of smart solutions		
Hardware	**Software**	**Orgware**
Pre-deployment assessment	Privacy	Business models
Technology assessment	Security	Data and data ownership
Impact on energy grid	Smart Grid ICT	
	User Interfaces	
Level of impact 2: Embedded outcomes of multiple smart solutions		
Hardware	**Software**	**Orgware**
Communicating infrastructure	Interoperability	Integrated vision on the smart city
Robustness of the system	Dashboards	Smart governance
		Windows of opportunity
		Stakeholder management
		Ownership
		Business models and split incentives
Level of impact 3: Upscaling and replication		
Hardware	**Software**	**Orgware**
		Integrated planning
		Innovation platforms
		Conditions for upscaling: finance, regulation (including standardisation), access to information and social aspects

From this table it can clearly be seen that the first level of impact is influenced by many hardware and software aspects, and few orgware aspects, while the opposite is the case for the higher levels of impact. Impact level “upscaling and replication” is even only influenced by orgware factors.

3. Liaison Groups

The framework is an important basis and guideline for the thematic Liaison Groups that were established in the RUGGEDISED project. Three thematic groups were formed; on hardware, software and orgware components. In each group at least one person from each lighthouse city participates. Moreover, the knowledge partners (TNO, SP and University of Strathclyde) are also part of the Liaison Groups (a list of the participants is included in Appendix B). The local implementation partners are welcome to join the discussions. The lighthouse cities take the lead in inviting them to the discussions. This is to ensure that the cities themselves orchestrate the process. The Liaison Groups meet twice a year during the first three years of the project. Sometimes the three groups meet all together and sometimes they only meet with the specialists of one of the tracks.

The liaison groups provide the local consortium partners with a seamless knowledge brokerage service. Within the Liaison Groups state-of-the-art knowledge, expertise and examples are discussed and learning experiences are exchanged. To ensure that the local consortium partners in in the lighthouse cities do not work in isolation, the groups are meant to engage peers in the other lighthouse cities, including those working in the follower cities. This peer to peer learning enriches the design of smart solutions and improves their implementation processes.

For the Liaison Groups the framework serves two main aims. First, it identifies the areas where the lighthouse cities require expert support and cross-city knowledge transfer. It are the enhancing and suppressing factors that the participants will continuously discuss. The knowledge partners will make sure that state-of-the-art knowledge feeds into the cities' processes. Moreover, they will also enrich the (academic) literature on smart cities by analysing and embedding the lessons learned from the Lighthouse cities. Secondly, the concepts of different impact levels (realisation and output, embedded outcome and replication and upscaling) and different components (hardware, software and orgware) serves as a structure to improve the integrated smart city design. The framework structure challenges participants of the Liaison Groups to think over how their implementation endeavours can be embedded in the broader context of sustainable impact.

During the RUGGEDISED projects the framework will be enriched by the experiences gained in the lighthouse cities. The enhancing and suppressing factors will be further elaborated during the course of the implementation process of the smart solutions. Together with the lighthouse cities the RUGGEDISED knowledge partners will dissiminate the rich empirics and contribute to the improvement of the smart city discourse.

4. Main challenges in the lighthouse cities

This chapter describes the main challenges that the RUGGEDISED lighthouse cities (Rotterdam, Umea and Glasgow) are currently facing. Each section starts with a brief recap of the challenges presented in the RUGGEDISED proposal. These are further elaborated, focussing on their specific hardware, software and orgware components. During the course of RUGGEDISED, as the project develops, these challenges will change and will be subject to a continuous dialogue in the Liaison Groups.

4.1 Rotterdam

Challenges presented in the RUGGEDISED proposal

The Heart of South district is a very large area (re)development of approximately € 330 million in the centre of the South of Rotterdam. The South of Rotterdam faces relatively severe social-economic challenges, like low education levels and unemployment, accompanied by a young and multi-cultural population. The area currently is dominated by a car-oriented infrastructure where citizens and visitors sometimes feel estranged.

The Heart of South district will undergo a serious transition in the upcoming years, consisting of the sustainable renovation of an outdated shopping centre, the renovation of the public transport hub and various large-scale multifunctional buildings (like a swimming pool, arts building, exhibition halls, congress centre and so on). Furthermore, the public space in the area will be drastically redeveloped. With a focus on the Heart of South, the city of Rotterdam will prepare the district for the future with the aim to achieve maximum energy efficiency and CO_2 reduction, in addition to the aim to achieve major socio-economic impact as well (jobs, new levels of participation of citizens, quality of life).

The entire renovation and the construction of the new buildings were innovatively tendered together with a twenty-year maintenance of the area by the municipality of Rotterdam. A coalition led by Ballast Nedam/Heijmans won the tender in 2013. The actual renovation and construction of new buildings will start in 2017 and will be finished in 2023. With the Heart of South project the city of Rotterdam as well as Ballast Nedam/Heijmans underline an enormous ambition for the area. And this ambition can be improved substantially by adapting the challenge to connect buildings, mobility, energy sources by using ICT-systems in a smart way.

The public-private partnership between the city of Rotterdam and Ballast Nedam/Heijmans is the most far-stretched form of public-private partnership to date. Never before a project with this scale and scope was tendered as a single PPP-project. Special attention is paid to maximizing the social impacts of the upgrade. By supporting easy involvement and participation of citizens to urban development - via better opportunities to effect and give feedback - Ballast Nedam/Heijmans significantly reduces urban planning timescale and amount of complaints about new plans. In the zoning- and urban planning process Ballast Nedam/Heijmans developed the knowledge to involve stakeholders in an interactive planning process so that maximum support is created among the population. It is exactly this knowledge that will be utilized to increase support for solutions such as the Geothermal heat-cold storage and heat pumps and the Energy Management system. The challenge is not only in the technical application of solutions, but certainly also in the organization of a region-wide collaboration in which all stakeholders contribute to the realization of an energy neutral area. The interactive approach by Ballast Nedam/Heijmans involves all major stakeholders in the region, without losing attention for the individual home-owner. Involving all stakeholders in the process is an important condition for realizing an intelligent, user-driven and demand-oriented city infrastructure.

4.1.1 Hardware components

The design scale of a smart energy system

Together with Technical University Delft, Rotterdam developed a stepped approach for optimized design from an energy point of view. This Rotterdam Energy Approach and Planning (REAP) (Tillie et al., 2009) is inspired on the Trias Energetica and consists of three steps:

1. Reducing the energy demand (e.g. isolation measures)
2. Reuse waste streams (e.g energy and material)
3. Use and generate renewable energy

In practice it is still difficult to skip the old last step "generate remaining energy clean and efficiently". See the figure below for the new stepped approach.

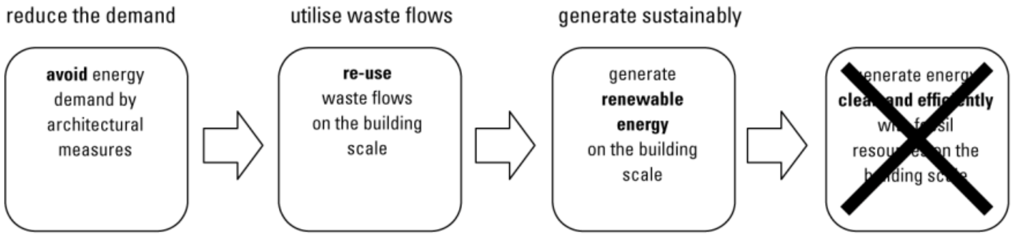


Figure 3 – REAP the new stepped approach

This REAP strategy is worked out for different scales, from building - to city-wide scale. It served as a framework for the Rotterdam RUGGEDISED project. See the figure below. The project in the Heart of South is at the district scale and connects at the city scale to the communal heating grid. It appeared to be impossible to reduce, reuse and generate sufficient renewable energy at the individual building scale. However, by connecting the buildings through a thermal and electrical smart grid, a common backbone exchanges, balances and stores the energy. This scale also stimulates economic feasibility, since common infrastructure can be shared.

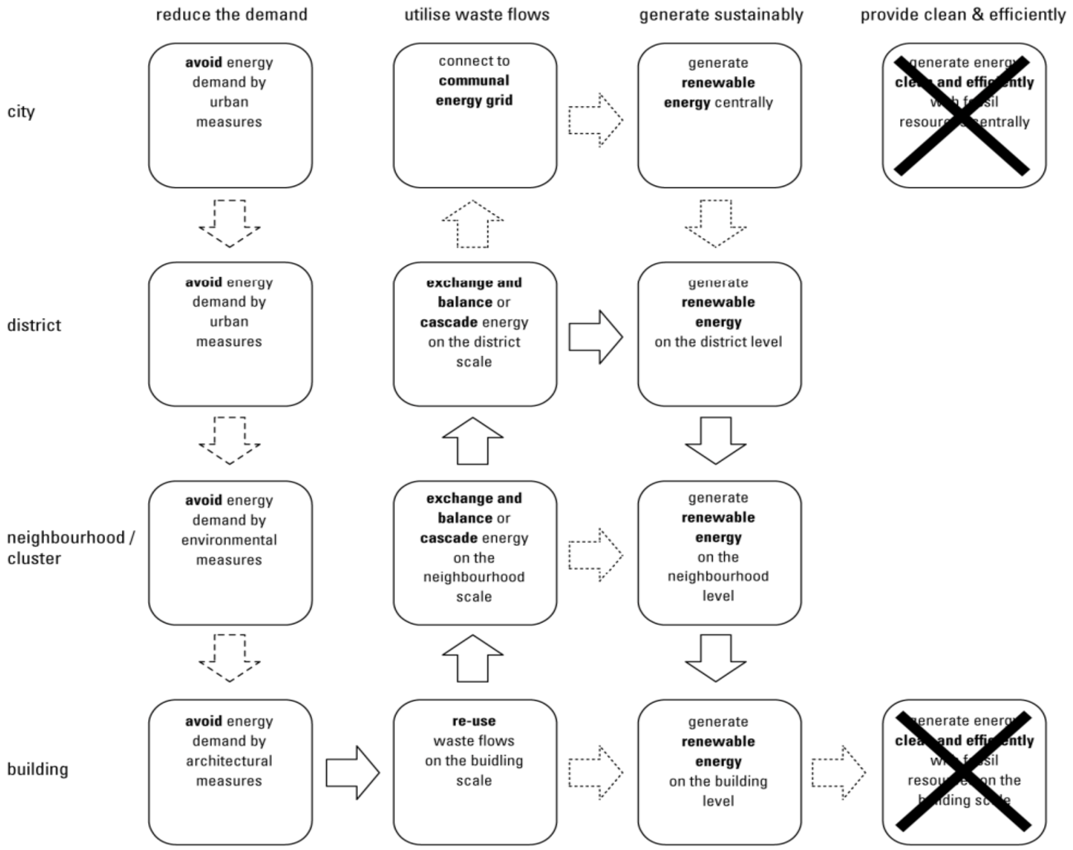


Figure 4 – REAP strategy

However, the big challenge is to interconnect the different measures, buildings and mobility infrastructure in a smart and interdisciplinary way, in order to establish an integrated energy solution for the area. The best example to illustrate this interconnectedness is the foreseen coupling of the electric quick charging point of the bus company via a DC cable to local generated solar energy which also can be stored in batteries. Mobility and energy come together. Another integrated solution is the smart thermal grid which connects the big buildings in the area to facilitate low temperature heating and high temperature cooling. From an efficiency point of view this solution is crucial, since it allows to exchange both heat and cold between buildings and store it in a seasonal aquifer thermal energy storage (ATES). Since it concerns various functions, for instance during summer time waste heat from the arts building can be used immediately by the swimming pool. The ATES can store the waste heat and cold for a short and long period and is used to balance the whole thermal system.

Baseline energy situation

The relevant success indicators (KPI's) for sustainable solutions, CO_2 reduction, will be monitored (in work package 5) and the effect of the measures will be calculated in respect to the baseline situation. There are several challenges here. For instance, looking at the smart thermal grid, the baseline situation is already quite sustainable in a sense. The city heating network is regarded as the baseline, which has already a high coefficient of performance (COP). Furthermore it is regarded as a low carbon energy source. This is due to the fact that its most important heat source, a waste incineration plant, is regarded CO_2 free. This is rather doubtful from a life cycle analysis (LCA) perspective since around half the amount waste has a fossil origin. Moreover, heat production is one of the primary targets of the incineration plant and therefore can be seen as a primary process. It is then logic to allocate the CO_2 emissions accordingly.

A second baseline challenge refers to the function of the smart thermal grid to cool the utility buildings (e.g. congress center, theatre and exhibition halls). Cooling with conventional compression chillers is considered as the baseline. This baseline situation already causes low CO_2 emissions since the CO_2 emissions from the national electricity grid are relatively low and, at the same time, the efficiency of the compression chillers is already high.

Finally, the low price of both heat and cooling in the baseline situation is a complicating factor in developing a positive business case for the smart thermal grid. Since the buildings are regarded as big electricity consumers, a real low electricity price is contracted varying from 5 to 8 cents per kWh. The price of the baseline city heating is calculated in reference to the price of natural gas heating with individual boilers, which is very cheap in the Netherlands, especially for big heating consumers.

Preventing a sustainability lock-in - energy demand versus demand reduction

An important first step in the above mentioned REAP strategy is to reduce the energy demand. This has a far better return on investment (ROI) than generation of sustainable energy to compensate the energy consumption. For heating and cooling, the challenge here is that this step lowers the density of the energy demand. This causes a relative big share of costs for infrastructure for exchanging energy between buildings. So there is a point where demand reduction on individual building scale causes a negative business case for exchanging energy between buildings. The key here could be to use relatively cheap common infrastructure, which is possible because of the relative low temperatures which prevent the necessity of insulated expensive pipes.

4.1.2 Software components

Data ownership

A smart city needs to be able to use all the data coming from the several measures. Rotterdam is building a datahub (data management and data lake) and a 3D visualization platform. The challenge here is that the city often only has access to data as a user, but isn't owner of the data. This makes multiple use of this data difficult. For instance, this problem arises for the data collection of smart waste management. A third party collects and owns the data.

Standardisation of software connections

A necessity for feeding in data to the datahub is a standardized connection for data sources for both the input and the output. Since there are a lot of measures which produce and use data, this is a challenge. It is also a challenge to future proof this standard. We will need good collaboration with all involved data stakeholders.

Energy management

For monitoring the energy performance of the buildings, all buildings will be fitted with an energy management system. The challenge is to build in a hierarchy in the system in order to control the different systems on building level. This is a necessity to be able to pro-actively exchange energy between buildings and functions. The smart thermal grid really needs this, not only for monitoring but finally also for managing the energy streams. Such a district energy management system does not exist yet, but will be developed during RUGGEDISED.

4.1.3 Orgware components

The design for the development of the Heart of South area started already 10 years ago. The contract was signed in 2013 and resulted in a highly ambitious public private partnership contract for an unprecedented long period of 20 years. Consequence of this long design and contract period is that several sustainability measures and goals are outdated. With RUGGEDISED the challenge is to make the area development again up to date and align it with the high standards of a smart city level.

The main challenge here refers to planning and timing. For some buildings the development phase just started, so the smart solutions of RUGGEDISED have to be fitted within the existing planning of the area development. This urges to be flexible from the side of the area development team, but also from the side of the RUGGEDISED team. Sometimes minor changes are needed in the original design to be able to implement measures from RUGGEDISED. The coordination between both teams is crucial.

4.2 Umeå

Challenges presented in the RUGGEDISED proposal

Smart city thinking is at the core of the City of Umeå's overall vision of continued social, economic and environmental sustainable growth, and this is outlined annually by the City Council as well as in the six development strategies adopted in the city-wide master plan. From a smart cities perspective, this results in the will to develop the city as a whole, focusing on:

- More efficient land use to optimise efficiency of new urban qualities in a growing city, such as additional housing and green spaces. This implies working to reduce needs for car parking, new solutions for urban drainage systems as addressed in this project's smart solutions. This will be an important contribution to the city objective to reduce fossil CO_2 emissions by 50 % by 2025 (compared to 1990).
- More public transport, cycling, walking (this share should be 65 % of total city residential travel share by 2022), as addressed in this project's smart solutions.
- Less car use, and promoting transfer to more sustainable motorised transport modes (e.g. electrified public transport, electric cars) to reduce climate impact, but also reduce noise and air pollution etc., as addressed in this project's smart solutions.
- Smarter energy system solutions, with lower climate impact, integrating grid owners and property owners

and involving end users to reach the objectives of a climate neutral energy system by 2018. Building on the city's move towards a climate neutral energy system, coupled with rapid urban growth, incurs a smart focus on curbing maximum power usage in developing the city, as is the outlined joint strategy of the partners in the innovation area of the University city, also addressed in this project's smart solutions.
- Open up relevant data created in the district to generate new knowledge and engagement with citizens, research, planners and other strategic uses, as addressed in this project's smart solutions.

Umeå will focus on an Innovation District that is situated immediately to the east of Umeå city centre, the University City area. This area includes a mix of residential, academic and research facilities from two universities, a regional hospital, and community, recreational and commercial buildings. RUGGEDISED will facilitate a unified 'smart district', which is underpinned by planned regeneration and new developments, existing smart city capabilities and committed public and private sector investments of at least 600 M€ in the period 2016-2025.

Umeå is the fastest growing city in Sweden, north of the Stockholm region. The University City area is the largest workplace hotbed in northern Sweden, and has both local, regional, national and international relevance. Despite its close proximity to the city centre, the Campus Innovation District has historically not always been perceived as an integrated part of the city. The neighbourhood is characterised by its young, student-influenced, population. As such, the neighbourhood is one of the least car-dependent neighbourhoods in Umeå. For example, the share of cars in the district is only 33% compared to the citywide 54%, and the share of bikes is 42% (citywide 25%). This makes the University City an interesting district for new smart solutions and business models that are more dependent on prevalent sustainable mobility options.

4.2.1 Hardware components

Umea currently faces challenges that are related to the software and orgware components, rather than the technical hardware side.

4.2.2 Software components

Data ownership
Regarding the open data platform one of the challenges is going to be to successfully communicate to different kind of stakeholders why they should contribute with their data. Some of the data that should be of interest for both the citizens and the public sector are today not officially owned by the city. In Sweden there still is a lot of scepticism towards releasing data, which means that a lot of work has to be done in communicating the value of an open platform, both towards stakeholders but also in relation to citizens.

Another problem could be that we have agreed with stakeholders to release their data when in fact it is owned by someone else, for instance the company providing the measuring tool. When the ambition (from the city) to open up and publish data for free collides with private interests difficulties may arise in finding a way that suits both interests.

4.2.3 Orgware components

Business models and split incentives in sustainable energy (exchange)
Current business models used in Umea handle a steady state relation between supplier and customer of energy. Today, however, this equilibrium is challenged by the local energy prosumers on the grids. There is a need to adapt the business models to better fit the new relation. This shift in market setup can be found all over the EU and through different utilities, therefore international knowledge exchange is crucial.

Another problem is related to the split incentive issue. Split incentives are currently hampering actors in taking energy efficiency measures across the value chain. This closely relates to innovative business model setup. The challenge is to develop value propositions that can create value across business interfaces.

Stakeholder management

A final consideration refers to stakeholder management. It is easy to forget about the consumer perspective, when looking at complex smart grids and different layers of hardware- software. How can the project involve stakeholders outside utilities and property owners? Can we share knowledge around involving customers in smart grid systems?

4.3 Glasgow

Challenges presented in the RUGGEDISED proposal

Glasgow is committed to long-term plans for transformation and sees the benefit of deploying smart city solutions in order to create a sustainable, connected and healthy city. This will be achieved through innovative smart city approaches, like the Future Cities Demonstrator; tackling environmental, infrastructural and socioeconomic challenges and providing resilient solutions that integrate with Glasgow's strategic priorities. Some of Glasgow's key Smart City projects are:

1. Sustainable Glasgow is the city's partnership for driving its ambition to be one of the most sustainable cities in Europe over the next 20 years. It brings together a range of partners from principal sectors with the aim of achieving progress across environmental, social and economic aspects of sustainability. One principal objective is to ensure that Glasgow achieves a 30% reduction target in CO2 emissions by 2020. Sustainable Glasgow has a SEAP as a guiding strategy for transition to a low carbon future.
2. The Energy & Carbon Masterplan (ECM) was initiated through the FP7-funded STEP UP (Strategies Towards Energy Performance and Urban Planning) Project. STEP UP sought to build on the original SEAP enhancing its actions and make it more robust. The ECM will achieve Glasgow's carbon reduction target through strategic actions like a waste to energy plant and district heating.
3. In 2014 Glasgow was named as a member of the Rockefeller Foundation's 100 Resilient Cities. Glasgow is developing a strategy that will help increase the resilience of the city in five key areas identified through engagement across the city: health & wellbeing, economy & society, infrastructure & environment, leadership, and strategy.
4. In 2013 Glasgow was awarded £24 million (32 M€) to act as THE UK demonstrator site for Smart City capabilities for Innovate UK. The Future City Glasgow programme developed an operations centre which integrates traffic management, security, and public space CCTV; a City Data Hub which hosts open data in health, energy and socio-economics; applications encouraging citizen engagement in active and social transport; mapping analysis of the city to identify opportunities for renewable energy; and Intelligent street lighting with sensors to demonstrate public safety and energy efficiency. 5. The Digital Glasgow programme aims to make Glasgow a leading digital city by 2020, establishing it as a centre of digital innovation. Through this programme free Wi-Fi access in the city was secured for the Commonwealth Games in 2014. The telecommunications provider BT have shown that this was used 250,000 times through 40,000 users during the 2014 Games.
6. Glasgow has responsibility for coordinating the Scottish Cities Alliance's 'Smart and Sustainable' strategic theme. Through this role Glasgow has a mechanism to engage and disseminate to other Scottish cities. Glasgow is also lead partner on the European Regional Development Fund programme for Smart Cities; 'Scotland's 8th City – the Smart City' focussing on Smart Infrastructures, Smart Services, Smart Communities and Data;
7. Glasgow is involved in a trans-European Interreg consortium. The Programme; BE-GOOD, is led by the Dutch Ministry for Infrastructure & Environment. The project looks at using Open Data to improve public service delivery by engaging with innovative businesses / SME's to develop commercially viable and

scalable Smart City solutions, around infrastructure, environment and city resilience;
8. Glasgow is developing two collaborative project proposals for the ERDF Programme. Firstly, Intelligent Street Lighting builds upon the demonstrator from Future City Glasgow. It will bring further control, quality, enhanced safety and a more proactive approach to maintenance and looks at how lighting can support smart parking, Living Labs, energy and waste management.

