OP-325-E
November 2019

Financing Smart Solutions in Cities: Smart Financing

Report on the Conclusions From the Workshops on Financing Solutions for Smart Cities

CARLOS CARRASCO
Researcher

PEDRO FRANCA
Research Assistant

JOAN ENRIC RICART
Professor of Strategic Management
Carl Schroeder Chair
of Strategic Management

JORDI SALVADOR
Researcher

ALBERT TAPIA
Research assistant

In conjunction with

Abstract

This document was drafted based on the workshops held at IESE Business School in academic year 2018-2019 with designers of smart projects and financial stakeholders with the goal of analyzing the best financing systems for the application of these smart solutions in urban areas for building retrofits, sensorization, and sustainable mobility.

Keywords: Financing; Smart Cities; Energy Efficiency; Electric Vehicle; Smart Financing; Sustainability

DOI: https://dx.doi.org/10.15581/018.OP-325

Last edited: 12/9/19

Contents

1. Introduction

One of the aspects which defines the 21st century is the increase in the urban population in countries all over the world. In 2015, almost 75% of European Union (EU) inhabitants lived in urban areas, and this proportion is expected to surpass 80% by 2050 (United Nations, 2018). The concentration of people, knowledge, and especially economic activity offers urban dwellers a series of advantages and opportunities, such as new jobs, higher salaries, and greater wellbeing, along with higher potential economic growth as a result of what are called "agglomeration economies."

However, the concentration of human activity in urban areas also creates challenges, such as an increased pressure on natural resources, a higher demand for basic infrastructures and public services, and greater socioeconomic inequality. Additionally, cities have a heavy environmental impact due to their high levels of energy consumption and pollution. Urban areas consume approximately 60% to 80% of global energy and emit similar proportions of carbon dioxide (CO_2) (United Nations, 2019). This can primarily be attributed to the energy mix used in both the building and transportation industries, as well as the inefficient energy consumption of much of the housing stock. It is estimated that 97% of the housing stock in the EU is energy inefficient, and that between 75% and 85% of these buildings will continue to be used until at least 2050 (Building Performance Institute of Europe, 2018).

In light of the problems associated with rapid urban growth, cities have to find a way to grow by harnessing all the technologies and resources available to them in a smart, coordinated way so they can become at once integrated, livable, and sustainable. In other words, they have to develop as smart cities: cities that use a high degree of innovation and technology in managing a series of services which improve citizens' quality of life while also increasing cities' competitiveness and capacity for economic growth. The incorporation of all this technology should contribute to overcoming the top challenges that cities are facing, especially the fight against climate change and reducing inequalities.

Smart city innovations, known as "smart solutions," go beyond the use of information and communication technologies (ICT) for a more efficient use of resources; it is also essential to consider more efficient urban transportation networks, improvements in the water supply and waste elimination facilities, and more efficient ways for maintaining building temperatures.

As cities try to modernize their infrastructures with smart technologies, financing these projects is a major challenge to introducing them on a large scale. Limited by tight budgets, cities need to promote business models that can help attract financing from multiple investors—public and/or private—to make the implementation of these solutions feasible.

This document was drafted based on workshops held at IESE Business School in academic year 2018-2019 with designers of smart projects and financial stakeholders and with the goal of analyzing the best financing systems for making the application of these smart solutions in urban areas possible. Each workshop addressed different solutions for the concrete development of the city of Barcelona as a smart city.

The topic of the first workshop was building energy retrofitting, in which active and passive measures to optimize the energy consumption of buildings, homes, and facilities were discussed. The discussion was divided into two different building models—residential and tertiary—and cases of public and private buildings were presented for each one.

The second workshop was about issues related to sensorization and monitoring in cities and their infrastructures. Some of the projects examined were smart towers, smart mobility, waste collection, and data integration.

The last workshop focused on sustainable mobility, and particularly on three issues that are becoming increasingly prominent: the transition process from conventional vehicles to electric vehicles, better integration of the urban transportation system, and last mile delivery.

This report, which reflects the conclusions on financing solutions in smart cities discussed in these workshops, is divided into two parts, each of which contains three sections (one for each of the topics described above): building retrofitting, sensorization, and mobility. To start out, the different smart solutions currently being implemented in both Barcelona and other European cities are presented, and the best financing instruments for each of these solutions are subsequently discussed.

2. Building Energy Retrofitting

Building energy retrofitting consists of implementing measures to optimize energy consumption in homes and facilities. The solutions to improve energy efficiency can be divided or grouped into passive and active measures. Passive measures are related to the building envelope, such as installing insulation and protection or replacing old windows with ones that insulate better; active measures are related to energy systems, equipment, and installations, such as: refurbishing boilers, heat pumps, and light fixtures; installing photovoltaic panels; and improving household appliances.

The workshops on energy retrofitting distinguished between residential buildings (homes) and tertiary buildings (belonging to the services sector, such as public facilities, offices, hotels, or stores, and buildings for industrial use such as warehouses or factories).

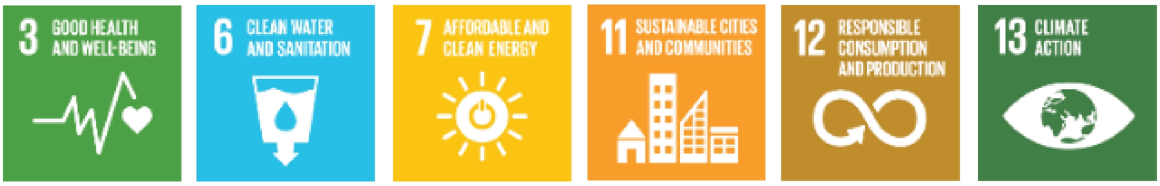
Structural rehabilitation projects can become an opportunity to apply active or passive measures that make buildings more energy sustainable. This helps lower costs compared to undertaking the energy project independently (as the fixed costs are divided between a higher total cost that can include structure measures).

In 2011, buildings' energy consumption accounted for around 40% of total energy consumption in the EU (Official State Gazette, 2012). In Spain, this consumption accounted for approximately 31% of the total in 2015, divided between 18.5% in residential buildings and 12.5% in the remaining buildings for tertiary uses (European Commission, 2017). Even though the building sector consumes the most renewable energy in Spain (54.9% of total consumption nationwide), the energy-saving potential is very high due to the age and energy inefficiency of the country's housing stock (Ministry of Development, 2013). According to the Catalonia Institute for Energy Research (IREC), 55% of homes were built before 1980, with 30% of them built between the 1960s and 1980s. Furthermore, less than 10% of the current housing stock was built following the Spanish Technical Building Code (CTE) in force since 2006.

In 2014, Spain had 25,492,335 homes, 19,113,128 of which were primary residences. In its long-term strategy for the energy retrofitting of the building sector (2014), the Ministry of Development estimated that for every million euros of total investment in the residential sector, 18 jobs were created and that for every million euros of public investment, that number was between 54 and 56, assuming that 25% of the total investment was subsidized. Furthermore, the Ministry of Development predicts that the pace of retrofitting will be 0.12% in 2021 and only 1.18% in 2030—far beneath the 3% cited by the European Union to effectively reduce buildings' pollutant emissions. However, these percentages would translate into approximately 1.2 million retrofitted homes in the 2021-2030 period. In parallel, as outlined in the same document, building energy retrofitting is estimated to generate returns for the public treasuries of at least the amount of public investment made, only considering the value added tax (VAT) and the reduction in unemployment costs.

The positive socioeconomic impact of building energy retrofitting is an opportunity to generate economic activity, reduce unemployment, spearhead technological innovation, improve citizens' quality of life, foster an energy transition towards more sustainable models, and consequently reduce the pollutant emissions generated by buildings, which contribute to global warming. In short, larger-scale building energy retrofitting would help fulfill Sustainable Development Goals (SDG's) 3, 6, 7, 11, 12, and 13 established by the United Nations in its *Horizon 2030 Agenda*, as shown in the figure below.

Figure 1
Sustainable Development Goals 3, 6, 7, 11, 12, and 13



Source: United Nations, https://sustainabledevelopment.un.org/?menu=1300

2.1. The Residential Model

There are different business models for residential building energy retrofitting depending on the type of user, their income, and the potential benefits in terms of energy savings. The types of models can be broken down as follows:

a) Type of user: A community or apartment building where most of the residents are renting is not the same as one in which the majority own their homes. In the former, the tenants capitalize on the benefits, but they take on none of the investment costs (assuming that the rent stays the same). In the latter, the owners benefit from the energy savings, but they have to shoulder the entire investment if there are no subsidies or other financing alternatives.

b) Users' income: The capacity to finance retrofitting projects can be closely tied to users' income and their ability to pay back the investment.

c) Potential benefits in terms of energy savings: The impact of efficiency measures on consumption can largely depend on the scale of the project as well as outside factors such as climate or even the customary practice of building retrofitting.

Recent experiences with retrofitting projects in and near Barcelona suggest that residential building energy retrofitting does not seem to generate enough savings to make it worthwhile, especially for two reasons: the return on investment (which would between 10 and 30 years, or in the best-case scenario between 10 and 15 years, as found over the course of the workshops) and the city's climate, which is much warmer than northern European cities. Below are more detailed explanations of these two reasons.

- The goal of the investment's temporary determining factor is to achieve attractive returns within a reasonable time frame for the investor. Extended return on investment periods are not interesting for private companies developing retrofitting projects nor for end users, who are averse to such long-term payments and see them as too similar to mortgages. For this reason, it is recommendable to apply solutions with a higher potential energy savings per each euro invested. In this regard, the installation of photovoltaic panels (active measure) is highly recommended, judging from several recent experiences in Barcelona. Furthermore, the usefulness of blending both passive and active measures to reinforce the potential savings seems a proven fact. However, the implementation of passive measures, such as insulating façades or windows or installing solar protections, may be highly effective for savings, but tend to not be financially sustainable because of their high cost.

- In climates like the Mediterranean, amortization periods of over 30 or 40 years are estimated for passive measures for energy efficiency, as shown in several energy retrofitting projects carried out in residential buildings as part of the European GrowSmarter project.

The new laws[1] in Spain have encouraged the installation of photovoltaic panels because they allow for self-generation and electrical consumption networks to be created. These electrical generation systems have very attractive short-term returns of around four years. However, the application of this kind of solution in conjunction with passive measures seldom seems sufficient to achieve reasonable amortization periods from the financial standpoint, although they do help shrink these periods considerably. For this reason, it is essential to seek new alternative forms of financing or ways of complementing the forms currently available.

