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Smart Cities Initiative: how to foster a quick transition towards local sustainable energy systems

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SEVENTH FRAMEWORK PROGRAMME

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Contents

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Introduction

The objectives of the European Union (EU) for the year 2020 in the context of its program 'Climate Action: Energy for a Changing World' are to reduce energy consumption by 20% with respect to the 2020 business as usual forecast, to reduce greenhouse gas emissions by 20% with respect to 1990 levels, and to have 20% of total energy consumption in 2020 obtained from Renewable Energy Sources (RES). On a longer time frame, even more ambitious objectives will be required to go towards a near-zero carbon energy system by 2050 (Jones and Glachant, 2010). The role of cities in achieving these EU energy policy targets follows from the need for collective action, the importance of the energy demand side approach, most appropriate in cities and the need for innovation in sustainable technologies and measures.

First issue is the need for collective action. Climate change is a global problem requiring a global solution, but governmental policies rely for a great extent on willing cooperation by citizens, organized or not, so that policies are needed at multiple levels to achieve collective action, i.e. polycentric approach (Ostrom, 2009)[1].

Second issue is that actions at the local level can then also leverage the local benefits associated with fighting climate change mainly through specific measures on the demand side leading to a large impact on energy efficiency. Such an energy demand side approach is crucial. In this respect, the role of city authorities is to lead by example towards a more sustainable energy future.

Third issue is the need for innovation in sustainable technologies and measures. Their development from research to demonstration and wide-scale deployment is hampered by a combination of market and institutional failures. Recent theoretical advances, supported by empirical evidence (Foxon, 2003), emphasize that innovation is a process where technology and institutions co-evolve accumulating learning effects[2] so that the institutional setup is typically adapted to the old technological system, which can then be a barrier for more sustainable technology and technical measures. In this respect, the role of city authorities is twofold. When city authorities manage their own energy use, they are subject to market failures, just like the private urban actors in the city environment. When managing the energy use of the private urban actors, city authorities are institutions that have their own institutional failures and can therefore slow down the uptake of sustainable measures in the urban environment.

The contribution of this report is to apply this analytical framework to the Smart Cities Initiative to derive recommendations for the organization of the initiative (European Commission, 2009a and 2009b). The EU has already been successful in voluntarily committing city authorities to reduce their CO_2 emissions by at least 20% by 2020 (Covenant of Mayors). The EU Smart Cities Initiative's ambition is to speed up this transition towards local sustainable energy systems by supporting pioneering cities (European Commission, 2009a and 2009b). The EU is therefore subscribing to the international trend of local governments becoming more involved in climate change policy-making and national governments supporting this trend. This report then also builds on studies analyzing these experiences, such as Deangelo and Harvey (1998), Kousky and Schneider (2003), Betsill and

[1] Ostrom (2009): *"If the only policy related to climate change was adopted at the global scale, it would be particularly difficult to increase the trust that citizens and firms need to have that other citizens and firms located halfway around the globe are taking actions similar to those being taken "at home".*

[2] Foxon (2003): *"Following the evolutionary approach, much learning take place in connection with standard economic activities, or routines, including learning-by-doing, increasing the efficiency of production operations through experience gained (Arrow, 1962), learning-by-using, increasing the efficiency of use of complex systems through experience (Rosenberg, 1982), and learning-by-interacting, increasing efficiency of the system through user-producer interactions (Lundvall, 1988)."*

Bulkeley (2006 and 2007), Bulkeley and Kern (2006), Aall, et al. (2007), Kern et al. (2007), Rabe (2007), IEA (2008a and 2009a), Satterthwaite (2008), Corfee-Morlot et al. (2009), Dodman (2009), Sippel and Jenssen (2010) and Croci et al. (2010).

The report first introduces cities as energy systems and city authorities as energy actors of the urban energy system (chapter 1: “Energy in cities: fundamentals”). We then discuss the most promising technical measures for energy use and management in the urban environment (chapter 2: “Likely elements needed for energy smart cities”). We consequently elaborate on the market and institutional failures that might prevent the wide-scale implementation of these measures (chapter 3: “Key barriers and difficulties”), followed by an assessment of the experiences with city authorities overcoming these failures (chapter 4: “Overcoming the barriers and difficulties”). Finally, this allows to propose an organization for the Smart Cities Initiative based on the evidence collected in the previous chapters (chapter 5: “Organization of the Smart Cities Initiative”).

1. Energy in cities: fundamentals

Cities represent simultaneously a challenge and an opportunity for climate change policy. So, it is crucial to clarify what is the role of cities within the world’s energy systems and its relation with the climate change issue and, then, what are the specificities that make city level an appropriate level to act.

1.1. Cities as energy systems

It is estimated that currently more than half of the world’s population is living in cities, and urbanization is expected to continue worldwide for the coming years (United Nations, 2008; Corfee-Morlot et al., 2009). Within the EU, high levels of population density and urbanization are common characteristics in most countries, where over 70% of the population lives in cities. This number is projected to continue growing to 80% by 2030, though the EU population is not expected to increase in the following decades (IEA, 2008c). Urbanization is closely linked with concentration of economic activities and production (Corfee-Morlot et al., 2009). This added to the fact that all resources aim directly or indirectly to reach people, the natural dynamics is that a large share of the available resources necessary to the development and well being (such as energy, water, food, etc) converge to cities. Thus, cities are responsible for the bulk of the world’s energy use and, consequently, for a significant share of the world’s greenhouse gas (GHG) emissions. Within the European Union, cities are responsible for about 70% of the overall primary energy consumption, and this share is expected to increase to 75% by 2030 (IEA, 2008c).

Cities expanding in size and population pose increased challenges to the environment, of which energy is part as a natural resource, and to the quality of life. Nowadays, most cities have already understood the importance of sustainability, both at their local scale as in terms of their contribution to sustainability at higher geographical scales. A trend exists to encourage cities to establish an informal accountability, e.g. through rankings of CO_2 emissions per capita per year. This accountability is likely to be refined in the future. Although the emissions associated to a person living in a city are usually less than the ones associated to a person living in some peri-urban and some rural areas, the fact that cities gather a large share of the population makes them to be responsible for also a large part of the CO_2 emissions and therefore make cities as crucial elements to achieving the EU energy policy targets. As stated in the “An Energy Policy for Europe” (European Commission, 2007c), the EU energy policy is focused on the three pillars of sustainability (economic, social and environmental) aiming at targets such as security of supply, reduction of energy-related CO_2 emissions and, additionally, the creation of jobs and the promotion of entrepreneurship and innovation.

Cities are the place where most energy services are needed and are therefore ultimately responsible for the use of natural resources. Nevertheless these natural resources are not all of the same nature neither do their uses have the same impact on the environment. Some are available locally or within the traditional city *hinterland*s, while others are taking from large distances; some are of renewable nature and others are of exhaustible nature and usable through pollutant processes, such as the combustion of all fossil fuels. This context prompts the prime relevance that shall be given to the exercise of matching energy supply and demand in cities. It requires the perception of a city as a complex and dynamic ecosystem, an open system, or cluster of systems, where the energy as well as the other natural resources are transformed to satisfy the needs of the different urban activities (Oliveira Fernandes, 1997, 2008). This ecosystem concept of the city helps to understand how the "inputs" and "outputs" of this metabolic process are highly dependent on specific characteristics of the city, such as its physical, economic, social and cultural elements. In fact, buildings (including residential and services) and transportation generally represent most of cities' direct energy demand, between 60% and 80% of the overall consumption. The amount of energy demanded from both sectors is strongly linked to characteristics, such as the climatic conditions, the urban form and morphology, the practices of the building construction, the main economic activities and cultural habits, which are particular for each city (Kennedy et al., 2009). Yet, there are substantial differences in nature as most of the final energy consumed in transports is fossil fuels through combustion while in buildings most of the final energy is electricity obtained from fossil sources.

Buildings, both residential and services are usually influenced by the local physical and social conditions. Characteristics such as shape, typology, solar exposure and insulation levels cannot be the same all over Europe. Instead they are adapted to particular factors such as climatic and morphology conditions, etc, to reduce heating and cooling needs. For example, the optimal thermal insulation depends on factors such as the outdoor temperature and solar radiation. It is therefore natural that the optimal solutions are not the same across all Europe. Also, some social characteristics, such as the preference for detached/single family vs. multi-family buildings, family size, average income, and dwellings' sizes, have an important influence on the energy demand from buildings. In Europe, there are significant differences on the average size of dwellings, creating different pressures on energy needs for lighting, heating and cooling. Besides, buildings in cities make streets and squares and modify the microclimate in the urban environment contributing to the creation of microclimates of higher polluted ambient air and with the so called 'heat island', a local increase of the ambient temperature that can go up to 10ºC, compared to the temperature on the periphery of the city. Those phenomena together with the street noise may lead to tighter buildings and the adoption of heavy mechanical systems for climatization, representing an additional and somehow unsuspected burden regarding the contribution to the climate change.

In terms of transport, the energy demand is also strongly linked with the specific characteristics of a city (urban mobility). Urban density and CO_2 emissions tend to have a direct, inverse correlation: in general, the lower the density of a city, the higher its emissions from the transport sector (Figure 1), suggesting that more compact cities are more energy-efficient regarding transport. This may be both because compact cities require inhabitants to travel lower distances but also because compactness is essential to create critical mass for efficient collective transport systems. Urban planning and its impact on the urban tissue is thus a key factor in the demand for transport. Furthermore the planning is responsible by zoning different services and conditions the movement of people and, consequently, also the need for transport. Moreover, the suitability of different mobility modalities, such as walking and cycling, depends on the morphology and dimensions of the city. Hence, the management of energy demand benefits from being done at a city level, which allows a tailored choice of the specific set of actions to undertake based on the local characteristics and expertise.

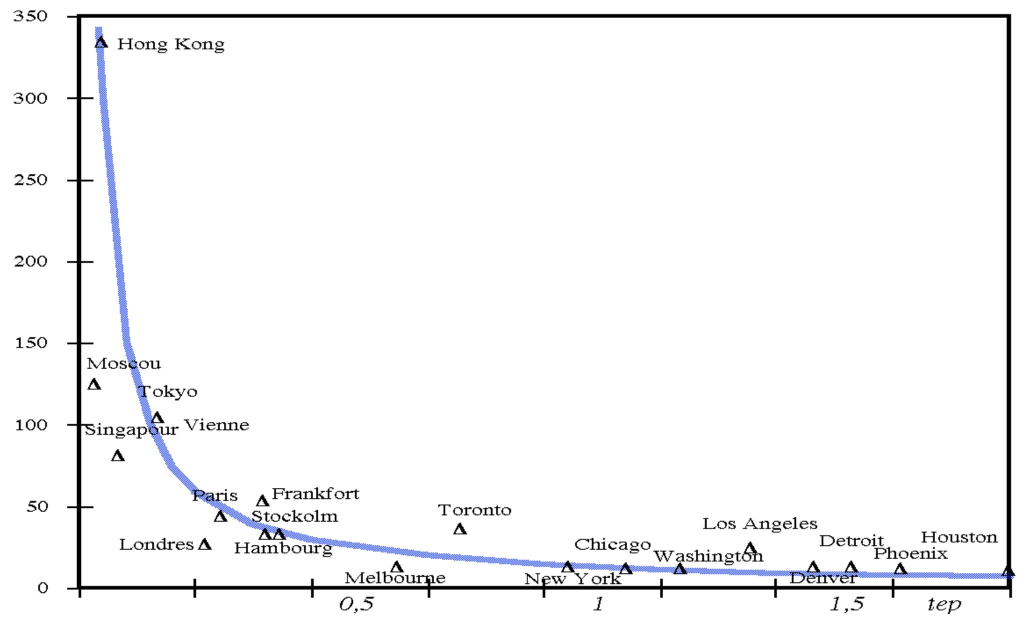

Figure 1. Relation between urban density and transport-related energy use – Energy spending per habitant, in tonnes oil equivalent per year (horizontal axis) vs density of the urban zone, in inhabitants per hectare (vertical axis) (Newman and Kenworthy, 1989)

Furthermore, the possibility of coordinating urban planning with the energy management should be seen as an opportunity to link the needs of energy services and the supply possibilities through a customized approach considering the locally available renewable resources.

1.2. Cities as energy actors

From an historical point of view, many European cities evolved from medieval towns, according to the human and physical factors that surrounded them. Thus, though having different characteristics associated to their own specificities, European cities are usually compact. The urban form of these cities is strongly constrained by their past, which in terms of form has positive consequences on their energy demand when compared e.g. with American towns that grew essentially after the spreading of the automobile led by cheap oil.

Major events such as the First and Second World War, that affected all of Europe, also strongly influenced the current tissues of cities. Various cities were devastated and a large share of the existing building stock was destroyed. This prompted to the construction of entirely new city blocks and the complete renovation of large urban areas during the 50s and 60s. Many of these buildings and open spaces were not significantly modified until today. Meanwhile many other cities followed a similar path while planning new urban extensions in the 50's and in the 60's. Thus, the histogram of the age of the existing building stock within European cities is very particular; there was not a normal evolution of the stock turnover, implying that a large share of the built environment is about 50 years old (about the middle of its lifetime), presenting poor thermal conditions as energy was extremely cheap in that era. During these two decades, there was also a boom of social housing constructions, both in the former Western as in the Eastern Europe, often without proper urban planning and very low thermal performance.

In fact, building thermal regulations were introduced only from the 60's e.g. in Germany and France with more consistency after the oil crises of 1973 and 1979. The current best practices already allow for building or retrofitting buildings with heating needs below 15 kWh/m^2.year in Central Europe.