Through the RUGGEDISED project, Glasgow will focus on creating a 'Smart Corridor District' that is situated along a section of George Street and Duke Street in the city centre, which has a mix of residential, community, academic, retail and industrial facilities. The Smart Corridor will address the challenges Glasgow faces from ageing infrastructure, fuel poverty and air pollution; by integrating planned regeneration and development with smart city capabilities. The corridor district has many offices, university buildings and houses which citizens and visitors use varying forms of transport to reach. Glasgow has a complex road network made up of five motorways running through the city centre. On the corridor, Drygate is a densely populated area with a high level of its residents facing fuel poverty due to high fuel costs and electrically heated housing. Investment plans relevant to the Smart Corridor and the wider city include, but are not limited to: ScottishPower Energy Networks' extensive plans to upgrade its ageing infrastructure across the city to improve network resilience; the Council's plans for installation new street lights across the city over the next 20 years; and the Wheatley Group's investment plans for its stock to improve energy efficiency and the delivery of heat and power to its residents. This ageing infrastructure brings high energy costs and frequent need for repair.

4.3.1 Hardware components

The choice of an appropriate communications networks

The key to most smart city and smart grid projects is interconnectivity of assets, which relies on a robust and pervasive communications network. Many communications carriers are available – from simple radio through to 4G – but the nature of application dictates what medium is most appropriate for the task at hand. For high-bandwidth applications that rely on a lot of data being transmitted, the likes of 4G and WiFi are the most appropriate communications media to use. For lower bandwidth applications, there are a number of simpler (and often cheaper) communications media available, such as LoRaWAN, Sigfox and NB-IoT. The advantages and disadvantages of each will be assessed against the specific application it is required for in each city, but the following factors should be considered when assessing any communications medium:

- Cost (initial hardware, ongoing support/maintenance, license fees);
- Availability (both in terms of geographical reach, but also in terms of support in the future);-
- Latency (do you need a response immediately, or are you happy to wait some seconds/minutes?); and
- Bandwidth (do you need to stream video, or is it data being output from a simple sensor that happens twice a day?).

Some cities may wish to deploy their own communications network – for example, Glasgow will be creating a low-bandwidth network to control its street lighting – however the cost of doing this should be weighed against using already existing networks provided by commercial carriers.

Level of control and response across connected assets in the energy system

When considering control of the connected assets that make up the smart city or smart grid system, the nature of each distributed system needs to be understood. If looking to provide simple demand response to reduce the peak loading on the network, speed and depth of response may be the key consideration and, therefore, only connected assets that are able to: a) respond quickly; and b) provide a lot of load reduction. The speed of response will be dictated by both the communications network and the nature of the asset connected. For example, if the system is something that is either on or off – such as an EV charger – it can be turned off relatively simply within seconds and with a known level of demand reduction (the rating of the charger). If, however, you are looking to provide demand response in a building with complex heating & ventilation systems, the speed of response is likely to be more graduated as the Building Management System considers what elements of the building it can shut down. The level of reduction will also vary considerably over time, as the building will only shut off what it can and, if it is a cold morning and the building is not yet at the desired temperature, the amount of load it can shed will be limited.

4.3.2 Software components

Centralised versus distributed control of the energy system

It is neither contractually possible, nor advisable in some circumstances that all assets across a city will fall directly under the control of a single system. For some critical assets – such as the street lighting network – it is unlikely the city authority lighting team will cede control as the priority will always be to ensure the city is safely lit. Assets such as electric vehicles may allow load reduction more often, but there will always be a limit to what they will allow as they are contracted to charge vehicles and must leave them with a level of charge that will allow the vehicle owner to drive away.

It is more practical to take a system of systems approach, whereby control requests are made to each individual system (such as the lighting controller), perhaps via an application programming interface (API), and they decide whether or not to allow the demand reduction to occur. This will reduce the need for control logic (complexity and cost) at the Smart City Controller – the decision to turn on or off is left with the distributed system – and it also maintains the all-important hierarchy of control so the level of service provided by the lighting/EV/heating system is consistent with what has been agreed for that service provision.

4.3.3 Orgware components

Stakeholder management

From Glasgow City Council’s perspective, it is imperative that, when developing solutions, stakeholder engagement is a priority. To ensure that the solutions being developed in any project meet with the strategic objectives of the local authority, regular internal stakeholder communications are developed that provide information on the status and future milestones of solutions. This takes into account any requirement for decision making at several different levels in the governance structures within the local authority. These can range from localised asset managers right up to the Executive Committee of the Council depending on the scale and impact of the decision.

In addition to the internal stakeholder management, there is a growing requirement to manage stakeholders in the city who will be impacted by the solutions. There is a need to have an open dialogue with these stakeholders living in the project district or affected by the developments within the district. It is possible that misrepresentation or misunderstanding of any aspects of the solutions could lead to a negative response from these stakeholders. Equally, if information on the solutions is not clear and understandable, this could lead to false expectations by these stakeholders, resulting in disappointment or dissatisfaction in the results of the solutions when implemented.

Utilisation of public forums to discuss land development in the city is a common occurrence and the tools and processes used in the development process (such as a charette, a public meeting or workshop devoted to a concerted effort to solve a problem or plan the design of something) are something we plan to adopt in RUGGEDISED to try to ensure that the people living and working within the project district understand what the solutions are, where the solutions are, and why the solutions are being implemented. The establishment of a Venture Café in Glasgow will give us the facility to host such events and to incorporate the views of the stakeholders living and working inside the district into the project.

Integrated aims

The RUGGEDISED project is not the only project in progress within Glasgow, in fact, it is likely that the deliverables of RUGGEDISED are dependent on the outcomes of other projects that are running slightly ahead or concurrently to RUGGEDISED. In addition to the known projects, there may very well be many other projects running or in development that are unknown to the RUGGEDISED delivery team. The challenge is to successfully identify the other projects that impact upon the aims or the RUGGEDISED project, either positively or negatively. Furthermore, there is an additional challenge of integrating the aims and objectives of these unknown projects into the RUGGEDISED project, or at least to find some common ground upon which the aims and objectives of both projects can be achieved successfully. The EU is developing programmes to bring together disparate projects that were funded by H2020 to explore the opportunities for knowledge sharing and identifying synergies and learning opportunities between these projects. This approach could be important in helping cities integrate the aims and objectives of other projects in their geographical area.

Procuring systems to serve the requirements now and in the future

The exponential growth of smart city technologies has led to a significant challenge for cities when procuring such technologies to improve aspects of their cities. This is a challenge in Glasgow, but also in other cities. The software and hardware that is being developed today is often superseded by newer, more sophisticated technology with 12 months. In addition, the technologies sold as being ‘open source’ are often not, and are tied into only operating to their potential if connected to other proprietary systems. When procuring solutions, cities need to be looking 5 to 10 years ahead and trying to understand who the technology or market will develop and how the cities requirements will develop to be able to procure a solution that remains relevant into the future.

5. Level of impact 1 – Realisation and output of smart solutions

The first level of impact of a smart solution starts with its realization. However, successful realisation of a smart solution does not automatically mean that the smart solution produces successful output. For that to succeed it is crucial that the solution is effectively and sustainably used during its lifetime and that it is well-embedded in the existing urban context. The embeddedness should not be seen as sequential step following on implementation. Implementing a smart city measure is fairly similar to traditional urban development and urban regeneration, although smart city solutions often have an added 'software component' related to ICT and data. There are several, rather established factors, that may enhance or suppress the implementation of urban developments, that also apply to smart city measures. In order to guarantee successful output, one has to take the following factors into account during the implementation phase. These factors are presented in Table 2 and are discussed in the sections below. The sections shed light on the most important challenges per factor, and present a quick overview of the state-of-the-art knowledge and expertise that is available to deal with these challenges. Where it concerns very specific city examples or instruments, they are presented in text boxes. The enhancing and suppressing factors are categorised along their 'hardware', 'software' and 'orgware' character.

Table 2 – Enhancing and suppressing factors to successful realisation and output of smart solutions

Level of impact 1: Realisation and output of smart solutions		
Hardware	**Software**	**Orgware**
Pre-deployment assessment	Privacy	Business models
Technology assessment	Security	Data and data ownership
Impact on energy grid	Smart Grid ICT	
	User Interfaces	

5.1 Hardware and smart cities

5.1.1 Pre-deployment assessment

Due to its complex nature and connectivity, the exact output and implication of a smart solution is difficult to predict. That is why planning and designing smart solutions is an iterative process that is facilitated by several decision support methods. Deciding on the specific architecture and design of smart solutions, such as thermic grids and electricity grids, requires detailed calculations, simulations and modelling to ensure that the architecture of the smart solution meets the requirements and goals set beforehand.

Many decision support tools to facilitate such pre-deployment assessments of smart city solutions are currently being developed. Some are specifically tailored at simulating the outcomes of the implementation of a smart solution, others are designed to weigh alternative techniques against each other, and a third category is dedicated to optimise the design and configuration of a smart solution.

Tools differ from each other in terms of the level of detail that they can include and the focus they have. A tailored decision on which pre-deployment instrument is used and what level of detail is assessed, improves the process of designing and optimising smart solutions. In the textbox below some examples of recently developed tools and experiences are included.

Glasgow experiences

A fully attributed, energy-oriented model of each proposed system deployment in Glasgow – addressing PV-based EV charging, multi-organisation CHP, smart street lighting, community-integrated renewable energy schemes, etc. – will be established and subjected to formal calibration prior to use. The model will then be simulated to explore likely performance against representative operating and boundary conditions. An analysis of simulation outcomes will be undertaken to identify options for performance optimisation, and proposed design changes reassessed by iterative model adaptation and re-simulation. The principal aim of the activity is to inform the specification of each technology for deployment. A secondary aim is to contribute to the evolving formation of a 3D city cadastre model for future use by a range of stakeholders involved with aspects of smart city development and management.

Urban Strategy

Urban Strategy (TNO) accelerates and improves urban spatial planning by making information from linked, high-tech computer models available interactively. The models simulate traffic, air quality, noise, external safety, sustainability, groundwater, costs and other aspects of our physical surroundings. Urban Strategy has been developed to the benefit of all stakeholders in urban planning, including local and provincial authorities, project developers, consultants as well as housing associations. Urban Strategy enables plans to be quickly developed and optimised, and makes communication between the specialists appealing.

Urban planning is a constant balancing act. Mobility and transport are essential from both an economic and a social perspective but they have an impact on the quality of our habitat and on safety. New housing or office development costs time and money. The considerable complexity that is involved makes quantitative information indispensable in spatial planning. Information that must:

− be cohesive; spatial development always influences many aspects of our urban habitat.
− allow insight so that specialists really do get the support they need.
− be interactively accessible; if scenarios change or alternatives are considered during the development path, the various effects have to be seen directly.

CHESS

CHESS is a simulator for hybrid energy systems including their operational control algorithms. Its acronym means <u>C</u>ontrolled <u>H</u>ybrid <u>E</u>nergy <u>S</u>ystems <u>S</u>imulator. The model is currently under development by TNO to operate in what is called '4th Generation of District Heating Networks' characterised by 1. coordination of multiple, decentralized, possibly uncontrollable thermal sources (e.g. solar thermal), 2. integration of low temperature heat sources (e.g. waste heat), 3. efficient distribution and 4. interaction with other energy infrastructures (e.g. electricity, gas), both direct (conversion technology) and indirect (coupled markets). Static design of thermic grids rely on worst case peak loads with additional margins which resulted in over-dimensioning and increased CAPEX and OPEX. CHESS relies on smart control and system-wide optimization, which is leveraged into efficient design and an holistic approach over all network time scales, from minutes (operation) to decades (investment). This results in a lean, dynamic network with lower CAPEX and OPEX .

5.1.2 Technology assessment

Smart city is an emerging field using emerging technologies. Emerging technologies may however be problematic. That is why technology assessments should be a crucial part in the design phase of smart cities. Larger companies are also joining in on this smart city market and provide everything from individual sensors to complete end-to-end solutions. However, creating a technical system for a smart city is not something that is bought off-the-shelf, a profound system development is needed to meet specific demands of specific cities. This takes time and is expensive.

Many traditional large companies, often from the automation industry, provide end-to-end solutions for smart cities. These include sensors, programmable logic computers (PLC's), servers, virtual machines, API's and tight integration of multiple technical systems. These companies claim that these end-to-end solutions provide increased reliability, manageability and faster disaster recovery of large and complex city systems.

In the last few decades, sensors have become cheap. As more and more of these sensors also become connected to the internet and their data collected, an increased possibility to create value is evident. The increased interest in society for maker spaces and open source movements has also spilled over onto hardware development. Big companies nowadays are keener on providing general hardware with open ends to enable increased innovation on top of their hardware. In this way, big companies can still take part in a development they do not control exclusively, by providing it with open hardware.

Also in terms of connectivity new protocols and transmission technologies are developed and old technologies are re-used for new purposes. Many telecommunication technologies have been decommissioned because of the need for increased data capacity. However, these old systems are now enjoying a revival. Low bandwidth, low speed networks are what is needed for transmitting data from sensors in an energy efficient manner.

In a city, 4 types of technical networks exists, PAN – Personal Area networks, LAN – Local Area Networks, MAN – Metropolitan Area Networks, WAN – Wide Area Networks. Different types of smart cities solutions reside in one of these four network types. For example, most of the Smart home solutions available today reside in the PAN/LAN areas. Other solutions such as LoRaWAN were created to reduce cost of inter-city communication from sensors. LoRaWAN and similar technologies reside in the MAN network. Traditional GSM and LTE and other cellular technologies are now re-used for low speed communication stretching from MAN to WAN sized networks. Between each type of network, gateways are needed. Each type of network has its own operators, business cases and cannot be used freely.

To link together ICT and IoT to create usable solutions for different types of processes in a city requires system architects and development. Multiple general purpose platforms such as Amazon AWS, Microsoft Azure or open source tools are available to create efficient implementation for data storage, API's, communication, sensor management and data analysis. Which type of technical platform that is chosen does not impact functionality, it however can change way things are implemented, but today most platforms are powerful and are able fulfil most needs. The choice of technical solution is therefore rather a matter of preference, already established knowledge, competence of available resources, relations or already bought equipment or licenses.

Off-the-shelf software for smart city concepts are also available, but such a product is in most cases a premature optimization, since all cities are different and has different needs, a choice of a complete "smart city solution" will probably not meet the demands of most cities. Thus, a system development is needed to tailor a solution for a specific city. The example from Gothenburg below shows the importance of such tailoring and a carefully undertaken technology assessment.

Example from Gothenburg

In Gothenburg, Sweden the Tele2 (phone carrier) has invested in establishing a LoraWAN MAN network. This is a controlled network were an end user is required to get the hardware and register their device and application on the carriers. Thus, the network cannot be used freely, you need to be allowed entrance (and this is probably going to be by paying a fee) and the rules when online on this network are strict. Used bandwith and communication frequency is strictly limited, not to choke the network. This is a problem with LoRaWAN and other low speed, low bandwidth networks, they eventually will choke when overloaded and this is a critical problem for smart cities, where performance, resilience, reliability and availability is key.

Technical improvements for energy efficient buildings

Smart and energy-efficient buildings will manage resources effectively, including electricity, heating & cooling, space, air, water, etc. This can include generation of renewable energy within or in close proximity to the buildings. This also includes communication between different components and systems within the buildings as well as the communication with the external grid infrastructure. In the future it will also include communication and exchange of energy with neighbouring buildings, e.g. to meet different heating and cooling demands. As a consequence of the recast of the Energy Performance of Buildings Directive all new buildings must be nearly zero energy buildings by 31 December 2020, which means that the energy performance of the building envelope together with the building services need to be energy efficient in order to on average use as much as energy as is produced in a building.

The solar cell market is showing and upwards trend (still with subsides in countries like Sweden) and many new applications of integrated PV's and solar thermal collectors in facade and roof elements are being developed. With local renewable energy production, the development of local short-term as well as long-term storage capacity also needs to follow. Here neighbouring buildings can share storage capacity to make use of excess heat during the heating season or for cooling during the summer months. There are also projects that investigate how to make better use of low-tempered heat and thermal storage in buildings.

The efficiencies of building services, such as heat pumps and ventilation heat exchangers for example, have rapidly improved over the years. And the development of communication with products that uses energy in the building is ongoing. For example, the owner of a new heat pump has the possibility to communicate with it without being at home. The indoor temperature in the building can be adjusted for energy savings, but also for having a comfortable temperature before arriving at home. The driving force for this development is mostly individual need for freedom and control. Those products can sometimes provide the need in the grid for flexibility, but not always. More or less advanced water saving taps have penetrated the new built market and hence decreased the use of domestic hot water and unnecessary water usage. Gradually this will be installed in the existing building stock as well. To minimise internal losses, e.g. from the heating and domestic hot water (DHW) system, is also very important in order to lower the total heating use.

Apart from having installations with high efficiency, the control system needs to be efficient and well-integrated and adjusted. So that for example the heat is used where it is most needed at a certain point in time. This can mean that heat for DHW can be prioritized over space heating at times.

The energy efficiency of white goods have been greatly improved the last decades and thanks to the Energy Labelling and Ecodesign Directives many of the household electrical appliances including lighting are also becoming more efficient, phasing out those with high consumptions. Still load shifting of the electricity consumption is a topic often discussed and with a presumable future increase in energy prices the incitement will increase. The automation of shifting loads is available on individual appliances, but to further increase the communication and connectivity of appliances (Internet-of-Things), and also connecting it to the energy price, is still in its early stages. One step in the right direction is of course the roll-out of smart meters according to the Directive of Internal Electricity Market, as well as the implementation of individual metering and charging (the Energy Efficiency Directive). The implementation of these directives give the customers the possibility to better control their energy bill if they choose electricity contracts where consumptions can be guided by the spot prices on the market.

In smart energy efficient buildings the energy use is also adjusted to how the building is actually used, which can imply for example occupancy sensors for lighting control. Another example is demand controlled ventilation, meaning that ventilation is automatically adjusted to pre-chosen times or requirements. The electricity use for ventilation can hence be reduced while still maintaining a good indoor air quality. This can particularly be useful in buildings with great variations in occupancy levels, such as schools. Yet another example is the smart control of lighting systems which constantly are under development. These systems usually combine electrical lighting and smart windows/solar shadings so that a sufficient light environment is created taking advantage of natural light but still avoiding over-temperatures.

To conclude, building systems have quite a long life-time, which means that it will take some time for new technology to get into the whole building stock, but the examples given here show that there are many possibilities for the development of smart and energy-efficient buildings.

Energy efficient buildings and neighbourhoods addressed in recent European projects

In recent years, the European Commission has funded several initiatives to bring first energy efficient technology, and later smart neighbourhoods and the related technology closer to the market. The first initiative of this kind were several CONCERTO projects, followed by a first round of Smart City Calls in FP7, and the current Lighthouse Projects within H2020. These initiatives can be understood as the state-of-the-art in energy efficient and smart neighbourhood development in Europe. The initiatives have related, yet different thematic foci. The foci changed over the years, as the technological development progressed.

CONCERTO

From 2005, several calls have launched in 6th and 7th in European Union framework program for research. CONCERTO was designed to demonstrate that the energy-optimization of districts and communities as a whole is more cost-effective than optimizing each building individually (Immendoerfer et al., 2014). All the projects aimed at delivering the highest possible level of self-supply of energy. Appendix C contains the projects funded by the CONCERTO initiative (Immendoerfer et al., 2014).

Energy Efficient Building and Smart cities in FP7

The Energy Efficient Building Public Private Partnership (PPP) was a Europe-wide initiative proactively addressing the challenges of creating a more sustainable business instead of high-tech building industry. PPP aimed to develop technologies and solutions helping to reduce energy consumption and greenhouse gas emissions. They also developed innovative and smart systemic approaches for green buildings and districts (Association, 2013). The smart cities FP7 was designed to offer low carbon cities regarding development of methods and tools for network integration of renewable resource, development and demonstration of optimized energy system for high-performance energy districts and the development and demonstration of new solutions for low-temperature district heating, local storage, new components and management ICT systems (Association, 2013).