Energy self-generation and the proliferation of local consumption networks which are semi-dependent on the conventional electrical grid (such as the smart grid) are a disruptive change in the business model of traditional electricity utility suppliers, which are grappling with new realities related to local electricity production and consumption. Within this context, new business models are emerging, many of them based on “Energy as a Service,” which offers solutions with regard to infrastructures, platforms, and software. The new energy scene also includes building retrofitting based on energy-efficiency criteria—projects that have been fostered by burgeoning environmental awareness.

Retrofitting Projects Spearheaded by the Government

In the Barcelona metropolitan area, residential building retrofitting is being led by the government, with the Housing Consortium of Barcelona and the Generalitat de Catalunya (the regional government of Catalonia) as the government entities that earmark the most resources. To a greater or lesser extent, their retrofitting model is framed within a comprehensive context which includes accessibility measures, such as the installation of elevators to improve residents’ quality of life.

Many of these actions are conducted in buildings more than 40 years old with a significant potential for energy savings and improved quality of life. The governments focus their policies on the least advantaged population strata with the greatest economic difficulties in undertaking comprehensive retrofitting projects. They are economically disadvantaged communities that live in poorly conserved buildings. Furthermore, the average resident of these buildings does not have easy access to financing. Given this, governments have to confront a new paradigm: They are no longer facing the need to subsidize or finance non-reimbursable retrofitting projects so much as actually managing and administering the projects, including the running costs of the operation. In short, the government is taking responsibility for being the driving force that generates instruments and attracts stakeholders who help solve pending problems.

By taking on an active role, the acting government’s functions are currently:

- To identify the cases and communities where it should intervene.
- To detect the user profiles. These may include those who cannot shoulder the investment costs, those who can partly defray them but still need public assistance, and those who can fully pay the cost but need some kind of financing.
- To contract the technical evaluation and studies needed.
- To carry out the project.

[1] Royal Decree-Law 15/2018, dated October 5, 2018, on urgent measures for the energy transition and consumer protection, and Royal Decree 244/2019, dated April 5, 2019, regulating the administrative, technical, and economic conditions of electrical energy self-consumption.

- To propose a financing model.
- To handle payments and even cases of nonpayment.

Retrofit Projects Spearheaded by Energy Service Companies

Some energy retrofitting projects are promoted by energy service companies whose goal is to diversify their business model in addition to offering added value to their main value proposition: providing energy and building homes.

This business model provided by energy service companies (ESCO) consists of offering building energy retrofitting in exchange for gaining customers' loyalty and ensuring them long-term savings. In an ESCO contract to retrofit residential buildings, the private company takes on the investment cost, but in exchange they secure long-term energy contracts. The customer, in turn, capitalizes on a hypothetical reassessment of their home or office, in addition to saving on the energy bills. The customer should compensate the ESCO for all or part of the savings achieved in the short term or establish a periodical fixed payment.

From the customer or investor's viewpoint (the homeowners' association or the owners themselves), in order for the retrofitting project to be attractive, it is essential to certify or prove that there are clear advantages and benefits, especially in terms of savings on bills, as well as improved comfort. To do so, it is essential to compare the situation prior to the retrofitting with the situation after energy-efficiency measures have been implemented, considering that there may be significant changes in end users' consumption. The net savings may not justify the investment if after the retrofitting, the user consumes more energy because of a change in habits, despite using a more efficient system. Therefore, it is essential to incorporate elements that also enable the increase in users' comforts to be assessed.

In consequence, determining the user's willingness to pay for greater comfort is an essential exercise for energy service companies which want to undertake energy retrofitting projects in residential buildings.For instance,Barcelona, where it seems harder to achieve significant energy savings, the appeal to users may lie primarily in a notable increase in comfort, quality of life, and health rather than energy bill reduction. In this sense, finding the customer segments that appreciate this comfort the most is a challenge facing energy retrofitting companies.

Finally, even though the financial benefits of a residential building energy retrofitting are uncertain, many projects do have a fairly clear environmental justification. In this respect, convincing residents—especially those that can cover the investment—is important. The goal is to make them see the positive aspects of the energy retrofitting, in addition to designing and setting incentives—including economic ones—to move forward with energy retrofitting models for residential buildings. In Barcelona, the retrofitting of a government-owned residential building as part of the European GrowSmarter project serves as an example of the challenges facing the project developer (the Barcelona city government) in getting residents to want to be an active part of the process and to feel satisfied with the results. Methods for achieving this include informative campaigns and periodic resident-satisfaction surveys.

Example 1: Energy Retrofitting of Government-Owned Residential Buildings in Barcelona

With regard to the retrofitting plans of government-owned residential buildings within the GrowSmarter project, the goals of the public institutions that promoted them was to improve comfort and livability, and, in Barcelona, to bear in mind the visual impact based on color studies of the building. In the study phase, the building was monitored to determine the inefficiencies and later quantify the real impact of the implemented energy-efficiency measures. In this respect, a notable reduction in gas consumption was achieved: up to a 50% reduction in many of the homes. During the project, awareness-raising campaigns were targeted at the residents to make them conscious of the impact of the measures being implemented, and especially to teach them how to maximize their savings. Finally, the importance of the end beneficiary of the project taking on some of the investment cost was stressed—something that had not been considered in the project—with the ultimate goal of end users becoming more involved in the energy retrofitting project by taking on part of the costs, for example by informing themselves about the technical aspects and how to maximize the potential benefits.

On the other hand, according to the IREC—based on other experiences—a comprehensive energy retrofitting costing around €15,000 per home in Barcelona's Eixample district has a linear return on investment of more than 40 years. If the energy factor alone is considered, this could rise to 60 or 70 years. With average annual consumption of €1,500 per home and savings of 50%, which affect the variable part of the cost, the estimated savings are around €350 per year. The energy retrofitting may make financial sense in some cases, if we only assume a reassessment of property value. Finally, there are certain advantages of scale, approximately 30% on average, in lowering the average cost per home. That is, the per-unit cost drops if the entire building is retrofitted instead of just one home per building.

Example 2: Energy Retrofitting of a Privately-Owned Residential Building in Barcelona

These are buildings from the 1960s in which both passive and active measures have been implemented, such as new façade insulation, window and boiler replacements, the installation of water-flow reducers, and a HEMS (home energy management system), with the goal of saving 36%.

In this case, the reassessment of the property value is crucial to offsetting the costs of implementing passive measures, as well as to ascertain the residents' willingness to pay for increased comfort levels. Plus, it has been proven that the energy savings are marginal, since these buildings are located in a temperate climate. According to the ESCO, retrofitting a building with similar characteristics in Madrid achieves greater energy savings, albeit with investment return periods that are still excessive according to the standards. In both cases—Barcelona and Madrid—the implementation of active measures helps lower average investment return times, although they are still verging on 30 years, taking into account a subsidy of between 30% and 40%. However, taking advantage of economies of scope (that is, sharing the fixed costs with structural retrofitting) does seem to be effective in reducing the total investment cost in implementing energy-efficiency measures, which translates into reduced investment return times to closer to 20 years.

In the case of a building with similar features in Madrid, the implementation of active measures which make shared self-consumption possible entails an improvement in the financial appeal of the retrofitting project, although not enough to offset the investment costs. However, with public subsidies of between 30% and 40% and harnessing economies of scope, the investment cost does seem to be offset in under 15 years.

2.2. The Tertiary Model

Even within the context of a temperate climate, the investment in building energy retrofitting for tertiary uses does seem to generate enough financial returns so as to describe this kind of retrofitting as a generally self-sustaining project or business model. However, this largely depends on the type of tertiary use, which also defines the building's energy consumption behaviors. That is, both the consumption and the potential savings of a gym with a swimming pool may not be the same as an office building or a hotel.

The energy retrofitting model of tertiary buildings benefits from potential advantages of scale, since the majority of actions are conducted in office buildings, libraries, old industrial buildings, auditoriums, or private facilities for mass use: often in buildings with large volumes and surface areas and high energy consumption.

The regulatory changes[2] with regard to energy self-generation and the installation of photovoltaic panels also boost the financial attractiveness of energy retrofitting in tertiary buildings, as they can share surpluses or cover energy deficits with a single local network extending throughout the building or neighborhood. This model is particularly attractive due to the higher energy savings of most tertiary buildings compared to buildings for residential use. However, that potential has yet to be exploited in Spain.

Therefore, as part of a structural reform, the public sector has promoted the energy retrofitting of tertiary buildings in public buildings that need rehabilitation or architectural transformation. In these cases, the prime goal of implementing active and passive measures is to maximize the energy savings (and therefore the benefits) resulting from the retrofitting and to internalize the positive externalities stemming from lower pollution, which benefits citizens. The impact is therefore not only economic, but also social and environmental.

Likewise, the private sector also finds this kind of retrofitting interesting in that it leads to energy savings and consequently in savings in operating costs. However, there are more and more companies that are deciding to establish themselves in energetically sustainable buildings for reasons that include brand image or corporate social responsibility (CSR), as well as taking action to support the sustainability of the planet.

In the case of tertiary buildings, the private sector does find a sustainable retrofitting model for its business, oftentimes without the need for public financing to make the project economically feasible. On the other hand, a legislative framework that is conducive to this kind of retrofitting is necessary.

Example 3: Energy Retrofitting of Three Privately-Owned Tertiary Buildings in Barcelona

One recent example of energy retrofitting of tertiary buildings in Barcelona was the implementation of energy-efficiency solutions at a sports center, a training center, and a hotel, respectively. These are three buildings with very different characteristics and uses; they are all for tertiary use, but have different energy consumption behaviors.

In the sports center, the energy-savings goal was around 53%, and the passive and active measures included the insulation of the roof over the pool, the installation of LED lighting, a new

[2] Royal Decree-Law 15/2018, dated October 5, 2018, on urgent measures for the energy transition and consumer protection, and Royal Decree 244/2019, dated April 5, 2019, regulating the administrative, technical, and economic conditions of electrical energy self-consumption.

boiler, a heat pump, a dehumidifier, a sectorized heat distribution network, and the installation of a BEMS (building energy management system). This is a positive example in terms of financial appeal because of the resulting high energy savings, primarily from the center's activities conducted inside the building (intensive energy consumption). In this case, the combination of passive and active measures was shown to be effective.

In the hotel, the energy savings goal was up to 60%, and the passive and active measures included insulation of the roof, new LED lighting, the installation of windows with low thermal transmittance and VRV (variable refrigerant flow) systems, and the implementation of a BEMS. Measures like insulating windows may be costly, but they do generate considerable savings, bearing in mind the consumption of this tertiary building, which is more energy-intensive. In this sense, the return period of the investment in a tertiary building is indeed financially attractive.