Yet, the needs of buildings over 50 years old are often above 200 kWh/m^2.year, and even those complying with the first enforced regulations are often still above 100 kWh/m^2.year (IEE, E-Retrofit-Kit). Thus, European cities face great challenges in terms of the renovation of the existing building stock, challenges that are very similar among them. The diffusion of best practices could therefore benefit from these similarities. The recent recast of the Energy Performance of Buildings Directive (91/2002 EC) constitutes a promising framework for the overall performance assessment of the EU building stock regarding energy and environment, including indoor air, a source of many recognized negative health effects. Without stating the limits for the performance levels for the different Member States, the trend is most probably buildings end by having, in the time, the same levels of energy consumption with different levels of insulation, the payback justifying e.g. over 20 cm thicknesses in the Northern latitudes against 5 to 10 cm in the Southern.

Furthermore, there are governance issues that prompt the city level as an appropriate level for action (after all, energy is often also a city based commodity), see Figure 2. Local authorities have responsibilities regarding land-use planning and management of resources (such as soil, water and waste) that interfere with the main activities in a city, its urban form and the use of resources (Dodman, 2009). As previously seen, it influences directly the needs for transportation and establishes a pre-condition for the potential of energy efficiency of buildings. The municipalities are typically in charge of the buildings' licensing. They are at first instance responsible for checking if the new and retrofitted buildings comply with international or local requirements, and in some cases they may even require performance levels for new buildings stricter than the national standards. Regarding the transport sector, they can have an important role in their management too. For example, cities often manage directly the bus and tram fleets, they decide on corridors for buses and other collective or soft transportation modes, etc. Cities may also condition private traffic e.g. through paid parking and entrance fees for vehicles coming from outside the city's boundaries.. Therefore, since city authorities directly affect the sectors responsible for the largest share of energy use (buildings and transportation), their responsibilities must also include the management of energy supply and demand.

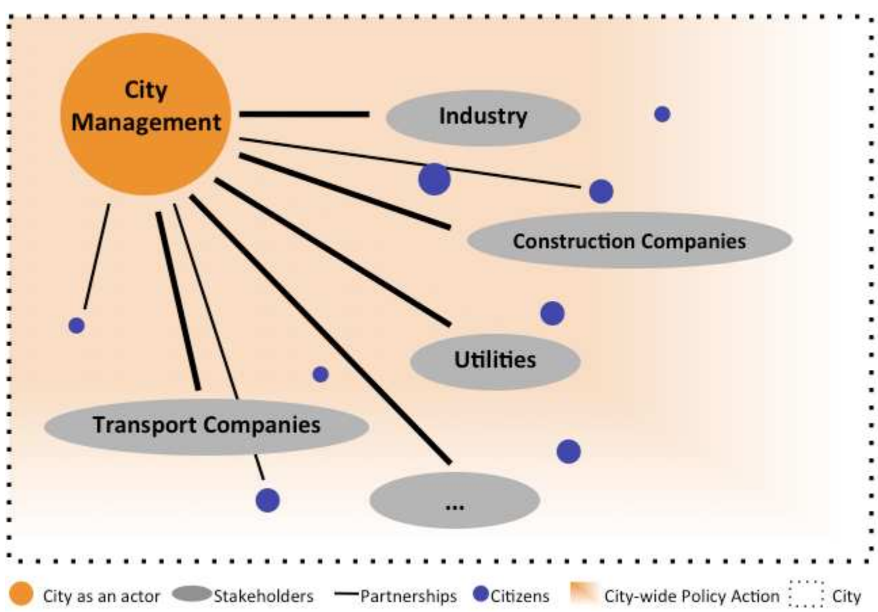

Figure 2. The role of cities as energy actors

Moreover, city authorities are themselves energy users, through buildings and municipal fleet ownership, public lighting, street semaphores, etc. This constitutes an opportunity for environmental responsible public procurement leading by example. For instance, local authorities can adopt the best lighting practices in their office and other institutional buildings reducing their energy demand and prompting other citizens to follow their example. Additionally, cities are the administrative level closest to people. This allows for a better understanding of the social and cultural dynamics, favouring the adaptation of the city and its energy services to the population needs.

Nevertheless, it is important to consider that city authorities have to act within the boundaries of policies defined at higher levels. For example, the national energy policy can condition the performance of a city by affecting energy price signals. If the price of some energy carriers (e.g. electricity), does not reflect their carbon content and other environmental loads, city authorities may have great difficulties on persuading their citizens to the most sustainable solutions through the proper choice of energy vectors. Additionally, the electricity mix is measured at a national level, and so, two different cities, one belonging to a country whose electricity is mainly produced from fossil fuels and other with electricity mostly generated from hydro, with the same level and patterns of energy use may end up with very different levels of CO_2 emissions per capita. That would require that due account of the primary energy balance for each country or city must be considered, in line with the balance of the CO_2 emissions and in parallel with the balance of the final energy. The non clarification of this issue is also a barrier to the establishment of proper policies and to the adoption of the most suitable practices for the sustainable use of energy.

The concentration of people and economic activities as well as the high level densities that characterize urban areas constitute an opportunity to the innovative forms of organization of energy supply and demand. One good example is the implementation of local co- or tri-generation with district heating and/or cooling (CHP) to supply energy. When it is possible to find clients for the heat (and/or the cold) nearby, this way of co-generating electricity is overall more efficient than the large-scale centralized power plants, where the produced heat is dissipated in the environment.

Additionally, cities can also work as a “test market” for certain innovative technologies and/or policy actions (Alber and Kern, 2009). Cities have the competences and authority needed for the implementation of demonstration projects in order to test the social response to certain technologies, such as electric vehicles and smart metering. The analysis of the outcome of such projects might help in the creation of strategies for the wide-scale deployment of innovation technologies. Furthermore, this suitability is also valid for testing the political response of innovative regulatory and policy actions (Lutsey and Sperling, 2007).

Besides their key role through the efficient management of energy demand, cities can also act to promote the use of locally available renewable energy resources (RES), even if the issue of on-site renewable energy sources is not specific for urban areas. In some case, some ambiguity may rise when using the words supply/demand for decentralized renewables. Solar panels for domestic hot water production, for instance, substitute the supply of electricity or gas (supply energy) while reflecting the expression of a decision from the demand side. Today there is a vast set of renewable technologies, some clearly suitable for urban areas, such as solar thermal for hot water, and others that benefit being installed outside cities’ boundaries, such as large-scale solar PV and thermoelectric or wind farms for electricity generation. The suitability of these technologies also depends on the resources available locally or within the city *hinterland*. For example CHP running on biomass may make sense only if there is biomass grown nearby. Nevertheless, there are still plenty of opportunities on local renewable energy resources that shouldn’t be underestimated at all. Solar passive (e.g. using the control of solar capture to decrease artificial lighting, heating and cooling needs), for example, is an effective way of using natural energy resources to reduce the building needs of conventional networked energy services for lighting and heating and cooling comfort.

Another implementation of the use of RES with high potential in cities could be the solar thermal for domestic hot water. The amount of energy used for heating water is significant in cities and, at least in some climatic zones. A large share of it could be provided in a cost-effective way by solar thermal collectors. Regarding the use of solar radiation to supply electrical energy photovoltaics will become suitable for use in cities as prices of the technology go down, in particular, when taking into account the integration of PV panels in buildings as a substitute of other materials in the envelope. That way it is possible to achieve a win-win situation reducing the use of material resources and increasing the use of RES without contributing to congestion in the electricity grid. This is therefore one of the areas where the public procurement role of city authorities may be very important. Yet, giving the lasting transition period from fossil fuels, it is wise not to devaluate the relevance of all efforts towards the reduction of the energy needs for each building or activity, before one starts designing and sizing renewable to be added on the energy providing systems.

2. Likely elements needed for energy smart cities

2.1. Smart City concept

This term has been used in various situations, as an object of academic research or as a marketing concept used by companies and cities, but a definition has not yet been established (Caragliu, 2009). There are three main characteristics that seem to be common to most uses of the expression, which are i) friendliness towards the environment; ii) use of information and communication technologies as tools of (smart) management and iii) ultimate goal of sustainable development.

The European Smart Cities Initiative is focused on the sustainability issues of the cities and, more specifically, on their energy systems (European Commission, 2010a). In this case, a Smart City is implicitly defined as a city that improves the quality of life and local economy, through moving towards a low carbon future. Investments in energy efficiency and local renewable energy, with consequent radical reductions of primary fossil forms of energy and of CO_2 emissions, are seen as tools that help achieving sustainability and quality of life in a city. A prospective Smart City is therefore considered as a pioneer city that undertakes innovative measures (regarding energy networks, buildings and transport) to strongly reduce the use of fossil fuels and CO_2 emissions by reaching targets stated for 2020 and beyond and boost its economy through the use of energy under a sustainable approach.

Each city has specific characteristics regarding its physical and human geography. Also, cities in different countries and different regions receive energy from diverse nature and quality. This fact generally results in cities having different performances regarding the supply and use of energy, and therefore, the most appropriate set of measures to improve their performances also differ. Nevertheless, a set of core technical energy measures that more often lead to a low carbon future and towards a sustainable supply and use of energy can be identified. The term “technical energy measures” is used here to refer to the measures of physical nature, to separate them from the “policy measures” or “promotion mechanisms” that intend to put the technical measures in place. However it is not limited to the introduction of technologies, but includes also management strategies with an expression in the physical world, e.g. the shift of people from individual to collective transportation. These measures might be combined in different ways, i.e. not all the measures are a good option for all cities, in order to adapt to the specificities of the city’s energy system profile. Nevertheless, it is expected that the set is varied and comprehensive enough so that the main technical energy measures or actions that any city needs to adopt in order to significantly improve its energy performance is included in this set.

The elements listed below are grouped in three categories of opportunities: i) the building stock; ii) the transport and mobility; and iii) the city management opportunities. The order by which they are listed bears in mind some rationality in terms of priority of intervention versus its impact on the objectives of energy efficiency and/or CO_2 reduction. The exploitation for renewable doesn't appear necessarily upfront as a first priority, given its cost and less assimilated technology and culture. However, independent of the technology, promotion and development should not at all be dismissed, as its development, in principle, contributes for both objectives above.

2.2. Building stock opportunities

In the building stock, a city of today may have to consider three major universes with specific aspects to be addressed. First group are the new and great rehabilitated buildings, of institutional, office and other services character. All those cases may need, depending on the climate, full climatization and other special energy intensive features thus offering a wide spectrum of challenges for innovative energy technologies to reduce the energy needs and the demand from the energy networks ('net zero energy building' concept) as well as for reduction of CO_2 emissions. The second group are the new residential buildings, where passive and other solar derived technologies can be used to approach energy needs as low as 15 to 30 kWh/m^2.year almost everywhere in the EU. The third group presents the existing housing buildings, to be retrofitted. This is a major task for Europe, where solutions must be somehow in between those relating to the other two groups, if significant energy and CO_2 reductions are to be reached without jeopardizing comfort and healthy environment indoors.

When referring to energy use in buildings all energy used is commonly attributed to 'buildings' not distinguishing between the energy used by buildings to fulfill their function as structures to behave as shelters (lighting, heating, cooling and, in general, good indoor environment) and the energy uses related to the activities in the building (appliances, kitchen, media, computers, etc.). Yet, when addressing the building performance it is meaningful to be able to separate the building fabrics, structure and architecture (orientation, openings, forms, claddings and color solutions) from the systems added on for comfort, be it just heating or ventilation or full air conditioning.

All the above makes up a wide spectrum of issues and, even wider, of solutions drawing on benefits from the progress in knowledge (technologies and other tools). At the same time, barriers of being innovative are faced by the actors of the commercial and technical professions on the field, not prepared to consider those innovations as more than just devices ('gadget culture'), i.e., as opportunities for systems with a performance that can be assessed and monitored.

Thermal upgrade of the envelope of existing buildings

A building has a typical life span of over 50 years, while it is considered that a complete stock renovation under natural circumstances would take about 100 years (Philibert, 2002). Note further that about 75% of the buildings stock that will still be around in 2050 has already been built today (Urge-Vorsatz, 2007; Ravetz, 2008). Therefore, in order to obtain quick results, besides increasing the level of demand on performance for new buildings, there is also the need to consider the improvement within the existent building stock. In fact, the built environment represents a great opportunity for reductions in the energy demand, as there is a substantial difference between the energy performance of buildings built some decades ago and current practice, and there are already techniques available to retrofit existing buildings to the passive house level (IEE, E-Retrofit-Kit, 2005). Taking into account that buildings are responsible for about 40% of the whole final energy use in the EU (IEA, 2007) and that about 50% of this value corresponds to the demand for space heating and cooling (IEA, 2008), thermal retrofitting can lead to significant reductions in the energy demand. The losses of heat through the envelope of existing buildings may be reduced by thermal improvements regarding essentially glazing, windows, doorframes and walls. There are also measures that can complement the improvement of thermal insulation and contribute to the reduction of cooling energy needs. The control of the impact of the solar radiation by shading the windows and other glazed surfaces to reduce the cooling needs is one of the most effective.

From an energy system perspective, and even accounting that the best-practice level cannot be achieved in all existing buildings due e.g. to limitations of the building architecture, a massive upgrade of the thermal performance of the existing stock might correspond to a reduction of at least 50% of the energy demand for heating and cooling in cities, which in turn would correspond to between 10% and 20% reduction in the overall energy demand in cities.

Upgrade of lighting in buildings

The technology and design practices regarding energy efficiency of artificial lighting has improved dramatically over the last 20 years. Therefore, lighting efficiency is a demand-side measure that must be considered when the aim is to reduce the energy demand in a city. Compact fluorescent lamps (CFLs) are far more efficient than incandescent lamps, and additional there is the promising LED lighting technology.