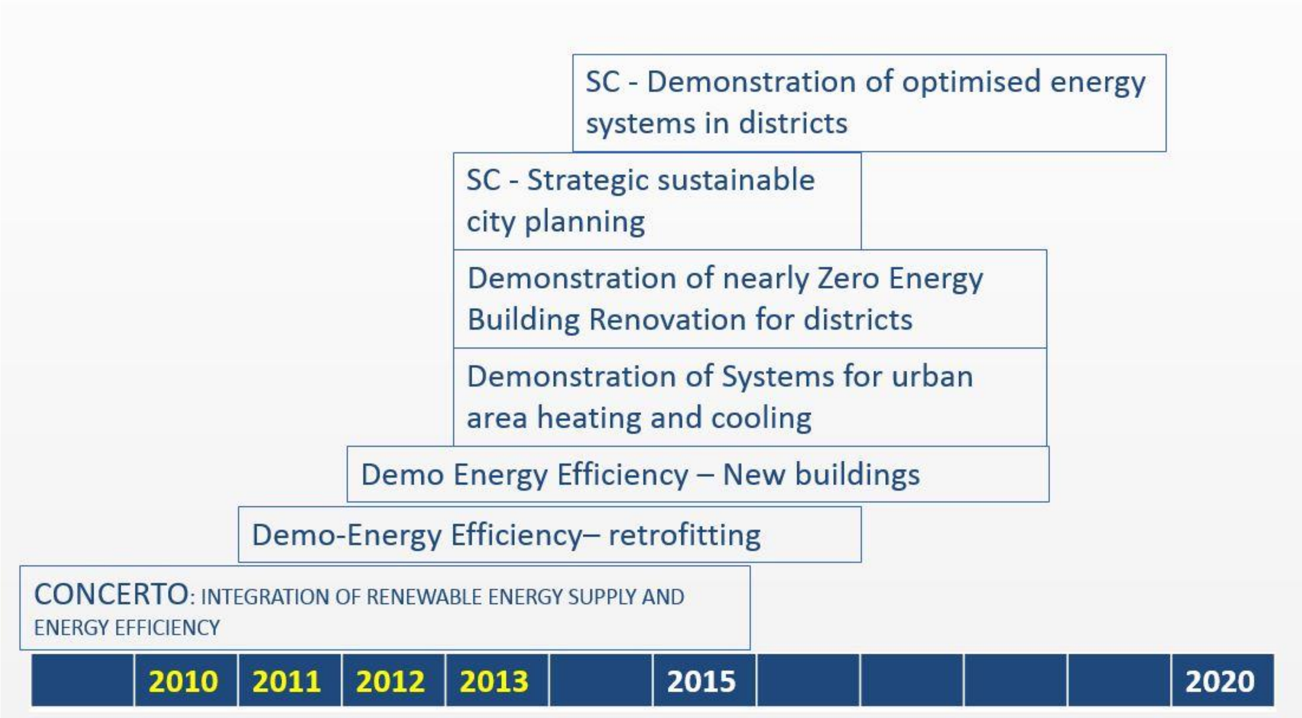


Figure 5 – From CONCERTO to energy efficiency in buildings to Smart Cities (SCIS, 2017[2])

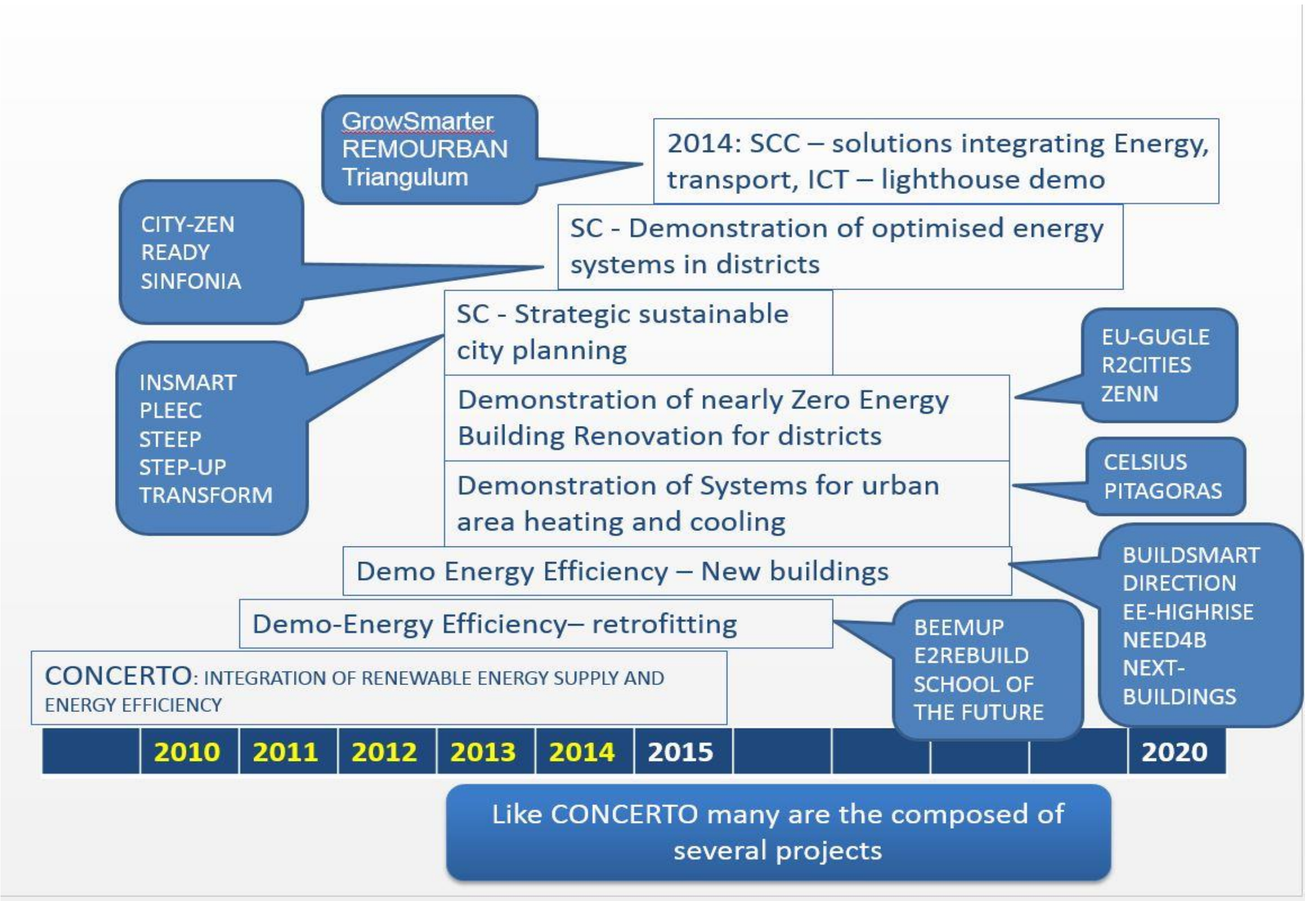


Figure 6 – Integration of mobility and ICT infrastructure (SCIS, 2017)

[2] SCIS - http://smartcities-infosystem.eu/ (Feburary 2017)

Smart city Lighthouse projects in Horizon 2020
From 2014 on, several calls for Smart City Lighthouse Projects have been launched in the Horizon 2020 program (see Appendix D for an overview). Lighthouse projects are designed to demonstrate and test holistic integrated approaches aiming at the integration of energy, mobility and ICT technologies (ICT) in cities. Each demonstration Lighthouse city is designed not only to be smart and sustainable but also to engage citizens (Horizon 2020).

The objective of the Lighthouse projects is to increase the overall energy efficiency in both the generation and consumption of energy, and to fully exploit the potentials of the integration of energy and mobility systems, and the use of ICT, leading to a significant reduction of energy consumption and GHG emissions. Smart grid management, incorporation of RES into the grid and waste energy storage concepts are deployed for achieving an energy system that is beyond state-of-the-art in terms of efficiency. Data integration is done via urban data platforms. Open data generated by the projects shall stimulate the creation of new services responding to needs of users in the area and later on the overall city level (Horizon 2020).

The energy reduction targets of seven of the current Smart City Lighthouse Projects range from 34% to 60%, leading to an estimated reduction of CO_2 emissions between 50% and 60%. All projects aim at fostering low carbon mobility and facilitating the roll out of electric vehicles at large scale. The electric vehicles deployed as part of the projects and other mobility solutions will reduce the CO_2 emissions of transport by 50-60% compared to the baseline. Different charging solutions and options for vehicle to grid integration are demonstrated in the demonstration sites. All projects understand themselves as Livings Labs. Citizen engagement and the co-creation of solutions are thus important features of the projects.

5.1.3 Impact of smart solutions on existing energy infrastructure

The energy transition will change the use of the distribution networks significantly. There are four major challenges here:

- electrification of vehicles
- introduction of large areas of photo-voltaic panels
- Increased use of electric heat pumps and electric pumps for the heat-transporting medium
- natural gas distribution may be phased out and existing networks may present opportunities for distributing climate neutral alternatives such as bio-gas or hydrogen.

Below the presented influences are examined and explained in more detail.

Electrification of vehicles
At present the numbers of electric vehicles, in the EU and worldwide, is still relatively small. The investments cost difference between a conventional vehicle (ICEV) and a battery electric vehicle (BEV) coupled with perceived uncertainty of practical usefulness and lifetime expectance prevent electric vehicles from a broad market uptake. The fact that the price difference is easily compensated by lower energy carrier (fuel vs. electricity) costs, is largely neglected, except for professional users. Quite a few professional users look at the total cost of ownership (TCO, all costs over the full vehicle life: purchase, energy carrier, maintenance and road tax) instead of just the purchase price. These professional users such as taxi drivers or parcel delivery services, know they can save money by opting for electric vehicles. Within a few years though, price parity of electric and comparably sized conventional vehicles is expected (Grantham Institute, 2017). After 2023 a steady, rapid increase in EV's must be anticipated. The electricity demand of an electric vehicle is comparable to the electricity intake of an average household (without EV). This means that if in a residential street half of the households buy an electric vehicle, electricity consumption goes up by

approximately 50%.

Another impact of the EV transition on infra structure will be very visible: parking lots will change into charging areas. At present this is done by adding charging poles one by one, but in a couple of years this may need to be done by converting complete lots (think large parking lots near shopping centres and offices). Collaboratively, charging cars form a great source of buffering and flexibility in the electricity grid and as such EV provides synergy for local sustainable generative capacity (like PV, see below).

Large scale introduction of Photo Voltaics (PV)
At present, few households have bought PV panels yet, mainly due to the cost of PV panels. At the same time, the average price per kW installed PV capacity, has been decreasing at an average rate of 24% per year over the last 40 years[3]. This means that in five or ten years PV may become widespread also in the North-West part of Europe. Simply because PV will be so affordable that many households will adopt PV panels to contribute to the sustainable energy future and have own, affordable energy supply. Large scale instalment of PV on residential roofs, and (later) perhaps on façades as well, will mean the maximum capacity of the distribution grid may get stressed at times of high solar irradiance and little or no (local) consumption. If a lot of PV has been installed, and no flexibility or buffering is introduced in the network, the amount of electric energy generated may approach or even exceed the maximum capacity. Smart grid technology can help little if there is little electric energy demand, so investments in buffering capacity or higher distribution capacity may be required.

Electric heat pumps
At the moment heating of dwellings must become sustainable. In many places electric heat pumps will form an attractive alternative. These pumps work by extracting low temperature heat from a large reservoir (e.g. a lake or an underground reservoir such as in Aquifer thermal energy storage (ATES) and electrically boosting it to a useful temperature for heating of buildings. The additional temperature step for provision of hot tap water, can be done in a booster boiler (this can be an additional heat pump). The upside of this is a very good efficiency of heating (approximately 4 to 5 times as much heat is available as energy put into the heat pump). Still the impact on the distribution network should be taken into consideration. The extra electric energy comes on top of normal demand, plus charging of EV's, plus distribution and buffering of locally generated electric energy. An estimate of the additional electric energy needed for switching to heat pump heating is 30% to 40% of the base electricity demand (strongly dependent on usage and the degree of insulation of the building to be heated).

Natural gas distribution network
Once the transition to sustainable heating is complete, it may be that a distribution network for natural gas remains unused. In special situations, it may be turned into a sustainable energy carrier network though. Possible candidates for fulfilling this function are bio-methane (e.g. from sewage digestion) or hydrogen (although not all piping and valves are suitable for it.)

5.2 Software and smart cities

5.2.1 Privacy

The extensive monitoring of the urban environment, key infrastructures and the flow of goods and people in smart cities already produces massive amounts of data. The promise of smart management extends to other sectors as well such as predictive policing, crowd control or public sentiment monitoring (Van Zoonen,

[3] BLOOMBERG NEW ENERGY FINANCE SUMMIT keynote Michael Liebreich, April 2016.

2016). Moreover, high resolution (time and space) data collection in the context of Smart Cities is set for a dramatic rise with the advent of next generation data generating information technologies in the Internet of Things (IoT) such as Sensor technology, Robotics, Artificial Intelligence, Blockchain and Augmented Reality. The granular datasets produced by these technologies in combination with existing user registries yield a very high potential for the construction of detailed personal profiles of citizens. This is an obvious threat to privacy and one which has been recognized only to a very limited extent in the recent General Data Protection Act[4] (GDPR), an attempt to harmonize EU Privacy legislation.

It is clear that smart city technologies and data developments are so quick and ubiquitous that official legislation may fall short for decades to come. In her article on privacy in smart cities, Van Zoonen (2016) describes the challenge to cities as threefold:

- identify which privacy concerns for their citizens may be at stake with specific technologies and data practices;
- identify if and how these are subject to the EU data protection regulation;
- develop a specific city policy on new developments that accommodates the concerns of citizens, beyond the bare legal necessities.

Different Privacy assessment and Privacy by Design frameworks have been proposed in the past years. A relatively common tool is the Privacy Impact Assessment (PIA) described in the box below. TNO/ Privacy Lab developed a comprehensive Privacy Framework (Respect4U) that can be applied to complex scenarios such as Mobility As A Service (MAAS). However more work needs to be done to address the privacy challenges of smart cities.

Privacy Impact Assessments (PIAs)

A PIA is a tool that allow projects to assess the nature of the data being collected, the relevance this may have to individuals involved and the impact it would have on the individuals if the data were either released to third parties, or are combined with other data sets that could build up a detailed picture of the individuals lives. The tool helps to:

- Identify the data sets that could be considered private/personal;
- Identify whether or not this data should be used by the project (i.e. is it justified);
- Identify how processes can be developed that can mitigate the risk that data is released to third parties, accidently or otherwise; and
- Identify the processes that must be in place to destroy data once it is no longer required by the project

Taken from the Privacy Impact Assessments Code of Practice document, issued by the UK Government Information Commissioner's Office (ICO, 2014), the following summary of what a PIA is given:
"Privacy impact assessments (PIAs) are a tool which can help organisations identify the most effective way to comply with their data protection obligations and meet individuals' expectations of privacy. An effective PIA will allow organisations to identify and fix problems at an early stage, reducing the associated costs and damage to reputation which might otherwise occur. PIAs are an integral part of taking a privacy by design approach.
Key points:

- A PIA is a process which assists organisations in identifying and minimising the privacy risks of new projects or policies.
- Conducting a PIA involves working with people within the organisation, with partner organisations

[4] General Data Protection Regulation entering into force in 2018.

and with the people affected to identify and reduce privacy risks.

- The PIA will help to ensure that potential problems are identified at an early stage, when addressing them will often be simpler and less costly.
- Conducting a PIA should benefit organisations by producing better policies and systems and improving the relationship between organisations and individuals."

The guidance provides step-by-step advice on how to create and populate a Privacy Impact Assessment document to ensure that your project does not, inadvertently or otherwise, compromise the privacy of the individuals involved. This protects both the individual and the project.

5.2.2 Security

While interconnected cyber-physical devices create the possibility for the cities to be run more efficiently, productively, sustainably, fairly and transparently, various problems may occur in the huge data machinery that is the smart city. Key concerns include trust, threats to data confidentiality, integrity, accessibility, protection and privacy.

This section will touch on recent EU proposals to regulate the free flow of non-personal data. While the GDPR[5] allows for the free movement of personal data within the EU, there are currently no common rules among Member States for sharing, accessing, transferring "non-personal data". "The issue of free movement of data concerns all types of data: enterprises and actors in the data economy deal with a mixture of personal and non-personal data, machine generated or created by individuals, and data flows and data sets regularly combine these different types of data", according to the draft Communication. That "enterprises and actors in the data economy will be dealing with a mixture of personal and non-personal data, and that "data flows and datasets will regularly combine both", is an important challenge for city managers responsible for the security and integrity of smart city solutions[6].

According to the draft Communication: "any Member State action affecting data storage or processing should be guided by a 'principle of free movement of data within the EU'. Broader use of open, well-documented Application Programming Interfaces (APIs) could be considered, through technical guidance, including identification and spreading of best practice for companies and public sector bodies. Public authorities could be granted access to data where this would be in the general interest and would considerably improve the functioning of the public sector, for example access for statistical offices to business data or the optimization of traffic management systems on the basis of real-time data from private vehicles".

Selling and acquiring databases could be regulated. "Access against remuneration": a framework based on fair, non-discriminatory terms could be developed for data holders, such as manufacturers, service providers or other parties, to provide access to the data they hold against remuneration. A data producer's right to use and license the use of data could be introduced; by "data producer", COM understands "the owner or long-term user of the device". This approach would "open the possibility for users to exploit their data and thereby contribute to unlocking machine-generated data".

[5] General Data Protection Regulation entering into force in 2018.

[6] For a review of the new Free flow of non-personal data proposals see https://pdpecho.com/2016/12/15/eu-commissions-leaked-plan-for-the-data-economy-new-rules-for-iot-liability-and-sharing-non-personal-data/

Rethinking liability rules for the IoT and Artificial Intelligence era

Even though Artificial Intelligence is not mentioned in the draft Communication, it is clear that the scenario of algorithms making decisions is also envisaged by the announced objective to reform product liability rules, alongside IoT. As the draft Communication recalls, currently, the Products Liability Directive establishes the principle of strict liability, i.e. liability without fault: where a defective product causes damage to a consumer, the manufacturers may be liable even without negligence or fault on their part. The current rules are only addressed to the producer, always require a defect and that the causality between the defect and the damage has to be proven.

The Commission proposes several approaches, which will be subject to consultation:

- “Risk-generating or risk-management approaches: liability would be assigned to the market players generating a major risk for others and benefitting from the relevant device, product or service or to those which are best placed to minimize or avoid the realization of the risk.”
- “Voluntary or mandatory insurance schemes: they would compensate the parties who suffered the damage; this approach would need to provide legal protection to investments made by business while reassuring victims regarding fair compensation or appropriate insurance in case of damage.”
- “Connected and automated driving” – used as test case.

The Commission intends to test all the proposed legal solutions, after engaging in wide consultations, in a real life scenario and proposes “connected and automated driving” as the test case.

Example Utilization of hackers to identify hidden opportunities in data

Participants (and organisers!) of the Future City Hackathons were invited to explore exciting challenges stemming from the themes of Energy, Public Safety. Transport, and Health. Each Hackathon took place over a 48hr period. The sessions were started with invited speakers giving some context on the aims and ambitions of the theme, and detail on the datasets available. The participants were then given a chance to pitch their ideas based on the introductory information, and call for participants to join their teams to help realize there vision.

Once teams were formed, they have to register by a set deadline which becomes the start of the 48hr Hackathon. This step is important, as the winning team will share a £20,000 prize fund. The venue will remain open to registered participants for the duration of the 48hr Hackathon. At the end of the Hackathon, the teams present their original concepts and working solution to a panel of judges who will decide on the winner of the £20,000 cash prize fund. The four distinct Hackathon themes used in Glasgow – public safety, energy, health and transport – are areas that directly or indirectly affect everyone who lives in the city. The challenge at each Hackathon is simple: pitch an idea that will make things better. There are no right or wrong answers, but the open-ended nature of the task creates its own obstacles – even if a team comes up with a concept they believe could win the £20,000, how does that team develop it in just 48 hours?

That time limit is a burning fuse, intended to quicken the pulse, focus minds and wring every ounce of creativity out of those taking part. But while spontaneity and improvisation are the lifeblood of hackathons, there’s no need to start completely from scratch: each Hackathon has a specific theme, Which is made public in advance of the event, so brainstorming can begin well in advance. Should a team try and improve general health in Glasgow, or target one particular area? What could be done to identify or redirect transport problems? The right groundwork could get concepts moving in the right direction early, allowing a more fully-realised version to be presented to the judges.

There’s a public perception of hackathons being populated entirely by brainiac student programmers hunched over laptops in a nest of wires and discarded energy drinks. Coding skills can be vital to implementing ideas since they can wrangle data and technology in innovative ways. But not knowing how to string code together is no barrier to entry – successful teams can be created by combining those with a novel concept with those who have the technical ability to realize that concept. Hi-tech, low-tech, smartphone-powered or people-powered … as long as the idea can enhance life in the city, it's as valid as the slickest app.

5.2.3 Smart grid ICT

ICTs play a vital role in smart grids, as well the electricity as the thermal smart grids. In most references and literature often smart grids refers to smart electricity grids. In traditional grids there is almost no bidirectional communication to the end consumers, except a yearly measurement. In these traditional grids this is also not needed since production can be easily adapted on the demand, which is indirectly measured (e.g. by the grid frequency). In future grids this communication will be needed since the production cannot be directly controlled (e.g. from wind and solar), and also production will take place at all locations in the grid and not only a few at the high voltage grids. So the grid will become 'smart'. There are several types of smartness/functionality varying from: smart meters (remote, variable tariffs), smart devices, new markets (capacity, aggregator roles), new business models.

First of all we need a clear and agreed set of methods, concepts and algorithms for the smart grid. A lot of work has already been done in this area. A result is for example the Smart Grid Architecture Model (SGAM) that has been developed as part of the Smart Grid Mandate M/490, issued by the European Commission and EFTA[7]. This model uses and is partly aligned with the GridWise Architecture Council Stack from NIST[8].

Although the model is widely accepted, it can be interpreted in different ways. Further, there are different market models, as well in today's markets (differences per country) as in future concepts (transactive energy). There are also different types of algorithms that can be applied to control the smart grid. They differ in concepts and their applicability depends on market models too. They vary for example from fixed tariffs, to variable tariffs set by the system or producers, to advanced methods as transactive energy methods[9].