Finally, in the training center, the energy savings goal was more modest: just 14%. Here, active measures were implemented, namely the installation of photovoltaic panels and a BEMS. Thus, given its moderate consumption, the savings potential was lower, unlike in the previous cases, and required overly long investment return times.

Example 4: Energy Retrofitting of a Government-Owned Tertiary Building in Barcelona

This case involves a former 19th-century industrial warehouse which needed a comprehensive overhaul, which included the implementation of energy-efficiency measures. The building was also connected to Districlima, a cooling and heating distribution network in Barcelona's Sant Martí district. The implemented measures consisted of improving the insulation, including the façade, floor, and windows; improving the lighting system with the use of LEDs; better use of natural light; and the installation of photovoltaic panels. The project was financed via a public-private partnership between the Barcelona city government and private companies. The contract was organized as follows: The city government financed the construction and managed the project; in exchange, it received an advance payment—equivalent to 15 years of the building rent—from the private company. The company also shouldered 41% of the maintenance costs. The contract was conditioned upon achieving specific energy savings goals.

Since this was a comprehensive restoration and energy retrofitting of a public building, the owner was interested in obtaining positive externalities, such as a decline in pollutant emissions and a positive impact on the local economy. These are direct and indirect impacts that are difficult to quantify, but they should be borne in mind when evaluating how attractive the project is to the public investor. Taking into account solely the expected income from space rentals and the savings on the energy bill, the project in the given building did seem to have a sufficiently appealing investment amortization period. Furthermore, in a more in-depth analysis, the capacity to monetize the impact of the positive externalities should be calculated to justify the public participation in energy retrofitting of tertiary buildings.

Key Factors For Scalability

Below is a list of the factors that characterize successful cases—and which should be borne in mind when considering their scalability—as well as the possibilities of replicating them.

Cost of energy. The monetary cost of the energy measurement units is the main factor that determines the potential direct benefits of an energy retrofitting project. The higher the cost of energy, the more incentives we will find to implement measures that help lower consumption in order to generate monetary savings. From the financial standpoint, the importance of the number of kilowatts or kilos of CO_2 saved shifts to the background.

Climate. In more temperate climates, since there are fewer differences between the outdoor temperature and the comfort inside homes or facilities, the potential savings from implementing energy-efficiency measures may be downgraded. For this reason, in these environments, there may be less of a need to undertake comprehensive building retrofitting based on energy-efficiency criteria than in more extreme climate conditions, since comfortable temperatures are more easily achieved with lower energy costs. However, the tendency towards global warming is going to increase our need for air conditioning in countries that are temperate today, which in turn will boost the need to apply insulating and photovoltaic production measures.

Property value and brand image. Energy retrofitting projects have a positive effect on the value of the properties that undergo these interventions, as their appeal on the market is boosted. This is because after an intervention, retrofitted buildings can substantiate better energy-efficiency certificates and savings in future energy consumption.

From the industrial standpoint, companies with a powerful brand projection and a CSR strategy aligned with the rising global trend in environmental awareness may find incentives to undertake energy efficient retrofitting of their headquarters, office buildings, warehouses, or other types of facilities with the goal of enhancing their corporate image, in addition to other benefits.

Type of user. It is essential to analyze the type of customer according to their ability to cover the investment cost. It is also important to bear in mind the technical know-how and level of environmental awareness of those who are going to use energy-efficiency measures. In this sense, using them well and making the most of HEMS or BEMS systems is crucial if the solutions are to be effective. Likewise, the role of the government as a supplier of technical studies, licenses, and quality control is essential to reaching a larger number of potential customers.

Uses of the building and consumption behavior. Distinguishing between buildings for residential and tertiary use is crucial, since these two types of buildings are very different from each other in both average consumption and peak consumption, and, in some cases, they even display opposite behaviors. For example, an office building consumes more electricity in the middle of the day, while a home consumes more at other times of day. This should be taken into account, since electricity prices are not static and fluctuate according to the hour-by-hour demand.

It is also important to keep in mind that energy rates or contracts vary depending on the type of building. Both homes and industries have different energy rate schemes (as reported by Eurostat in its methodology to calculate energy costs in Europe). There are also notable differences among tertiary-use buildings: The energy consumption per square meter in a gym tends to be much higher than in an office building, as shown in several examples in the city of Barcelona.

Key Factors For Scalability (continued)

To summarize, the financial feasibility of undertaking a building energy retrofitting should be carefully analyzed according to its use and functions.

Economies of scope and scale advantages. The implementation costs of energy-efficiency measures can be considerable. Oftentimes, these are in-depth interventions which require construction projects in buildings to change their insulation, roofs, lighting systems, or windows. However, in buildings that need some kind of conventional or structural retrofitting, the additional implementation of energy-efficiency measures is recommended to take advantage of the opportunities that the retrofitting they need entails in terms of costs and labor.

Legislation and public sector. Having an appropriate legal framework to deal with environmental energy challenges is a crucial factor in undertaking energy retrofitting projects. In Spain, recent legislative changes, such as Royal Decree-Law 15/2018 and Royal Decree 244/2019, are a significant step in this direction as they allow for collective electricity self-consumption. However, in Spain there is still some uncertainty, since after the legislative changes which eliminated disincentives for citizens to participate in energy production, consumption, storage, and sale, there is still no clear procedure for registering self-consumption installations.

Financial certainty. The implementation of energy-efficiency measures in building retrofitting projects requires a major financing capacity. These measures have an advanced technological component which requires outlays of significant amounts of money. In order for the retrofitting project to be financially successful, it is essential to having the backing of financial entities, committed stakeholders, low-risk customers, and the support of public institutions.

Customer commitment and participation. There are many examples of energy retrofitting in cities as disparate as Barcelona, Cologne, and Stockholm, which demonstrate the need for cooperation and understanding between energy companies and their customers. The customer, owner, user, or resident must feel like part of the implementation project, since their acceptance and cooperation are needed, especially to make the most of the active energy-efficiency measures. In this sense, it is preferable if the customers are informed about how to use the different energy-efficiency solutions available to them so that they know how to adapt their consumption habits and thus maximize energy savings.

Verification and tracking the results. Verification of the results is a key factor in being able to replicate energy retrofitting projects. It must be demonstrated that they yield savings and that the financial results are attractive and economically sustainable. In this way, potential customers will feel a keener interest in implementing energy-efficiency measures in their buildings. For this reason, verification measures such as monitoring systems which bear in mind the changes in consumption behaviors are needed.

3. Sensorization in Cities

One of the main challenges in solving or alleviating the different problems that 21st-century cities are facing is that they are places where the different characteristics of the ecosystems coexist and interact (Kapelan, Savic, & Walters, 2005). This means that due to unpredictable behaviors and the existence of nonlinear relationships among the elements comprising cities, cities have become increasingly complex (Batty, 2013). In other words, traditional management systems are no longer sufficient to meet the social, economic, and environmental needs of today's cities.

Cities are increasingly large and complex, and they are growing quickly. Thus, dealing with problems like mobility, pollution, health risks, and new infrastructures no longer depends exclusively on urban authorities (with traditionally top-down approaches). Instead, the new complexity is increasingly forcing urban authorities to enlist the participation of end users and other interested parties. In this respect, public-private cooperation is one of the cornerstones of cities' sustainable development and consequently one of the key factors in mitigating the effects of climate change.

Efforts to make urban centers more livable have yielded many positive, gratifying results; the role of technology has sped up this process and contributed to the existence of smart cities all over the world aimed at achieving higher levels of livability. In turn, this leads to an improvement in the provision of services thanks to the exchange of data and information, among other factors. The monitoring of critical problems like climate patterns, mobility, emissions, sanitation, security, and economic activity has improved considerably. Furthermore, real-time solutions have been designed and implemented in several cities (Allam, 2018). The use of advanced technologies like big data, the Internet of Things (IoT), and artificial intelligence (Allam, 2018) have allowed for these problems to be monitored.

The current urban development scene and the prevalence of smart cities are promoting data-centered cities. From predicting traffic in real time to tracking the physical state of infrastructures, advances in the new technologies and the use of data in different fields are influencing urban development. This section summarizes the possibilities and challenges faced by sensorization and monitoring projects for cities and their infrastructures.

Technological and scientific advances, especially when they are integrated, are offering a rich array of solutions that can help make cities more sustainable places for living. Several examples of this technological integration include the production and management of self-generated energy (like district heating systems, smart measurement, and smart public lighting), smart storage (like heat pumps, V2G—vehicle to grid—or the transmission of vehicles' energy to the grid, innovative batteries, etc.), smart mobility (such as electric vehicles—EVs, EV charging infrastructures, and shared automobile use), city information platforms (such as the smart city platform of open data and urban monitoring), and citizen participation and co-creation approaches and solutions (such as applications to visualize energy consumption) (Angelakoglou et al., 2019). In light of such a swift energy transition, there is an increasingly clear need for strategies that help cities integrate technological solutions in a smart fashion. This creates new sources of income for projects, new business models to capture value, and new opportunities for investors (European Commission, 2019). Accelerating the transition to a competitive, sustainable economy is both an urgent need and a major opportunity for European cities (European Commission, 2016).

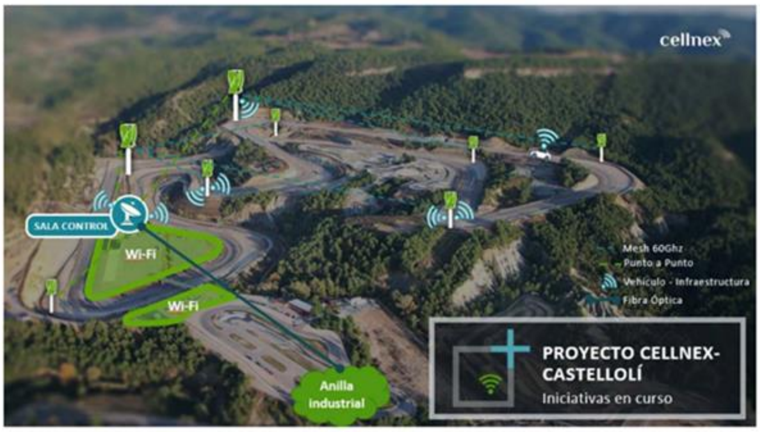
3.1. Smart Towers

We are currently living in a context of hyperconnectivity which will only increase in the near future. Nowadays, humans are connected to many devices, and there is a need to monitor, react to, control, and know what is happening in a city. This situation means that communications infrastructures have a growing need to adapt to and situate themselves close to where these services are being generated and consumed. In other words, the network of communication antennas and towers needs to be densified. To fulfill this need in an orderly, controlled way, a network of micro-locations in urban settings must be deployed. This transformation should ideally be made taking advantage of existing urban equipment, from the canopies over bus stops to traffic lights and streetlights. Of this existing equipment, the lighting infrastructure stands out as one of the most effective points from which the new densified communication network can be deployed. Thanks to the density of the lighting systems already in place, they are ideal candidates to become smart towers. In addition to offering lighting, smart towers enable other communication services to be generated as well, from providing connectivity services to integrating sensors in order to monitor what is happening in the city.