Besides the change of incandescent lamps for other more efficient types, there is also the possibility of catching properly the light of the sun in order to decrease the need for artificial lighting during daytime. Nowadays, there are commercially available automatically controlled lighting systems that increase and/or decrease the artificial light intensity according to the natural light available. Appropriate lighting controls can yield substantial cost-effective savings in energy used for lighting purposes.

Considering that in some commercial buildings the energy used for lighting purposes can represent almost 50% of the overall energy demand, a huge reduction can be achieved just by performing lighting improvements.

Solar thermal for domestic hot water

Domestic hot water is one of the main ways of the use of energy for heating purposes, as it happens in nearly all residential buildings and in many non-residential buildings as well. In this case, since there is no need for high temperatures, there are relatively simple and mature technologies in the market which can provide exactly the same service as conventional energy carriers such as electricity or gas. Because solar radiation may not be enough during some days of the year, it is still necessary to have a conventional source with an auxiliary system. Although recently many systems for this purpose with biomass boilers (especially pellets) or efficient air-water heat pumps appeared on the market; when the solar thermal system is properly installed and the utilization is appropriate, the shift to solar thermal for hot water purposes can result in a reduction of 40% to 90% of the energy demand for domestic hot water, depending on the climate. Considering that domestic hot water typically accounts for about 15% to 25% of the primary energy use in a residential building, this option would represent a reduction of around 10% to 20% in the overall primary energy use of a household.

Nevertheless, it must be taken into account that, depending on different local conditions, the cost-effectiveness of this solution is not always obvious; there are certain factors, such as climate, typology of buildings, cost of conventional energy and, of course, initial investment cost in the market that lead to differences in the technical and economic performance of the technology from city to city, i.e. from region to region. Even so, the use of solar thermal for domestic hot water is in most cases already cost-effective.

Boilers (biomass and condensing) and chillers (absorption chillers)

Energy used for heating and cooling purposes represents for the whole European Union a large share of the final energy consumption in the building sector. Therefore, all the equipments that are commonly used for these purposes should be optimized in their dimension and their use in order to reduce the overall energy consumption.

In terms of space heating, there are several technologies available in the market with better performance levels than the conventional boilers (running on natural gas). Biomass boilers e.g. are available on the market from 2 kW onwards; and these can be installed during a building's refurbishment, in substitution of fossil fuel boilers since the heat distribution installation and radiators are the ones used with the previous installation. Condensing boilers can also be an option. Their advantage is that they are able to extract more energy from the combustion gases by condensing the water vapor produced during the combustion, achieving a fuel's efficiency higher than conventional boilers. Also, in this case, the replacement of a conventional boiler by a condensing one does not imply major changes on the rest of the heat distribution installation; and the price of a condensing boiler is not significantly different from that of a conventional one.

For cooling purposes, the technology of absorption chillers might be a good option. The electricity consumption associated to the use of absorption chillers is almost negligible; in a simple effect absorption chiller e.g., the energy can be provided by solar thermal collectors or residual heat and the sink of energy can be a cooling water tower or a lake. Since these devices are available for power classes from 5-10 kW to hundreds of kW, they can be used to produce cold for industry, buildings and/or the tertiary sector.

Heat pumps

Heat pumps are a very well known solution for heating and cooling purposes. They are composed by two heat exchangers: in winter, the heat exchanger located outdoors will absorb heat from the environmental air, transferring it to the indoor exchanger to heat the indoor environment; and, in summer, the role of each part is inverted. These devices can be used to produce heated and cooled fluids with particularly high efficiency rates.

Heat pumps performance depends on both indoor and outdoor air temperatures; the smaller the difference between those two values, the higher the efficiency of the heat pumps. Therefore, it is convenient to reduce the difference between them as much as possible to increase their performance. A possible solution to increase typical performance value is to use the ground or ground water as a source in winter and a sink in summer of heat, since at a certain depth the ground temperature doesn't suffer significant fluctuations throughout the year. The electricity consumption in this case could be 25% lower than the case of an air-water conventional heat pump (Table 1). This reduction is higher than the case of an air-air cycle for which general data is not available.

Table 1. Comparison of the performance (in terms of primary energy) of a conventional boiler, a condensing boiler, a heat pump and a ground heat exchanger to generate 1 kWh of final energy (Covenant of Mayors, 2010)

Technology	Final Energy (kWh)	Performance Ratio[3]	COP[4]	Primary Energy Factor	Primary Energy (kWh)	Primary Energy Saved (%)[5]
Conventional Boiler (natural gas)	1	92%	-	1	1.08	-
Condensing Boiler (natural gas)	1	108%	-	1	0.92	-14.8%
Heat Pump (electricity)	1	-	3	0.25 – 0.5	1.32 – 0.66	+22% to -38.8%
Ground Heat Exchanger Pump (electricity)	1	-	5	0.25 – 0.5	0.8 – 0.4	-25.9% to -62.9%

Mechanical ventilation with heat recovery and free cooling

With mechanical ventilation, it is possible to ensure a certain air flow and to decrease or even eliminate uncontrolled infiltrations of air through the envelope. This often allows lower average air exchange rates than with natural ventilation, resulting in lower demand for thermal energy for comfort. Furthermore, if both air supply and exhaust ducts exist, it is possible to install a heat exchanger ("heat recovery") between them. The use of mechanical ventilation with heat recovery can significantly decrease the heat losses, and therefore, the energy demand for heating purposes. Yet, this ventilation system requires additional electric energy for operating the fans. Therefore, the effectiveness of this system in terms of primary energy is not guaranteed under all conditions: it tends to render positive results in cold but neutral to negative results in mild climates.

Free cooling is a process that can also be linked to mechanical ventilation but with cooling purposes. Within this concept, the air flow is increased, by electric fans, when the indoor environment needs cooling and the outdoor air temperature is relatively low. As for heat recovery, a trade-off is needed to assess if the energy saved by the decrease of cooling needs compensates for the additional energy consumed by the electric fans.

Efficient electrical appliances

Another key issue regarding the decrease of energy use through demand-side management measures is the exchange of old electrical appliances for new and more efficient ones. In residential buildings, the share of electrical appliances in the overall consumption has been rapidly increasing, corresponding to 21% of the final energy demand[6].Therefore, the improvement of their efficiency represents significant potentials for energy demand reductions. For example, in case of refrigerators, the energy demand of one labelled A^{++} is typically less than half of one labelled B (Figure 3). For commercial buildings and some service buildings, such as bars and restaurants, the impact of electrical appliances on the overall energy demand can be even larger, and therefore also the importance of their efficiency.

[3] Based on the Lower Heating Value (LHV)
[4] (Coefficient of Performance) This ratio is a function of the outdoor temperature or ground temperature.
[5] (-) is saving and (+) is wasting in comparison with the first case of the table.
[6] 2005 value for countries within IEA_{19} (IEA, 2008b)

A++	A+	A	B	C	D	E	F	G
<30	<42	<55	<75	<90	<100	<110	<125	>125

Figure 3. Table with the energy consumption index of refrigerators, according to their labelling (Europe's Energy Portal, 2010)

Passive buildings

The building sector is considered by the IPCC as the one with the highest CO_2 mitigation potential as well as the one with better results for lower investment levels (IPCC, 2007), i.e. most of the technical measures to reduce CO_2 emissions within the building sector have a negative cost, indicating a net benefit to the economy over the lifecycle of the measure.

New buildings typically last between 30 to 50 years before a major refurbishment is carried out; so, the choices made at the initial design and construction have a crucial impact on the building's energy demand for a long period. Meanwhile, with current knowledge and materials, it is possible to achieve an almost 100% passive level for new residential and many non-residential buildings in most of the range of European climates[7]. Passive buildings are buildings that maintain indoor comfort temperature with only very little energy needs (e.g. less than 15 kWh/m^2.year for heating). Yet, if this represents nowadays the best practice, its spreading under the market conditions could be very slow, first of all because of the fact that most of the building stock is already built and, also, because the proper good practice that favours its generalization is not yet in place. Therefore, the enforcement of higher performance standards through building codes for new buildings, i.e., stricter than the ones at the EU level (European Commission, 2008), has a very important role on the reduction of energy demand within the building sector. Besides, this could contribute to promote innovation and create new jobs related to the integration of new techniques in buildings design and the development of new materials and also in existing buildings.

Smart metering

The implementation of advanced meters or smart meters, which are capable of collecting interval data and remotely communicate with the meter agencies, can be designed to be also used as tools to improve load management, favouring a "smarter" use of energy. These metering technologies would allow the adoption of active demand response strategies, enabling end-users to control the use of their appliances, e.g. according to price signals. Possible effects can include lowering system peak-load levels or lowering overall demand, by informing consumers about the cost of electricity (Olmos et al., 2010a). Smart metering can further be useful to manage micro-generation and large-scale generation from RES, avoiding network congestions and optimizing the balance between supply and demand.

Yet, it is important to mention that smart meters alone do not necessarily cause a decrease of the energy demand. In order to achieve this it is necessary to also incorporate mechanisms to make customers aware of their (in)efficiencies and/or of controlling automatically some equipments. Nevertheless even if not coupled with overall reduction of energy use, load management alone already brings some advantages such as ensuring security of supply with a smaller capacity margin.

[7] For low energy buildings the additional upfront cost has been estimated in a range of 3-10% for the United Kingdom, France, Portugal, Spain and Italy and 4-6% for Germany, Austria, Sweden and Switzerland where more of these houses have already been constructed (Attali and Pindar, 2007; European Commission, 2009c).

2.3. Transport and mobility opportunities

The transport sector is, after the building sector, the second main originator of energy consumption and cause of CO_2 emissions in a city. It is somewhat more challenging than the building sector in the sense that most of the measures that can significantly diminish their consumption of fossil energy implies measures that take long time to produce effects, changes of attitudes or introducing technology that is not yet fully mature.

Lowering the mobility needs

The first measures to consider when aiming at the reduction of energy use within the transport sector should be the reduction of the transportation needs. There are several factors that influence these needs: some are social characteristics, such as population's age, average income and wealth; others regard physical specificities, such as climate conditions and city's topology; others, such as the distribution of different activities among the territory and city's density, are mainly linked to urban planning issues.

Table 2. Travel impacts of Land-Use Design Features (VTPI, 2005)

Design Feature	Reduced Vehicle Travel (%)
Residential development around transit centres	10
Commercial development around transit centres	15
Residential development around transit corridor	5
Commercial development around transit corridor	7
Residential mixed-use development around transit centres	15
Commercial mixed-use development around transit centres	20
Residential mixed-use development around transit corridors	7
Commercial mixed-use development around transit corridors	10
Residential mixed-use development	5
Commercial mixed-use development	7

Among these factors, urban planning is currently done at the city level; city authorities are usually in charge of the land-use planning within city's boundaries, and the influence of urban planning issues in the demand for transport is unquestionable. "There is a fundamental relationship between transportation and land-use, because the distance between one's origin and destination will determine the feasibility, route, mode, cost and time necessary to travel from one place to another" (Wegener). For example, in a compact city where residential areas are developed at a walking distance from facilities such as hospitals, schools, commercial stores, the demand for transport would be highly reduced. Additionally, an integrated planning including both land-use and transport may lead to strong reductions on travelling needs, as illustrated for a specific example in Table 2.

Shift from individual to collective transport

Additionally to the reduction of the demand for transport, it is possible to reduce the energy intensity associated to transportation, i.e., to reduce the amount of energy needed to perform a certain journey. Concerning passenger transportation the shift from private to collective transportation modes seems to be the most effective in achieving this goal. Within the EU, 73% of the annual passenger.kilometres are from individual road transportation, i.e. individual vehicles, while 8% and 6% are, respectively, from collective road and rail transport and only 1% is attributed to metro and tram passengers (European Commission, 2009d). However, the energy intensity per passenger.kilometre (pkm) of most types of collective transportation is much lower than for individuals. For example, in Western Europe, collective transports have, in average, less than half of the primary energy intensity per passenger than that associated to individual transports (Figure 4); and, in Eastern Europe, this difference is even more evident (Kenworthy, 2003).

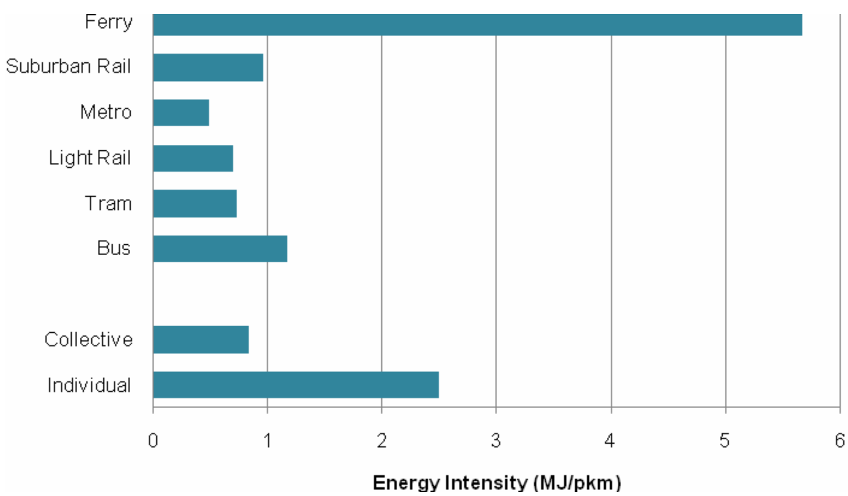

Figure 4. Energy intensity of different modes of transportation in Western Europe (Kenworthy, 2003)

Besides the decrease in energy use for transport purposes, the increase on the number of citizens choosing collective modes of transport instead of individual motorized vehicles might also lead to an improvement in the quality of life. Firstly, the decrease in emissions of pollutants related to transport would improve air quality in the city and the avoidance of congestions would contribute to decrease the average time of journeys.