A lot of standards can be applied in smart grids. M/490 published the current set of standards[10]. A choice needs to be made, some do not have to be used, some are required, and some standards are missing. Also several other (de-facto or open) standards are available, proposed or in development. All devices and actors in a smart grid need to be interoperable (being able to interact and operate with each other). This is not trivial and means much more than applying a set of standards. Interoperability was also one of the topics of M/490 and a working group has published a report on this topics[11].

The telecommunications and IT domains are fast changing domains, where technologies are being replaced

[7] for more information https://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartGrids/Pages/default.aspx

[8] for SGAM see [M/490-NAM] Smart Grid Coordination Group, Document for the M/490 Mandate Smart Grids, Methodology and New Applications, Date: 11/2014
ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/SGCG_Methodology_Overview.pdf

[9] see [PNNL-TEF] The GridWise Architecture Council: GridWise Transactive Energy Framework Version 1.0, January 2015
http://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf

[10] [M/490-SoS] Smart Grid Coordination Group, Document for the M/490 Mandate Smart Grids, Smart Grid Set of Standards, Oct 31th 2014, ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/SGCG_Standards_Report.pdf

[11] [M/490-WGI] CEN-CENELEC-ETSI Smart Grid Coordination Group, Methodologies to facilitate Smart Grid system interoperability through standardization, system design and testing, Date: 31-10-2014,
ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/SGCG_Interoperability_Report.pdf

with newer versions soon after one another. The innovation speed in the energy domain is lower and the used technologies remain stable for a longer period in time. With the addition of ICT to the energy domain these two paces appear to be incompatible. An example is the current roll-out of smart meters in the Netherlands with a GPRS (2G) communication interface, while telecom providers are currently rolling out the first 5G network deployments (pilots) and 2G is soon to be turned off (earlier then the end of life of the smart meters).

5.2.4 User interfaces

Well-designed user interfaces are crucial in deployment of smart grid devices. Depending of the level of acceptable abstraction, integrated building performance simulation can be applied at scales ranging from a single building (high resolution representation) to a national building stock (low resolution representation per building). In each case, simulations can be undertaken that address a range of relevant performance parameters – such as energy use, comfort conditions, air quality, and environmental emissions – in support of the identification of acceptable trade-offs. In the context of smart cities, it is helpful that the approach can also be applied externally: to the lighting and air quality of urban canyons; and to the interaction between buildings and smart grids comprising hybrid supply technologies, including control based on demand management and/or demand response. By assessing a proposed scheme in a realistic manner at the design stage, more effective operational performance is assured. In short: if it cannot be simulated, it should not be built. The opportunity exists to apply the approach to specific schemes being proposed by partner/ follower cities.

5.3 Orgware and smart cities

5.3.1 Business models

Europe has committed itself to face grand challenges in terms of sustainability and energy conservation implying that many of the potential solutions require long term investments and pooling resources into innovation where market failure is dominant (Rowley and Moldoveanu, 2003). In the RUGGEDISED project, the lighthouse cities are forerunners in the transition towards a low carbon and resource efficient economy. The main purpose for these cities is to provide novel smart solutions to significantly increase each city's overall energy and resource efficiency of building stock, energy systems, urban (e-)mobility and public space. Such actions will bring profound economic, social and environmental impacts for the cities, resulting in a better quality of life (including health and social cohesion), competitiveness, jobs and growth. However, many of the innovation initiatives in these domains lack well-defined business models (Tukker and Butter, 2007). At the same time, research on sustainable innovation has tended to neglect the way in which firms need to combine a value proposition, the organization of the upstream and downstream value chain and a financial model in order to bring sustainable innovations to the market (Boons & Lüdeke-Freund, 2013). Smart cities create a fertile innovation environment for new business opportunities by actively creating interactive collaboration between government, businesses and citizens.

Since smart cities are based on horizontal collaboration between different stakeholders this has important implications for business and governance models to organize and realize smart cities. A smart city usually is based on a (combination of) different business models. Kuk and Janssen (2011, p. 42) describe a taxonomy of possible business models for e-government, a specific aspect of smart cities.

Table 3 – Taxonomy of possible business models for e-government (Kuk and Janssen, 2011, p.42)

E-Government Business Model		Description
1	Content provider	Providing static and dynamic content, including contact information, organization information, product and service information, and news
2	Direct-to-customer	Directly providing services to customers and/or businesses. Various stages can be determined, including the information, communication, and transaction stage
3	Value-net-integrators	Collecting, processing, and distributing information from several organizations. This is a networked type of business model that often focuses on a particular customer segment; for instance, entrepreneurs
4	Full-service provider	Enabling interaction through directly providing information and services. This involves the collaboration of several departments and/or organizations to create a one-stop shop
5	Infrastructure service provider	Providing infrastructural services to support the creation of an online presence
6	Market	Matching the supply and demand with regard to information, human resources, services, or goods; for instance, matching volunteers with requests for volunteers
7	Collaboration	Providing the instruments and tools needed to participate in activities like policy-making projects and decision-making, including visualization and simulation tools that can be used to predict the implications of policies.
8	Virtual communities	Providing a community of recurring customers, including user generated and shared content and the sharing of content

Local governments that need to transform themselves into smart cities need to embrace new business models and find a match between their business rationale and their information architecture (Kuk and Janssen, 2011).

According to Teece (2010) a business model “[…] articulates the logic and provides data and other evidence that demonstrates how a business creates and delivers value to customers. It also outlines the architecture of revenues, costs and profits associated with the business enterprise delivering that value” (Teece, 2010, p. 173). Following an activity system perspective a business model thus specifies the content (what activities are performed), structure (how are activities linked), and governance (who performs and controls the different activities) of the activity system of the innovator firm and its network of partners (Zott & Amit, 2010). Key elements that describe a firm’s business model are its target market, value proposition, and place in the industry’s value chain (and linked to these the firm’s cost and revenue streams). These different elements of a business model are interconnected with each other and form as such a system.

Innovation of a business model happens when there are one or more 1) changes in the target market (new types of costumers), 2) changes in the value chain (changing collaboration patterns, changes in power structure, etc.), 3) changes in the firm’s value proposition (product innovation, ways of appropriating, pricing schemes, mix of products and services, etc.). Because of their interconnectedness, changing one element of a business model often implies changes in other elements of the business model as well. For example, changes in the target market often imply changes in the value proposition (and vice versa), and sometimes also changes in the value chain. For example, changes in the value chain often imply changes in a firm's value proposition towards partners and sometimes changes towards a firm's main target market. Implementing a new (technological) invention for an organization typically involves a process of designing an appropriate new business model by linking and integrating the various elements of the new business model. Therefore, we see business model innovation as an organizational design process. Also, by definition, new business models influences one or more value chain partners of the firm. Therefore, one says that the business model concept has a boundary-spanning nature (Zott, Amit, and Massa, 2011). Hence, business model innovation crosses the boundaries of a single firm and thus has inherently an interdependent (or open) perspective. Technological inventions do not generate economic value per se, and it is only through a business model that a technological breakthrough can create and deliver value in a profitable way. New technologies do not guarantee business success and should therefore be coupled with a business model defining their 'go to market' and 'capturing value' strategies. In its most complete form a technology-based innovation business model transforms the firm's innovation capability into market applications. Notwithstanding the importance of technology and its commercialization, business modelling in predominantly service-related instead of technology-related or science-related environments also deserves appropriate attention. Lusch and Vargo (2006, 406) stresses the distinction between Product Dominant Logic (PDL) and Service Dominant Logic (SDL) in business models. For example, business models based on products do not rely much on what customers do. SDL-business models require shaping the relationship with the customer, thinking about co-creation (Dhondt et al., 2013). Therefore, we approach business model innovation as 1) an organizational design process, 2) with an interdependent (or open) innovation focus, and 3) relevant for the smart sustainable city context.

The **Business Model Canvas** (see Appendix E) is a template for developing new or documenting existing business models. It is a visual chart with elements describing a firm's or product's value proposition, infrastructure, customers, and finances. It assists firms in aligning their activities by illustrating potential trade-offs. The Business Model Canvas was initially proposed by Alexander Osterwalder (2003). For the analysis and development of business models in smart cities we develop a taxonomy of different types of business models with different levels of complexity. The taxonomy is based on two dimensions (see Figure 8): Ownership of the business model, which can be a private company, a city government or a public-private partnership public; Focus of the business model, which can be vertical (focuses one specific functional application area, such as mobility management) or horizontal (focussed on cross silo collaboration and data sharing)

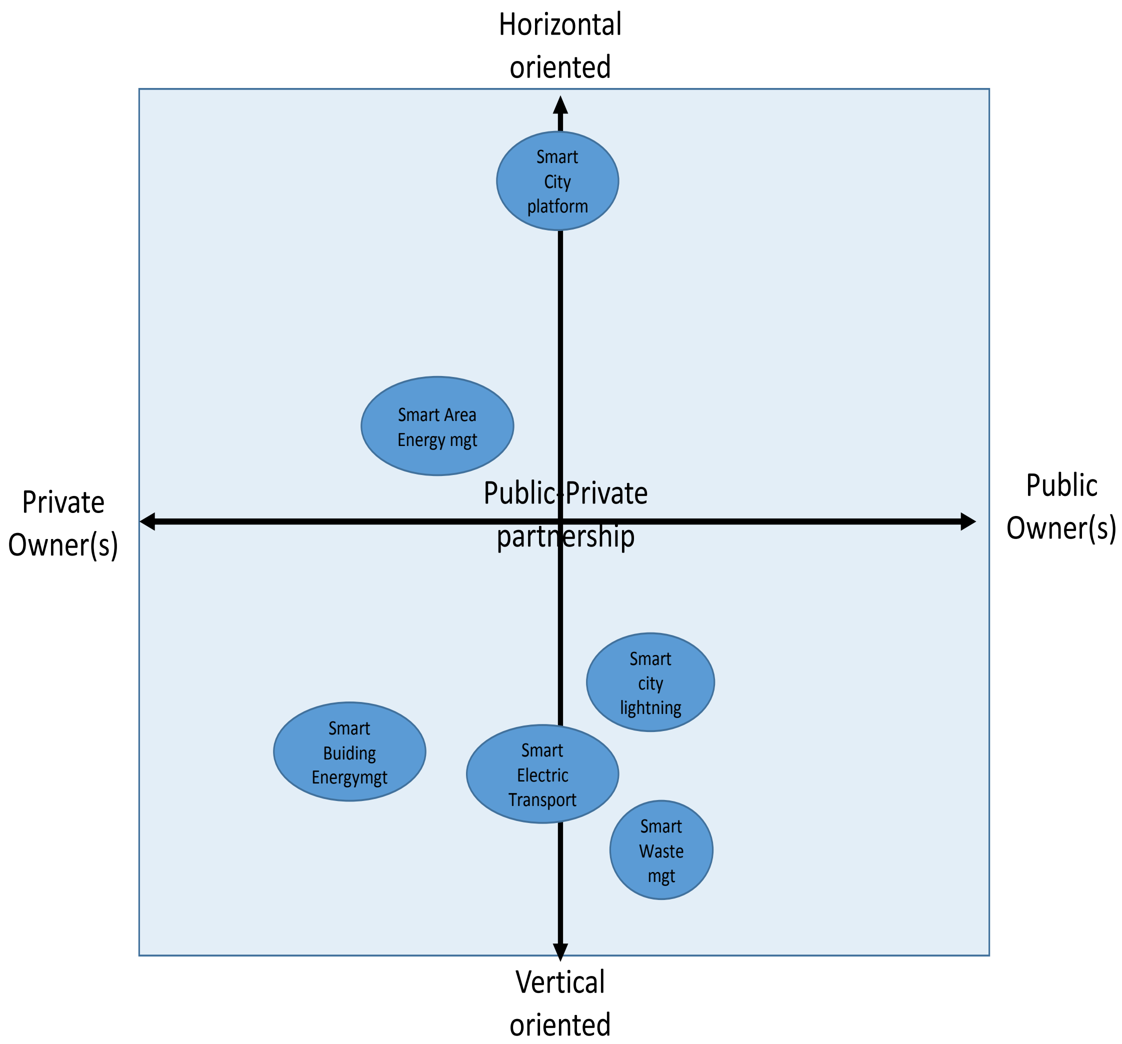


Figure 7 – Taxonomy of business models in the context of smart cities

Local business models

Every stakeholder in the smart city will develop one or several business models for its core products and services. Examples of these local business models are described in Table 4. These local business models provide an important basis for collaborative (sharing) business models and services to emerge. Especially regarding smart grids, the issue of business models through changing legislation is interesting.

Current legislation is developed and well applicable for the traditional smart electricity grids. For future smart grids current legislation is often too restrictive. For example network companies need to connect any load, and are not allowed to pay (temporary) for reduction of loads etc., although this can reduce the overall system costs. Also consumers cannot be billed for peak demands (from EVs or Heat Pumps) nor rewarded for their flexibility (of EVs, Heat Pumps or shifted demand from for example washing machines).Adapted legislation will be needed to enable multi stakeholder cooperation, new business models, billing with flexible tariffs (e.g. time-of-use).

Table 4 – Examples of business models

Application	Owner	Value propositions	Generic Business Models	Customers
Thermal grid	Energy company	Performance Cost reduction Status (”green image”)	Cost cutting	Building owners
Energy management system	Energy company	Cost reduction (based on reduction of energy use) Performance (optimize use of renewable energy) Convenience / usability (optimal climate) Customization	Value Net Integrator Market Collaboration Cost cutting	Building owners
Waste management	City	Cost reduction (less collection trips, reduce energy need) Convenience (enhance citizens satisfaction) Customization (specific pick up depending on capacity use of garbage containers)	Cost cutting	Citizens
Route- and resource planning	Public transport operator	Cost reduction (optimize integration of electric business) New revenues (use batteries for storage and trading of energy) Status (”green image”)	Cost cutting Market (energy trading)	Citizens

5.3.2 Data and data ownership

“Urban governments are increasingly urged toward data-driven decision making and policy development. The transition from a traditional to a data-driven governance has serious internal organizational implications. But also to the external world, as data user and provider, governments have to be aware of their role amidst many other users and providers of data. Models and procedures are needed to support data exchange, as opposed to open data platforms that passively provide certain data. This raises important issues with respect to ownership and privacy of often individual data. Moreover, relevant data for urban governance are of a distributed nature. Ubiquitous data challenges the relationship between data and policy and raises questions on how to improve the process of transforming data into useful information for the policy process. This question becomes ever more important, as the quality of the data is often not reflected on. Governments that are responsible for the maintenance and management of infrastructure increasingly assume to have access to accurate, real-time data, but tend to lack both expertise and means to assess and process these data and make appropriate interventions.” (Van Dalen, et al., forthcoming).

Table 5 – Key dimensions of big data (Van Dalen, et al., forthcoming)

Key dimension	Description
Volume	Usually including a comment that the amount of data ever created in the world has doubled in the past two years and will keep to do so in the future. Bytes are the units in which the size of data is currently expressed, with brontobytes of data considered to be the next level of 'big'. Big, however, is evidently a relative concept for different academic disciplines and can also refer, for instance, to thousands of transcribed interviews.
Velocity	Referring to the speed in which new data emerge and old data become obsolete, and to the possibility to use and analyze data in real time, as they are created.
Variety	Indicating that the deluge of data comes in many different forms and from many different technologies that range from sensors to social media, and are by and large unstructured; especially in comparison to older and smaller data that used to be purposively collected and structured.
Veracity	Addressing how one can assess the quality of data, their correctness and their vulnerability to measurement error.
Variability	Regarding, in the terms of classic measurement theory, the validity of data (what exactly do they represent) and their robustness (do they mean the same thing tomorrow).
Visualization	Concerning that big data need to be represented in an easily understandable form, through graphs and plots, but also bringing up the question if and how these visualizations form an analytic tool in themselves.
Value	Identifying that big data have become an unmistakable resource for the management of traditional business and services, but also have turned into a profitable new sector itself.

6. Level of impact 2 – Embedded outcomes of multiple smart solutions

In order to reach 'embedded outcomes' cities try to fully connect the different smart city components and solutions with each other. The factors that influence the establishment of such connections and thus are relevant for this impact level are depicted in table 6.

Table 6 – Enhancing and suppressing factors to embedded outomes of multiple smart solutions

Level of impact 2: Embedded outcomes of multiple smart solutions		
Hardware	**Software**	**Orgware**
Communicating infrastructure	Interoperability	Integrated vision on the smart city
Robustness of the system	Dashboards	Smart governance
		Windows of opportunity
		Stakeholder management
		Ownership
		Business models and split incentives

6.1 Hardware and embedded outcomes of smart solutions

6.1.1 Communicating infrastructure and standardisation

Before developing any system, cities should first get a clear view on what their use cases are and the functionality required to develop them. Then the challenge is to understand what each of the technology/service providers are doing currently and what they are planning in their development roadmap, as there could be functionality coming that can be tapped into by the wider system. Thereafter, the overall system can be specified and the level of internal development required understood. This is preferable to the creation of bespoke control/functionality within your own project that will be difficult and costly to design and maintain, and which is likely to be obsolete within months.

Once the applications are understood and the use cases developed, agreeing on shared standards and protocols for hardware and software is essential. Taking communications, utilising the same network will not only ensure that all connected assets are working to the same level of service – latency, cost, etc – the means by which any data is backhauled or control instructions issued should be similar (if not identical), which in turn should reduce the cost of integration with other systems as each data stream will be presented in the same manner. That said, the same communications network should only be used if it is appropriate for the application it is serving. For example, there is no need to pay for a higher bandwidth network if a lower bandwidth, IoT-type protocol will suit.

Moving onto specific standards for individual aspects of a system, there are many which can be specified when developing a smart solutions. For example, the buildings in a previous demand management trial were audited using the European Standard EN15232:2012, which helped understand the current level of control and the potential for adding controllable loads in the future. Each building was audited using this standard, which made comparisons between the performance of different buildings very easy. For electric vehicles, there are attempts within the industry to harmonise standards so that EVs can be used for demand management in a smart city/grid application[12]. For street lighting control, standards such as DALI (Digital Addressable Lighting Interface) – specified by technical standards IEC 62386 and IEC 60929 – are commonplace, therefore any system should ensure they are specified when procuring such equipment.

The use of APIs to exchange data and provide external control to third-party (often single use) control systems is heavily recommended as it: a) reduces the integration effort required to allow multiple systems to communicate; and b) allows software/functionality updates to be made to a third-party control system, but the core API functionality should persist. This may be extra control not previously available, so the overall complexity and utility of the Smart City/Grid system will improve over time, but without the need for project development.

Challenge – specify need for upgradability, configurability, costs involved
Another reason is that the required functionality for (ICT) components in the grid are mostly functional. Non-functional requirements get less attention. Some (maintainability, replace-ability, testability) more then others (configurability, upgradability, scalability, ….). If for example upgradability and configurability are not clearly specified, suppliers will save on these, which after updates or new configurations can lead to serious robustness and security issues.

6.1.2 Robustness of the energy system / smart grid

Creating a robust smart grid infrastructure system is a challenging task. It is technically difficult, because of the complexity of the total system. Traditionally the energy system has proven to be very robust with the total number of minutes of unavailability per year in the range of minutes, whereas ICT is known for crashes due to software bugs, among other things. One other reason of the decreased robustness of ICT supported domains is the vulnerability to hackers or cyberattacks. The topic of security often gets too little attention during the design process. And IT Security is another specialism where good experts are scarce.

Also M/490 has worked on Smart Grid Information Security[13]. This report list several possible standards to be used, but does not give much guidance on methods and design. A next step is really needed: “Plan to fail”, already during the design of a system, take implicitly into account that it will fail someday. Incorporating this way of thinking into new design methods, has been (and still is) part of many current research programs. There are many different terms to indicate more or less the same principle; to name a few: robust design method (Taguchi), robustness by design, disaster tolerant design, disaster recovery planning.

One of the reasons of low robustness of ICT is that the system is not optimally designed. This is often caused by a lack of attention for robustness but also a lack of enough highly skilled ICT architects in the this energy domain. Due to this scarcity, the really good architects are hired by the companies that pay most. Another consequence of the scarcity is that many people from other sectors that become unemployed are retrained to become ICT experts, not necessarily according to the highest standards. Being able to properly judge the quality of ICT experts is another challenge. Robustness is really technically difficult.

Another challenge is that the more complex the (ICT based) system is, the less likely it will be to test it for all potential events. That is the reason why security by design and robustness by design are required. Designing the system in such a way that a certain level of security or robustness is guaranteed.

[12] https://cleantechnica.com/2016/01/01/ev-charging-time-single-fast-charging-standard-now/
[13] see [M/490-SEC] CEN-CENELEC-ETSI Smart Grid Coordination Group, Smart Grid Information Security, Date: 2014-12 ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/SGCG_SGIS_Report.pdf

The good news is that the problem can be solved. Enough technology and concepts are available in this domain like redundancy, cloud computing, using flexibility, enabling scalability. One may convincingly say that ICT can increase the robustness of grids. In a future grid is should be feasible to keep (the often low power) communication equipment up and running, for example powered by local batteries or batteries from electric vehicles.

6.2 Software and embedded outcomes of smart solutions

6.2.1 Interoperability

New generations of digital technologies are driving a rapid evolution of urban infrastructures[14]. Disruptive and diverse smart city developments associated with new platform based services such as AirBnB, Uber, Smart Lighting, Autonomous Driving and more are placing very specific demands (latency, privacy, security, ...) on network infrastructures, resulting in smart solutions that risk to be fragmented, disconnected and closed. While the vision of an overall reference architecture for smart cities implemented across Europe seems a pipedream given the dynamics of the smart city ecosystem, the need for coordination and interoperability between smart city subsystems is more acute than ever. Coordination and cooperation is essential to ensure good governance when digital platforms and services stand to have very significant impact on core values such as access to data, privacy, (cyber)security, market and vendor lock-in, citizen participation, sustainability, and healthy living.