Generally speaking, public lampposts are managed via their own systems following a vertical or siloed solution. This means that it is difficult to have a comprehensive picture and a shared lighting management system. In fact, one of the conclusions of the GrowSmarter project is that it is usually recommendable to implement public city lighting systems that allow for remote management solutions via web services or an API (application programming interface) in order to facilitate the interoperability with other urban service management platforms.

Figure 2
Cellnex-Castellolí Project

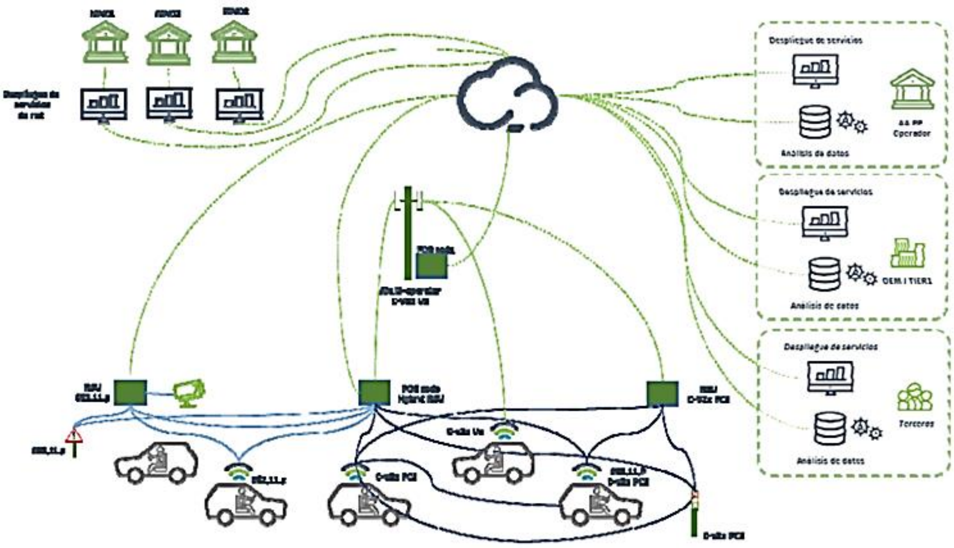
SMART TOWERS: **EXPERIENCES/Connected and Autonomous Mobility**



Source: Document provided by Cellnex, 2019.

This is vitally important in an environment with connected vehicles (see Figure 3), since they have to know what is happening around them in real time. Depending on central networks is not an optimal option because the latency is too high. In this regard, smart towers play a crucial role by providing a dense network of low-latency communications.

Figure 3
Smart Towers



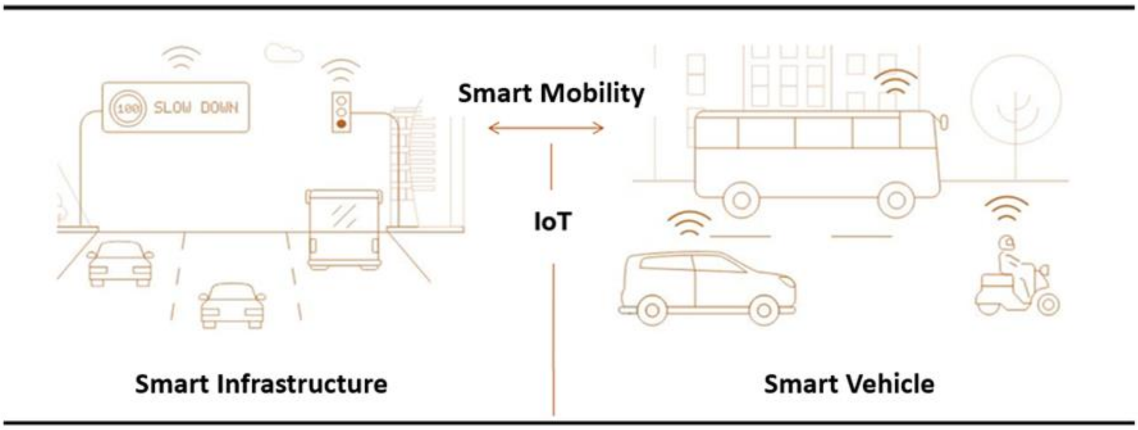
Source: Document provided by Cellnex, 2019.

3.2. Smart Mobility

Smart mobility is one of the strategies destined to alleviate the effects of pollution in our cities. Better management of both infrastructures and vehicles can save time, money, and emissions. This management can strongly benefit from information generated via sensorization and the integration of the following two systems via the IoT: infrastructures and smart vehicles.

The aforementioned sensors include hardware to capture information in real time on matters like traffic conditions, environmental quality, management of traffic signals and lights, and weather. For example, Sensefields (see Figure 4) has solutions to better manage traffic lights that reduces the number of traffic jams. By collecting presence data of vehicles, information from different points (different traffic lights) can be combined and operate as a single system with the goal of diverting the flow of vehicles as efficiently as possible. Likewise, these sensors allow Sensefields to provide alarm services when certain pollution, noise, and suspended particle limits are reached.

Figure 4
Sensefields Business Lines



Source: Document provided by Sensefields, 2019.

On the other hand, in relation to smart vehicles, sensorization applications in cities are focused on exchanging information between vehicles and infrastructures, public transportation services, shared or rented vehicles, and finally fleet management. All of these applications include geopositioning systems, geofencing, remote on and off functions for vehicles, safety and maintenance alerts, speed controls, alarms, etc.

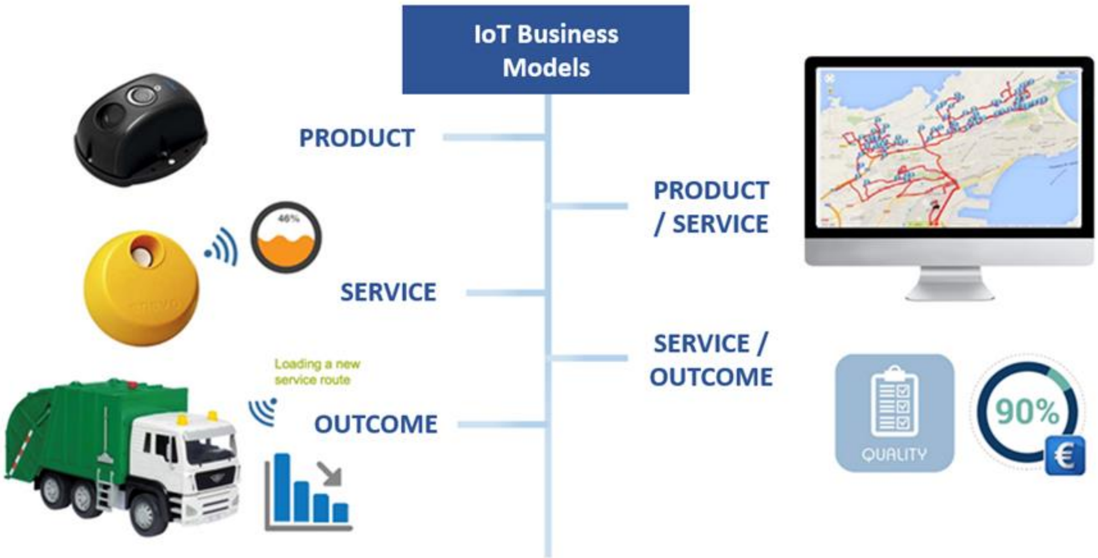
3.3. Waste Collection

Waste collection and street cleaning services consume around 20% of annual municipal budgets. At the same time, the amount of waste generated in urban areas is increasing 70% every ten years. Therefore, this is not only a financial burden on our cities but also a problem with a high environmental impact. In this respect, sensorization of many of the processes involved in waste collection becomes one of the opportunities to generate value for citizens using the IoT.

One clear example of the benefits stemming from the use of sensorization in waste collection is Everis's experience in smart waste solutions. Digitization can lead to greater efficiency, productivity, and transparency by providing more information on what is happening in the day-to-day service provision, and potentially higher quality as well if sound decisions are made. This, in turn, allows the service to be continuously improved, since we gain a better understanding of what is happening and the consequences of the changes made.

For example, knowing how full dumpsters actually are (see **Figure 5**) enables the collection routes to be adapted or more precise decisions to be made on what dumpsters are emptied on what day. In addition to this dynamic information, studies for the middle term can also be conducted. It is thus possible to analyze to what extent the dumpster network is efficient based on how the dumpsters are used, whether any need to be moved, whether a particular area needs more, or whether they need to be moved, even if only slightly, in order to optimize the garbage truck's route.

Figure 5
Smart Waste Collection



Source: Document provided by Everis, 2019.

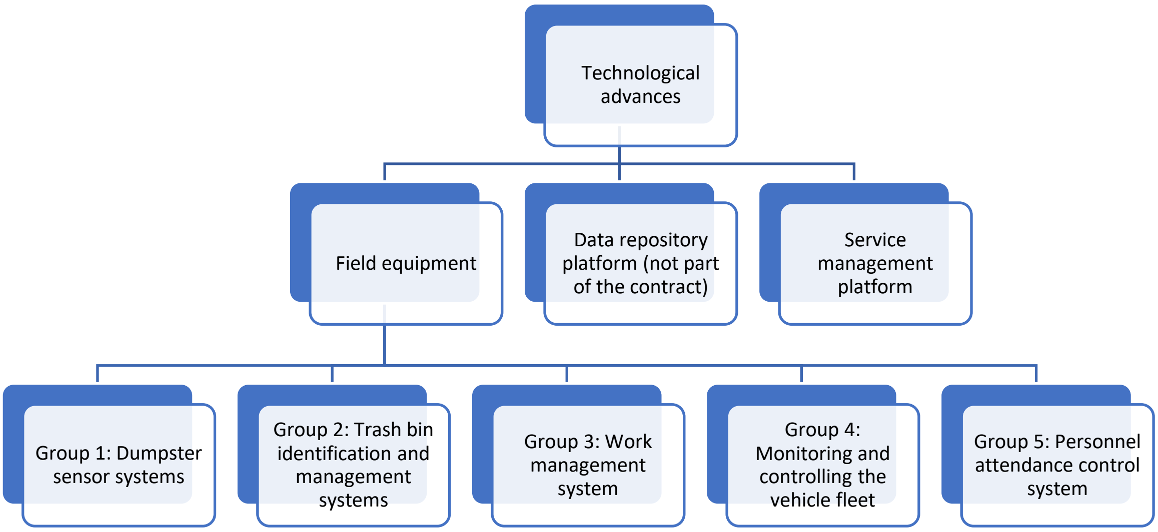
All of this information leads to savings—up to 40%—in operating costs. These savings include route distance, collection times, and even adapting the vehicle fleet to real needs.