Different modes of collective transport might be suitable for different cities, or even different groups of people within a city (Kenworthy, 2003). For example, rail is good for long distance journeys that are common to a large number of people, such as the daily pendulum movements in-and-out of town, while metro and bus are more suitable for journeys within the city's boundaries. In case of journeys common just for few citizens, car-pooling, i.e. the sharing of individual cars among people that intend to do the same or a similar journey, might be the best option.

Additionally to the shift from individual to collective transport, there is also the opportunity to improve the efficiency of the later. This could be achieved by the use of ICT infrastructure to predict journeys and common movements within the city, leading to a better balance between supply and demand. Besides being an improvement by itself, this could also work as a motivation for people to shift to collective modes of transport.

Soft modes of transport

Enabling the use of soft modes of transport, such as cycling and walking, within the city is a way of improving quality of life whilst reducing air pollution. These are individual modes of transport, i.e. they still have the independency of route and schedules of the individual vehicles, but, at the same time, they do not require fossil energy and are not harmful to the environment.

Due to the cities' density, there are several short distance journeys that could easily be travelled without the need of any motorized vehicle. Obviously, the suitability for walking and cycling is influenced not just by the distance between origin and destiny but also by other factors, such as the existence of specific paths, the topology of the city, the travellers' conditions. Nevertheless, if the citizens are aware of the benefits of choosing these modes of transport instead of others with higher energy intensities and city authorities are able to provide the necessary conditions for them to walk and to cycle, it is possible to make these as the primary modes of transportation within the urban context. For example, in Zurich, there are several hills and the weather is not the most attractive for people to cycle during winter, and still the share of passengers using the bicycle as their main transportation mode is very significant. Additionally, both cycling and walking can also be used as an intermediary mode to reach/exchange between mass transportation modes, such as train or metro, promoting inter-modality and the use of different modes of collective transport. With the use of an integrated approach between transport and land-use planning, it would be possible to develop routes matching most citizens' daily journeys that would only include the use of collective transportation modes and small walking and/or cycling travels to link different modes.

Integration of electric vehicles in the urban environment
Electric vehicles are conceptually seen as a key-instrument to decrease the pollution within cities and, if coupled with further promotion of non-fossil energy based forms of generation of electricity, may also lead to a significant decrease of the CO_2 emissions. The large-scale deployment of electric vehicles in cities is a subject that has been largely discussed and there are already some pilot projects in European cities. Their suitability for the city scale is mainly explained by the limited battery storage capacity, which constraints the use of this type of technology for long-distance journeys. One should, however, also take into account that in a city the number of residents having access to a parking spot where the vehicle can be charged during the night (e.g., a garage), might be limited. Within a medium-size city, however, the daily journeys of most drivers do not exceed 50 to 80 km. Therefore the first generations of electric vehicles are capable to provide this service without the need of being charged during the day.

2.4. City management opportunities

Shift among energy carriers
There are several forms of bringing energy or providing energy services to the end-users: electricity, gas, heated or cooled water, solar radiation, etc. These are the so-called energy carriers or forms of final energy.

However, these carriers must be produced from primary sources available in nature, or harvested from renewable flows sometimes with relatively low efficiencies as in the case of conversion into electricity. Therefore the efficiency of the conversion from primary to final energy (and then to useful energy) strongly depends on the energy carrier used. If the resource is a fuel, the inefficiency means pollution burden at all environmental scales and, if the resource is renewable the inefficiency may represent just a (temporary) barrier to its economical feasibility. A system approach requires the search of the best match between energy service and energy carrier, and often this is achieved by shifting to the most suitable vector to provide a specific end-use. As examples, solar thermal collectors bring heat from solar radiation (from both direct and diffuse radiation) into domestic hot water at a temperature close to conditions of use while PV installed in a house produces electricity from direct solar radiation at a quite low efficiency and can be linked to the grid and may be forced to inject all its production into the grid. Combined heating (and cooling) and power production, is another type of way for converting a fuel, nowadays, mostly biomass or natural gas into electricity, a universal carrier, plus hot an d cold water for heating and cooling purposes (see below). In most cities, there are (or can be developed) distribution networks for several of the energy carriers, thus enabling the opportunity of such shifts.

The energy needed for heating purposes, e.g., is one of the biggest opportunities to the shift among carriers e.g. by shifting from electricity to natural gas or even solar thermal. Cooking, for example, is one of the energy uses where fewer energy comparisons have been made; in countries where more than 30% of the electricity is generated from thermal power plants, gas has an advantage over electric plates for cooking purposes.

Upgrade of street and traffic lighting

As for artificial lighting indoor buildings, technology for street lighting has evolved considerably in the last years and this area offers significant opportunities for improvements. In this case, the exchange of the lamps that represent today's current practice by LED lamps would correspond to improvements that could reach a significant reduction (promising results were for instance obtained in the Ann Arbor pilot project (C40, 2010)). Furthermore, some improvements such as the use of more efficient ballasts or adequate control techniques are also suitable to avoid the excess of electricity consumption.

Meanwhile, the replacement of incandescent halogen bulb traffic lights by more energy efficient and durable LED yields a significant reduction on the electricity consumption with this purpose. Besides the significant reduction in electricity consumption, there are also reductions on the maintenance costs, due to the higher durability of LED. The management of the street lighting infrastructure is typically exclusive of city authorities, which increases their ability to take measures.

Combined heat and power with district heating and cooling

The fundamental idea of combined heat and power (CHP), also known as cogeneration, is to produce electricity in places where there is demand for the heat generated during combustion (that cannot be transformed into work, due to thermodynamic and technological limitations), which is dissipated to the environment in conventional power plants. Through a district heating network, the recovered heat can be used to provide several heating services in buildings, being domestic hot water and ambient heating. Considering that only a small fraction of the heat released in the combustion cannot be used, due to technology limitations, CHP can generate heat and electricity in an exergetic more efficient way compared to separate generation. Understandably, the economic viability of CHP has been higher in the Northern climates, where the need for heat is more expressive.

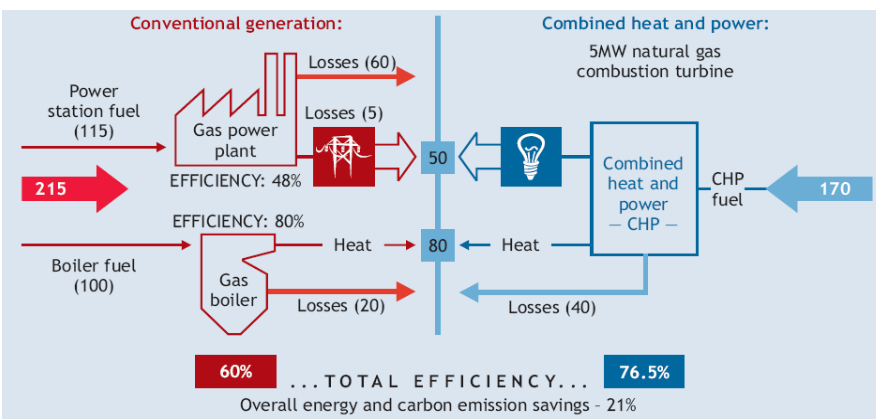

Figure 5. Sankey diagram comparing conventional power plant with combined heat and power technology (IEA, 2008)

Nevertheless, besides the use of heat for domestic hot water and ambient heating, the increasing development of absorption chillers technology made it possible to use heating also for delivering cold water and therefore provide cooling. In this way the district heating and cooling (DHC) networks coupled with tri-generation may be options for a wide range of climates.

The efficiency of CHP depends on the effective use of the recovered heat, so this implies that in a city CHP must be linked to a network of district heating and cooling (DHC). Due to the compactness and density of cities, the city or neighbourhood scales seems to be the right geographical level for this type of networks. Since there is a significant demand for energy for acclimatization within a small area, the heat and cold produced do not have to travel long distances from the plant to the user, avoiding high losses to the environment (Figure 5). The overall lowering of fossil energy enabled by this technology can be even better if the fuel used is renewable, such as biomass or waste.

Electricity generation from renewable sources in the urban environment ("Micro-generation")

The generation of electricity from renewable energy sources, which usually occurs in developments outside cities such as dams in river basins or wind farms in the countryside, may also occur in the urban environment. In buildings, for example, solar PV panels can be integrated in the building surface or sometimes even replacing other envelope materials and the electricity generated can be used locally or injected the distribution network. The same technology can also be used for supplying electricity to street lighting and traffic lighting, substituting the use of electricity from the grid. In what concerns wind, there are many commercial micro-turbines available, although the fact that wind within cities is often either weak or has poor characteristics, creates difficulties for integrating wind micro-generation in the urban environment.

The suitability of RES micro-generation thus strongly depends on the city's conditions, both climatic and morphologic. For example, the typical annual solar radiation and the solar exposure of most buildings are characteristics that firmly influence the effectiveness of installing solar PV on buildings tops or façades.

Currently the mid and large size generation units out of the city's boundaries involve technology that are more mature and a larger scale favours efficiency and lowers operational and maintenance costs. The cost-effectiveness of renewable generation still tends to be favourable outside the urban environment, especially if close to already existing power transmission or distribution lines. To conclude, the uptake of several RES technologies in the urban environment might be hampered because of two main reasons (Coenraads et al., 2007; Ragwitz et al., 2007; European Commission, 2007a and 2007b; IEA, 2008b; Martinot et al., 2009). A first issue is that RES is not so easy to integrate in the urban environment because of its low energy density (at least compared to fossil fuels). The second issue concerns the fact that RES technologies often require connection and access to the existing local energy networks that are often congested (e.g. electricity grids (Meeus et al., 2010) or simply missing (e.g. district heating and cooling (Constantinescu, 2006; IEA, 2007b).

Development of smart grids

The possibility of large-scale integration in the distribution networks of electricity generated in the urban environment, e.g. from RES micro-generation and micro-CHP, requires management capabilities that the current distribution networks do not have. However models and demonstration projects of such grids have been developed and can be considered as being in a pre-commercial stage. Besides enabling a higher integration of micro generation, smart grids may also enable better quality of service, e.g. quicker rebound after occasional interruptions. They may also be important to enable the best strategies for the charging of electric cars if the number reaches significant shares in the vehicle stock.

Information and communication technologies (ICT)

Many of the technical measures explained so far can have their effects maximized if managed in an effective (*smart*) way through the use of information and communication technologies. Examples are the possibility of collective transport customized in real time according to the demand, the management of electric appliances inside buildings and the operation of smartgrids. ICTs could also play a key role in the dematerialization of citizens' daily life, substituting high carbon products and activities by low carbon alternatives. For example, one of the largest opportunities identified within dematerialization is *teleworking*, where people work from home rather than commuting everyday into an office, reducing significantly the needs for transport. Furthermore, the role of ICT on raising the awareness to climate change problems should not be disregarded. These technologies provide the opportunity to measure and inform private citizens as well as businesses on their own footprint and their contribution to GHG emissions. This could be important to mobilize people to be more active on reducing their energy needs. Regarding these ICT possibilities, the EC is engaged in a forum towards these aims, i.e., the ICT for Energy Efficiency forum (ICT4EE).

Still, it is important to refer that ICT is not a technical measure in itself in what regards the energy efficiency of cities. It should be considered as a useful tool to enable or optimize the technical measures presented previously. Its integration in different sectors and activities might be very helpful to reduce energy demand. However, one should also bear in mind that ICT in itself can become (and even already is) a major consumer of electricity (Koomey, 2007), with potentials for higher efficiency in itself.

3. Key barriers and difficulties

In general, the implementation of the technical energy measures or actions outlined in chapter 2 have been facing difficulties and barriers of different natures, which explains why the wide-scale implementation of most measures is not in place yet. The barriers are not the same for all the technical options (depending also on the actors involved) and are further commonly interrelated, i.e. with the cumulative occurrence of some difficulties others may become more relevant. This chapter first discusses the key difficulties corresponding to the uptake of technical energy measures by urban actors (market failures). Second, the causes and profiles of the disincentives of city authorities to move towards sustainability are identified (institutional failures).

Note also that increasing the uptake of energy efficient technologies does not necessarily reduce the use of energy because there is a so-called rebound effect, i.e., the money savings from a higher efficiency can also increase the demand for energy services (Brookes, 1990). This effect can be significant (Greening and Green, 1997; Binswanger, 2001; UKERC, 2007).

3.1. Market failures

A possible way to categorize the barriers designated 'market failures' is to divide these into two categories according to their type or character i) economical; and ii) Informational and behavioural. The following sections address the main difficulties and barriers faced towards the wide-scale implementation of the technical energy options previously presented. This analysis is based on academic research as well as on previous experiences from pioneer cities.

3.1.1. Economic type of barriers

Economical factors are believed to be very influential on the success or failure of the wide-scale implementation of most of the technical energy measures. The economic viability of measures is very relevant for the wide-scale implementation of certain measures. Often, this implementation can occur naturally without the use of promotion mechanisms other than information, if the cost-benefit analysis is clearly favourable, the upfront cost is low and the return-on-investment period is short. But the usual situation is not that simple and transparent.

Price distortions

For various reasons, there are situations where the price for certain energy carriers or services does not reflect their actual cost. Price distortions are not exclusive for the energy sector but in this specific subject they can raise important barriers to some of the proposed measures. These distortions can result in prices being artificially low. There are different possible causes for the later: it may derive from an incomplete internalization of the externalities into the prices at the end-user level, e.g. neglecting environmental costs; or, it may also be a consequence of subsidies or other financial support at the national level. For example, in Portugal, the national government allows the electricity sector to accumulate a debt to the tariff in order to keep the electricity prices lower than their due supply cost. So, under this scheme, electricity may be cheaper during some periods of the day or of the week than natural gas or, at least, with such low price differences that there is no stimuli to shift from electricity to natural gas for 'heat services'.