The Smart City, a dynamic, self-organising ecosystem of platforms and services

The current crop of smart city projects are focusing predominantly on partial solutions. The standards work group of the EIP Smart Cities and Communities aims at the development of a high level Smart City

[14] Prominent developments include Big Data and Machine Learning, Blockchain, and Virtual/Augmented Reality; network technologies such as Lora, RFID and other sensor technologies and a little further down the road 5G. These technologies will be linked through new network paradigms such as Internet of Things, Software Defined Networking (SDN) and Information Centric Networking (ICN).

Reference architecture based on common design principles[15] for Urban Platforms. Although a useful and important effort to boost interoperability at EU level, the framework is too generic and in other parts overly prescriptive. It is an important starting point but it will have to tie in with developments at city level.

Bottom-up or top-down: towards a community driven smart city architecture
To achieve better alignment between top-down efforts at EU level and local efforts a process approach can be considered. The EIP conceptual architecture or 'blueprint' can be the starting point of a community based cyclical process aimed at continuous refinement of blueprint components.

Through practical multi-stakeholder work in local and regional use cases such as in RUGGEDISED experiments, the blueprint will converge by defining generic solutions based on local experiences. The blueprint will converge towards a common architecture but it will never be final given the dynamic, fast evolving nature of smart city platforms and services. In this way a community driven blueprint will balance innovation and interoperability. Import steps in the blueprint process include (1) Community mobilization to discuss and agree initial EIP inspired blueprint and components; (2) Validation and extension in local, often ongoing use cases; (3) Evaluation and update of the blueprint based on generalizing the results of local experiments and developments. Here the link to external projects and standard setting activities is important.

The blueprint is not prescriptive in technical solutions but defines common services, functionalities and interfaces at different levels of the stack from the hardware layer to the applications layer. It can also addresses issues such as data quality, storage, semantics, robustness and resilience of networks (privacy, Identity /Authentication / Access control (IAA), encryption and data breach prevention).

RUGGEDISED can align with the EIP workgroup and community adopting common design principles across the pilots while at the same time contributing with concrete, where possible generic (across the participating cities) solutions in areas (CO_2 reduction, energy, mobility) as addressed in the smart solutions.

6.2.2 City dashboards

Nowadays, many smart cities are developing city dashboards, under different names, like "smart city cockpit", or "smart city dashboard". They have in common that these ICT applications mainly serve two goals. First, dashboards provide city planners and decision makers with an overview of the status of their cities, based on (near) real-time data. This may well increase the quality of decision making, because it stimulates to start policy - and decision making from a fact-based 'as is' situation. Second, dashboards provide citizens with transparent data on their cities. To give citizens access to data in an open and easily interpretable manner is vital to a modern democracy. Within the context of smart cities, there is a large global push to make data more open. The RUGGEDISED lighthouse cities are all developing or improving their own dashboard. The textbox below provides experiences from Glasgow and Rotterdam.

Glasgow
Glasgow City Council, as part of the Future City Glasgow project used CKAN [16]as the core engine for the City Data Hub (https://data.glasgow.gov.uk/). Additional functionality, not available with CKAN when it was being developed (such as versioning) was added to the Glasgow Data Hub.

[15] Such as Capability based, Layered, Standards based, Market and vendor agnostic, No prescription of solutions nor technologies, Modular, Incrementally achievable. The overal architecture is proposed to be based on The Open Group Architecture Framework (TOGAF), for developing an enterprise architecture.
[16] CKAN is a fully-featured, mature, open source data management solution. CKAN allows to easily publish and find datasets, store and manage data, engage with the community, and customize and extend the features because it's all open source. (taken from https://okfn.org/projects/ckan/).

One learning from the City Data Hub is that, although the data is open and available for all to access, there is still a level of knowledge required to interpret the data to be meaningful to your average citizen. In view of this, Glasgow will be developing a layer on top of the City Data Hub that will allow simple queries to be made by people with little or no specialist data knowledge, ensuring that the data is truly open to all. The output of these queries will be simplified as much as possible – using simple graphical representations, for example – to allow people to interpret and respond to the findings of any queries they make.

Rotterdam

The Rotterdam Dashboard (or Decision Support System) aims to completely align the physical city and how it is projected in the digital world. The development of the I&C platform, based on the 3D model of the city is in progress. At this moment the team is working on the first proof of concept. The team then hopes to proof that it is technically possible to create such a platform by visualising two different (real time) datasets within the 3D model.

Within this proof of concept the team develops a first version of a datahub (data management and data lake) and a 3D visualisation platform. It also develops (together with the EU-project Espresso) a standardised connection for data sources to be connected to the datahub (input) and a standardised connection for using the data out of the datahub (output).

In this process the team encountered different problems, such as the kind of standardisation of software connections, data availability and data ownership. Especially the latter seems to be more common: in several cases the municipality only has access to data as a user, but doesn't own them (in Rotterdam for example the smart waste collection data). This makes multiple use of data difficult.

The second proof of concept will show the ability of the platform to be information driven. The purpose will be to answer an information driven question of a real case. The third proof of concept is about the communication aspect of the platform. Instead of sending information the challenge will be to create an interactive community around a real issue in the city (see Figure 9 for the architecture of the platform).

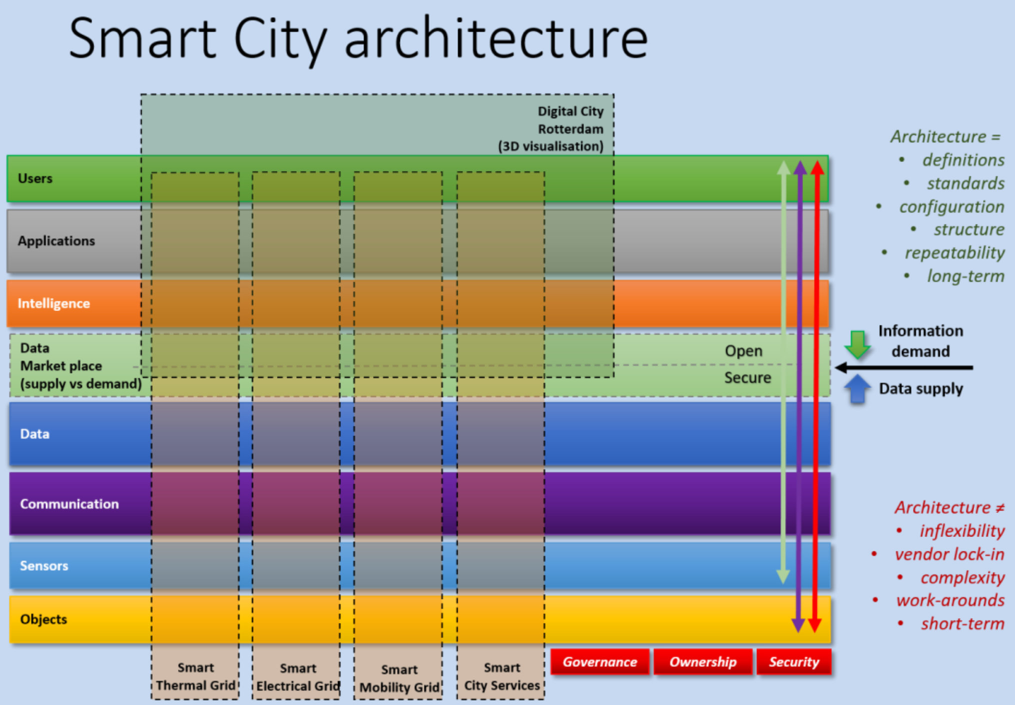


Figure 8 – Smart city architecture Rotterdam

6.3 Orgware and embedded outcomes of smart solutions

6.3.1 Integrated vision on the (smart) city

An integrated vision is seen as a key factor to realize a smart city. Different visions can conflict with each other; however modern cities must be able to combine multiple visions (Nam & Pardo, 2011). Smart city governance can help to coordinate the various components in a smart city. It has the ability to combine principles, factors, and capacities from various stakeholders and can cope with the conditions and demands of the knowledge society (Willke, 2007). Nam and Pardo (2011) argue that for example an objective to increase accessibility of transportation and the objective to improve air quality contradict each other but through an integrated vision, policies can be made that addresses both objectives. Additionally, visions must have a long-term strategy where an analysis of a city's context and metabolism must be made to see whether strategies matches needs of the city to avoid unnecessary development of for example ICTs (Goh, 2015; Nam & Pardo, 2011; Shelton, Zook & Wiig, 2015).

6.3.2 Smart governance

Over the last decade, an increasing amount of attention among academics, urban politicians and professionals around the world has been given to the concept of 'Smart Cities' where the use of Information and Communication Technologies (ICT) could help to overcome barriers and solve challenges cities face (Bolívar & Meijer, 2016). Caragliu et al. (2011) state that a city is 'smart' when "investments in human and social capital, and traditional (transport) and modern (ICT) communication infrastructure, fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance" (p. 70).

Based on literature research on the concept of smart cities, Meijer and Bolívar (2016) stress a smart city generally consists of three elements: technology, human resources, and governance. They argue that much attention in literature has been given to technology and in lesser extent to human resources as the defining characteristics of a smart city. However not a lot of research has focused on the governance element of the smart city, while cities feel an increased need for better governance to manage smart city initiatives and projects. It has become clear that the sole use of technologies is not sufficient to manage a smart city. Nam and Pardo (2011) emphasize the fact that 85% of IT public projects in cities mainly failed due to non-technical factors such as organization, policy, and management. This stresses the need for governance that can address and redress the possible outcomes of ICT applications and use, and can lead SC initiatives in the right direction (Walters, 2011).

In the context of a smart city, the new, innovative and ICT-based form of governance has been conceptualized as smart city governance. Smart city governance involves using ICTs allowing city governments to function more effectively and efficiently, and strengthen urban governance while actively involving and collaborating with stakeholders (Meijer, Gil-Garcia, Bolivar, 2016). It can help governments to design new governance instruments that enable an effective management of SC initiatives, and of a city's complexity and the challenges it faces, and is seen as an important factor in the development and the transition from a city, to a smart city (Belissent, 2011; Chourabi et al., 2012; Giffinger et al., 2007). Bolivar and Meijer (2016) highlighted six key elements of smart city governance: 1) The use of ICTs, 2) External collaboration and participation, 3) Internal coordination, 4) Decision-making process, 5) E-administration, and 6) Smart outcomes.

Challenges and Solutions

Smart city governance brings several challenges. A first challenge is the interconnectedness of above described elements. For example, smart initiatives need to be managed correctly, to reach a certain goal.

Also the connection and collaboration with other smart initiatives is important as they can strengthen each other due to, for example, data sharing or exchanging expertise to reach their goals. This can also positively influence the overall goal of a city.

New challenges also appear from the use of ICTs in the smart cities. The implementation and management of ICT solutions can bring unintended or perverse effects such as privacy issues or an unequal division of benefits between stakeholders (Meijer, 2016). Besides this, urban governance is changing towards a more horizontal, relational and collaborative approach due to the increased importance of non-state actors and decreasing governance capacity, leading to increased interactions between stakeholders.

In order to establish SC governance, the changing roles of city government and other stakeholders are becoming increasingly important as they can significantly influence the governance of a smart city. Local governments are up to a challenging task as they are expected to collaborate and work more with other stakeholders in networks in which they have less authority, but are still held liable for performances and better outcomes (Span, Luijkx, Schalk & Schols, 2012). The way how a city is managed plays a key role here for effective governance (Provan & Kenis, 2008). Citizens can share their opinions and knowledge, and private companies can bring in developer expertise, financial power, and technology in smart city projects (EP, 2014). Governments of smart cities have to cope with complexity and uncertainty, and therefore have to build competencies and attain resilience (Scholl & Scholl, 2014). It is however a challenge how the different stakeholders can collaborate and help to improve the urban environment. Companies have different goals than citizens and city governments. For companies, smart city initiatives should be profitable while for citizens and governments they should improve the urban environment. Creating public/private partnerships is therefore a big challenge as there are multiple or conflicting goals. Proper communication and collaboration can however solve issues such as legislation or policies that can prevent companies from implementing smart initiatives.

It is sometimes forgotten how valuable the social infrastructure, such as intellectual and social capital, can be to smart cities (Albin, Berardi & Angelico, 2015). Smart, educated and informed people can participate and engage with smart city initiatives and in this way affect the success of these smart initiatives. They can do this by using (smart) services that are made available to them, and by participating in the governance and management of the city (Chourabi et al., 2012). Mulligan (2013) stresses that a smart city cannot develop without asking citizens' opinions, and should engage citizens in the process of deciding how these opinions are used. It can however be an issue in how to engage citizens in decision-making processes. It should be made clear by, for example the government, that participating also has a positive effect on them. Something very important for current and future research and practice is the difference regarding empirical and theoretical studies. Theoretical studies argue that the classic hierarchical model of public administration does not work anymore, and a more collaborative, horizontal, and integrative approach must be taken in order to successfully govern the city (Bolivar, 2015). However by contrast, empirical experiences and urban practitioners in smart cities advocate a more government-centric model where stakeholders are involved providing knowledge and ideas, but where the local government keeps the leading role of the management of the city (Bolivar, 2016b). Bolivar (2016a) argues that the difference between theoretical and empirical studies could be due to the different publication dates of smart city governance studies. Data has indicated that most of the empirical studies have been published before the theoretical ones. This could mean that city governments were confronted with the development of a smart city, and acted what they thought was best, before a deep analysis of these new cities was made. This could explain why empirical studies analyze that city governments play a key role in the management of smart cities. The theoretical studies that were published later analyzed these empirical findings and proposed different models and approaches in order to successfully manage the smart cities. Over the last couple of years, open government, and the increasing involvement of citizens have been deemed appropriate and probable. This could be an explanation of why current theoretical studies focus on the collaborative and participatory models of governance in contrast to the empirical ones (Bolivar, 2016a). At this moment, these new models and approaches of governance have to be tested in practice in order to find out which one is considered best, or what elements should be focused on. This could lead to finding new challenges and solutions in smart city governance research.

6.3.3 Timing and windows of opportunity

Whether smart solutions can successfully be implemented in a city heavily depends on the smart city policy making process. As mentioned in the introduction, smart city solutions are characterised by interconnectivity and embeddedness within their urban environment. Inherently, in smart city developments many stakeholders, interests, policy domains and institutional settings are involved. In order to understand how such a complex structure may produce smart solutions, a better understanding of policy processes is helpful. The policy process has been described in a variety of ways, but one of the most influential frameworks is the Multiple Streams Framework, which is closely associated with the work of scholars like James March, Johan Olson and John Kingdon[17]. The basic premise of the framework is that policy decisions should not be understood as fully rational attempts by political actors to deal with discrete societal problems, but rather as a set of largely independent streams which come together occasionally to produce meaningful change. Traditionally, decision making in institutions is viewed as a process that moves from problem definition, through extensive analysis to rational outcomes. In contrast to this view, the streams framework acknowledges that decisions are often made based on the availability of potential solutions, the perceived importance of a problem and a set of actors willing to bring those together. This description of the way in which decisions are actually made was first put forward by Cohen, March and Olsen's and called the "Garbage Can Model of Organizational Choice". The garbage can metaphor is based on the notion that potential interventions are proposed and discarded within many organizations, but emerge again once a particular problem becomes more acute, and decision-makers are looking for fixes. At that point, the decision-makers are more likely to pick something from the "garbage-can". This is especially the case under conditions of great uncertainty, since the ability to decide about a course of action is more difficult when it is completely unclear how to forecast its potential outcomes. John Kingdon applied this framework to policy communities, which include elected officials, but also agency staff, academics and advocates in a particular policy-area. In his influential book Agendas, Alternatives and Public Policies, Kingdon focuses on the "pre-decision processes", through which the agenda for decision-makers is set, and the process by which the alternatives that decision-makers choose from emerge. He describes these pre-decision processes which make up an important part of the policy process as follows: "We conceive of three process streams flowing through the system – streams of problems, policies and politics. They are largely independent of one another, and each develops according to its own dynamics and rules. But at some critical junctures the three streams are joined, and the greatest policy changes grow out of that coupling of problems, policy proposals, and politics." (Kingdon, 1995).

[17] Most of this section is cited from: Magnuszewski P. (CRS), Sodomkova K.(CRAN), Slob A. (TNO), Muro M. (CRAN), Sendzimir J. (CRS) and Pahl-Wostl C. (UOS), 2010. Report on conceptual framework for science-policy barriers and bridges. Final version 22.12.2010 of deliverable No. 1.1 of the EC FP7 project PSI-connect. EC contract No. 226915. July 2010, Delft, the Netherlands.

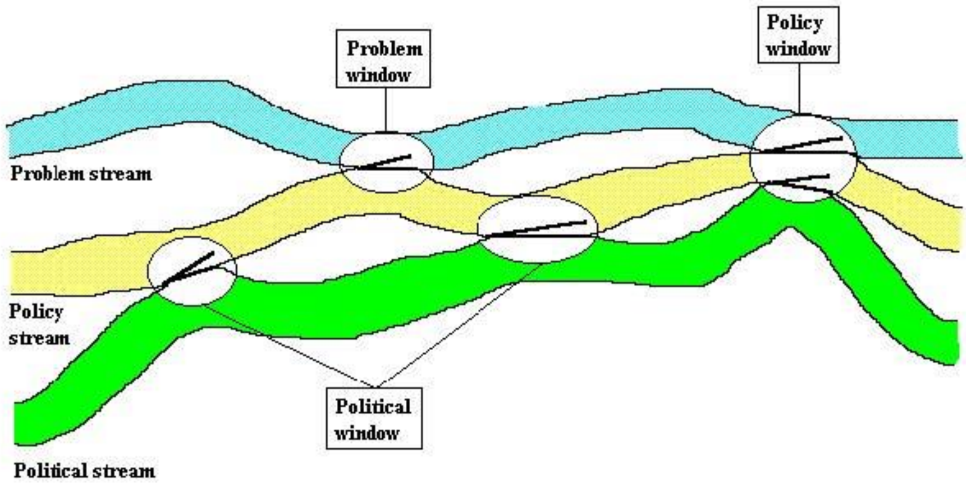


Figure 9 – Windows of Opportunity (Kingdon, 1995)

The moment, or period during which these streams are coupled provide a window of opportunity for significant policy change. These policy windows are opened, according to Kingdon, "(…) either by the appearance of compelling problems or by happenings in the political stream." (1995: 20). The role of science in this model has traditionally been conceived as one of signalling, studying and framing problems and of developing and advancing potential interventions or policies. Since these streams may show windows of opportunity at different times without overlap and hence a problem may not be tackled and scientific knowledge may not be used until the problem has reached such a level of urgency and damage that action is mandatory.

The theory above shows that policy making in general, and smart city developments in particular never start from scratch. They always result from history and interests brought from the different streams that together produce urban policies. That means that smart city design and smart city outcomes are often the result of path-dependencies and do not follow on deliberate optimisation. What follows is what Sorensen (2015, p.30) calls 'layering' and 'conversion'. Layering refers to the creation of new policies or developments without eliminating the old ones. In the smart city context this would mean that a new energy infrastructure is developed without eliminating the old infrastructure. Consequentially, two different energy infrastructures are used next to each other. Conversion refers the idea that implementation (and interpretation) of existing policies change, where formal policies and rules remain unchanged. This potentially happens when regulations are broadly interpretable and the involved actors have weak veto possibilities. In the smart city context this idea of conversion is highly relevant. Do cities dare to design new policies to facilitate the transition towards a smart city or do they rely on a changing interpretation of old rules and policies? The idea of path-dependency is that the latter may never produce optimal outcomes.

6.3.4 Stakeholder management

Smart City developments deal with complex issues Complexity refers to a changing vision on what reality, real knowledge and understanding is about. [18]Whereas (eco)systems - such as cities, organizations, societies, river deltas, nature reserves, infrastructures weather systems etc. - in the past (modernist view) were regarded as closed, more or less independent systems, a 'complexity view' of the world acknowledges that such systems are fundamentally open (Cillier, 1999). They are embedded within and in continuous

[18] Most of this section is cited from RESIN (2017) deliverable D6.3 "Coping with Complexity, handling Uncertainty". http://www.resin-cities.eu/fileadmin/user_upload/Complexity/D6.3_RESIN_Complexity_and_uncertainty_TNO_20170228_1_.pdf

interaction with their environment. Moreover, they are continuously moving from one state to another, from order, to disorder and new order. "This continuous movements leads to irreversible and non-linear change, to be described herein as emergence and self-organization, and adaptation and co-evolution" (Boonstra, 2015). Due to the innumerable interactions within a system (i.e. a city) and between a system and its environment (i.e. a city region or an urban-rural interface), complexity thinking reflects a fundamental shift in the extent to which systems can be understood. In the academic literature this is well illustrated by saying that in the past we looked at **complicated** (but understandable) systems, and now we look at **complex** (and non-understandable/predictable) systems. "Complex systems are systems that can produce unexpected dynamics, because of nonlinear interactions among components" (Cillier 1999).

