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Research article

Key aspects of building retrofitting: Strategizing sustainable cities

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ABSTRACT

Many cities are making efforts to develop an urban transformation strategy in order to transition from traditional cities to sustainable ones. Improving the energy efficiency of buildings, especially existing ones, is key to combating climate change. This paper uses a business perspective to analyze and compare three major retrofitting interventions under implementation in three different European cities, Nantes, Hamburg and Helsinki, to capture the principal needs and challenges and to identify governance recommendations for local authorities on building retrofitting replication and scale-up strategies. The authors analyze the municipal business models of residential building retrofitting interventions, which are very different from those of private companies, through two innovative business tools: the Value Creation Ecosystem (VCE) and the City Model Canvas (CMC). Sustainable development in terms of social inclusion, environmental protection and financial viability is the principal axis of the study. The bottleneck for residential building retrofitting is owner engagement, due to the high up-front cost. The analysis of the three cities' business models has shown interesting ideas for promoting this type of interventions. The development of a costumer customer interface lead by the municipality; the offering of funding schemes, the promotion of risk-sharing schemes and guaranteed saving, through the implementation of EPC, and the owners' involvement in co-creation strategies using 4 P approaches could all help city governments to increase the ratio of owners willing to participate. These results and the discussion will help public managers to prepare their cities' strategies in terms of business models when they try to implement building retrofitting projects.

1. Introduction

Cities of the 21st century strive to offer the best possible services to their residents in areas such as housing, mobility, healthcare, education, water and waste management, and public safety and security (Pardo-Bosch et al., 2019), with the aim of increasing the well-being of their inhabitants. Urban areas are facing unprecedented population growth (Carli et al., 2018); the United Nations (2018) estimates that 65% of the world's population will live in cities by 2050. This rapid growth makes cities' governance challenging (Pujadas et al., 2017), at the same time as the large concentration of humans and concomitant need for services raises questions about sustainability (Phillis et al., 2017). Cities play a key role in fighting against climate change, decreasing greenhouse gas emissions and improving energy efficiency (Ahvenniemi et al., 2017). Municipalities must make decisions related to urban development on their broadest dimensions. Because these decisions will exert a strong influence on the future of cities and those who live in them, they must be made from a strategic point of view, with a long-term city vision.

Buildings are one of the most relevant elements of cities. They are the center of human activity and contribute to the welfare of the population (Pearce, 2017). However, their social contribution comes with economic and environmental costs (Ahmad and Thaheem, 2018). In fact, buildings are among the most important energy consumers and greenhouse gas emitters (Jiang et al., 2013; Russell-Smith et al., 2015; and Zhou et al., 2016). According to Gynther et al. (2015) and Liang et al. (2018), buildings use 40% of all energy in developed countries. Thus, improving the energy efficiency of buildings should be a critical element of combating climate change (International Energy Agency, 2006; and Li and Colombier, 2009). Due to the large ratio of existing buildings to new construction, governments, technicians and scientists are aware of the crucial role in this battle that is played by retrofitting existing buildings. Therefore, and according to Loh et al. (2010), the deployment of public policies on tackling this issue is a priority.

In fact, as shown in Journeault (2016), organizations, both public and private, have special concerns about how to implement the strategic integration of the three axes of sustainability (economic, social and environmental). In this case, no matter what type of retrofitting intervention is projected, the most critical factor to be considered, according to Zhou et al. (2016), is economic viability, due to uncertainty

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about the investment required and the potential benefits achieved with it (El-Darwish and Gomaa, 2017). This is the principal barrier to undertaking retrofitting projects among investors and apartment owners. By offering plans and regulations with advantages for building retrofitting interventions, local governments would push these projects to a higher level of market penetration (Shaikh et al., 2017).

Zhou et al. (2016) found that there is no lack of technical/engineering studies on building retrofitting, although very limited studies focused on operation strategies to solve this real problem. Moreover, to the best of the authors' knowledge, none of them—and despite the growing interest on these projects—makes a holistic analysis at the municipal level in terms of sustainable management. Aware of that concern, this paper uses a business perspective to analyze and compare three major retrofitting interventions under implementation in three different European cities (Nantes, Hamburg and Helsinki) with the goals of capturing the principal needs and challenges and identifying governance recommendations for local authorities. As suggested in Nilashi et al. (2015), this is the preliminary stage toward the design of a proper municipal strategy.