Meanwhile, the prices for energy services can also be kept artificially equal across time and space, though it is known that there are significant differences in the supply costs at different times of the day or even between urban and rural areas. One of the possible causes is the partial regulation of most energy services which creates a regulated tariff, applied at a national level. Also, since most energy services are considered as a primary need, it is common to consider a unique price for all national territory to promote equity and avoid disparities. Finally, this artificially uniformity might also derive from the lack of real time metering.

Cost-effectiveness perception

The possibility of recovering the amount of money invested within the lifetime of the technologies involved is one of the most relevant factors when deciding whether to invest or not. Indeed, some of the measures reported in chapter 2 are not cost-effective at the current energy prices, while for others the cost-effectiveness is not always obvious or not enough attractive to mobilize (Figure 6).

There might be different causes for a technology or management measure not being clearly cost-effective. These are often divided between issues of technology maturity and of market uptake.

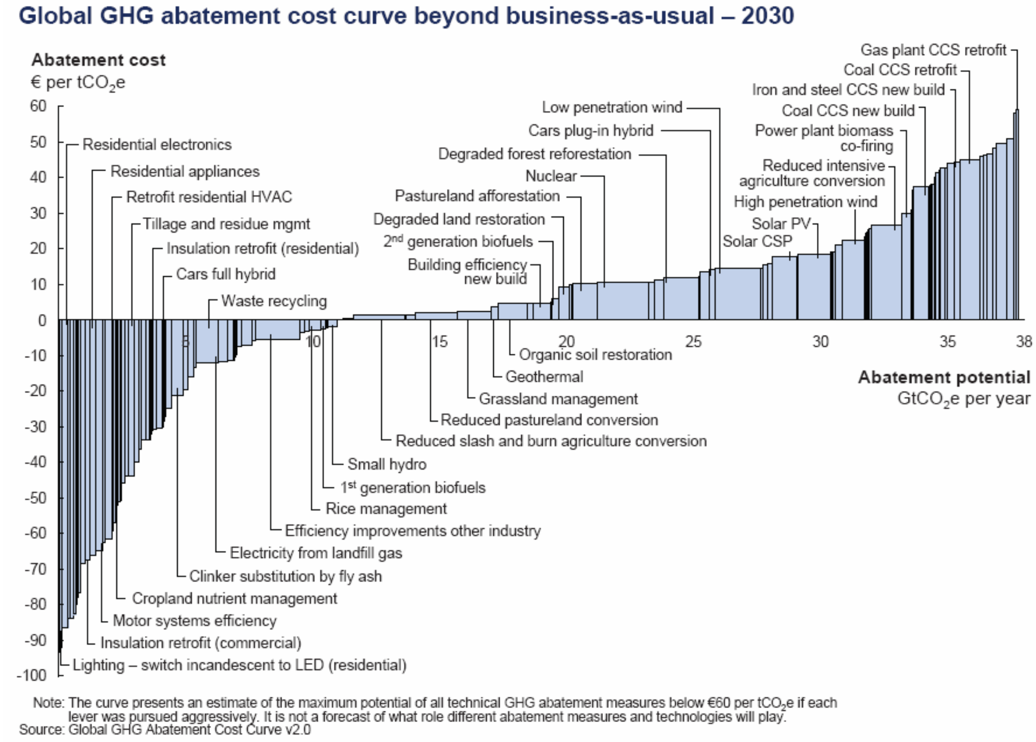

Figure 6. Global cost curve for greenhouse gas abatement measures (McKinsey, 2009)

Issues of market uptake refer to products that can be economically competitive but only if sold with significant scale. This seems to be the case of solar thermal collectors or triple glazing; these solutions are competitive in markets where it has become largely adopted, but they remain uncompetitive in markets where the numbers sold are very low and therefore require the fixed costs to be distributed amongst low numbers of units sold. Issues of technology immaturity refer to cases in which, even if sold in high numbers, the manufacturing cost is higher than that of competitor technologies (e.g. current PV technology). Yet there are recent experiences by which national programs to stimulate the diffusion of solar thermal collectors ended up by increasing significantly the price of the equipment and the cost of the installing and banking services. All intermediary were claiming to be entitled to take a share on the subsidy (Solar Thermal Program, 2009).

It must however be noted that most cost-effectiveness studies are performed at current energy prices, even for projects whose life-span or effect in time are some decades. This is somewhat questionable as it is largely anticipated that energy prices in the future tend to be higher than today. And, certainly, in the future a more rigorous accounting of the environment externalities, such as CO_2 emissions, will impact more on some energy costs.

High-risk of investments

Investments with high-risks involved are usually related with measures that involve extremely variable costs/prices, or with technologies that are not sufficiently tested to have predictable performances. Most actors are not willing to cover that risk, requiring that, in order to invest, some other entity covers the risk.

High upfront costs

The requirement of high upfront investments is very common when dealing with energy efficient and RES technologies. Often such up-front investment capital is not available and cannot be obtained from financial institutions, even if these investments allows for an interesting return in the future. Many actors typically prefer the opposite when purchasing an appliance, facility or infrastructure (Jaffe and Stavins, 1994; European Commission, 2006; Schleich and Gruber, 2008; Eichhammer et al., 2009; IEA, 2009b). For example, in many countries the investment in micro-generation is highly subsidized and, consequently, its cost-effectiveness is assured. Nevertheless, private owners still hesitate before investing due to the high upfront costs.

Long payback periods

Some measures, even if clearly cost-effective and not implying high upfront costs still need incentives to be deployed at a wide-scale. A long payback period might explain this. The time of full recovery of the investment can strongly influence the decision whether or not to invest. Nowadays, due to the accelerated dynamics of markets and/or society, many companies and individuals have only a short to mid-term vision of their businesses or lives. Therefore, if they are not able to recover their investment within such or even shorter periods, they do not invest. This is e.g. the case for solar thermal for domestic hot water; despite the fact that during half of its lifetime all the savings would constitute profit, people might still be averse to invest if they do not know whether they will continue to live in the same building during the next 10-20 years.

3.1.2. Information and behaviour type of barriers

In addition to the barriers presented above, there are difficulties associated with lack of proper information that can help to explain why the implementation of some of the measures mentioned in chapter 2 is not done. The informational deficit can include the lack of customized information and the lack of public awareness on climate change issues, but also the insufficient qualification of staff for complex integrated tasks at the public entities and service providers levels.

Lack of information and information asymmetry

When aiming a wide-scale implementation of measures, barriers related to information problems might be crucial. This applies both at the level of decision makers as at the level of practitioners who must implement the actions on the floor. If information is not available or is not provided in a clear way, non-informed decisions cannot be avoided and, consequently, the selected measures, techniques, materials, technologies, etc will hardly be the most. When the problem is the absence of information, targeted actors may not have access to the pros and cons of the different options or do not even know all the options available. Indeed, if end-users do not have access to cost-effectiveness analysis or the potential savings of a certain option, they might choose a worse solution just because they do not know which one is the optimal. The lack of information frequently appears as a barrier to private owners that intend to refurbish their buildings. E.g. typically buildings of more than 30 years need to go under a firm renovation process and, at this moment, the owner could use the opportunity to improve the thermal performance of the building without a significant increase in the total costs. However, if there is no information available regarding which performance targets should be asked from the designer, the owner will probably opt for other options rather than the "responsible" one.

Besides the lack of information, there are also some barriers raised by information asymmetries, i.e. the information is available but it is presented in an inconsistent way that may confuse the interested parties instead of supporting their decisions.

A typical example in this regard is the landlord-tenant problem, i.e., the landlord will not make a higher upfront payment for energy efficient technologies, because the corresponding energy bill savings go to the tenant who is not willing to pay more rent for this because of the information asymmetry between the two (Blumenstein et al., 1980; Scott, 1997; IEA, 2007a; Gillingham et al. 2009; Schleigh, 2009; Davis, 2010).

Lack of expertise

The successful implementation of innovative measures regarding use and supply of energy implies specific knowledge regarding the new energy technologies or energy systems involved: it requires expertise. The lack of a sufficient number of professionals is a critical issue for some technologies entering into the market. This difficulty can lead to two problems: the measures are not implemented as there are not enough actors with the skills to do it (e.g. architects, designers, etc); or, the implementation takes place but it is not done properly, which may create bad reputation for the technology and increase even further the market resistance to its penetration (e.g. first generation of heat pump systems).

The first problem often happens often with construction companies. For example, when new techniques to improve the thermal performance of a building are developed, some time is required until designers feel comfortable to adopt them in new constructions and/or renovation processes. The company needs to have an expert who has learned how, when and where to use it.

The wide-scale installation of smart metering systems in households could serve as example for the second consequence. In fact, in some countries there were programs to promote the large-scale deployment of smart meters in order to facilitate the demand side management of energy; however, since end-users were not taught to use them properly, they are still not able to control demand in an effective way.

Perception of quality of life

The definition of quality of life varies from place to place and from person to person. The implementation of some of the proposed measures might interfere with some of those concepts, requiring the change of people's habits that relate to their perception of well feeling and of quality of life. This does not mean that the referred changes would imply a decrease in the quality of life of the actors involved. The implication on people's lives by shifting from individual to collective modes of transport is one of the most obvious examples of such a barrier. Such a shift would certainly require some adjustments of schedules and the user would have less independence regarding other travellers. Also, in some cases the use of collective transport can lead to an increase in the time spent for travelling, as well as a decrease of what can be seen as comfort (available seats, possibility of choosing ambient temperature, etc). However, if not too expressive, these objective disadvantages can be offset by the availability to read during the trips, avoiding the stress of driving, etc.

Divergence of interests between different actors involved

Since there are various activities that require the coordination of different actors from different sectors or with different functions within the same sector, the divergence of interests is a frequent obstacle to the sustainability in a city. The coordination of actions between people with different interests is complex, and usually requires some effort from both parties, which the regulatory mechanisms shall make sure to be sufficiently compensated by benefits to motivate all.

Examples of divergences that might occur regarding the proposed measures are: i) between owners and tenants in what concerns investments on upgrading rented houses and services buildings, and even on new buildings to rent; ii) between micro-generators and system operators, regarding the connection of micro-generation sites to distribution networks.

3.2. Institutional failures

This section discusses the difficulties and disincentives city authorities can have in undertaking action towards sustainability, i.e. institutional failures (mainly of political and administrative nature). Drawing on Sippel and Jenssen (2010), Corfee-Morlot et al. (2009) and Bulkeley et al. (2009), Bai

(2007), the main institutional failures are: 1// “not on my turf” (spatial dimension); 2// “not in my term” (temporal dimension); 3// “not my business” (institutional dimension).

3.2.1. Spatial dimension

First issue is “not on my turf”, i.e. spatial dimension. An overall challenge in this sense is the so-called “Tragedy of the Commons”. This refers to the fact that the climate change issue is a global (common) problem, and actions or measures that you might take, do not result in direct benefits for you (in terms of mitigating climate change).

Local governments have a diversity of priorities, as social issues, public health and ensuring economic growth, amongst others. Therefore, if climate action and sustainability is to be put on the agenda, it will have to compete with these other priorities, as the local resources (both human and financial) are limited. After all, the city budget will always have to be taken into account as a boundary condition. Especially in relatively poor Member States, it can be expected that climate change will not become a priority, if the population suffers from poverty, bad health care and high rates of unemployment[8]. Furthermore, also in wealthy cities, examples exist of climate policy having to compete with local environmental problems, e.g., cities suffering from pollution of small particles from diesel engines, might promote a shift to gasoline engines, which emit more CO_2.

An example worth mentioning is the prohibition on the use of natural gas in micro CHP in the city of Athens, because of NO_x pollution. Another example concerns cities stressing the need for increasing travel demand, motivated by economic considerations, obviously conflicting with the effort to reduce demand for sustainability reasons (Bulkeley and Betsill, 2003).

3.2.2. Temporal dimension

Second issue is “not in my term”, i.e. temporal dimension. Politicians are concerned over their re-election, and hence, tend to think and act on the short term. Actions and money spent need to demonstrate clear benefits and added value for their voters, while the transformation towards a sustainable city might take decades. This might turn city officials reluctant to invest in measures that do not immediately show benefit, and rather opt for short term ‘patched’ solutions. A quick transition towards local sustainable energy systems implies that typically shorter term measures will be demonstrated. Still, the importance of longer term urban planning should not be overlooked as it has only recently been integrating concepts of sustainability, taking into account issues such as local and global environment, social equality, quality of life, public health, etc. (Wheeler, 1998). Furthermore, regarding pay back periods, evidence from US cities shows, that these choose measures with short payback periods, typically no longer than 5 or 10 years (Kousky and Schneider, 2003).

3.2.3. Institutional dimension

Third issue is “not my business” (institutional dimension). Mayors are not necessarily energy experts (at least not in general terms). Quite often, the people elected have little introduction and appetency for the concepts of local sustainability and the related new culture of a new energy paradigm made of diversification, decentralization of sources and conversion facilities and of priority to the demand approach. Given the cross-cutting nature of climate change, and the corresponding wide variety of relevant issues (e.g., energy and all activities that are strongly dependent on energy, e.g., transport, buildings, industry, leisure, normal citizen life), it is everything but straightforward to have the required expertise at all these levels. Competence regarding sustainability might be limited, or it might be centralized (e.g., at the environmental department, which often has to deal with a whole

[8] The aspect of poverty merits specific attention in this regard. Some sustainable measures could have adverse distributional effects, which would then require compensating measures. This is a complex issue that needs to be investigated further, but is out of the scope of this report.

range of environmental issues), not being able to spread its expertise or even its values and culture horizontally throughout all the levels/departments required. Hence, climate action and sustainability involve a wide range of elements and are intrinsically multidisciplinary in nature. Integrated solutions are required covering urban planning, buildings licensing, energy infrastructures (electricity, natural gas, district heating/district cooling, etc.), transport, water and waste management. However, these domains are often classified under different departments, all having their own targets and budgetary constraints (and often even different interests and priorities).