Following the complexity view, policy developers and decision makers are confronted with so called complex (environmental) problems, sometimes even characterized as "wicked" (Head & Alford, 2015) or "super wicked" (Levin et al., 2012) problems. "Wicked problems are generally seen as associated with social pluralism (multiple interests and values of stakeholders), institutional complexity (the context of inter-organizational cooperation and multilevel governance), and scientific uncertainty (fragmentation and gaps in reliable knowledge)" (Head & Alford, 2015). In addition Funtowicz and Ravetz (adapted from Van der Sluijs, 2012) provide a very helpful typology of complex (environmental) problems by distinguishing 6 typical issues that decision makers have to face in complex policy making situations:

- Decisions should be made in an early stage, before enough scientific evidence is in place
- The error costs of decisions are high
- Many different values, and values are in dispute
- Large uncertainties within the knowledge base
- Assessment dominated by models, scenarios and assumptions
- Many hidden value loadings in problem frames, assumptions and chosen indicators.

Such wicked problems, which include smart city development, require decision-making processes that take into account pluralist and self-organizing networks of interdependent governmental, private, non-governmental, and societal actors. Controlled top-down decision making within neatly confined governmental structures are no longer appropriate to answer the challenges faced. There are several reasons why we should involve stakeholders. In complex environmental problems responsibilities, knowledge and power are distributed among the involved actors: governmental bodies, businesses, and stakeholders. This gives already the answer why we should involve stakeholders in the policy process: because they are responsible for certain aspects of the environmental problem, because they have certain knowledge that should be brought into the process, or because they have a certain power: power to obstruct or power to realise.

The core[19] of stakeholder involvement is that governments develop policies from an early stage in consultation and co-operation with stakeholders. Edelenbos (2000) defines stakeholder involvement as "the early involvement of individual citizens and other organized stakeholders in public policy-making in order to explore policy problems and develop solutions in an open and fair process of debate that has influence on political decision-making" . Stakeholder involvement as a process differs from traditional public consultation procedures in that stakeholders are involved early enough to influence policies when they are formulated. It makes sense, thus, to involve stakeholders in policy problems that are complex, and we should do that from an early stage of the policy process, i.e. when the problem is framed.

[19] The following section is adapted from Slob, A. (2010) "From Aliens to Allies" paper presented at the Nordrocs 2010 conference; 3rd Joint Nordic Meeting on Remediation of Contaminated Sites 15-16 September 2010 in Denmark.

Who are the stakeholders?

To identify the stakeholders a stakeholder analysis can be performed. In this stakeholder analysis one should make a list of all people and organizations who influence the policy problem or who can help to solve it. After identifying the most important stakeholders one should identify the interests and goals of these stakeholders in the process by interviewing them. For each stakeholder the following questions should be answered:

- What will the stakeholders contribute to the process?
- What kind of knowledge do they possess?
- What are the relevant interests and goals of the stakeholders?
- How do the stakeholders interpret the issue at hand?
- How well informed are the stakeholders about the issue?
- What are the (possible) motives for these stakeholders to participate, or not to participate?

Stakeholders do not necessarily share the same view or perspective (Thompson et al.,1990; Schön and Rein, 1994) With perspective we mean the set of values through which the world is perceived, and that causes to interpret situations and occurrences differently. We researched the different perspectives of actor groups (businesses, policy organizations, stakeholders) on sediment management through surveys and interviews. We found three dominant perspectives: users, controllers, and guardians (Slob et al., 2008).

How should we involve stakeholders?

First we need to know what kind of role we want to give to the stakeholders. Do we only want to inform them or do we want to engage them in the policy making process? According to Gerrits and Edelenbos (2004), involvement of stakeholders in policy processes can be arranged from low to high involvement:

- Information: providing information to the stakeholders
- Consultation: consult stakeholders to hear what they think that must be done
- Advising: stakeholders give advice about the policy or measures that should be taken. Their recommendations should be taken into account by the policy organisation
- Co-producing: stakeholders are regarded as equal policy makers but decision-making remains in the political domain
- Co-deciding: decision-making power is handed over to stakeholders.

The process itself should be designed in an open and transparent way by professionals who are used to design these processes. It should be divided into logical steps (for the stakeholders) and contain stakeholder meetings. This process design, together with their role in the policy making process should be communicated and presented to the stakeholders in the beginning of the process.

Stakeholder knowledge for policy processes

One of the arguments to involve stakeholders is that they possess unique knowledge. In policy processes we make a distinction between the use of procedural knowledge, scientific knowledge and local knowledge. Procedural knowledge is knowledge about which laws and regulations are applicable, the procedural stages of these laws or regulations, and the timing of them. Scientific knowledge is the formal knowledge, most of the time encoded in reports or models, that can be used to understand the problem or to find solutions. Local knowledge is tacit knowledge of the people living in the area that resembles specific knowledge about certain aspects of the environment. Stakeholders can bring in all three types of knowledge to the process, but especially the last one can be of great importance to the policy problem. In the process design, therefore, much attention should be paid to create opportunities to bring in knowledge, to articulate the important questions and to produce new knowledge together.

Well-designed collaborative knowledge production processes help to generate meaningful results for the involved policy makers, scientists and stakeholders by joint production of documents, models, etc. People who can combine different fields of knowledge and can attach to different communities play an important role in the processes that guide the activities.

6.3.5 Ownership

Ownership is an important topic in smart cities. Who owns the infrastructure, buildings, land, ICT software and the data? Moreover, who is responsible for malfunctioning systems? In order to understand the importance of ownership, analysis of property rights within institutional economic theory provides helpful clues. “The property rights approach is based on the basic thoughts of property rights theory, originally introduced in the work of Coase on social cost (Coase, 1960). When rights are well defined and the cost of transacting is zero, resource allocation is efficient and independent of the pattern of ownership (Coase, 1960). This implies that, theoretically, the question of ownership is irrelevant, as market outcomes will always be efficient regardless of the initial assignments of rights and liabilities (Coase, 1988).” (Van der Krabben, 2008, p. 2871) “Lai and Hung (2008) have systematically spelled out the practical applicability of this theorem for city development and land and property markets by focusing on the corollary version of the Coase theorem: if markets are characterized by the existence of transaction costs, we need to have a close look at institutions and ownership to explain market outcomes, since these institutions have affected the assignment of rights and liabilities (pp. 208-209).” Institutional economists argue that the concept of ownership and property is not as straightforward as it seems. To understand how ownership incentives actors one should take into account the bundle of different property rights the ownership is subject to. Moreover, ownership is a cultural factor as well. For instance, different economic world orders like capitalism or communism fundamentally disagree in their ideas about property and about (land) ownership in particular (Woestenburg et al., 2013). Ownership “represents deeply rooted moral beliefs” (Needham, 2006, p. 10).

Due to this deeply rooted moral beliefs changes in the way we look at ownership and delineation of property rights are not very likely to occur. However, environmental circumstances (such as climate change) and technological developments (for instance in the field of smart cities) may give rise to rethink how society has defined ownership. New technologies change the way in which traditionally goods have been divided in categories; private, common, club and public goods (see figure 11). For many years these categories have defined the role of public bodies in providing several goods, such as infrastructure. However, technologies change the way in which goods are subject to potential ‘rivalry’ and ‘excludability’. Through new technologies (such as individual sensors on air pollution) it is possible to demarcate the property rights differently. Research has shown that indeed a different demarcation and delineation of ownership (for instance ‘polluter pays’ mechanisms) may have significant effects on market outcomes (such as air pollution and noise reduction).

	Excludable	Non-excludable
Rivalrous	**Private goods** food, clothing, cars, personal electronics	**Common goods** (**Common-pool resources**) fish stocks, timber, coal
Non-rivalrous	**Club goods** cinemas, private parks, satellite television	**Public goods** free-to-air television, air, national defense

Figure 10 – Categorization of goods

6.3.6 Business models and split incentives

We also observe that many of these complex, multi-stakeholder projects needed for sustainable innovations fail to achieve scale (either within or after the project) and its intended development progress stagnates because of the partial rationality of the individual stakeholders, mostly for financial reasons or “not being able to work out the short term business case”. Often, this results from implicit but nevertheless misaligned or outright conflicting interests of stakeholders and large dependencies within the multi-stakeholder network who hold power within that network (Rowley and Moldoveanu, 2003).

The business case is one of several methods described in the literature to analyse the effects of an investment decision. The business case analyses the financial effects for a single stakeholder and a single innovation, in a certain area and confined period of time, usually a short term. Longer term values are discounted and virtually evaporate. Implicitly thereby a choice for the dominant value, i.e. financial values, specifically cash flows, is made. Based on monetary costs and benefits, the business case calculates the net present value that a stakeholder expects to make. A business case only incorporates financial (cash flow) values that are part of an implicitly assumed fixed business model of the stakeholder concerned. The business case method is able to provide a general overview of the financial value of an innovation for all stakeholders combined, by simply combining their business cases. Typically, this aggregated business case to identify overall financial value is not by default part of any project. If all business cases lead to a positive outcome, i.e. all stakeholders involved have a positive cash flow and those required decide to invest, there is no need for further analysis with respect to go-ahead decisions. (Assuming the go-ahead decision of this project does not compete with that of others.) However, this is not always the case. Furthermore, the effects of implementation of the project may affect a scope larger than that of the involved stakeholders. Taking only the (financial) values of stakeholders into account is often not enough. One has to consider the whole systems of stakeholders and effects on short, medium and long term. It is therefore questionable whether a traditional financially oriented business case is an adequate method to come to an investment decision in complex multi-stakeholder projects, as the costs and benefits vary for the different stakeholders that need to be involved (Van Scheppingen et al., 2012). The type of innovations we are considering in the RUGGEDISED project often requires a role or position change, has a strong interdependency with decisions of other actors and typically has a high level of opacity and uncertainty.
For some innovations it can be clear what type of effects (e.g. emissions) it will generate, and to some extent also whether it will be little or a lot. In most cases, however, a more precise indication of the expected performance of an innovation and identification of the conditions in which this will take place is needed. This comes at a cost, as quantification requires access to data and takes effort. Often effects are expressed in monetary terms, where it is assumed that more money is preferred over less, but also that an extra monetary unit is appreciated equally by all stakeholders. In the multi-stakeholder projects we consider, we cannot expect a commercial company to value a euro of profit equally as a euro of social cohesion, as the latter does not reflect a short term cash flow towards the company. It also brings forward the need to distinguish the expected "absolute" and objective performance of an innovation in terms of effects and the acceptance level for stakeholders with respect to this effect. Put differently, the need to quantify certain effects implies that stakeholders have a subjective sensitivity to these effects. "How much effect will the innovation generate?" and "How important is this effect to the stakeholders?" are the questions that need to be answered. The latter is specifically relevant when the innovation does not address or meet minimum levels of values that are important to a specific stakeholder, as that will cause the collaborative innovation to halt. Sensitivity will guide the collaborators towards values on which the innovation should be improved upon with potential for achieving acceptance.

Consensus and shared value creation

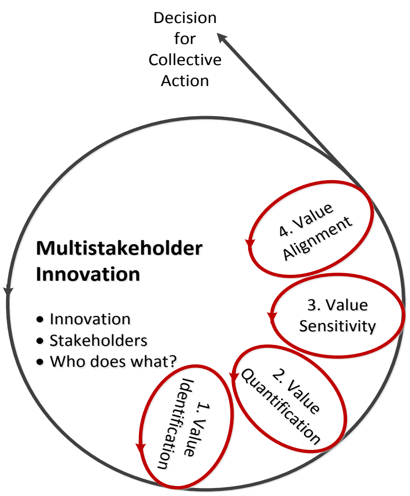
In 1993 Normann and Ramirez introduced the idea of a value constellation, referring to the group of stakeholders who work together to create new value and innovative products (Norman and Ramirez, 1993; Vanhaverbeke and Cloodt, 2006). This state that "strategy is no longer a matter of positioning a fixed set of activities along a value chain [...] successful companies do not just add value, they reinvent it" (Norman and Ramirez, 1993). They suggest that reinvention coincides with a co-productive network of actors who aim to increase overall value production. They propose a new way of thinking for companies in terms of partnerships and cooperation, but they do not touch upon how to successfully integrate these networks into a cohesive constellation. While companies may know that change is required in order to achieve a successful implementation of an innovation, drastic changes are not always feasible due to the company structure (Utterback, 1994). These companies may have ideas expanding beyond their typical way of working or company structure, so a change in the value constellation of their innovations is not a likely next step. Many large, mature companies show some form of strategic inertia. Collaboration with suppliers, customers and competitors is needed to change current value constellations and change the company's structure and long-term strategy (Dittrich et al., 2007; Dittrich and Duysters, 2007; Porter and Kramer, 2011; Vanhaverbeke and Cloodt, 2006).

The Value Case Methodology (VCM) as an extension of the generic multi-stakeholder innovation, is aimed at positive decisions to go-ahead with the innovation (Dittrich et al., 2015). Once the innovation is defined, stakeholders are selected and an initial overview of who-does-what is produced, the VCM can be initiated by performing the following steps (see Figure 12):

1. **Value Identification**. For each stakeholder the relevant values that the innovation should affect are elicited. A qualitative insight on who gets what values is produced.
2. **Value Quantification**. In case the distribution and impact of the qualitative values identified cannot be determined unambiguously, additional insights are needed and the who-gets-what and who-does-what are quantified in appropriate units and measurements.
3. **Value Sensitivity**. Based on the definition of the innovation, the range of acceptable values for the innovation for each stakeholder are elicited from testing modest deviations from the base project definition. These are visualised and analysed and a list of alignment opportunities is the result.
4. **Value Alignment**. A structured process aimed at getting an overall acceptable project definition for the innovation, based on the alignment opportunities is performed.

The Value Case Methodology is an iterative decision-making process (see Figure 3). Within one iteration of the VCM, the elements required for the generic innovation process are assumed to be known. The elements only change when a new iteration starts. We assume that the VCM is applicable when:

- (Innovation) project description and purpose of investment are given
- There is a fixed set of necessary stakeholders.
- Each stakeholder has sincere intention to undertake collective action
- The stakeholders have decision-making power
- There can be multiple stakeholders within one organization
- The overall costs and benefits are known and agreed upon
- The business case cannot be made or is indecisive for each individual stakeholder



Typically when an innovation has a platform character and it is complex in nature, future outcomes have interdependencies and uncertainties, the innovation will likely have to involve multiple stakeholders with different roles, backgrounds and values. We suggest some means and methods to perform each of the steps and to put the VCM into practice. VCM devices a focus on value elicitation and satisfaction of all stakeholders by shaping the project based on these values. The VCM requires some additional effort and techniques, but provides the opportunity for systematic value alignment. The presented VCM thus is a practicable means to shape innovation projects such that these are valuable for all involved.

Figure 11 – Illustration of the Value Case Methodology as a process

Collaborative (sharing) business models

In order to develop collaborative (sharing) business models it is important to create a (shared) perspective on smart cities and its smart solutions and components. To this purpose we have developed a layered architecture model on smart cities in figure 3. We used the smart city architecture model of the City of Rotterdam as the basis. One the one hand the architecture is based on (existing) vertical oriented applications and silos within the municipality and companies. On top of that it includes horizontal cross-application and cross silo collaboration and data sharing. The architecture model is based on combining public and private data sources into a data marketplace and extending these with (open) data sets to create a digital city platform, which can be the basis for new business models and smart city applications and services. We distinguish the following eleven layers (see Table 7 and Figure 13).

No	Layer	Description	Examples
11	Users	users of digital city collaborative platform or services	citizens, government, companies, knowledge institutes, visitors and objects
10	Channels and devices	Different channels and devices can be used as interface for applications and services towards the (end) users	smart phone apps, websites, displays (such as smart home devices, public video displays)
9	Applications and services	(3rd party) service providers who develop specific applications and services, using the data from the data market place	Mobility, smart city planner, environmental monitoring etc
8	Intelligence	Intelligent services using the data market place	sharing, fusion, import/export, interpretation, statistics and data science analytics services
7	Data market place	the core platform and infrastructure for the smart city, including protocols, parameters and a (data) catalogue	
6	Integration	Open integration, based on open APIs. Ontologies and semantic web services provide an important interoperable data representation standard. Languages like W3C, RDF-S, and OWL enable the exchange of data across city's domains by collecting intra-domain concepts and defining relationships among them. Visualization APIs expose data on the web on a common visualization structure	
5	Functional applications and platforms	Specific (vertical) platforms and applications to create value focuses on a specific application area	Smart energy management, dynamic route planning, smart waste management
4	Data	proprietary and open data	Sensor data, customer data, social data
3	Communication	Fixed or mobile IP-based communication	
2	Sensors	Sensors to track location, status (based on certain values), sound, speed, temperature, movements, visual	
1	Infrastructure and Objects	Infrastructure layer, consisting of networks for energy, mobility and objects (that can be equipped with sensors)	Networks: energy networks, transport networks

			Objects: energy meters, electricity charging devices, solar panels, electric cars and busses, garbage cans etcetera

Table 7 – Business models and layers

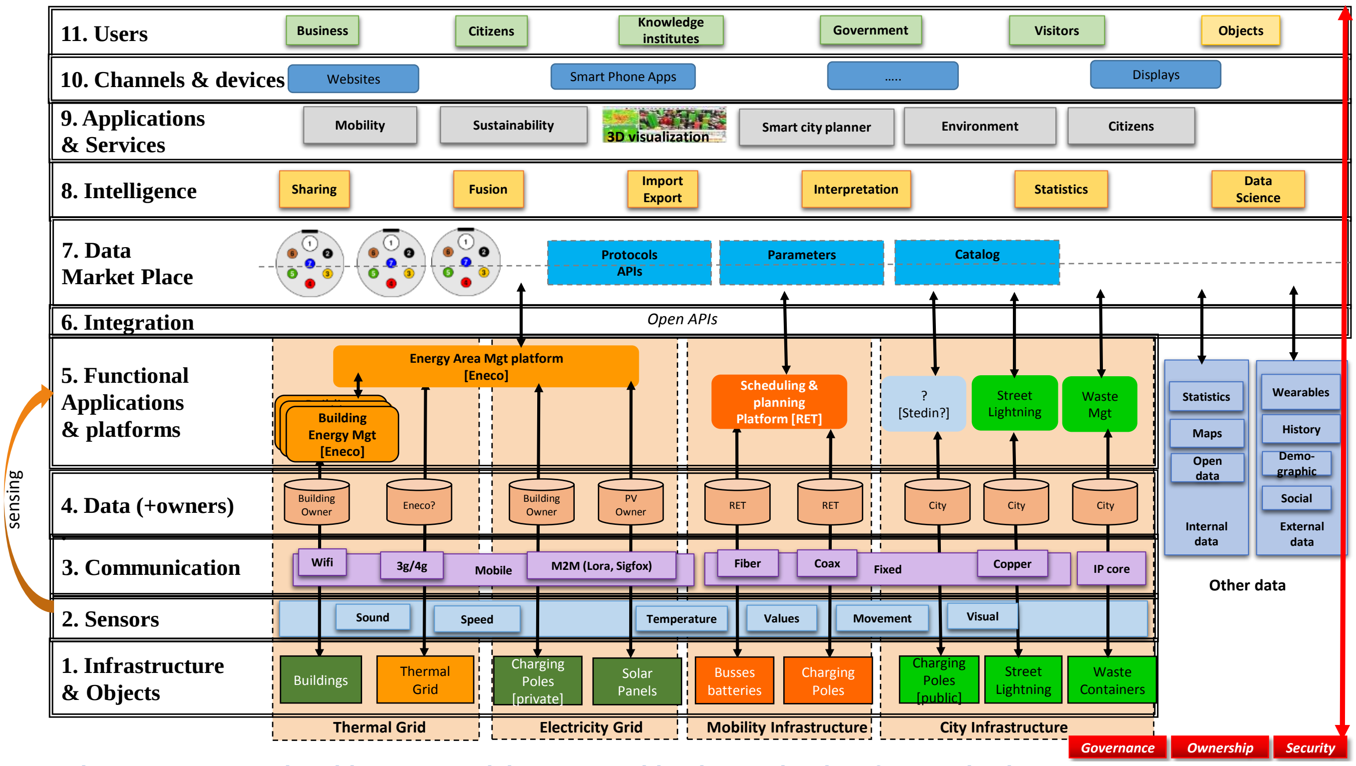


Figure 12 – Layered architecture model on smart cities (example City of Rotterdam)

Financing and engagement models for smart city initiatives

There are different financing and engagement models to develop Smart City initiatives, such as the development of a digital city collaborative platform. Besides funding by the government, increasingly these initiatives will be developed in a public-private collaboration model. Forrester describes several creative engagement models, which tech vendors can pursue in engaging with smart city initiatives and local governments (Bélissent, 2010):

- Develop revenue-generating (or cost-cutting) initiatives: Revenue-generating and cost-cutting initiatives, such as fee and tax collection or electronic government procurement, can become self-funding and prove appealing both for budgetary and political reasons
- Forming revenue-sharing agreements and brokering public-private partnerships: Partnerships with a vendor, service provider, systems integrator, or even real estate developer on a revenue-sharing basis can defray upfront costs and risks of a new initiative
- Enabling larger city IT departments to become service providers (towards other cities): Excess capacity from large municipal IT infrastructure or applications deployments can be provided to neighbouring cities or organizations, with the larger city IT department acting as a service provider or through a managed service provider
- Facilitating multicity initiatives, using economies of scale: Upfront agreements to pool resources and share infrastructure facilitate the launch of large IT initiatives
- Enabling data monetization: The use of primary data generated by instrumented infrastructure provides a potential revenue source for data owners

Next to these creative models vendors also use more traditional business models in smart city contexts:

- Leasing and financing: provides flexibility in case of budget shortfall or other political contingencies
- Barter or in-kind exchange: Exchange of product testing or customer references for new technologies is a way of overcoming budget shortfalls, particularly for universities or research facilities with skilled developers and users.