In this vein, a good example is the city of Santander. In its waste collection contract, the city government acts directly as the service contractor. One of the noteworthy features of the agreement is that it stipulates the requirement to include technological advances as a necessary condition for the contract to be awarded (Piedra, 2018). More specifically, the contract states that the bidding company must include "technological infrastructures meant to guarantee efficient, sustainable service management, namely an open solution that can be integrated with solutions from other municipal services and can interact with them in the future, allowing for comprehensive optimization of municipal services"[3] (see **Figure 6**).

Specifically, the new systems include field equipment (sensorization/action/monitoring infrastructures to collect data), a data repository platform (space to store the data from the sensors, as well as to standardize and organize it), and a service management platform (which includes the possibility of connecting with other existing city government platforms to jointly and efficiently manage resources and services).

[3] List of technical conditions for contracting the concession of the Public Municipal Urban Waste Collection and Transportation Service, Road Cleaning, Beach Cleaning, and Other Additional Services (Santander), (2012), p. 49.

Figure 6
Management of the Public Solid Waste Service in Santander



Source: Piedra, 2018.

3.4. Data Integration: The Role of Platforms

Just as in the majority of technology projects, the use of advanced hardware is not sufficient for optimal management. The data generated should help improve decision-making, and it is important to avoid the "Diogenes data syndrome." To do so, it is useful to create platforms that provide standardized access to normalized data integrated via one or several API's. One example of this is found in the deployment of a platform in Barcelona as part of the European GrowSmarter project. This platform not only serves as an aggregating repository and data normalizer, it also offers data services to promote the co-creation of applications and urban services to administer and monitor the city.

Specifically, the platform, which is organized horizontally, manages and shares data from the GrowSmarter measures implemented, so it acts as a middleware component in a big open data platform that compiles and standardizes different types of data with the goal of offering them in a common market where commercial applications, like business intelligence algorithms, monitoring applications, etc., can use the integrated data. This solution enables large amounts of heterogeneous urban data to be processed and shared in real time to support decision-making applications; it therefore provides interoperability and standard management.

However, the design, creation, and implementation of platforms still run into some barriers. The challenge is to feed them with enough data from the sensorization. Once you have the data, the concept of the horizontal platform also makes it possible to work with vertical services. Plus, the modular concept allows the platform to provide new functionalities or process new types of data sets without altering its previous characteristics. This is extremely important in order to give the platform a long enough shelf life to offset the initial investment; instead of being designed for specific data, it is designed to capture and analyze different data formats which can be united through common fields, with an ontology and semantics to join them.

One noteworthy aspect is that this solution of a horizontal platform based on standards and open-code components is a measure that can be applied and is easily scalable and replicable in any other city, since it is independent of specific data sets and application domains.

Key Factors For Scalability

Purchase volume. Many of the measures implemented by cities are purchased in volumes which are not the optimal value in terms of scale economies, especially if they are purchased according to each city's own specifications (European Commission, forthcoming, 2019). Therefore, there is a tradeoff between the homogenization and/or standardization of the supply and the heterogeneity of the demand. Cities can no longer allow themselves the luxury of operating as islands (in terms of time, money, and innovation). Just like people, they are individual and unique; however, all cities are systemically quite similar, just like all humans (European Commission, forthcoming). In this sense, the radomes implemented by Cellnex in Barcelona are a clear example of adaptation to local needs without sacrificing scalability. Thanks to these radomes, there is no need to renovate the lighting infrastructure, since by simply adding the devices needed to the existing ones, the same service can be provided as the one that would be offered with a newly built tower. In this sense, the modularity and adaptability shown by Cellnex's solutions are a good example of scalability in heterogeneous environments.

City size. Small cities (which, collectively, represent the largest market) have difficulties accessing and communicating with industry, especially if they act independently. Given that cities want to support their local economies, there is a need to create a fair market for both large external industries and local SMEs (European Commission, forthcoming, 2019). In this way, one possible solution is to merge, for purchasing purposes, different small cities with similar needs. Provincial councils, federations of towns, and other supramunicipal entities must play a key role in ensuring that they reach small towns with competitive prices.

Ethics, legality, and data protection. The IoT involves a large number of objects, data, and people that are connected via the Internet anytime and anywhere to provide homogeneous communication and contextual services. Therefore, it is creating a new social, economic, political, and ethical scene which needs new legal and ethical measures that make it possible to protect privacy, data security, and property, and to improve trust and the development of appropriate standards.

Multiplicity of actors. Many of the sensorization solutions require interaction with different governmental bodies or departments within the same organization (such as permits or licenses, ownership of the data generated, etc.). This interaction between government, companies, and even departments within the same organization is often not easy. Institutional inertia, routines, or organizational culture often create frictions and hinder the cooperation needed to extract and capture all the value generated by the sensors.

Strategic alliances. One of the major challenges of sensors is creating cooperative ecosystems in which multiple actors can benefit from the infrastructure deployed. These alliances can be created to share infrastructures or use the data and information generated from the deployment of sensors in both the public and private sector. Additionally, the management of any given infrastructure can benefit greatly from incorporating data from outside of it, usually from private actors.

Smart governance: the way to implement smart solutions. One of the main conclusions of the GrowSmarter project is that a successful plan is closely linked to successful leadership and the creation of networks among partners. Understanding who needs to participate, as well as who should be motivating and supporting these people during the project, is extremely important, since often it falls outside their official jobs, roles, and organizational responsibilities. Even though this may seem self-evident, cities should be sure that they have the resources and time needed to plan and prepare, and that they are familiar with the processes needed to implement and evaluate smart solutions, especially when these types of solutions are new to the cities.

4. Sustainable Mobility

Improving a city's mobility is essential to its sustainable development. This improvement entails having a transportation system adapted to social needs which guarantees that people can move about easily, thus improving access to schools, jobs, and services and doing so in a safe, economically efficient way. The more accessible and connective the city is for its citizens and companies, the more attractive and competitive it will become.

Sustainable mobility should try to improve traffic congestion while reducing pollution from greenhouse gas (GHG) emissions, noise pollution, and energy consumption. From this standpoint, an efficient, flexible transportation system that offers smart mobility models is essential, not only from the environmental standpoint but also for the economy to work properly and thus to ensure citizens' quality of life.

The mobility we see today largely depends on private vehicles, which have ended up defining citizens' lifestyles and cities' structure. However, this way of getting around poses significant and rising challenges to the environment and human health.

The sustainability of mobility is a complex issue, since in the majority of cities substantial changes are needed both in the transportation system and operations and in the mobility behaviors of people and companies. Furthermore, the provision of certain services may depend on multisector cooperation and the potential development of future technologies.

Transportation is an important factor within the context of sustainable development due to the pressure it exerts on the environment, its economic and social repercussions, and its connections with other sectors. Given the constant population growth in urban areas, the transportation and logistics sectors have grown steadily in recent years, and this upswing is predicted to continue. For this reason, having a sustainable transportation strategy is currently a priority on the local, national, European, and global scale.

Below we analyze three different innovations that promise to develop sustainable mobility through the projects undertaken by a variety of companies related to mobility.

First, we will examine the development of infrastructures and technology to pave the way for a greater use of electric vehicles. The companies Electromaps and Nissan have mobilized to promote a change in the conventional automotive sector, which has been the source of highly pollutant emissions, to turn it into an industry that produces electric cars with a lower environmental impact.

Next, we will present a transportation integration system which was tested in Vienna, Austria called Smart City Wien–SMILE. The goal of this project was to create a platform for smartphone applications that would enable users to use and combine different means of transportation (subway, train, bicycle, and electric car) as simply as possible.

Finally, we will examine a case of last mile deliveries in Barcelona. The company Vanapedal coordinates an urban consolidation center (UCC) which distributes last mile cargo with *e-cargobikes*, offering outstanding opportunities for goods to be delivered without GHG emissions while lowering traffic congestion.

4.1. Charging Stations

With the goal of promoting forms of mobility with low carbon emissions, cities in Europe and the rest of the world are installing networks of charging terminals for electric vehicles. Electric mobility, along with the investment in technological innovations, is a growing market as we move towards a transformation of the automotive sector with a strong potential to help reduce pollutant emissions and noise pollution.

Two operators of different services related to this market participated in the workshop that addressed the topic of charging stations for electric vehicles: Electromaps and Nissan.

Electromaps is a company that has developed an application that shows a map with all the electric vehicle charging stations in the world. This map is dynamic and provides information on the stations' operations in real time. The company also offers electric charging station management software as a product.

In turn, Nissan, one of the leading car manufacturers in the world, is developing an ecosystem that connects electric cars with households, companies, and electric grids, developing new ways of reusing batteries. This ecosystem is possible thanks to electric charging terminals and Nissan's electric vehicles, which are designed with two-way V2G technology which allows an electric car with an overcharged battery to return its electrical energy to the grid, making the entire charging system more efficient and extending battery life. The idea is for the electric vehicle's battery to store clean energy (such as solar) and/or low-cost energy generated by photovoltaic panels installed in homes or commercial buildings. At times of peak energy demand, which happen to be the hours when the price per kilowatt hour is the highest, the energy from the car battery, which is already charged with cheaper energy, can give back to the electric grid and be used as a charging source, thus lowering the total cost of energy in the home or building.

Electromaps operates with two different business models. The first is B2C (business to consumer), in which consumers are users who sign up and pay for the application that allows them to use the recharging stations. The second is B2B (business to business) and is based on selling a platform which enables the charging infrastructures provided by public and private companies to be managed and monitored.

The business model of this new service which Nissan is developing is B2C, focused on the vehicle user. The plan is to commercialize the system to be used in homes, buildings, or any other place that uses an electric grid, and for the vehicles to be able to park nearby in order to facilitate these energy exchanges.

The electric vehicle charging station market is still in its infancy and is fairly small in Spain, but the number of charging points is increasing exponentially. Users and companies increasingly trust electric vehicles, which today have greater capacity and autonomy and are quicker to charge. Therefore, this is an expanding market.