For instance, in the absence of internal coordination, a city may have an energy agency to promote information campaigns while the next-door office is promoting the construction or upgrade of public buildings with poor energy performance.

3.3. Identification of the energy actions and respective potential barriers

To synthesize, Table 3 presents a tentative identification of the main barriers, according to the description presented above, faced by each of the key-measures identified in chapter 2.

Table 3. Identification of the main barriers faced by each of the key-measures identified in chapter 2

	Energy Technical measures	**Key barriers**
Building Stick Opportunities	Thermal upgrade of the envelope of existing buildings	Divergence of interests (costs to the landlord and benefits to the tenant) Long payback periods Lack of information (no additional costs if the building is undergoing major renovation)
	Upgrade of lighting in buildings	Lack of information (regarding its importance on the overall consumption and potential for improvements) Lack of expertise (on the opportunities of daylight and proper efficient control) High upfront costs (associated with control devices and designing process)
	Solar thermal for DHW	Price distortions Lack of expertise (non-existence of an unified and reliable community of installers)
	Efficient boilers and chillers	Lack of information (no large additional costs if undergoing renovations)
	Heat pumps	Lack of information (regarding the installation process and the changes required to move from a conventional boiler)
	Mechanical ventilation with heat recovery and free cooling	Lack of expertise (absence of trade-off analysis between savings of heating/cooling and energy used to move the fans) High upfront costs (without the guarantees of proper results)
	Efficient electrical appliances	Lack of information (to incentivize a quicker stock turnover) Lack of motivation (due to the lack of incentive's programs)
	Passive buildings	Asymmetry of information (misleading terms as NZEB and passive building) Regulatory framework (absence of national mandates to stricter building codes) Lack of expertise (non-diffused best practice)
	Smart metering	Divergence of interests (regarding who supports the costs) Lack of information (the user needs to know how to take advantage of it)

	Energy Technical measures	Key barriers
Transportation and Mobility Opportunities	Lowering mobility needs	Urban planning (impossibility of designing the city from scratch) Regulatory framework (most transport planning is done at the national level) Lack of cooperation (among neighborhood municipalities) Short-time horizons (urban planning has long-term results compared to the time that government officials are in office)
	Shift from individual to collective transport	Regulatory framework (most transport planning is done at the national level) Lack of coordination (between different transport modes/intermodality) Perception of quality of life (independency from other users and time issues)
	Soft modes of transportation	Lack of information (walking & cycling are usually not seen as transport modes) Cultural barriers Perception of quality of life (necessary to change the perception of comfort, e.g.)
	Integration of EV in the urban environment	Early-stage (10 years are not enough for a strong impact) Regulatory framework (its success is dependent on the electricity mix) High upfront costs (to build the infrastructure and to buy the cars)
City Management Opportunities	Shift among energy carriers	Price distortions (best match between use and carrier is not always the cheapest) Divergence of interests High upfront costs (undesired costs to perform the shift)
	Upgrade of street and traffic lighting	High upfront costs (compared to the financial capacity of the municipality)
	CHP with district heating and cooling	Price distortions (on the final energy and inappropriate CO_2 accounting) Cost-effectiveness perception Lack of cooperation (among neighborhood municipalities)
	Electric production from RES in the urban environment	Lack of information (unclear meaning for the investors) High upfront costs Divergence of interests (between generators and distributors/system operators)
	Development of smart grids	High upfront costs Divergence of interests (regarding who supports the cost of the infrastructure)
	ICT	High upfront costs Lack of expertise (on how to take advantage of ICT to reduce energy consumption)

4. Overcoming difficulties with a local approach

This chapter first discusses how market failures can be overcome with a local approach, dividing the possible actions by city authorities into three levels of city smartness. We consequently explain how existing pioneering cities have overcome the institutional failures that are associated with a local approach to end the chapter with a discussion of the limitations of a local approach.

4.1. Overcoming market failures with a local approach: three levels of city smartness

In what follows, besides the cities-wide policy action, we distinguish, between three levels of city smartness in the actions by cities to overcome market failures with a local approach, (Figure 2), i.e. respectively self-managing actions, managing actions of private urban actors, and managing coordinative action of urban service providers and users.

4.1.1. First level of city smartness: self-managing actions

When managing themselves, the city authority can be seen as an actor, and similar difficulties (market failures) as discussed earlier apply. In this case, both the costs and the benefits are accrued by the public budget. As was demonstrated in the previous chapter concerning market failures, it is clear that costs (or funding) often play a key role. Especially the higher (upfront) cost of sustainability measures may have a significant impact, requiring a higher share (more financial resources) from the city budget.

Well-known examples are local governments deciding to make their municipal fleet green and there are many cities that have taken such actions. This will have an impact on the budget as it is more expensive than a regular fleet. Furthermore, the vehicles owned and operated by the local authority likely constitute only a marginal fraction of overall transport. As a matter of fact, such a measure will be anyway of little impact if it is not part of an overall municipal policy on this same theme. Other examples can be found in relation to public buildings, such as schools, etc.

Joint green public procurement is also worth mentioning, as it constitutes a great opportunity (e.g., in transport, or for improvements regarding public buildings energy demand). There are several examples of city authorities that developed procurement policies that promote the purchase of efficient appliances and lighting bulbs for schools, and other services buildings owned by the municipality. The EC has issued a manual for public authorities regarding this joint green public procurement (Pro-EE).

4.1.2. Second level of city smartness: managing actions of private urban actors

When managing private actors, the public budget will accrue costs, while the benefits are not necessarily for the local budget. There can be costs with regards to the required administration, monitoring, and enforcement, as well as costs that need to be made to increase awareness among locals with awards, education, information centers/campaigns, etc. Conceiving and implementing second level of city smartness concepts is therefore more challenging than the first level, but they have a potentially larger impact.

Well-known examples are the Merton rule in the UK where 10% of the energy consumed by new buildings has to be locally produced with renewable. Another example is Barcelona that requires the installation of solar thermal collectors for the hot water supply. In Freiburg, the municipality created a network between energy companies and citizens, so the latter can rent their roofs to promotors interested in investing in photovoltaics. In Växjö, the municipality promoted the use of district heating for heating purposes by making compulsory the connection to the district heating network and by not allowing the use of conventional heating systems in buildings (IEA, 2009a). In Lisbon, at the Expo'98 site (Fernandes et al, 1997), about 40000 people are live and work in a part of the city emitting less 40% of CO_2 per capita then the other Lisbon citizens on the other side of the street by installing a district heating and cooling network and enhancing the performance of the public promoted buildings.

City authorities do not necessarily have the institutional flexibility, i.e. human and financial resources, to implement such policies. There can also be exceptions where regulation generates an income, like in the case of city entrance charges or higher parking prices as part of a transport policy. A well-known example of the first is the creation of a "congestion charging scheme" in London, i.e. all the commuters entering and leaving the city have to pay a municipal fee; this action led to a significant decrease of traffic in central London (Alber and Kern, 2008). Other cities, as Stockholm, have followed the example. These types of transport pricing regulations can also be used to increase the attractiveness of low-carbon transportation modes. A good example is the reduction of parking prices within the city for electric or other low-carbon vehicles; in cities as Malmo and Växjö e.g., free parking was made available for environmental vehicles as an additional incentive to their purchase (IEA, 2009a; Malmo Environment Department, 2009). In Copenhagen, the local government has recently decided to reserve 500 parking slots exclusively for electric cars.

4.1.3. Third level of city smartness: managing coordinative action of urban infrastructure service providers and users

Urban infrastructure service providers can implement city-scale demonstrations of innovative infrastructures to enable a more sustainable use of energy, but they often do not because demand participation is not ensured. City authorities can then take up the role of working with the infrastructure providers to ensure that the services associated to their infrastructure innovations are used. Note that in some cases the city authority owns the infrastructure service providers, while in other cases the city authority will need to work with a private company (e.g. via a public private partnership or a softer form of cooperation). In this cooperation, the city authority is well-placed to ensure that the services associated to infrastructure innovations are used because they are users themselves, and because they condition the use of these services by private actors. In other words, third level concepts of city smartness encompass the first and the second level of city smartness and can be more ambitious and innovative because infrastructure service providers are involved.

Well-known examples are several Danish municipalities (Aarhus, Middelfart and Fredericia) that signed joint ventures with a provider of electric vehicle charging infrastructure (Better Place), to accelerate uptake of electric vehicles. Towards this aim, the municipality of Aarhus further partnered with the energy provider NRGi. This way, these authorities attempt to promote the use of environment-friendly vehicles, to set up recharging depots and provide battery-exchange stations for electric cars in the city. The city of London aims for 25000 charging points for electric vehicles by 2015. The so-called 'electric vehicle group' will therefore partner with London's borough councils, central government, public and private sectors. All new developments with parking will have to be equipped with electric vehicle charging points.

Table 4. Overview and illustration of the different levels of city smartness.

Conceptually			Examples
First level of city smartness	Self-managing actions by city authorities	City authority as an actor	Public buildings (e.g. schools, social housing infrastructures, etc) Street lighting, municipal fleet
Second level of city smartness	City authorities managing private actors reluctance to act	City authority as a policy maker	Regulation: land-use (urban planning), building codes, city entrance charges Facilitation: info centers, trainings, subsidies
Third level of city smartness	City authorities managing coordinative actions infrastructure service providers and users	City authority as a coordinator	Combined action with city-scale demonstration of innovative infrastructures that enable a smarter use of energy, in combination with actions from city authorities to promote the use of the associated services

4.2. Overcoming the institutional failures of a local approach

In what follows, we explain how pioneering cities have overcome their own institutional failures, respectively by discussing city authorities' internal and external incentives.

4.2.1. City authority's internal incentives

The institutional failures of the previous chapter can also become incentives: 1// "yes on my turf" (spatial dimension); 2// "in my term" (temporal dimension); 3// "it is my business" (institutional dimension).

First incentive is "yes on my turf", i.e. spatial dimension. Sustainable energy measures can sometimes be the best way of dealing with a local problem. Examples include the following: the city of Freiburg's action towards sustainability originated from protest against a possible nuclear power plant being built nearby; the city of Växjö was confronted with severely polluted lakes, and hence, decided to undertake action; the city of Güssing faced high numbers of unemployment and corresponding migration to other regions. As one of the poorest cities in Austria, it was barely able to pay its energy bill. Therefore, the city decided to take action and move towards a fossil free energy system (IEA, 2009a). Expo'98 site in Lisbon become a pioneer 'smart city' on a site of 350ha of a derelict area on the right bank of the Tagus river which soil was totally decontaminated and the space rebuilt from scratch. (Fernandes et al, 1998)

Second incentive is "in my term", i.e. temporal dimension. To get local sustainability on the agenda, so called "policy entrepreneurs" tend to play an important role. Such leadership has been determined as key factor (individual political champions are often reported to have established novel financial mechanisms). As a condition, however, especially within the local government, a broad supporting basis needs to be created. This basis needs to remain in place for a long time period, as the path towards local sustainability requires time. This support is typically also dependent on the political parties that are in power in the local government. The possible presence of NGOs in the city is also identified as driver for getting sustainability on the political local agenda (Brody et al., 2008).

Third incentive is "it is my business", i.e. institutional dimension. Becoming a pioneering city in itself might further be partly motivated by possible first mover advantages, trend-setting, building a reputation of 'green' city, serve as a role model and gain (inter)national recognition. This recognition on its turn can then provide the incentive for city authorities to further strengthen their actions. Being a pioneering city could translate in business opportunities for local companies (green jobs), involving various stakeholders (public, local utilities, universities and local companies) and so leading to strong economic growth, and/or even attract tourists. As an example, the city of Växjö involved local companies and its university in its actions to become carbon free. As a result, business opportunities and strong economic growth have been reported. Another example concerns the island of Samsø, which now serves as a model community, and attracts several thousands of tourists each year (IEA, 2009a). The management body of Lisbon Expo'98, a private company of public funds, doesn't have any more jurisdictions over the site, returned to the municipalities of Lisbon and neighbor Loures and is now extending its knowledge to dozens of cities and sites all over the world with similar type of problems.

4.2.2. City authority's external incentives

In what follows, we give examples of Member State and EU practices that have been used to encourage cities to take action, which can be divided into: 1// "tambourines"; 2// "carrots"; 3// "sticks".

First are "tambourines", which are "soft" instruments whose main objective is to raise awareness among city authorities on what is expected from them. This type of instrument can therefore help solving the information problems that were mentioned in the previous section. The instrument can be dedicated to a specific part of the urban environment or even to a single technology, while it can also be used to raise awareness of city authorities in general. The most commonly used instruments include the development of information centers, the promotion of best practices, and networking. For instance, over 350 of energy agencies exist across Europe (national, regional and local) that often combine several of these instruments.

Second are "carrots", which are instruments that go beyond tambourines because they are about enabling city authorities to act. Three examples of Member States providing incentives to local governments through carrots will subsequently discussed, i.e., Sweden, the Netherlands and Finland, respectively (Gupta et al., 2007; VROM, 2007; Jollands et al., 2009; Berns, 2009; Baker and Eckerberg, 2007; Granberg and Elander, 2007; Swedish Environmental Protection Agency, 2009).