7. Level of impact 3 – Upscaling and replication

"It is a joint action of different elements that would limit or facilitate the possibility for a project to be successfully implemented at a higher scale or in other contexts" (European Commission, 2016). There is no single solution to tackle the challenges of smart solutions being successfully upscaled or replicated. However, the presence of an innovation ecosystem in which policy -, business – and knowledge partners collaboratively initiate projects in a context that facilitates continuous learning. Replicability is an important part of the RUGGEDISED project. It is a check on the robustness and flexibility of the smart solutions and lessons learned, in the sense that it shows the impact of a different institutional context on the success of the implementation.

Table 8 – Enhancing and suppressing factors for upscaling and replication

Level of impact 3: Upscaling and replication		
Hardware	**Software**	**Orgware**
		Integrated planning
		Innovation platforms
		Conditions for upscaling: finance, regulation (including standardisation), access to information and social aspects

7.1 Hardware factors for upscaling and replication

Scaling one or a set of smart solutions, i.e. changing the size (normally a larger size) of the solutions within a given environment generally requires development of collaboration methods, business models or ICT-integration. These aspects are described in the sections on Software and Orgware. For the hardware part the main considerations for scaling is the effect on the surrounding systems. Limited demonstration projects can normally be carried out with no or marginal effect on the surrounding system level. With upscaling of a smart solution, the effect and interaction with the system becomes crucial. As an example, a limited demonstration on polygeneration of electricity by solar panels, may power grid congestion. Similarly, an upscaling of charging stations for vehicles may, without taking the capacity of the electric system into account may cause voltage problems. A more moderate consequence is that lack of integration and system perspective can cause sub-optimisation in other parts of the energy systems, e.g in financial terms.

Apart from the fact that any upscaling of smart solutions requires high performing equipment, the consequences of an upscaled solution or a set of solutions, is achieved by a careful strategy for monitoring of the different hardware components. Applying equipment, certified by authorized organisations with proven performance is also a way of assuring an understanding of any impact on systems before deployment. Furthermore, systems analyses and scenarios by using state-of -the-art simulation tools can provide the necessary understanding of the effects on heat and electricity systems.

The hardware aspect is of high relevance of high importance for a successful replication of one or a set of smart solutions. Replication, i.e the transfer of a solution into a different environment requires an elaborate understanding of the surrounding environment in order to assess the successful transfer of technologies and solutions. For instance, climate conditions and solar radiation influences the potential and the relevance of technology components and solutions.

7.2 Software factors for upscaling and replication

A key challenge to the upscaling and replication of smart city solutions is the diversity and fragmentation of ICT frameworks, approaches, and standards (see also 6.2.1). To achieve alignment between top-down efforts at EU level and local efforts a new bottom up standardization approach should be considered. The EIP conceptual architecture can be the starting point of a community based cyclical process aimed at continuous refinement of a smart city ***blueprint***. Through practical multi-stakeholder work in local and regional use cases such as the RUGGEDISED experiments the blueprint can converge by ***defining generic solutions based on local experiences***.

The blueprint will converge towards a common EU architecture but it will never be final given the dynamic, fast evolving nature of Smart City platforms and services. In this way a community driven blueprint will balance innovation and interoperability. Import steps in the blueprint process include

1. Community mobilization to discuss and agree initial EIP inspired blueprint and components;
2. Validation and extension in local, often ongoing use cases such as the RUGGEDISED experiments;
3. Evaluation and update of the blueprint based on generalizing the results of local experiments and best practices. *Here the link to external projects and standard setting activities is important*.

The blueprint defines common services, functionalities and interfaces at different levels of the stack from the hardware layer to the applications layer. It can also addresses issues such as data quality, storage, semantics, robustness and resilience of networks (privacy, Identity /Authentication / Access control (IAA), encryption and data breach prevention). The blueprint approach can guide the process in RUGGEDISED to ensure Smart City solutions are compatible and complementary across the participating cities.

Glasgow city best practices

Integration of models of city deployments within the Glasgow 3D Cadaster for use in upscaling and replication studies undertaken by others in future.

The detailed simulation models formed for each technology deployment (as indicated above) can be archived by the city and added to an evolving whole-city model alongside existing, lower order models comprising geometry-only representations and estate inventory information. Such a resource may be regarded as a significant deliverable from the project since it provides a relevant new appraisal capability to the many stakeholders engaged in future city developments.

City GIS and building modelling capabilities including full consideration of policy constraints. Glasgow City Council has previously established a GIS-based tool that generates maps of technical opportunities and policy constraints throughout a city. This allows developers to identify sites where planning permission is likely to be granted, where there is good grid access potential, and where the local substation is not congested. It would be possible to extend this tool to accommodate data relating to other partner/ follower cities.

Deployment of sensors in domestic properties to demonstrate impact of solutions.

Glasgow City Council has previously established an ‘e-service’ for the quality assurance of building upgrades, with the automatic sign-off of individual projects based on monitored data spanning pre- and post-upgrade periods. These data are collected via low cost, wireless, open source, open common, multi-sensors that record a range of indoor conditions at high frequency; and via metered energy use. The opportunity exists to trial the e-service in the context of a specific building upgrade activity undertaken by a project partner.

7.3 Orgware factors for upscaling and replication

7.3.1 Integrated planning

In novel approaches of city planning, complexity theory is used to describe the interdependency, interconnectedness, and non-linear dynamical behavior of problems that cities are confronted with.
The complex systems approach is a promising new way to describe and explain how cities form, evolve, adapt, and evolve in response to changing conditions (Sanders, 2008). The complexity approach emphasizes the city as a whole, the relation between its composing parts, and the underlying interacting variables, structures and dynamics that together lead to emerging situations (problematic or not) in cities. It, therefore, can be used for a holistic view on city problematics, and offers a framework for integration. Complexity challenges the planning paradigm as planning and surprise don't relate well. Planning in complexity asks for approaches that are better able to cope with self-organization, emergent behaviour and surprise: a step-by-step approach instead of the 'design of the future' approach. New approaches like adaptive management, and co-creation fit better to this.

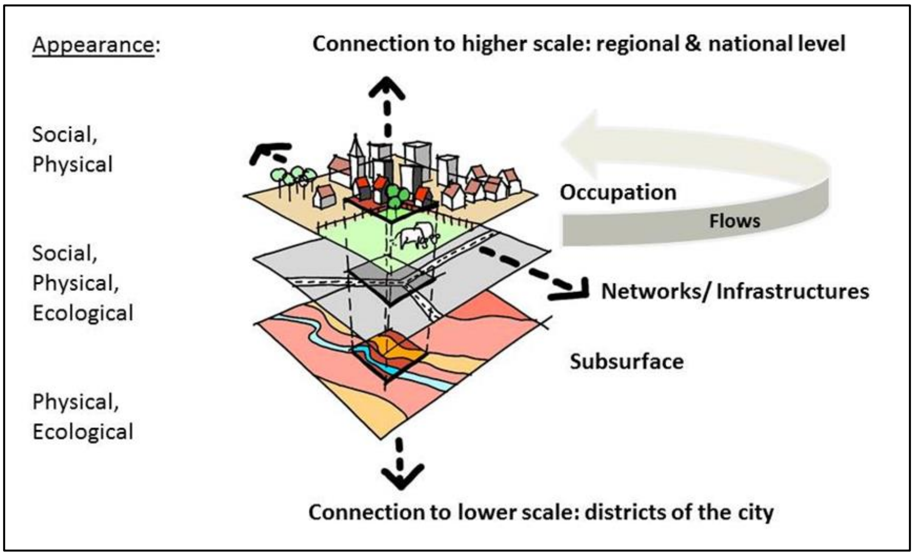


Figure 13 – City layers

The '**layers approach**' (Priemus, 2004) is a holistic planning method that emphasizes three interconnected layers that influence one another: the layer of the subsurface, or substratum, the layer of the networks, or infrastructures, and the occupation layer, the layer where people live, work, recreate etc. It is, in fact, a system approach. The layer of the subsurface contains the interlinked soil, water, groundwater, and sediment processes and the link with the ecological system. It is the layer upon which the other layers are built. The networks layer contains the physical (infrastructures) and social networks. The networks layer fosters horizontal connectivity from neighbourhood to city to other cities and the infrastructures carry the flows of data, material, mobility (people), energy, water, etc. The occupation layer is the layer where activities of people take place and contains the physical structures (houses, offices, etc.) for these activities. Each layer delivers the conditions for the functioning in the other layers. The subsurface layer contains for instance the soil conditions which influence the type of buildings, the configuration of the built environment, or influence what kind of activities can be organized in the occupation layer. The idea is that change in the layers will take place in different time scales. The subsurface layer will change on a geological time scale, with a magnitude of about 100 and more years. The physical appearances in the network and occupation layer , i.e. the infrastructures and buildings, can change a little bit faster, in a time frame of 30-50 years, while the social networks and activities in the occupational layers can change much faster (in less than a year).

Bringing both approaches together delivers a conceptual model that emphasizes:

- the importance of connectivity. Horizontally between districts and cities, vertically between the subsurface, infrastructures, networks and people (the social-ecological system);
- the interdependencies between different levels of scale on district, city, and national level;
- the networks and infrastructures as social and physical forms that foster the connectivity and support the flows of energy, mobility, material, data, etc. in the city. The network or infrastructures layer plays an important role for the functioning of the city system ;
- the concept of self-organization and emergence that asks for planning system that can better deal with bottom-up processes and surprises;

This conceptual model allows for integrating planning of energy, mobility and land use and facilitates the selection of measures that fit in the integration.

7.3.2 Innovation platforms

A crucial element to enhance upscaling of smart city solutions seems to be the presence of local innovation platforms or innovation ecosystems. On this topic a lot of expertise has been gained in recent years, especially in Sweden. In June 2013 four cities were awarded national funding to develop innovation platforms; Gothenburg, Malmö, Borås and Lund over a two-year test phase. Interaction between local actors such as businesses, municipalities and universities have historically played an important role in the development of innovations, but it is only relatively recently that responsibility for innovation supportive measures actively transferred to the municipal level. Innovation platforms were seen as a way of gathering relevant stakeholders to promote urban innovation.

The ambition of the platforms have been go develop structures and methods for working with enhancing the ability to support development and innovation in close collaboration between public (municipality, region), private (e.g real estate owners) and academia (universities and research institutes). Throughout the initial test phase the innovation platforms have developed in different directions, where some have focussed more on internal practices that support or hinder development of innovative ideas (Borås, Gothenburg), and some have focussed more on inviting private and external actors to initiate innovative actions and tests in the urban environment (Malmö, Lund). After the two-year test the main results have been:

- an increased local capacity to conduct innovation issues in the context of sustainable urban development.
- efforts to establish innovation platforms developed more time and more resources than what was originally adopted. The reasons for this have been the challenge to establish forms of collaboration and inexperience with Innovation concept as such, especially regarding how it is understood in a municipal urban context.
- the development of Innovation Platforms has brought challenges especially the interpretation of various actors' traditional roles. Partly this has meant the municipal and private has to some extent interfered into each other's spheres and challenged established notions of responsibility, professions and actions.

The overall evaluation of the test phase showed significant results and since 2016 the original innovation platforms have been granted a 3-year extension. New Innovation Platforms have also been established in Stockholm and Kiruna. As a general rule, the four original platforms have extended their ambition from a district focus and small scale tests to larger city wide ambition, focus on major policy processes, and large scale testing of innovative concepts.

As stated the innovation platforms have been adapted to local contexts and with different focus. As a general rule, the following aspects are of importance to all of them (Table 9)

Table 9 – Aspects of innovation platforms

Aspect	Description
Education and skills initiative	The platforms prioritise to identify the need for capacity building for strengthening the innovation capacity of the participating organisations, so that a specification of interventions can be developed. In the first phase, the focus is on municipal organisation because several platforms term strong need to find ways to strengthen the understanding of innovation and innovation capacity in the existing municipal operations
Innovation Fund	A municipality or city innovation efforts need financial resources at different levels. The resources needed for the organization of work, for example, to set up and operate management and support functions for Innovation in the city. Resources are also required to initiate development projects, implementing pilot and implement new solutions on a large scale. This involves both supporting individual innovation projects, and the funds for additional costs in the form of technological leaps and wide scale of new solutions that are initially more expensive than existing technologies and services. Finally, the necessary funds for monitoring, documentation and dissemination of knowledge.
Value Calculation and financing	Today the no value calculation for the social values that investment in physical construction and renovation generates or degenerates. This means that in all the sectors seem to sustainable urban development is difficult, and sometimes impossible, to know what efforts need to be made and / or the consequences of actions may be. A changed view on value creation that takes into account the social values can significantly improve the possibilities to develop financing instruments for urban innovation.
ICT - digitisation as support for smart sustainable cities	ICT, information and communication technology is a strong enabler for sustainable urban development, and several of the towns in innovation platforms are already working in the field. ICT departments and strategists of a municipality tend to be business oriented and focus on the ICT municipality as an organisation need to be able to work and develop a city. A visionary and coordinating responsibility for how ICT can support the development of the city is needed. A more holistic approach and a strategic role of the city as the provider of ICT as basic societal infrastructure is of major focus for Stockholm.
Innovation Platform policy lab	Living Labs as innovation and problem-solving environment is a tool to locally develop new solutions and overcoming structural barriers in the organisation. Borås will develop concrete tools and procedures for strategic and operational innovation management and will take responsibility for a common learning in the context of national coordination. The innovation platform will support projects with a high level of innovation, from concept to implementation. The platform will serve as dissemination and knowledge hub and train officials in including: service design, problem solving, conflict management, innovation management and norm creative innovation. The platform will also support strategic projects to overcome the structural barriers in the organization. The platform will provide structure and practices of innovation management in the public sector, training and, tools.

7.3.3 Conditions for upscaling and replication

This section provides an overview over the most common upscaling and replication barriers for smart city technologies. It is based on analysis of an online document produced by the Smart City Information System (SCIS[20]) project. Smart city development faces different challenges. Besides technological challenges, there are also regulatory, financial and social challenges. The tables below represents several and barriers and suggested solution to overcome these barriers in the smart city. It is categorised into three subcategories: (Table 10) energy efficiency in buildings, (Table 11) Low-carbon Technologies and Renewable Energy Sources, and (Table 12) Mobility and Transport. The data presented in this table was collected as a contribution to the Smart Cities Information Systems database.

Table 10 – Conditions for upscaling and replication (Energy Efficiency in Buildings)

Energy Efficiency in Buildings	
Dimension	**Barriers**
Finance & other economic aspects: Financial and economic barriers are related to the cost of the technology or to real or perceived risks for project developers, building owners or tenants.	**Financial cost** The costs of energy efficient new and refurbished buildings can often deter investors and ultimately block the initiation of projects. There are three specific barriers to low carbon technologies and renewable energy sources that fall under the category of financial costs: • High upfront cost • Access to capital • Long payback time
	Financial risks Financial risks could be related to underdeveloped markets or to uncertain investment viabilities.
	Hidden and Unforeseen costs The developers cannot anticipate these costs, which lead to an increase in the overall cost and risk of the project. Hidden and unforeseen costs often appear in large projects or projects implementing new technologies.
Regulation and governance: There different administrative structures and administrative regimes in place in all over Europe. These can significantly hinder the upscaling and replication of smart city solutions. Examples for common barriers are: as hostile regulatory regimes, administrative burdens and even the lack of commitment of the public authorities	**Inhospitable Regulatory Regime** In energy markets where due to regulation energy tariffs are lower than the actual cost of production, there is no economic incentive for consumers to reduce their energy consumption or to switch to low carbon energy sources. In particular, this is the case in Central and Eastern European countries.
	Lack of Standards and Regulations Building standards and regulations often do not keep pace with technological development. Developers are often reluctant to install new technologies, which are not specifically mentioned in the building codes and regulations.
	Improper Incentive Structures This is mainly related to fiscal or tariff structures, which sometimes fail to encourage energy efficiency.
	Administrative Burdens The number of permits and approvals needed to develop a building project with very high energy efficiency can constitute a major barrier in the implementation process. Also, the coordination with different bodies of government can hinder the implementation.

[20] SCIS, http://smartcities-infosystem.eu/policy-and-finance/policy-and-finance, March 2017

	Lack of Political Willingness Energy efficient refurbishments and construction of buildings cannot be implemented at large scale without some backing from local and national politics. If there is not sufficient backing, the project is very likely to be failed.
Access to information and social aspects: Access to information about the importance and viability of such projects is sometimes limited. This can refer both the level of public authorities and the level of individuals. Smart City projects can also face social barriers such as split incentives between stakeholders, resistance to change and the rebound effect.	**Split Incentives for Owners and Tenants** Energy efficiency measures are usually carried out by the landlord, while the utility bills are paid by the responsibility of the tenants.
	Rebound Effect Energy efficiency measures sometimes lead to a so-called "rebound effect", i.e. consumers actually consume more after the refurbishment of their building.
	Information and Awareness among Consumers Often, energy efficiency measures are not evaluated thoroughly due to lack of time, incorrect financial incentives or lack of knowledge. As a result, information and awareness among Consumers is not sufficient.
	Access to Information and Professional Skills in Public Authorities Especially in the smaller cities, the lack of information and skilled professionals in the public authorities can constitute a major barrier.
	Access to Qualified Workforce Without access to sufficiently skilled workers, energy efficient building technologies cannot be implemented correctly.

Table 11 – Conditions for upscaling and replication (Low-carbon Technologies)

Low-carbon Technologies and Renewable Energy Sources	
Dimension	**Barriers**
Finance and other economic aspects: Projects related to low carbon technology and renewable energy sources often face issues related to financial cost and risk. Conventional energy sources are still often more cost-effective than low carbon technologies, which can make it difficult for low carbon and RES project to get access to capital. This can slow down or even terminate the project development at a very early stage.	**Financial Costs** There are four barriers for low carbon technologies and renewable energy sources that fall under the category of financial costs: • high upfront costs • access to capital • cost effectiveness • long payback time
	Financial Risks Financial risks could be related to underdeveloped markets or to uncertain investment viabilities
	Hidden and Unforeseen Costs The developers cannot anticipate these costs, which lead to an increase in the overall cost and risk of the project. Hidden and unforeseen costs often appear in large projects or projects implementing new technologies.
Regulation and governance: There different administrative	**Excessive Regulatory Regime** In many member states, some regulation still favors centralized energy generation and supply. These kinds of regulations can significantly hinder the market uptake of Renewable Energy Systems (RES)

structures and administrative regimes in place in all over Europe. These can significantly hinder the upscaling and replication of low carbon and RES project. Examples for common barriers are: as hostile regulatory regimes, administrative burdens and even the lack of commitment of the public authorities	Lack of Standards and Regulations Standards and regulations related to low carbon and renewable technologies sometimes do not keep pace with technological development. Developers are therefore often reluctant to install new technologies, which are not specifically mentioned in the standards and regulations.
	Administrative Burdens The number of permits and approvals needed to develop RES projects can constitute a major barrier in the implementation process. Also, the coordination with different bodies of government can hinder the implementation.
	Inconsistency of Policies and Regulations Policies and regulations related to RES are still dynamically changing. Sometimes inconsistencies of policies and regulations can be observed. This can have negative impacts on the viability and economics of a project.
	Lack of Political Willingness RES cannot be implemented at large scale without some backing from local and national politics. If there is not sufficient backing, the project is very likely to be failed.
Access to Information and social aspects: Information about low carbon and RES projects is not always available due to lack of proper documentation or privacy issues. This limited availability of information can result in a level of reluctance among both public authorities and citizens about clean energy solutions. Low carbon and RES project projects can also face social barriers such as split incentives between stakeholders, resistance to change and the rebound effect	Access to Information and Professional Skills in Public Authorities Especially in the smaller cities, the lack of information and skilled professionals in the public authorities can constitute a major barrier.
	Access to Qualified Workforce Without access to sufficiently skilled workers, EE technologies cannot be implemented correctly.
	Information and Awareness among Consumers Often, energy efficiency measures are not evaluated thoroughly due to lack of time, incorrect financial incentives or lack of knowledge. As a result, information and awareness among Consumers is not sufficient.
	Not in My Back Yard Some people like to support clean energy sources only as long as they are not deployed close to the place where they live. This phenomenon is called 'Not in My Back Yard' (NIMBY).
	Split Incentives for Owners and Tenants Energy efficiency measures are usually carried out by the landlord, while the utility bills are paid by the responsibility of the tenants.