The current infrastructure was primarily financed with public subsidies. Some private actors have built their own infrastructures, but they are limited by the high costs. Specifically, the cost of the hardware exceeds €10,000 and the installation is another €30,000, plus operating costs. Today, these charging stations are not heavily used and have a narrow margin per kilowatt. As a result, a significant volume of vehicles is needed to offset the investment costs.

There is some distortion in the competition in electrical charging infrastructures because of public chargers with free charging. These public chargers not only limit competition, given the difficulties private operators face in competing with a public operator, but they also fail to promote efficient energy use, since they are free and lead to excess consumption. Plus, since the user does not have to pay for the repair costs, it has been found that they tend not to take care of the equipment.

In terms of the costs of electric charging, a survey conducted by Electromaps showed that users are in favor of paying for the amount of energy consumed instead of for the charging time, but it should be charged for time once the battery is fully charged. Nissan believes that it is essential to charge for the service and establish different prices according to the type of recharging used (in terms of the type of technology and the number of kilowatt hours consumed).

Three barriers to increasing the number of electric cars on the roads were identified in the workshop:

- The price of electric vehicles (one possible solution would be to eliminate any kind of VAT on these cars).[4]
- The autonomy of electric vehicles (even though technological advances are allowing for greater autonomy).
- The lack of charging point infrastructures for cars.

Nissan's electric cars are targeted at urban consumers who can charge their vehicles at home. Users that want to hire this company's service should bear in mind the household electrical rates for charging cars. That is, they should adjust the amount of power they have contracted (and the contract itself) to the vehicle's charging needs, for example by taking advantage of lower nighttime rates. On the other hand, the quick-charging infrastructures in public places should only be used occasionally.

Spain's geography, which is not very densely populated except on the coast and in the central plateau, will make the network of rechargers less efficient in non-urban areas. To ensure that the mobility corridors in these low-population regions have electrical chargers, the public sector will need to get involved.

One way to begin to reduce pollution in urban areas is to invest first in replacing the conventional vehicles which are on the streets most of the day (such as taxis, buses, garbage trucks, etc.) with electric vehicles, and then later gradually replace private vehicles.

4.2. MaaS and Integration of Mobility Services

An application to promote sustainable mobility (MaaS, Mobility as a Service) was put into practice in Vienna, as part of a project called SMILE, from where it was analyzed its operation and results.. The SMILE project consisted of an online platform in the guise of a mobile application in which public transportation users in Vienna and its surroundings could find all the available services offered by public and private operators according to their preferences and needs.

This measure was a pilot experience based on a public-private consortium that brought together the most important urban mobility actors in the city, taking advantage of each member's knowledge of mobility services, engineering and software development, usability, system design, environment and sustainability, and project management, all with the goal of offering an attractive, integrated, and efficient public transportation system that was sustainable for the city.

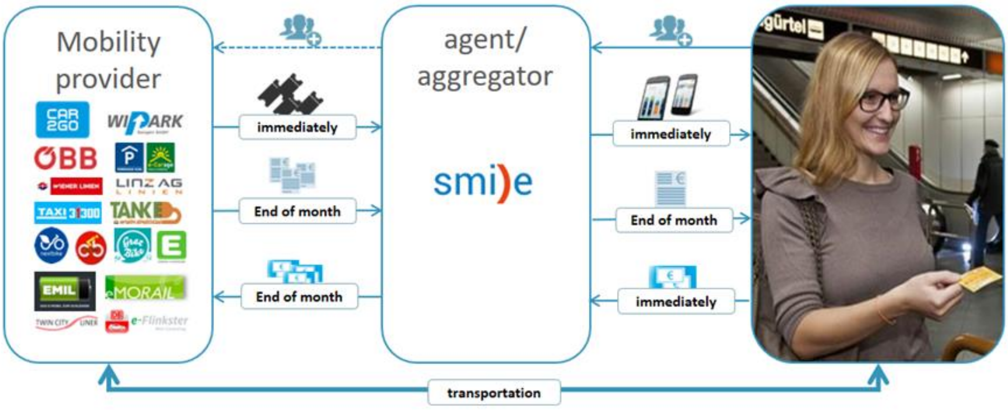
[4] Eliminating the VAT on electric vehicles would have a positive impact for both buyers—who would benefit from lower costs—and the environment, due to lower emissions from the vehicle fleet. However, we cannot ignore the fact that this would mean lower revenues coming into the public coffers, which would have to be earned from other sources.

Operators from the municipal public transportation system and the national railway company, along with private companies involved in taxis, river transportation, e-bike and e-car sharing, parking, and electric car recharging participated alongside companies specializing in providing information on transport routes and mobility.

In Vienna, the problems related to traffic congestion and the city's public transportation system were identified. The quality of this kind of transportation service can be improved, and the fee system can better adapt to the real use of the transportation system. Furthermore, the inefficiency of urban traffic aggravates problems like air pollution caused by the use of private vehicles.

The SMILE platform (see **Figure 7**) integrates information on traffic and public transportation routes with the different e-mobility and bike-sharing options. Thus, it is possible to plan a trip with intermodal public transportation (using and combining different services) and pay for it with a single ticket.

Figure 7
SMILE Project – Simply Mobile



Source: Document provided by Everis.

The SMILE application can be installed on smartphones and allows users to find out what travel options are available to go from one point in the city to another. Suggestions of combined trips are created from the individual services offered. Customers can choose the route and means of transportation, reserve their trips, and buy a ticket that covers all the mobility services they have chosen, allowing them to pay in a single step. The platform works as a mediator and facilitator between the transportation system and the user.

In 2014, the application was made available to the public and had more than 1,000 users over the course of a year. When the pilot phase was evaluated in a survey, the results revealed that the mobility platform could be used to increase car-sharing and mobility services that use electrical energy while also lowering the number of trips made in private cars. A total of 26% of the participants stated that they had begun to use public transportation more frequently, and 21% of the pilot users surveyed said that they used their private cars less often.

One key factor in the successful development of this integrated mobility and payment system is financial support from the institutions that can collect for the provision of the service and later distribute this income among the service providers.

4.3. Last Mile Delivery

In recent decades, the Barcelona city government has regulated parking access and options for vehicles that run on fossil fuels in certain areas of the city. Due to this regulation, carriers can only access the city center with their vans at certain restricted times. However, electric tricycles have easy, unlimited access to all areas of the city.

Given this, the company Vanapedal has created a UCC to provide a last mile delivery service using electric tricycles. The UCC's main activity is operating as a micro-distribution center which receives packages brought by carriers and delivers them to their final destination on electric tricycles.

The current business model is B2B. Vanapedal offers the service to traditional shipping companies and more recently to e-commerce companies as well. Regarding the service with large traditional carriers, the Vanapedal employee wears the corporate clothing of the client company and the tricycles are painted with the same corporate colors and the same symbols as the companies for which the service is provided.

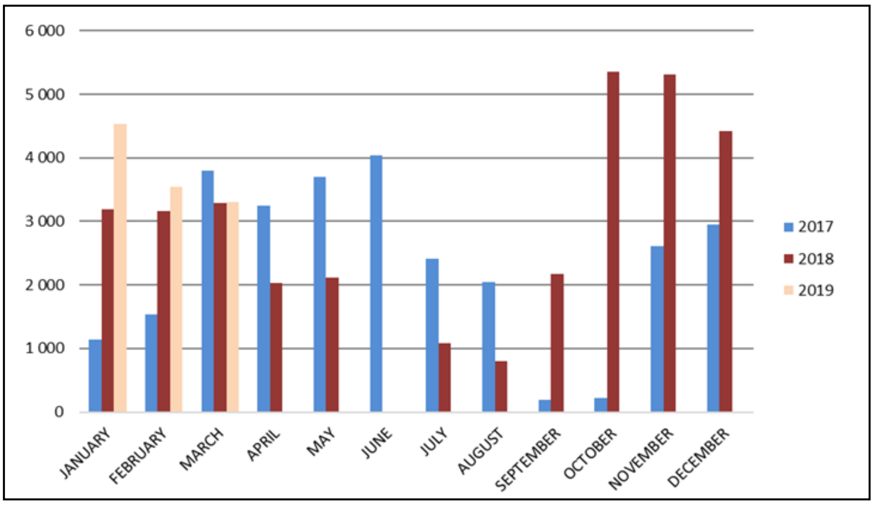
Vanapedal is also considering the possibility of expanding the service it offers carriers beyond the last mile and starting delivery service operations from the vendor to the consumer.

The installation of a UCC to deliver goods in the last mile in a central area of Barcelona reduces the congestion in pedestrian and/or highly populated zones, in addition to reducing delivery times, costs for traditional carriers, and pollutant emissions.

Another added value of this business is improvements in the delivery service to customers, since they have the option of receiving their goods in a broader time frame than what traditional carriers offer.

In the case of Vanapedal, as shown in Figure 8, the number of deliveries made in the past two years rose considerably in October 2018, when the company began to make deliveries for one of the leading e-commerce competitors.

Figure 8
Changes in the Distance Traveled by Electric Tricycles (in km)



Source: Document provided by CENIT.

One possible weakness of this business model is that approximately every five years new electrically charged tricycles need to be bought. These vehicles entail a high investment cost, bearing in mind the moderate cash flow in an SME like Vanapedal. That is, in the year in which the tricycles have to be replaced, there are significant deficits for the company that need to be financed. These days, at least in Barcelona, there is no market to lease this kind of item. Leasing benefits logistics companies because it prevents them from having to pay VAT on sales, which is paid by the leasing company, and it allows them to deduct up to three times the tax depreciation of the taxable base of the business tax.

Key Factors For Scalability

Location of the facilities. One important factor in getting an appropriate return on investment is the location of the electric charging stations for private vehicles. They should be located where the target audience is the most likely to use them, that is, in residential or shopping areas where people have the purchasing power to buy electric vehicles, since they are still more expensive than conventional vehicles.

Focus on the vehicles that pollute the most. The conclusion of the workshop in which Electromaps and Nissan participated was that the policies of exchanging traditional vehicles for electric ones should put into practice with the entities that pollute the most (urban buses, taxis, etc.). Private urban vehicles which are used just a few hours every day or occasionally are not very problematic from the standpoint of pollution. The government should focus its efforts on the vehicles that pollute the most.

Strategic alliances and multiplicity of actors. To stand out from concurrent applications that also inform users of the different ways to get from point A to point B, a platform like SMILE has to offer the option of paying for and/or reserving the use of (multimodal) transportation via a smartphone, thus making it easier for application users. In this case, the managers of this application have to work with all the means of transportation to guarantee that the platform can serve as an intermediary between the user and urban mobility services.