This paper is divided into six sections. Having outlined the aims of the research and its significance in this Introduction, Section 2 will present a review of the literature on sustainability, building retrofitting and business models. In Section 3, the authors will present the methodologies used to study the retrofitting projects. In Section 4, the three real cases projected in Nantes, Hamburg and Helsinki will be analyzed in depth. The Discussion, in Section 5, will compare cities' strategies for implementing and scaling up retrofitting interventions. Finally, the conclusions will be presented in Section 6.

2. Theoretical background

2.1. Sustainability and building retrofitting projects

Governments and scientists are leading the debate on how new urban plans could contribute to sustainable development (Dirks et al., 2009; Wang et al., 2017; and Büyüközkan and Karabulut, 2018), since the urban scale has been recognized as a key to achieving this ambitious target (Yin et al., 2018). According to World Commission on Environment and Development (1987), sustainable development is the capacity to meet the needs of the present without compromising the ability of future generations to meet their own needs. In fact, the sustainable development of cities has been understood by several authors (Wu, 2014; Addanki and Venkataraman, 2017; Shealy et al., 2018; and Yin et al., 2018) as a challenge and also as an opportunity, and it could fix the problems arising from inadequate or unwise urban planning (Ribeiro et al., 2018).

Urban sustainability should be based on social inclusion, financial viability and ecological preservation (Mori and Christodoulou, 2012; Huang et al., 2016; Pardo-Bosch and Aguado, 2016; and Lopez-Carreiro and Monzon, 2018). Environmental sustainability focuses on assessing the positive and negative impacts of human actions on natural resources. It highlights the integration of humans in natural ecosystems, ensuring that anthropogenic impacts remain within bounds, preserving ecological systems and reducing the environmental footprint. Its objective is to promote the production of services respecting the carrying capacity of the natural ecosystem, limiting growth and preventing environmental degradation. Similarly, economic sustainability focuses on an organization's financial capacity to carry out its activities while maintaining debt and likely incomes at reasonable levels. In terms of the public sector, Drew and Dollery (2015) observed that economic sustainability of local governments is cause for great concern among policymakers. Pressure on the public sector has grown, as its sources of revenue have been reduced and its expenditures increased due to growing demand for services, in terms of both quantity and quality. Finally, social sustainability focuses on ensuring equal rights of people to access resources and opportunities (Bansal, 2005; Torugsa et al., 2013; and Wijethilake, 2017), providing long-term well-being. In other words, this branch of sustainable development is dedicated to building cities where people want to live and work. It is essential to dedicate part of public revenue to financing social spending to provide the most essential public services: housing, healthcare, education, water and waste treatment, and public transport, among others. While the vast majority of works have been environmentally focused (Büyüközkan and Karabulut, 2018; and Ahmad and Thaheem, 2018), urban studies are now extending their approaches to global analysis, considering what is known as a triple bottom line—paying special attention to the social and economic axes of sustainability (Thomé et al., 2016; and Ferrer et al., 2018). The pressure for organizations to take care of sustainable development is constantly growing, and most of them view the economic and social axes as being equally strategic to the environmental one (Büyüközkan and Karabulut, 2018; and Joyce and Paquin, 2016).