Sweden is responsible for one of the oldest local investment programs in the EU. In this case, the initiative allocates subsidies to projects proposed by city authorities that have significant impact in the reduction of CO_2 emissions. The subsidy is partly fixed, and partly variable, with the variable part depending on the performance according to preset targets. Only the cities that have already developed a local action plan towards a sustainable urban development are eligible. In order to receive funding, cities must go through a double selection process: firstly, cities are ranked according to the quality of their action plans and the evaluation is based on criteria such as the involvement of both the private sector and the involvement of the citizens in the plan; secondly, there is a selection of projects within the winning action plan, which is done according to their cost-effectiveness. The competitive design of this initiative counteracted the cooperation between municipalities but, at the same time, it worked as an incentive to develop strong proposals and clear strategic plans. Plus, the municipalities receiving funding have reported a multiplier effect. Though ambitious, most proposals lacked innovation during the first phase of the program, which according to experts resulted from the fact that subsidies were not enough to cover the risk. Currently, the financed projects are expected to reduce annual GHG emissions by over 1 Mton of CO_2 equivalent.

The Netherlands feature a unique case in what concerns subsidies to mobilize city authorities towards the reduction of CO_2 emissions (VROM, 2007). Within the *Climate Covenant*, the allocated subsidies cover part of both the investment linked with the evaluation of the current situation and the investment linked with the implementation process. The grants are defined according to the ambition of the targets taken by the municipality. When applying to this program, city authorities have to perform an energy audit (subsidized by the program), where an independent entity sets the targets and actions that can be subsidized. The CO_2 emission reduction due to the first phase of this program is estimated to be around 900 thousand tons. One of the biggest successes of this case is the achievement of an integrated approach, involving different local actors, which might derive from the fact that the targets and actions are not defined by the municipal government itself but by an independent entity.

In Finland, as part of the *Energy Efficient Agreements*, city authorities can receive subsidies for energy efficiency projects that concern municipality owned equipment and companies, and these are proportional to the energy saved and dependent on the technologies involved (higher the innovation level, higher the subsidy). The subsidies' allocation is done through project competition, according to the quality of the cities' strategy. The selection criteria focus on the ambition and feasibility of the plan, which has to be based on a subsidized energy audit. Both energy audits and the monitoring of the implementation are done by a specialized public-private company, and city authorities that do not follow their commitments can be expelled from the program.

Third are "sticks", which are instruments that go beyond carrots because they are about regulating the performance of city authorities and sanctioning the lack of it. For example, in Norway, the central government issued a circular requiring to municipalities the development of local climate plans aiming at reducing CO_2 emissions and increasing sequestration. Also in Germany, the central government created a regulation requiring local authorities to create urban plans but only regarding land use and buildings; in this case, the regulation also specifies the plans' contents. Most Member States however only define planning guidelines at the national level.

Many of pioneering cities have also received some form of EU support. Examples include support from the European Regional Development Fund (ERDF), or from specific EU programs targeted at or available to the urban environment, such as the City Vitality Sustainability project (CIVITAS), Intelligent Energy Europe Program, ManageEnergy, CONCERTO, BUILD UP, Eco-building concept, Municipal Finance Facility (for new Member States). Financing can further be obtained from specific instruments, such as the European Local Energy Assistance (ELENA), and the Joint European Support for Sustainable Investment in City Areas (JESSICA).

4.3. Limitations of a local approach

In what follows, we discuss the limitations of a location approach, i.e. the boundary conditions set by the broader institutional context in which a city operates and the potential caveats of a local approach.

4.3.1. Institutional boundary conditions

Local governments are constrained by the broader institutional context in which they operate, but it is not within the scope of this report to discuss whether these constraints should be relaxed or tightened. Instead, we consider them as boundary conditions for the Smart Cities Initiative. The main institutional boundary conditions include: 1// national energy policies; 2// legal authority and financial independence of local governments.

First issue is national energy policies. The absence of support from the central government is reported as important constraint. In absence of clear national regulations and targets on key areas, it might become very difficult for a city to undertake and get support for appropriate action. Divergences can be influenced by basic political divergences among the actors or divergent strategic approaches between municipal and inter-municipal or interregional policies or projects. For example, in what concerns micro-generation, if the national government supports PV micro-generation, through tax-incentives, it might be difficult for a city to promote biomass micro-generation, even if this is the resource with the highest potential within the area. However, with overall increasing awareness, external political pressure sometimes exists to get elements of sustainability higher on the local agenda (e.g., in the UK, local governments have to take action concerning energy efficiency, according to national legislation).

Second issue is legal authority and financial independence of local governments, which differs widely across member states. One of the most common difficulties, in what concerns the action at the city level, is the coordination with policies and actions decided at higher levels of the administrative chain. These difficulties depend mostly on the autonomy of city authorities regarding national and international governments. Local governments commonly have limited power and responsibility over energy-relevant issues what might constrain some of the actions at this level. Thus, city authorities cannot act independently from higher-level governments, having the need to format their actions according to national and international policies. There are typically unitary states (e.g., Sweden, the Netherlands) that have relatively strong and independent local governments, while strong hierarchical countries with multiple intermediate governance levels like the UK tend to have local governments that have less resources and capacities to act, and are therefore more dependent of the higher levels of governance. The authority on issues as raising specific taxes (e.g., environmental taxation) or implementing specific building codes might be limited at the cities level, thereby significantly hampering profound action towards sustainability. As an example, the city of Copenhagen is willing to implement a congestion charge, but the national government does not allow this. Examples, however, exist, of the devolution of local transport responsibilities to the local level, e.g., in France and the Netherlands (Crass, 2008). Furthermore, because of the widely liberalization and unbundling of mainly energy supply and transport, local governments have little control over these utilities.

There are additional difficulties regarding the lack of cooperation with different stakeholders – locally, regionally and at other policy levels (Figure 7). At the local level, there is a wide range of actors involved in providing the required infrastructures and implementing the required mitigation measures; thus, the lack of cooperation between local governments and local stakeholders can constitute an important barrier. Furthermore, due to the spatial mismatch between institutional responsibilities and jurisdictional boundaries of a city, the implementation of certain measures depends on the cooperation of neighborhood cities, e.g. the case of metropolitan areas.

For instance, transport-related measures within a city are usually more effective if cover areas going beyond city boundaries, including suburban regions or the metropolitan area, since a large share of the daily journeys are not exclusively inside city boundaries.

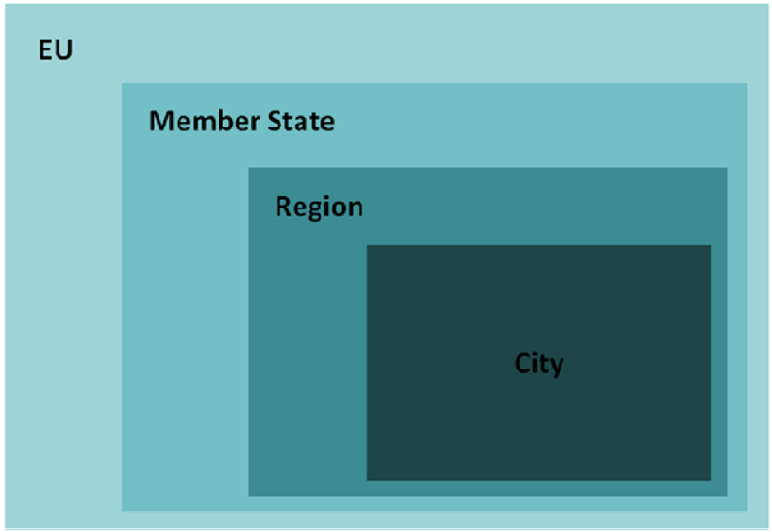

Figure 7. Different administrative levels

4.3.2. Potential caveats of a local approach

In what follows we argue that there can also be caveats to a local approach so that a city should not necessarily do everything it can within its institutional boundary conditions. We illustrate for transport and standards and interoperability.

First illustration is transport. City entrance congestion-charging and specific parking policies have been mentioned as examples of a city managing the actions of private actors by regulation. Other options include promoting cycling and walking. These are all shorter term measures, which may be helpful to some extent, but do not necessarily address the actual source of the problem (Calthrop, 2000; Proost et al. 2002 and 2009; Anas and Rhee, 2006).

Longer term measures include the promotion of a compact city (Southworth, 2001; Muniz and Galindo, 2005, EEA, 2006). In this regard, the problem of urban sprawl merits careful attention (EEA, 2006; Bart, 2009). This typically extends city boundaries, and needs to be addressed at a higher political level. According to Bart (2009), the climate change impact of urban planning does not justify it to still be under national, regional or local government authority. Recognizing the wide diversity in urban decision making (appropriate level of subsidiarity) and acknowledging that the EU has significant limitations in developing policies on urban planning, Bart (2009) proposes several possible measures at EU level. These should be adoptable without unanimity and not voluntary. Examples of potential measures include public transport access requirement, maximum parking space requirements and a trading scheme to reduce transport emissions involving parking place-providers.

Second illustration is about standards and interoperability. We want cities to be laboratories of innovation, but we for instance do not want that every city would end up having different electric appliance labeling, smart metering standards, or electric vehicle charging point infrastructure "plugs". Setting standards is a careful balance between waiting long enough not to constrain innovation, and not waiting too long to avoid lock-in. The EU is currently moving towards a common charger for electric vehicles (EU, 2010). The main objectives mentioned by the EU are to have safe charging, to ensure interoperability and to allow for development of smart charging. The standard is expected to be ready by mid-2011 (EU, 2010), and is especially relevant to car manufacturers (de Boncourt, 2010). It is then important that local approaches subscribe to this ongoing process to avoid lock-in a city level.

5. Organization of the Smart Cities Initiative

Building on the evidence collected in the previous chapters, in this chapter we first propose why and how to support a portfolio of smart cities to then provide guidelines for the organization of the call that will select the cities to be supported.

5.1. Supporting a portfolio of smart cities

In what follows, we respectively discuss why to create a portfolio of smart cities, and then how to support this portfolio.

5.1.1. Why to create a portfolio of smart cities

It is not enough to support existing pioneers for what they are already doing. In what follows, we respectively argue why a portfolio of smart cities needs to be created 1// to support pioneers to further cultivate their excellence; and 2// to indentify groups of cities that could have a significant impact, but where pioneers have not yet emerged.

First issue is to further cultivate excellence. The reason to continue to support city pioneers is that they are niche markets for the technical measures (chapter 2: "likely elements needed for energy smart cities") that can make our local energy systems more sustainable. With continued support, niches can grow and accumulate learning effects, so that they may eventually displace the current mainstream dominant design, i.e. so-called strategic niche management[9]. However, to avoid supporting these pioneers for what they are already doing, the focus of this support would need to be on conceiving and implementing third level concepts of city smartness, which are promising, but more complex to manage for a city authority because it requires the authorities to work with infrastructure service providers, while also ensuring a demand for the associated services (chapter 4: 4, section 4.1.3: "third level of city smartness: managing coordinative action of urban infrastructure service providers and users").

Second issue is to indentify groups of cities that could have a significant impact, but where pioneers have not yet emerged. Even though European cities have elements in common (chapter 1, section 1.1: "cities as energy systems"), the most appropriate set of technical measures and/or the policy or promotion measures that intend to put the technical measures in place can differ significantly among groups of cities (chapter 2, section 2.1: "smart city concept") because of the differences in physical and human geography, and also because of the institutional context in which the city authorities need to operate (chapter 4, section 4.3.1: "institutional boundary conditions"). Furthermore, the current group of pioneers is not representative for the population of European cities, for instance, because certain European Member States (chapter 4, section 4.2.2: "city authority's external incentives" where we gave the examples of Finland, the Netherlands and Sweden) have been more ambitious in providing public support via national programs and initiatives. In general, city pioneers have been motivated by a combination of specific local circumstances and existing support schemes, which have allowed them to overcome their institutional failures (chapter 4, section 4.2: "overcoming the institutional failures of a local approach"). As a result, the current pioneers do not necessarily belong to the groups of cities that could have the largest impact. For example in Eastern Europe, less pioneers have emerged, while cities in this part of Europe often have in common that there is an aging district heating infrastructure that could be renewed with a more sustainable one. This is then a group of cities with a large potential impact and promising opportunities for replication. Note also that in areas of Europe, were pioneers have not yet emerged, it could be justified to support city authorities to conceive and implement first and second level concepts of city

[9] Foxon (2003): *"The idea promoting shifts to more sustainable regimes through the deliberative creation and support of niches, so-called 'strategic niche management' has been put forward by Kemp and colleagues (Kemp et al., 1998)."*

smartness instead of jumping to the third level (chapter 4, section 4.1: "overcoming market failures with a local approach: three levels of city smartness").

The success of the Smart Cities Initiative depends on the portfolio that will be created, which in turn needs to rely on a carefully designed typology of European cities. The relevant parameters include the size of the city and the characteristics of the context in which the cities operate, such as the socio-economic conditions, climatic zones, multi-governance structures, etc (Croci et al., 2010; Corfee-Morlot et al., 2009; and European Commission, 2010a, EuroStat, 2009), but opinions seem to diverge with regards to the relative importance of these parameters and how to combine them to create groups of cities that should be represented in a portfolio of smart cities. A more profound analysis is therefore justified, but out of the scope of this report.

5.1.2. How to support this portfolio of smart cities

City authorities are both actors that are subject to market failures and institutions that are subject to institutional failures that can prevent them from managing the energy use of the private actors in the urban environment (chapter 3: "key barriers and difficulties"). Supporting the portfolio of smart cities can then be about 1// supporting the city authorities as actors, and 2// supporting city authorities as institutions, which we respectively discuss in what follows.