Financial institutions. Integrated mobility platforms like SMILE must have the support of financial institutions so that they can provide users with integrated payment methods for mobility services and later distribute these payments among the operators.

Legislation and public sector. In order for the last mile delivery business to be successful, it is very important for public authorities to be willing to restrict polluting motor vehicles, such as cars and vans, in certain areas of the city. This regulation fosters a potential market in which electric tricycles have an edge over other means of product delivery.

Taking advantage of the digital market. In the example of Vanapedal, we find that e-commerce is leading to more and more deliveries, generally small or medium-sized packages which can easily be loaded onto a cargo tricycle. As e-commerce grows, the last mile delivery business is going to have a higher potential of taking advantage of this new form of consumption.

5. Financing Instruments

The investment in innovative solutions in the fields of energy, transportation, and ICTs in cities still ultimately follows the same investment principles applied to any other kind of project. However, city-dwellers have a higher population density, higher income levels, and better access to financial services.

Investments are decisions to acquire assets, either real—in the form of fixed capital (that is, land, buildings, installations, facilities, etc., as well as patents, registered trademarks, etc.)—or financial assets (that is, securities, deposits, etc.), bearing in mind the operating costs of the investment throughout the lifetime of the projects (Medarova, et al., 2013). Therefore, the financing decision refers to the question of what capital a company needs to assemble in order to finance its projects and what combination of financing (capital/debt) it should use. Companies can accumulate capital either through their own net operating cash flows or externally, through capital markets, corporate bond markets, or the banking system.

The financial system acts as a channel through which savers' surplus liquidity is distributed among the companies that need capital to make investments. However, many companies, especially SMEs, need financing through financial intermediaries, such as commercial banks, insurance companies, pension funds, and venture capital funds, which act as agents between the end beneficiaries and the suppliers of the capital.

Financial intermediaries, in turn, offer a variety of financial instruments for those wishing to invest in their businesses. Depending on the purpose of the investment or the volume of investment needed, each project will have different financial instruments that best fit it. This logic is no different for smart solutions, although they entail a higher risk than traditional projects since they are innovative business models without a credit risk history.

Below we present the best financing instruments for the groups of solutions discussed above.

5.1. Financing for Building Energy Retrofitting

The financial instruments for investments in buildings' energy efficiency, according to the *Residential Retrofits at District Scale* report developed by the IREC, Aiguasol, and InnoEnergy in 2019, are shown in **Figure 9**:

Figure 9

Summary of the Financial Instruments for Investments in Buildings' Energy Efficiency (A score of 3 is adequate; 1 is minimally useful; and 0 is not applicable.)

Mature financial instruments	Commercial	Public	Public rental	Private rental	Owner occupied
Dedicated credit lines	3	2	3	3	3
Energy performance contracting (undertaken by private sector)	3	3	3	1	1
Risk-sharing facilities	2	1	2	2	2
Direct and equity investments in real estate and infrastructure funds	2	1	1	2	0
Subordinated Loan	1	1	1	1	1
Covered Bonds	1	1	1	0	0
Leasing	0	1	0	0	0

Emerging financial instruments	Commercial	Public	Public rental	Private rental	Owner occupied
On-bill repayment	2	1	2	3	3
On-tax finance (PACE)	2	1	1	2	3
Energy efficiency investment funds	3	2	2	1	1
Energy services agreement	3	3	2	1	1
Public ESCOS for deep renovation of housing	0	0	3	2	2
Factoring fund for energy performance contracts	2	2	1	1	0
Public ESCOS for deep renovation of public buildings	0	3	3	0	0
Green bonds	2	1	0	0	0
Citizens financing	0	0	0	1	2

Source: SALOM, J. & Pascual, J. (2018). Residential Retrofits at district scale. Business Models under Public Private Partnerships. IREC - AIGUASOL

Of these instruments, we see that the most appropriate ones for building energy efficiency projects are the following:

Credit lines. Credit lines are designed for investments in energy efficiency and may be supported by public financial institutions. In some cases, credit entities themselves define specific objectives and offer a simplified, standard procedure for accessing credit.

Energy performance contracting (EPC). This is a contractual agreement between the party contracting the building retrofit and the supplier of the energy-efficiency measure which is verified and overseen throughout the entire length of the contract. The investment is mainly paid through the energy savings generated from the implementation of energy-efficiency measures. This kind of contract defines the most common business model of ESCOs.

Risk-sharing mechanisms. They lower the risks for banks and investors by covering part of the risk of default. They have the advantage of eliminating some of the uncertainty and risk, thus encouraging the use of larger private instruments.

Energy efficiency investment funds. These are funds which are solely dedicated to energy-efficiency projects and seek profitability based on the savings attained. Some of them are associated with governments.

Energy services agreements. These agreements are reached between a third-party investor and the owner of a property to provide energy savings as a service; it is an evolution from the traditional shared-economy model provided via the EPC. The investor provides funds to carry out energy-efficiency projects and operates the energy equipment needed for the property owner, who, in turn, promises to pay the investor the previous amount of their electricity bills throughout the length of the contract.

Public ESCO's for renovation. These are companies that manage the investment in energy efficiency and guarantee the customers savings on electricity; they act as a counterpart of an EPC financed with public funds.

Lastly, we present a private financing mechanism that is becoming increasingly common, PACE (Property Assessed Clean Energy):

Property Assessed Clean Energy (PACE). This is a financing mechanism that enables energy efficiency, renewable energy, and water conservation projects to be financed at a low cost and over the long term. PACE financing is paid with an added charge on the regular property tax bill.

The property owner and a contractor determine what clean energy improvements make sense for receiving funds via the local PACE program.

One hundred percent of the up-front costs of the project, including the least expensive ones, can be financed via PACE, which eliminates the need for owners to have recurring expenses.

PACE is a type of financing based strictly on the property and is guaranteed by the property taxes. Therefore, the owner is not personally obligated to pay the tax, which can be charged to their tenants. PACE enables rehabilitation projects of multi-family dwellings (like entire apartment buildings) to be undertaken and financed without needing unanimity or offering personalized financing to the owners who have a lower purchasing power, while also helping homeowners improve the energy efficiency of their properties without any negative effects on their rental income. PACE can be compatible with social assistance schemes which provide total or partial fee exemptions for residents who cannot pay them. At the same time, the tenants' costs may be lower thanks to the annual energy savings, which can actually offset the cost of the payments for the financer of the project.

PACE financing is available with flexible maturity of up to 20 years and with simple paybacks of up to 12 years. In turn, the dilution of the cost of reimbursing the financing over this period of time enables the property's operating costs to be lowered throughout the entire PACE maturity.

PACE is added to the real estate tax bill, and when the property is sold, the obligation to repay the financing is automatically transferred to the new owner, as are the energy-savings benefits generated by the project. This eliminates any concern that the owner may have about possibly selling the property in the near future; that is, it encourages energy production, even if the owner does not expect to hold on to the property during the entire amortization period.

The financing tends to be provided through specialized financial companies which use capital from the private sector to invest in PACE projects. A local government unit "administers the loan" by assessing the property each year, billing the real estate tax along with other taxes on the property tax bill, and turning over the amount due to the financer of the project. The local government can also assert its tax-collection rights to ensure the financer is paid.

According to the information available, after having completed hundreds of projects to date, PACE initiatives seem to be successful for all kinds of commercial properties,[5] including non-profit buildings, offices, stores, industrial buildings, farm buildings, multifamily dwellings, etc. In order to benefit from this source of financing, the national legislative framework has to be adapted to the new law on the sustainable economy to allow cities to develop municipal ordinances for specific actions.

The EU has a pilot program called EuroPACE which started in the city of Olot (Girona) in October 2019.[6]

5.1.1. New Proposals for PPP Financing

Public-private partnerships can be complemented with alternative financing proposals for energy retrofitting projects in order to attract more investments. Below we suggest two proposals worth bearing in mind for future energy retrofitting projects.

a) Calling for bids for the retrofitting project to take advantage of potential scale advantages

In cases in which the public sector sees an interest in or identifies a need for retrofitting, it can outsource the project to a private or public-private stakeholder so it can carry out different actions while also benefiting from the advantages of scaling the project up. In this case, it is essential to draw up a pre-contract between the public and private sector which considers the risks that each party is going to take on. These include risks in design, construction, additional investments, or income.

Whether there are scale advantages for projects that merely entail construction is debatable. The building industry, which is highly competitive, has extremely tight margins. However, it is possible to find this sort of advantage in the aggregation of users of an apartment building or neighborhood thanks to the accumulation of materials or scaffolding issues, among other reasons.

On the other hand, there seem to be clear advantages in scaling energy-efficiency solutions. The example of photovoltaic panels is one of the clearest, since very few tertiary buildings, and even fewer residential buildings, have these installations yet. The implementation of active solutions, such as solar panels, is still a market yet to be developed where the installation costs are high and therefore there are savings options if they are done on larger scales.

b) Calling for bids for the management of retrofitting projects and collection of bills and payments in exchange for debt securitization

This is a public-private partnership in which the public party takes on the costs of carrying out the rehabilitation project and later amortizes the debt by calling for bids to handle users' payments. That is, the government sells users' debt packages, similar to what is currently done with mortgages, allowing them to be managed and the income to be received (debt securitization).

[5] For more information: www.pacenation.org/wp-content/uploads/2016/05/The-benefits-of-PACE-for-CRE-FINAL-1.pdf.

[6] For more information: www.europace2020.eu.

In the case of residential buildings, we see how the expected costs in the form of energy savings often do not offset the investment cost since energy is not consumed intensively. For this reason, a contract between the public and private sectors that matches the income risks must be designed. Furthermore, it could be difficult to place all the debt if it cannot be paid with the fees and profits from the project.

There are few precedents of a public-private partnership like this, none of which are in Catalonia. However, there are examples of such cases in New York City, since the public entity that promotes energy retrofitting projects there securitizes the debt and sells it to interested financial entities.

5.2. Sensorization in Cities

Budgetary flexibility. Even if a city has sufficient budget to purchase the hardware needed to deploy a sensorization network, this is not always the best option. Exploring alternative possibilities, such as the use of ESCO (energy service companies) contracts or renting allows resources to be invested in other areas that require more attention, depending on the city's characteristics (such as economic promotion, social services, etc.). In this way, it is important to bear in mind contracts that neither generate debt nor consume part of the budget in the short term. Additionally, this kind of contract can better adapt to new technologies, given that it is not associated with a developmental level which could become obsolete, and it ensures that only technology that is truly available is paid for, speeding up the pace of renovation and thus the expected economic and environmental benefits.