Managing the built environment that supports human activities is fundamental to achieving long-term sustainability (Pearce, 2017). Mata et al. (2018) argue that the energy renovation of existing buildings is a necessary strategy to accomplishing this goal. The building sector accounts for almost 40% of total energy demand, and buildings are the major greenhouse gas emitters in cities. Furthermore, and according to Ürge-Vorsatz et al. (2015), in frozen scenario in terms of policy and technological developments, total residential heating and cooling energy consumption is not expected to decrease over the coming 30 years. Implementing energy efficiency measures and carbon emission mitigation through retrofitting projects is associated with multiple benefits (Li and Colombier, 2009; and Nilashi et al., 2015). Among these, the authors highlight access to new energy sources and reduced dependency on energy from others; improvement of air quality, indoor comfort and quality of life; minimization of global warming; reduction in operational and maintenance costs; and increased social well-being, especially for low-income households. In fact, building retrofitting is essential to tackling energy poverty, one of the most important social problems faced by our society (Pacheco-Torgal, 2017). Taking into account these possible outcomes and the fact that in Europe the majority of existing buildings are more than 40 years old and require extensive energy conservation measures (Martinopoulos, 2018), many countries encourage building retrofitting projects, confronting costly investments with long-term expectations (Nik et al., 2015). Nevertheless, it is not possible talk about energy efficiency without considering the potential effects of Jevon's paradox, or the so-called rebound effect. Savings made thanks to high-performance buildings may be an incentive to increase energy consumption through rising comfort standards Copiello (2017), so homeowner behavior has significant impact on building energy efficiency results after retrofitting (Pacheco-Torgal, 2017). The retrofitting activity implies modifying existing equipment, features and structures from existing buildings with additional or new ones in order to reduce energy consumption. The European Union (EU) clearly pushes its member states to carry out deep reforms in order to transform existing buildings into nearly Zero Energy Buildings (nZEBs), which means, according to Directive (2010)/31/EU, buildings with a very high level of energy efficiency, or low amount of energy required. The retrofitting of buildings is a priority issue for the EU in its commitment to reducing greenhouse emissions by at least 40% by 2030, compared to 1990 levels. Europe has the need to increase the proportion of renewable energy consumed and achieve energy savings in line with ambitions at European level, as well as improving Europe's energy security, competitiveness and sustainability (Directive, 2018/844/EU). The EU is trying to overcome obstacles that prevent the implementation of energy efficiency measures in buildings. These obstacles refer to economic, technical and social dimensions related to retrofitting. Regarding the economic dimension, the barriers are the high up-front costs, transaction costs, cost efficiency criteria, risk sharing, public financing, private investment, and paybacks, among others (Menegaki, 2012; Fredericks et al., 2015; Hargreaves et al., 2017; and Regnier et al., 2018). As for the technical dimension, the main obstacles include the complexity of large-scale renovations, lack of concrete integrated definitions, and lack of experience in the industry (Moschetti and Brattebo, 2016; Streicher et al., 2017; and Regnier et al., 2018). In terms of the social dimension, and especially regarding owners, the main concerns are lack of information and awareness of energy issues, absence of clear financing and funding schemes, and the overlap of public and private retrofitting programs (Economidou and Bertoli, 2014; Frederiks et al., 2015; Webber et al., 2015; and Lesic et al., 2018). Given these challenges, municipalities have to play a crucial role, at least in an initial phase, in the deployment of projects of this type—by reducing the risks and uncertainties and by acting as leaders, regulators, facilitators, operators (owners) and customers.

2.2. Business models and public value

During the past 20 years, the business model concept has gained prominence; today is it recognized as an essential element in the development of a product or service by a private company. The earliest reference to this concept is found in Drucker (1994), although in this case the author spoke of "theory of Business" in order to answer questions such as who the customer is and what the customer values. Magretta (2002) complemented Drucker (1994), stating that business models are stories about how companies work and they usually answer the following questions: How do we make money? What underlying economic logic explains how we can deliver value to customers at an appropriate cost? But exactly what *is* a business model? According to Osterwalder and Pigneur (2009), a business model is a rationality that explains how a company creates, delivers and captures value. Magretta (2002) stated that business models are for managers the equivalent of the scientific method for researchers, declaring that both begin with a hypothesis that must be validated with a test, and that can be revised if necessary. In that sense, Seelos (2014) explained that the implementation of common frameworks helps in explaining what works and what does not work to create value in each specific business. Taking into account that business models are based on hypotheses, another key aspect is testing the solutions before their scale-up. This considerably increases the chances of success, because it enables organizations to address problems that they could not have imagined in advance (Wynn et al., 2009). Nowadays, according to De Reuver et al. (2013), the most prominent and popular tool for practitioners to design business models is the Business Model Canvas (Osterwalder and Pigneur, 2009), which is based on nine building blocks. According to its developers, these building blocks cover the four main areas of a business: customers, offer, infrastructure and financial viability, yielding a holistic business idea.