Table 12 – Conditions for upscaling and replication (Mobility and Transport)

Mobility and Transport	
Dimension	**Barriers**
Finance & other economic aspects: In the field of mobility and transport financial and economic barriers are one of major issue due to big investment required for making transportation system	Financial barriers (Mobility & Transport) • Uncertain cost-effectiveness • High up-front costs • No or limited direct return on investment • Underdeveloped market • Hidden and unforeseen costs

more efficient as well as low carbon. Another upscaling and replication barrier in the field of mobility is the way external cost are accounted for. Energy efficient mobility solutions tend to cause comparatively external cost. However, this does not necessarily mean that energy efficient transport solutions offer a comparative cost advantage for the users, as external cost are not or only partially internalized by the current systems of taxation and transport regulation.	
Regulation and governance: Information about projects in the fields of transport and mobility is not always available due to lack of proper documentation or privacy issues. This limited availability of information can result in a level of reluctance among both public authorities and citizens about clean energy solutions.	Lack of an integrated approach Integrated policy making is very important in mobility planning, as mobility planning has links to other fields: urban land-use planning, health, economics, environment and climate protection, reliance on fossil fuel imports, social issues (e.g. ageing, income levels, cultural backgrounds, housing.
	Lack of standards and regulations Standards and regulations for sustainable mobility technologies sometimes do not keep pace with technological development. With an optimal level of standardization and regulation at a European level, a more rapid market breakthrough could be achieved.
	Administrative barriers The number of permits and approvals needed to develop sustainable mobility projects can constitute a major barrier in the implementation process. Also, the coordination with different bodies of government can hinder the implementation.
	Inconsistency of policies and regulations European Union policies are often regarded as very ambitious in the global context. Nevertheless, there are still many inconsistencies when European principles meet national or local level policy objectives.
	Lack of political willingness Sustainable mobility projects are sometimes hotly debated and criticized in the local community. Therefore, they cannot be implemented at large scale without some backing from local and national politics. If there is not sufficient backing, the projects are very likely to be failed.
Access to information and social aspects : When innovative mobility measures are implemented, subjective barriers often play an important role. In order to	Lack of qualified workforce in public authorities Especially in the smaller cities, the lack of information and skilled professionals in the public authorities can constitute a major barrier for demonstration projects in the field of sustainable mobility.
	Lifestyle and behavior aspects Lifestyle and behavior aspects play an important role in the acceptance of new mobility innovations. Awareness raising and citizen engagement are therefore important for the success of sustainable mobility projects.

successfully implement a new mobility measure, social and cultural issues must be considered as seriously as technical and scientific aspects. Mobility and transport projects can also face social barriers such as split incentives between stakeholders, resistance to change and the rebound effect	
	Rebound effect **Efficiency measures in the field of mobility can cause rebound effects that diminish the efficiency gains.**

8. Conclusions

Based on literature review and input from participants, this report presents and structures the challenges that the RUGGEDISED lighthouse cities (Rotterdam, Umea and Glasgow) are facing in successful implementing their smart city solutions. The Smart city innovation and implementation framework is aimed at managing these challenges through building awareness concerning the factors that could suppress or enhance implementation and providing relevant knowledge to tackle these challenges.

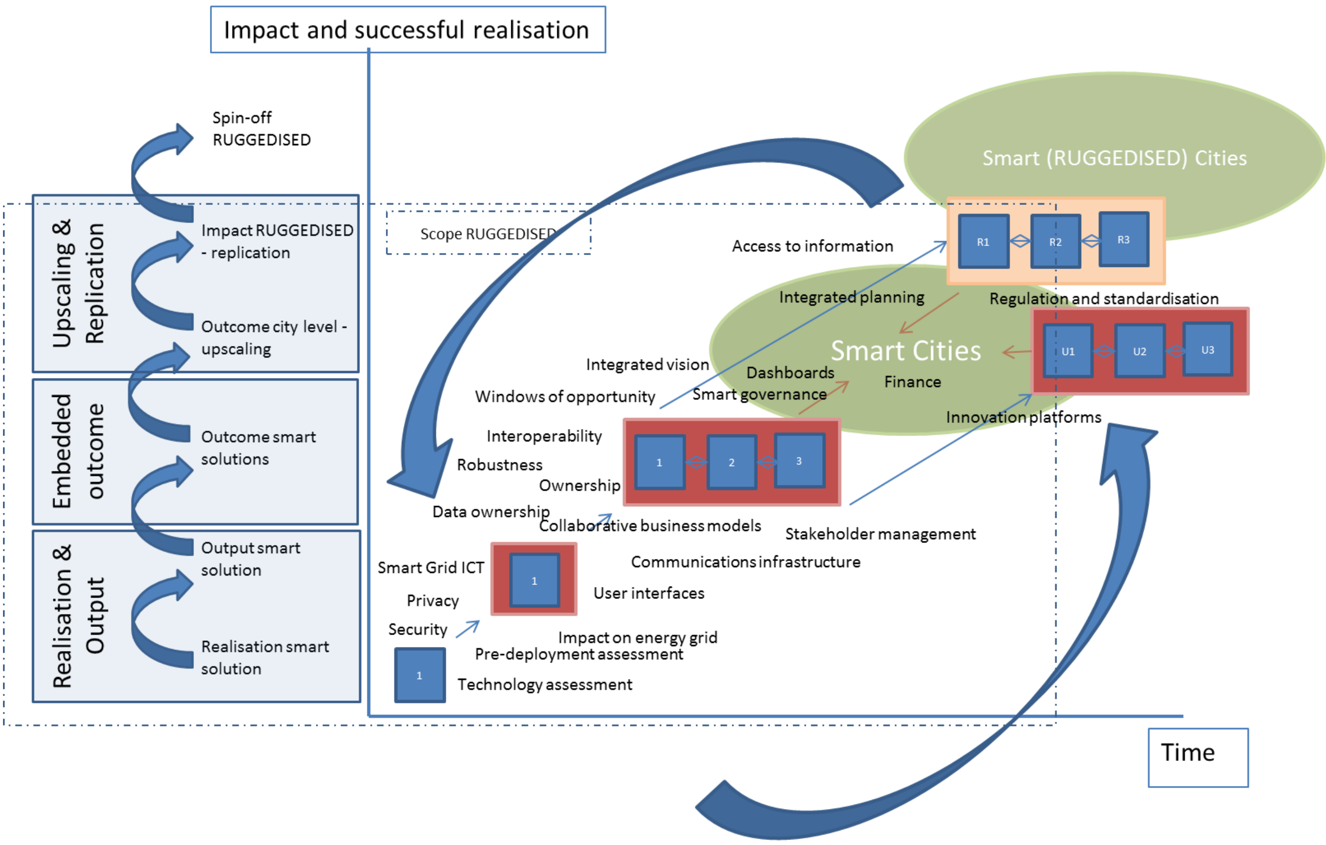


Figure 14 – Overarching Innovation and Implementation Framework revisited

The enhancing and suppressing factors for the three levels of impact that were explained in this report are plotted in Figure 15. Many different factors influence the levels of impact, which poses a big challenge for those who want to implement smart solutions in cities. Especially the connection between different smart solutions in order to have impact on the level of multiple smart solutions, is influenced by very many factors and, thus, is very challenging. Connecting different smart solutions into a set of multiple smart solutions is exactly what is needed for a city to become 'smart'. As smart solutions concern quite complex *technical* city developments, one could have expected that simply implementing these technical solutions would be the most important challenge. However, from the analysis presented in this report, this challenge is complemented by managing many different aspects of mainly a social, economic and institutional character. The concept of smart cities does not only encompass implementing technical solutions, it first and foremost refers to connectivity, which is influenced by many socio-economic aspects. Using technological innovations in the city domain will probably increase the complexity of the urban system and providing profound insight and monitoring its behaviour is needed to gain insight in the real impact of the innovations.

Looking at all implementation factors it is evident that the more the focus shifts towards the levels of smart city outcome, upscaling and replication, the more the enhancers and suppressors have a 'softer' orgware character. This finding is relevant for at least two reasons. Firstly, these soft process factors often gain less attention in urban development, especially as it concerns highly technological innovative projects. Secondly, factors such as cooperation, stakeholder management and business models are important for upscaling and replication. These factors are very receptive to local urban contexts, which could hamper replicability in a one to one manner. Often these aspects need to be tailored to the specific urban context.

The overview of relevant aspects in this report shows a wide variety of implementation factors that enhance and suppress implementation of smart city solutions. Dealing with these factors requires an interdisciplinary and integrated approach towards city development which may have its consequences for how cities are organised at this moment. Very often they still rely on a departmental organisation that hamper the integrated approach. Interdisciplinarity and integrated planning are profound challenges. This does not only concern alignment and sharing of knowledge, but first and foremost this requires collaborative knowledge *development* and developing a common vocabulary: learning how to manage the smart city together is an important challenge for smart city implementation.

This requires a continuous learning cycle towards better policy making, instead of a linear process. Which is also the main conclusion from the analyses of the factors in chapter 6 and 7. In order to successfully link smart solutions with each other and get to upscaling and replication, it is evident that aspects like ‘smart governance’, ‘stakeholder management’, ‘interoperability’, ‘ownership’, ‘integrated vision’ and ‘communications infrastructure’ should be in place well before and during the realisation of individual smart solutions. In that sense it is no matter of linearity (realisation → collaborative outcomes → upscaling and replication), but rather a continuously iterative process of checking whether what is being done fits the overall perspective of upscaled and replicated smart cities.

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Abbreviations

AI – Artificial Intelligence
API – Application programming interface
ATES – Aquifer thermal energy storage
BEV – battery electric vehicle
CAPEX – Capital Expenditures
CHP – Combined Heat and power
COP – coefficient of performance
DC – Direct Current
DHW – Domestic Hot Water
EV – electric vehicles
GHG – Greenhouse Gases
ICEV – conventional vehicle
ICTs - Information and Communication Technologies
IoT – Internet of Things
KPI – Key Performance Indicator
LAN – Local Area Networks
LCA – Life Cycle Analysis
MAN – Metropolitan Area Networks
OPEX – Operating Expenditures
PAN – Personal Area networks
PLCs – programmable logic computers
PPP – Public-private partnership
PV – Photo Voltaic (solar panels)
RES – Renewable Energy Systems
WAN – Wide Area Networks

Appendix A – RUGGEDISED smart solutions

Smart Solutions in Rotterdam		
Number	**Title**	**Responsible partner(s)**
1	Geothermal heat-cold storage and heat pumps	BN / ENE
2	Thermal energy from wawste streams	BN / ENE / ROT
3	Surface water heat-cold collection	BN / ENE
4	Pavement heat-cold collector	BN / ENE / ROT
5	DC grid, PV and storage for mobility	RET / BN / ENE / EUR
6	Smart charging parking lots	RET / BN / ENE / EUR
7	Optimising the E-bus fleet	RET / EUR
8	Energy management system	KPN / ENE / BN
9	3-D city operations model	KPN / ENE / BN
10	LoRa-network	KPN / ENE / BN
11	Efficient and intelligent street lighting	KPN / ENE / BN
12	High performance servers in homes	ENE
13	Smart Waste Management	KPN / ENE
Smart Solutions in Umea		
Number	**Title**	**Responsible partner(s)**
1	Smart City connection to 100% renewable energy	UEAB
2	Peak load variation management and peak power Control	UEAB
3	Geothermal heating/cololing storage	VCC / UEAB / AHAB
4	Intelligent building control and end user involvement	AHAB / UME / UEAB / UU
5	Energy optimised electric BRT-station	UME / AHAB / UEAB / UU / UPAB
6	E-charging infrastructure hub	AHAB / UEAB / UPAB / UME / VCC
7	Energy-efficient land use through flexible green parking pay off	UPAB / AHAB / UME
8	Smart Open Data Decision platform (cocreative design platform)	UME
9	Demand-side management	UU
Smart Solutions in Glasgow		
Number	**Title**	**Responsible partner(s)**
1	Heat and Cold exchange – connection of buildings to district heating network	GCC / US / TCB / WG
2	Deployment of a suitable battery storage technology in the project district	SIE / GCC / TS
3	CHP surplus pwer storage in Charching hub battery storage	TCB
4	Optimisation oft he integration of near-site RES, potentially linked into battery storage. Integration of REnewable Energy Sources	GCC
5	EV charging hub in city centre car park	GCC
6	Intelligent LED street lights with integrated EV charging functionality, wireless communications network, and air pollution monitors	GCC
7	Smart open data Decision Platform / Central management system	GCC
8 - 10	Implementation of demand-side management technology in street lighting, in domestic and in non-domestic properties	SIE / SPPS

Appendix B – Liaison Group participants

Name	Institution
HARDWARE	
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Jorgen Carlsson	Umea Energi
	Transport Scotland
Colin Reid	Wheatley-group
Mark Bolech	TNO
SOFTWARE	
Roland van der Heijden	City of Rotterdam
Ebba Sundstrom	City of Umea
Ciaran Higgins	City of Glasgow
Bas Kotterink	TNO
Claus Popp Larsen	RISE
Joe Clarke	University of Strathclyde
ORGWARE	
André Houtepen	City of Rotterdam
Carina Aschan	City of Umea
Gavin Slater	City of Glasgow
Alexander Woestenburg	TNO
Adriaan Slob	TNO
Hakan Perslow	RISE
Hans Martin Neumann	AIT
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Appendix C – List of CONCERTO projects

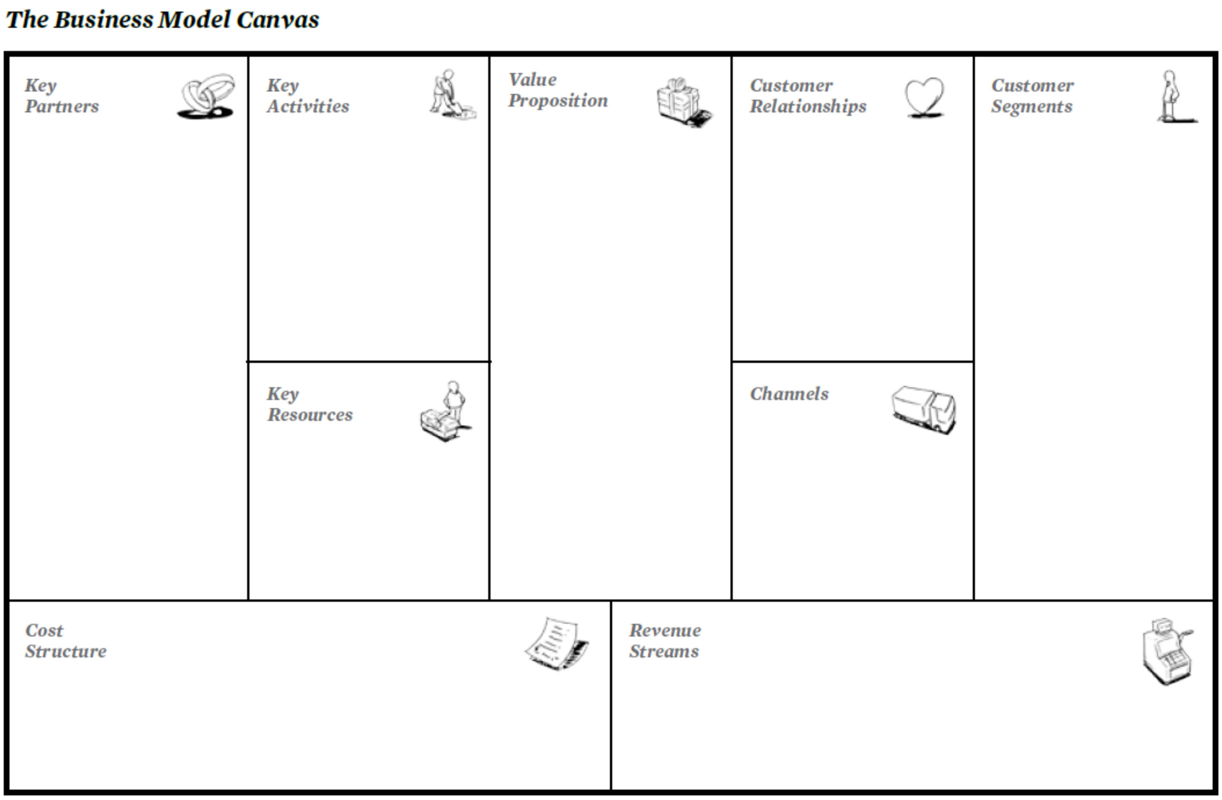
Name of the project	Description
TETRAENER	Optimal balancing of demand and supply through RES in urban areas (2004)
SESAC	Sustainable Energy Systems in Advanced Cities (2004)
RENAISSANCE	Renewable energy acting in sustainable and novel community enterprises a concerto coordinated initiative (2004)
POLYCITY	Energy networks in sustainable cities (2004)
ECOSTILER	Energy efficient community Stimulation by use and Integration of Local Energy Resources(2004)
ECO-CITY	Joint ECO-City developments in Scandinavia and Spain(2004)
CRRESCENDO	Combined Rational and Renewable Energy Strategies in Cities, for Existing and New Dwellings and Optimal quality of Life (2004)
ACT2	Action of cities to mainstream energy efficient building and renewable energy systems across Europe (2004)
STACCATO	sustainable technologies And Combined Community Approaches Take Off (2006)
SORCER	Stimulating Obtaining Results in Communities in relation to Energy-efficiency and Renewables (2006)
SERVE	Sustainable Energy for the Rural Village Environment (2006)
SEMS	Sustainable Energy Management Systems (2006)
REMINING-LOWEX	Redevelopment of European mining areas into sustainable communities by integrating supply and demand side based on low exergy principles (2006)
HOLISTIC	Holistic Optimization Leading to Integration of Sustainable Technologies in Communities (2006)
GREEN SOLAR CITIES	Global Renewable Energy and Environmental Neighborhoods as Solar Cities (2006)
CONCERTO AL PIANO	the Integrated Urban Villages of ALessandria (2006)
CLASS1	Cost-effective Low-energy Advanced Sustainable Solutions (2006)
GEOCOM	Geothermal Communities (2008)
SOLUTION	Sustainable Oriented and Long-lasting Unique Team for energy self-sufficient communities (2008)
PIME'S	CONCERTO communities towards optimal thermal and electrical efficiency of buildings and districts, based on MICROGRIDS (2008)
ECO-Life	Sustainable Zero Carbon ECO-Town Developments Improving Quality of Life across EU- ECO-Life (2008)

Appendix D – List of Smart City Lighthouse Projects

Name of lighthouse project	SmartEnCity	SMARTERTOGETHER	REPLICATE	SHAR-LLM"SHARING CIYIES"	GROWSMARTER	Remo Urban
Expected Result	• Retrofitting of about 2,500 dwellings and over 165,000 m2 • Benefits for 29,300 inhabitants • Energy savings of about 30,000,000 kWh/y • CO2 reduction of 19,000 Tn/y • Increased use of renewable energy sources for heating • Smart lighting concepts • Innovative strategies for sustainable mobility (electric vehicles, bike and car sharing, biogas buses etc.)	•151,800 m2 of refurbished housing estate with an energy and CO2 reduction of 50% •14,6 MW of newly installed renewable capacity in the districts •95,5 T / year CO2 15 new e-mobility solutions saving 95,5 T/year of CO2 •1400 newly created jobs	•Building retrotifiting in 696 dwellings and 34 commercial premises District hearing system)(saving 50%) •Smart Grid and demand side platfrom •Monitoring of 27 EV cars,26 e-mots,4 e-buses,112 e-taxis,32 e-bikes •advanced charging infrastructure,256 chating points,transport managment service for citizens •Smart city platfrom integrating current Local IT system deployment of service asnd sensors •Public smart lighting high speed wireless mobile netwrok deployment based on post IMAX technology	•aggregate demand and deploy smart city solutions:89 cities engaged and 50 cities using products •Deliver common and replicable innovative models :10 replicable solutions •Attract external investment:€500 million in external investment •Successfully engage with citizens:Prove the active participation of at least half of the 15,000 locals affected by the building renovations •Accelerate take-up of smart city solutions:identify three business models that prove the acceleration of uptake (e.g. refurbishment, smart lamp posts) •Pilot energy efficient districts:reduce energy bills by €600,000 per annum for 15,000 district residents •Shift thinking irreversibly to local renewable energy sources:100 cities engaged and 50 cities using products •Promote new models of e-mobility:make at least 10% of local citizens choose electric over fossil fuel vehicles •Foster innovation at local level, promote the creation of new businesses and jobs:Create at least 100 jobs in three districts	Reducing the need for energy (60%), Reducing the greenhouse gas emissions from energy use andincreased use of renewable energy -(more than 60% Reducing the emissions of transports (60%) Increased cost efficiency by lowering the combined capital and operational cost. (reducing costs for energy, reducing costs for maintenance, investment, depreciation period, interest rate) Increasing economic growth (locally, regionally, nationally, internationally) Better options for urban transport Better deliveries of goods Better waste handling Cost efficient refurbishment (100000 m2) Improvement in street environment Lower energy costs Increased job creation (1500)	District: Energy reduction: 34% ,CO2 emissions reduction: 50% Mobility:Energy reduction: 5,1% ,CO2 emissions reduction: 5% Reduction of the human activities impact in the cities by 5% in CO2/person·yr emissions and kWh/person·yr of energy consumption: -Reducing the building energy demand by 40% and increase to a 30% the distributed energy generation ratio -Increase the thermal and electrical energy distribution and efficiency by 10% through public and private investment with less than 15 years RoI in buildings/districts and 5 years RoI in energy supply interventions. -Increase low carbon mobility solutions by 5% (25% at medium term), meaning a 50% of CO2 emissions and reduction of delays and door-to-door journey time by 10% -Increase the citizens awareness contributing to reduce of a 10% of the emissions and energy consumption per capita

Appendix E – The Business Model Canvas

The business model canvas (Osterwalder et al., 2010) provides a structured template to describe a business model and its components.



Element	Description
Customer Segments	the different groups of people or organizations an enterprise aims to reach and serve
Value Propositions	the bundle of products and services that create value for a specific Customer Segment. Elements that provide value include • Newness • Performance • Customization • Convenience / usability • Design • Brand/status • Price • Cost reduction • Risk reduction • Accessibility
Channels	how a company communicates with and reaches its Customer Segments to deliver a Value Proposition
Customer Relationships Building Block describes	the types of relationships a company establishes with specific Customer Segments. This included categories such as: • Personal assistance • Self-service • Automated services • Communities • Co-creation
Revenue Streams	the cash a company generates from each Customer Segment (costs must be subtracted from revenues to create earnings). Ways to generate Revenue Streams include: • Asset sale • Usage fees • Subscription fees • Lending/Renting/Leasing • Licensing • Brokerage fees • Advertising
Cost Structure	all costs incurred to operate a business model
Key Resources	the most important assets required to make a business model work. These can be categorized as: • Physical • Intellectual • Human resources • Financial
Key Activities	the most important things a company must do to make its business model work
Key Partnerships	the network of suppliers and partners that make the business model work. There are four different types of partnerships: • Strategic alliances between non-competitors • Coopetition: strategic partnerships between competitors • Joint ventures to develop new businesses • Buyer-supplier relationships to assure reliable supplies

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