Performance risk in concessions. Many sensor technologies require cooperation among different stakeholders (both public and private). This entails the risk that one of the stakeholders may not be capable of providing what has been specified in the contract or call for bids. If the operator is a large telecommunications company, the performance risk is relatively low. Therefore, it is important to bear in mind not only the technical feasibility of the solutions but also their financial solvency when establishing and delimiting the risks that each stakeholder must take on.

5.3. Sustainable Mobility

Renting or leasing. In this case, the contractor gains the use of energy-efficient machinery or equipment, such as taxis, vans, or electric cargo tricycles for last mile deliveries. The renter has use of the property while the company reserves the real right to use the equipment. The renting company takes on the technological risk and the operational management.

For the public sector, updating of the mobile fleet quickly will clearly reduce emissions while acting as an example for the other economic sectors. Many of the future renting fees will be offset by the lower cost of fuel and maintenance, so ultimately the budgetary cost of the investment should be easy to take on.

Payment system. The development of an integrated public and private mobility system requires a system to collect and distribute income among the different transportation operators. The financial sector should facilitate this payment system in a simple, transparent way.

6. Conclusions

Below we present the conclusions stemming from the analyses in the previous sections regarding building energy retrofitting, sensors in cities, and sustainable mobility.

6.1. Building Energy Retrofitting

As gleaned from the workshops held at IESE Business School during academic year 2018-2019, there is currently not a very large demand for energy retrofitting in Spain for a variety of operational, regulatory, or climatic reasons.

It seems difficult to get reasonable returns on investment (between 10 and 30 years, without interest) in settings in which little energy is consumed. However, in some cases, the implementation of active measures, especially photovoltaic panels, does yield better returns.

The greater cost-benefit efficiency comes with large-scale actions on entire buildings or city blocks in lower-income peripheral neighborhoods. However, if the projects are not spearheaded by the public sector, they are very difficult to finance due to the multiplicity of private stakeholders. Thus, many public-private experiences in Barcelona have not been successful. The creation of a legal framework that facilitates PACE-type financing schemes seems to be the best way to give this type of action the impetus it needs.

In an increasingly environmentally sensitive social and political context, governments do seem to want to promote energy rehabilitation projects. There is a willingness to make public investment, but new financing formulas must first be explored to shift away from subsidies and instead towards dissemination, facilitation, subsidies of studies, and energy certificates.

Below are some of the opportunities for the financial sector in the short and middle term (without the support of the public sector). In the short term:

- Identifying the most appropriate groups from both the financial and energy standpoints.
- Launching joint campaigns (between the financial sector and some energy utility operators) to promote energy retrofitting projects, prioritizing measures which have been proven to be more effective in yielding savings and improving quality of life (photovoltaic panels, boilers, and replacing inefficient household appliances).

In the middle term:

- Promoting environmental awareness-raising and information campaigns on the benefits of building energy retrofitting, while offering dissemination and subsidies from the government.
- PACE: Creating a special tax that would take shape in supplements on the property tax collected by the government, which financial institutions can consider in order to finance the implementation of energy-efficiency measures, peripheral actions, or comprehensive projects that include them.
- Risk mitigation, either through the government or the European Investment Bank (EIB). The limited public resources must be spent to leverage private financing, not to replace it.

6.2. Sensorization in Cities

In this section, we can divide the conclusions into two major groups, depending on the context in which they are applied. First, if we are talking about direct financing (infrastructure deployment), the financing needs depend on the scale of the project. Even if the technology is relatively affordable for small projects, it can be costly in large-scale deployments. Furthermore, the fact that technological development leaves some hardware obsolete within a relatively short period of time allows more flexible financing formulas to be explored, such as leasing sensors.

Secondly, there are opportunities directly linked not to the deployment of sensor infrastructures, but to the management of different assets based on the data generated by the hardware deployed. In the example of garbage collection, one possibility worth exploring is having dynamic fleets in which the circulating collection vehicles are used according to the needs in each area at any given time. This could lead to major savings for the concessionaire, as well as an opportunity for flexible financing for this kind of vehicle. Finally, it is also important to highlight the possibility of capturing greater value through the use of the data generated. Many of the data generated by financial institutions can be mixed and analyzed for better decision-making in cities, so this itself is a business opportunity. The direction, depth, and ease of this possibility largely depends on the existence of use cases and cases of good practices, so this is a middle-term alternative which, despite its high potential for the data economy, requires new forms of cooperation between private enterprise and the public sector.

To make these investments profitable, it is essential to use them in the “digitization” of the provision of public services by improving their economic and environmental efficiency. This should be assessed in the new calls for bids for municipal concessions: breaking the historical inertia is unquestionably a much more complex challenge than technology.

6.3. Sustainable Mobility

During the workshop on sustainable mobility, it became clear that the transportation and mobility sector is undergoing a paradigm shift. Innovations and alternatives are emerging through changes in energy use, with electric vehicles and new and more energy-efficient technologies; greater digital connectivity for the integration of public and private transportation; and new business models that offer services like last mile deliveries with a low environmental impact.

However, achieving a full transition towards more sustainable mobility requires major investments in infrastructures which, in view of governments’ budgetary limitations, must take place in the form of private financing to support the investments needed. Operating leases is the financial mechanism that best fits the management of technological risk and quick updates with a limited budgetary capacity.

In parallel with the updating of the public fleet, it is also important to encourage updates of the fleets used the most often in urban areas: logistics vehicles and taxis. Since most of them are owned by freelance workers, it is essential to promote the range of financing systems that meet their needs. Once again, renting and leasing should play an important role.

For investments in infrastructure, the public-private alliance (PPA) model may be the most appropriate; however, several financial instruments can be provided for new business models for smart solutions in the field of mobility and transportation so that the company is successful and drives innovations in the sector.

In terms of mobility as a service, payment methods should be available that facilitate payment integration (beyond the service) and the subsequent distribution of the income among the transportation operators.

References

ANGELAKOGLOU, K., Nikolopoulos, N., Giourka, P., Svensson, I. L., Tsarchopoulos, P., Tryferidis, A., & Tzovaras, D. (2019). A Methodological Framework for the Selection of Key Performance Indicators to Assess Smart City Solutions. Smart Cities, 2(2), 269-306.

ALLAM, A. (2018). World Sustainable Development Outlook 2018: Public private partnerships for the implementation of the 2030 Agenda for Sustainable Development, World Association for Sustainable Development (WASD).

BATTY, M. (2013). Big data, smart cities and city planning. Dialogues in Human Geography, 3, pp. 274-279. doi: 10.1177/2043820613513390.

BUILDING PERFORMANCE INSTITUTE OF EUROPE (2018). 97% of buildings in the EU need to be upgraded. Retrieved from bpie.eu/publication/97-of-buildings-in-the-eu-need-to-be-upgraded.

BOLETÍN OFICIAL DEL ESTADO – Official Journal of the European Union. (November 14, 2012). L 315/1. I (Actos legislativos). Directivas. Directiva 2012/27/UE del Parlamento Europeo y del Consejo, de 25 de octubre del 2012, relativa a la eficiencia energética, por la que se modifican las Directivas 2009/125/CE y 2010/30/UE, y por la que se derogan las Directivas 2004/8/CE y 2006/32/CE. Retrieved from www.boe.es/doue/2012/315/L00001-00056.pdf.

EUROPEAN COMMISSION (2016). Sustainable Urban Development in the EU. https://ec.europa.eu/regional_policy/sources/policy/themes/urban-development/sustainable_urban_development_2016_en.pdf

EUROPEAN COMMISSION. ERESEE 2017 (2017 update). De la Estrategia a largo plazo para la rehabilitación energética en el sector de la edificación en España. Retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/es_building_renov_2017_es.pdf

EUROPEAN COMMISSION. (no date). Developments and Forecasts on Continuing Urbanisation. Retrieved from ec.europa.eu/knowledge4policy/foresight/topic/continuing-urbanisation/developments-and-forecasts-on-continuing-urbanisation_en.

EUROPEAN COMMISSION, GrowSmarter, 2019, forthcoming publication.

EUROSTAT (n.d.). Energy statistics - electricity prices for domestic and industrial consumers, price components. Retrieved from (https://ec.europa.eu/eurostat/cache/metadata/en/nrg_pc_204_esms.htm)

GAIDAJIS, G., Angelakoglou, K., & Aktsoglou, D. (2010). E-waste: Environmental Problems and Current Management. Journal of Engineering Science and Technology Review, 3. doi: 10.25103/jestr.031.32.

GOVERNMENT OF SPAIN – MINISTRY OF DEVELOPMENT. (January 2013). Análisis de las características de la edificación residencial en España. https://www.fomento.gob.es/recursos_mfom/pdf/9DFC55DD-B6F8-4C40-8634-8B199A6770A8/135887/INF_CARAC_EDIF_RESID_2001.pdf

GOVERNMENT OF SPAIN – MINISTRY OF DEVELOPMENT. (June 2014). Estrategia a largo plazo para la rehabilitación energética en el sector de la edificación en España en desarrollo del artículo 4 de la Directiva 2012/27/UE. www.fomento.gob.es/recursos_mfom/pdf/39711141-E3BB-49C4-A759-4F5C6B987766/130069/2014_article4_es_spain.pdf.

INNOENERGY, IREC, & AIGUASOL. (2019). Residential retrofits at district scale.

KAPELAN, Z., Savic, D., & Walters, G. A. (2005). Multiobjective design of water distribution systems under uncertainty. Water Resources Research, 41(11). doi: 10.1029/2004WR003787.

MEDAROVA K., Volkery A., Sauter, R., Skinner, I., Withana, S., & Núñez J. (2013). Study on the optimal use of EU grants and financial instruments in the next Multiannual Financial Framework to address the climate objective. For DG Clima.A.2/ETU/2012/0002R.

UNITED NATIONS (n.d.). Smart Sustainable Goals. Retrieved from www.un.org/sustainabledevelopment/sustainable-development-goals/

UNITED NATIONS (2018). Department of Economic and Social Affairs, Population Division (2018). World Urbanization Prospects: The 2018 Revision, Online Edition.

UNITED NATIONS (2019). Cities and Pollution contribute to climate change. Retrieved from www.un.org/en/climatechange/cities-pollution.shtml

PIEDRA, J. et al.. Gestión del servicio público de residuos sólidos (Santander). PPP for Cities case study, forthcoming publication.

SALOM, J. & Pascual, J. (2018). Residential Retrofits at district scale. Business Models under Public Private Partnerships. IREC-AIGUASOL. https://aiguasol.coop/wp-content/uploads/2018/12/Residential_Retrofits.pdf