First option is to support city authorities as actors. Although the focus is on private actors, the EU did recently launch several new initiatives and partnerships to support actors in sectors that are relevant for the urban environment by providing public funding for the research, development and demonstration of sustainable energy technologies. For instance in the context of the Strategic Energy Technology Plan (SET-Plan), six so-called European Industrial Initiatives have been proposed of which four have been launched in 2010, i.e. an initiative with the wind sector, the solar sector, the electricity grids sector, and the carbon capture and storage sector. In the context of the European Economic Recovery Plan, three additional Public Private Partnerships have been added, i.e. a partnership with the automotive, construction, and manufacturing sector. Cities should be encouraged to leverage these existing initiatives and partnerships that could provide the necessary support to implement certain concepts of city smartness that will be proposed in the context of the Smart Cities Initiative. For instance to implement third level concepts of city smartness, the European Industrial Initiative on Electricity Grids could fund city-scale demonstration of innovative grid infrastructure (such as smart metering), and The Green Cars Public Private Partnership could fund city-scale demonstrations of innovative transport infrastructure (such as electric vehicle charging point infrastructure).

Second option is to support city authorities as institutions. The EU already has experience with initiatives that increase the awareness of city authorities, promote networking and cooperation among them, and provide funding for city level demonstration projects (chapter 4, section 4.2.2: "city authority's external incentives", and see also Annex I). Considering that most of the SET-Plan and the European Economic Recovery Plan is already focusing on addressing the reluctance of actors to research, develop, and demonstrate sustainable measures, the Smart Cities Initiative could fill the gap by focusing on city authorities as institutions and support them to become institutions that will accelerate rather than slow down the uptake of sustainable measures in the urban environment. Supporting city authorities is then about providing them with the necessary human and financial resources to conceive and implement concepts of city smartness (chapter 4, section 4.1: "overcoming market failures with a local approach: three levels of city smartness"). This would then allow city authorities to build up the necessary "institutional flexibility" to integrate sustainability concepts in every policy decision they make.

Still, it cannot be excluded that the implementation of certain smart city concepts will require private actor support that is not yet covered by the above mentioned sector initiatives and partnerships. Furthermore, these initiatives and partnerships focus on private actors so that support for a city authority as a public actor is not necessarily available, which could then also be provided in the context of the Smart Cities Initiative. An example could be with regards to retrofitting of public buildings where the city authorities could lead by example, while the existing Eco-Buildings partnership focuses on the private sector.

5.2. Guidelines for organization of the call

In what follows, we provide guidelines for the organization of the call that will select the cities to be supported. We respectively discuss the issue of reporting requirements, rewarding of ambition and innovation, and criteria to take into account when selecting winners.

5.2.1. Reporting requirements

The EU has already been successful in voluntarily committing city authorities to reduce their CO_2 emissions with at least 20% by 2020 (Covenant of Mayors). In the context of the Covenant, a methodological framework has been developed to help signatories to elaborate their baseline emissions inventory and their so-called Sustainable Energy Action Plans (SEAP). It is also mandatory for Covenant signatories to produce a report every second year to monitor progress.

Even though the portfolio of smart cities to be supported via the Smart Cities Initiative is not necessarily going to be a subset of the cities that already signed the Covenant (see above, existing pioneers are not necessarily representative for the population of European cities), it should be a condition for cities that will receive support from the Smart Cities Initiative to sign the Covenant. Both initiatives can then reinforce each other, building on a common set of rules (or at least compatible rules) for the monitoring of energy consumption, CO_2 emissions, etc. The SEAP template already requires city authorities to set targets, and list a set of actions to reach the targets, with the built environment, the local energy networks, and the urban transport systems integrated in one plan.

Within this existing framework, the Smart Cities Initiative should however be stricter with regards to reporting and monitoring than its voluntary counterpart to facilitate replication of the good practices that will be supported. Cities often use different approaches in defining what sectors to include in their reporting, in establishing the geographic boundaries of the area included (i.e. what is a "city"), as well as in aggregating data in different ways (Croci, 2010; Corfee-Morlot et al., 2009), and the Covenant also allows cities the use of different accounting methodologies. This type of flexibilities that have been built into the Covenant could then be removed to evolve towards a more uniform methodological framework for smart cities.

The smart cities reporting and monitoring framework should then also enter into the project level, while the Covenant stays at a more aggregated level, and the smart cities framework could also account for context to improve comparison between groups of cities that will come out of the topology of European cities to be included in the portfolio of smart cities. It will also be important to measure the effect of the plans against a "likely future without a plan" rather than against the present. This issue is particularly relevant to filter out the ongoing changes at the higher policy levels that have an impact on the performance of the local level, such national policies that impact the generation mix in a certain country and therefore the emissions associated with consuming electricity on the local level (chapter 4, section 4.3.1: "institutional boundary conditions").

5.2.2. Rewarding performance and innovation

Sanction mechanisms are often limited to the expulsion of the cities from the program, which seems to be also the case for the Covenant of Mayors and which should then also be the case for the Smart Cities Initiative. Though this seems to have no economic or political consequences, it can have a strong impact on the city's public image (chapter 4, section 4.2.1: "city authority's internal incentives").

Furthermore, there have been good experiences at the Member State level with conditioning party of the subsidy city authorities can get to the final output (chapter 4, section 4.2.2: "city authority's external incentives"). The case of Sweden is an interesting implementation of performance based rewards with subsidies that are partly fixed, and partly variable, with the variable part depending on the performance according to preset targets. Sweden has a program that has been successful at reducing CO_2 emissions, but the program has been less successful in promoting innovative approaches. The Dutch and Finish cases provide state of the art examples of how this could be remedied, where the degree of innovation (or ambition) has an impact on the amount of public funding that city authorities can receive from the national program (chapter 4, section 4.2.2: "city authority's external incentives").

5.2.3. Criteria to take into account when selecting winners

The Smart Cities Initiative should not simply rank proposals and select the most ambitious ones. Instead, a typology of cities can help to make sure that the winners that will be selected are spread over the different groups of cities that need to be represented in a portfolio of smart cities (chapter 5, section 5.1: "supporting a portfolio of smart cities"). Then on the more detailed level of comparing competing proposals that would serve the same purpose within the portfolio, additional criteria to select winners could include commitments and institutional capacity the city has demonstrated in previous initiatives (e.g. Covenant of Mayors, CIVITAS, CONCERTO, etc), stakeholders involvement (e.g. public consultation, partnerships with local businesses), innovative forms of cooperation with other cities (e.g. "city twinning"), financial capability of the city authority to implement the proposed plans (e.g. ability to leverage funding sources from existing programs and initiatives at Member State or EU level), the technical and financial consistency of the proposed plans (e.g. Neves and Leal, 2010), which have all been ingredients of success for pioneering cities.

Recommendations

City smartness essentially stands for integrating concepts of sustainability in every policy decision that is made on the local level so that cities will become institutions that accelerate rather than slow down the uptake of sustainable energy measures.

For organization of the Smart Cities Initiative

- **Carefully select and support a portfolio of smart cities** to increase the excellence of the current pioneers, while also giving opportunities to cities in parts of Europe where there is a promising potential, but pioneers have not yet emerged.
- **Promote third level concepts of city smartness.** Within the three levels of city smartness identified in the actions of the current city pioneers, especially the third level is challenging so that this is where city excellence can be further promoted by the Smart Cities Initiative, i.e. to combine city-scale infrastructure demonstrations that enable a smarter use of energy with actions by city authorities to promote the use of associated services.
- **Establish a strict performance reporting methodology for smart cities.** A set of rules is needed to set targets at the local level, prioritize actions to reach these targets, and measure progress and performance during the implementation stage (taking into account that there are different

groups of cities). Performance can be a combination of ambition (in reducing CO_2 or energy use), innovation (infrastructures that enable a smarter use of energy), cooperation (performance of a twin city), etc.

- **Make support for smart cities conditional to signing the Covenant of Mayors**. More than two thousand cities have already signed the Covenant. The Covenant already includes a reporting methodology for cities. Even though the Smart Cities Initiative needs a stricter methodology, there should be consistency between these two initiatives so that they reinforce each other and indicate a progress and allow for a follow up that is important not only in the actions but on the way they are selected and conducted.
- **Make public funding subject to performance**. Smart cities support can be (partly) dependent on the ambition and innovation of the proposed plans, and the performance of the cities when implementing their plans.

Increasing the impact of the Smart Cities Initiative

- Legislative initiative to oblige all cities, including those that are not taking action, to report about their progress or lack of progress.
- Use this information to make an annual benchmark report to "**name and shame**".

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ANNEX : List of EU instruments, initiatives and partnerships mentioned throughout the report

CIVITAS

CIVITAS is a European Commission's initiative that aims to support and evaluate the implementation of ambitious integrated sustainable urban transport strategies. CIVITAS' main contribution lies on the different demonstration projects, which usually include integrated packages of technology and policy measures in the field of energy and transport. The program is also responsible by the diffusion of best-practices, through information tools and also awards.

Main Sources:

CIVITAS, 2002, http://www.civitas-initiative.org/main.phtml?lan=en

Managenergy

Managenergy was launched in 2002 to support the work of actors working on energy efficiency and renewable energies at the local and regional level. This support is provided through training and workshops as well as through the diffusion of information. Lately, they have also been creating some individual projects fully dedicated to the education of the younger generations.

Main Sources:

Managenergy, 2002, http://www.managenergy.net/

CONCERTO

CONCERTO is a wide initiative addressing the challenges of creating a more sustainable future. Their support to local communities refers to the development of concrete strategies and actions towards a low carbon future, and it includes the interaction with experts, academics and private companies, as well as the promotion of demonstration projects.

Main Sources:

CONCERTO, 2004, http://concertoplus.eu/cms/index.php?option=com_content&view=frontpage

BUILD UP

BUIL-UP is an initiative created to raise awareness to all parties in the building chain regarding the potential of energy-saving measures in buildings; a web-portal tool was created in order to promote networking and transfer and promotion of the existing information and knowledge for energy saving measures in buildings across Europe.

Main Sources:

BUILD UP, 2009, http://www.buildup.eu/

Eco-Buildings

Eco-Buildings is a program created by the European Commission in order to promote energy efficiency in buildings by the use of demonstration projects, for both construction of new buildings and retrofit techniques.

Main Sources:

Eco-buildings, 2010, http://www.ecobuildings.info/

Convenant of Mayors

The Convenant of Mayors refers to a voluntary commitment by towns and cities across Europe to reduce their CO2 emissions beyond the EU's 20% by 2020 target. Participant cities are required to develop and implement their own Sustainable Energy Action Plan (SEAP), and to report and be monitored on their implementation of the SEAP's. Cities willing to sign up for the Convenant of Mayors but lacking the skills and/or resources to fulfill its requirements have access to some Supporting Structures

Main Sources:

Covenant of Mayors, 2009, http://www.eumayors.eu/

JESSICA

JESSICA (Joint European Support for Sustainable Investment in City Areas) gives Member States the option to use some of the Structural Funds (as the ERDF) to make repayable investment, such as guarantees and loans, in projects forming part of an integrated plan for sustainable urban development.

Main Sources:

European Investment Bank (EIB), http://www.eib.org/

ELENA

ELENA (European Local Energy Assistance) is a technical assistance grant facility to help local and regional authorities to unlock their sustainable investment potential; its objective is to increase the investment in projects in the areas of energy efficiency, renewable energy sources and urban transport. ELENA support covers a share of the cost for technical support that is necessary to prepare, implement and finance the investment program; summarizing, they help cities to prepare their projects funding.

Main Sources:

European Investment Bank (EIB), http://www.eib.org/

Public-Private Partnerships

Public-Private Partnerships (PPPs) were launched in order to promote research efforts in three large industrial sectors – automotive, construction and manufacturing. The initiative for the construction sector is called Energy Efficient Buildings' PPP and it will consist on a financial envelope of €1billion to support the promotion of green technologies and the development of energy efficient systems and materials in new and renovated buildings. The European Green Cars initiative, the PPP for the automotive sector, has a financial envelope of €5billion to support the development of new, sustainable forms of road transport.

Main Sources:

Pubic-Private Partnerships (PPPs), http://ec.europa.eu/research/industrial_technologies/lists/list_114_en.html

Intelligent Energy Europe Programme

Intelligent Energy Europe Programme (IEE) supports cities' actions by subsidizing concrete projects that help achieve the EU's targets. These projects need to present a clear European added value and to promote partnership with other countries.

Main Sources:

Intelligent Energy Europe Programme, http://ec.europa.eu/energy/intelligent/

Municipal Finance Facility

Municipal Finance Facility (MFF) is a program created by the European Investment Bank to strengthen and deepen the municipal credit markets by promoting the building, upgrading or refurbishing of small municipal infrastructure investments.

Main Sources:

European Investment Bank (EIB), http://www.eib.org/

European Regional Development Fund

The European Regional Development Fund (ERDF) is a EU financial support mechanism that aims at promoting public and private investments to help reduce regional disparities across the EU.

Main Sources:

European Regional Development Fund (ERDF), http://europa.eu/legislation_summaries/employment_and_social_policy/job_creation_measures/l60015_en.htm

PRO-EE

Pro-EE aims to improve energy efficiency through sustainable public procurement. For this purpose, pro-EE brought together producers and consumers, implemented energy-efficient Green Public Procurement (GPP) procedures in local administrations, and organised training for municipalities' procurement staff.

Main Sources:

Pro-EE: http://www.pro-ee.eu/

ICT4EE Forum

The aim of the ICT for energy efficiency forum is (a) to invite the ICT industry to develop a framework to measure its energy and environmental performance and set itself energy efficiency targets by the end of 2010 and 2011 respectively; and (b) to look at ways in which the ICT sector can lead to more energy efficiency in other sectors such as buildings, transport and energy.

Main Sources:

ICT4EE: http://www.ict4ee.eu