Although most business models focus their attention on just the focal firm, Pfeffer and Salancik (1978) and Johanson and Matsson (1992) have observed that organizations -both public and private-must work with other companies and establish solid value chains (Cristopher, 2016) in order to produce products and/or services, as they are not capable of carrying out all the needed activities by themselves. Moreover, Zott and Amit (2010) advocated drawing attention to the whole range of activities performed by third parties (partners, suppliers, customers). Each actor increases the value of the product and/or service along the value chain, and in so doing, each actor can capture part of that value (Lepak et al., 2007), which in many cases goes beyond economic value (Agandoña, 2011).

Civil society cannot neglect the production and delivery of public value. Public administrations should conceptualize how they articulate their activities or resources for offering public services as private enterprises do through business models. In this regard, Williams and Lewis (2008) recommended that public managers use private sector tools for ensuring a holistic and accurate analysis. Duggan and Moon (2008) remarked that business models are strategic tools that can help public administrations manage their activities and resources through which they offer public service to their residents, fulfilling their democratic mandate. According to Timeus et al. (2019), by using business models, public organizations understand the logic of how they offer value, to whom they offer it, and how they can sustain it over the long term. They can use it because the value proposition -a business model central element-does not necessarily have to be defined by profit; it can be defined just by social and environmental benefits. In fact, as shown in Seelos and Mair (2005) and Yunus et al. (2010), other nonprofit organizations and social enterprises use business models to analyze their services production.

To make the transition from a traditional city to a sustainable one, each municipality needs to use tools for articulating the logic of how it creates value for and with its citizens and companies in the long term, as an essential part of its global strategy. This is the only way through which the municipality will be capable of integrating the improvement of very different public services into a global and well-articulated systemic vision (Lataifa, 2015).

3. Materials and methods: business model tools for strategizing sustainable cities

The holistic city-level analysis of the retrofitting interventions projected in Nantes, Hamburg and Helsinki examines the chain of actors that produces services for citizens; and inside this chain, the logic of how municipalities create, deliver and capture part of value. Analyzing similar projects in three different cities allows the authors to obtain comparable results that in turn will help municipalities to understand what interventions are replicable and under what conditions. To this end, a research strategy of a qualitative nature was implemented to allow the authors to create and validate the findings with each city. The research was conducted through deep interviews and seminars with key actors and review of secondary sources such as specific literature on the topic. Through these sources, key information was gathered to define the conceptual tools of the business models and perform the comparative analyses.

3.1. Value Creation Ecosystem

As argued in the above section, any business model should define the entire ecosystem of activities and the actors participating in it. The literature offers different theories for drawing and analyzing the set of activities needed for deploying new products or services. Rowley (1997) and Key (1999) presented the network model, where each stakeholder can also be a stakeholder of other firms. This model is useful for understanding the multilateral contracts among the stakeholders and for defining sub-hubs of stakeholders, but it does not describe what kind of relations are stablished among actors and what value they each create for the ecosystem. At the other end of the spectrum, Tian et al., 2008 presented a framework for the modeling and design of a network of interconnected business enterprises. This framework assesses the performance of the business model and provides insights regarding value distribution among stakeholders under different scenarios. The tool incorporates game theory analysis and multiagent systems as essential parts, conferring consistency and robustness while at the same time making it a complex methodology for recurrent use. Between these ends of the spectrum we can find the model presented in Allee (2000), where actors (nodes) are connected through two single-headed arrows, showing the connections among them and the value exchanged, which can be of three different natures: 1) goods, services and money; 2) knowledge; and 3) intangible value. While this is a simple methodology in terms of its conceptualization, it is complete and rigorous in terms of supplied information.

Based on Allee (2000) theory, the authors propose using a tool (Fig. 1) called Value Creation Ecosystem (VCE) to construct the ecosystem that develops a retrofitting intervention. VCE connects each actor to as many nodes as necessary. For each relation of a node A (actor A) with a node B (actor B), two links are generated: one from

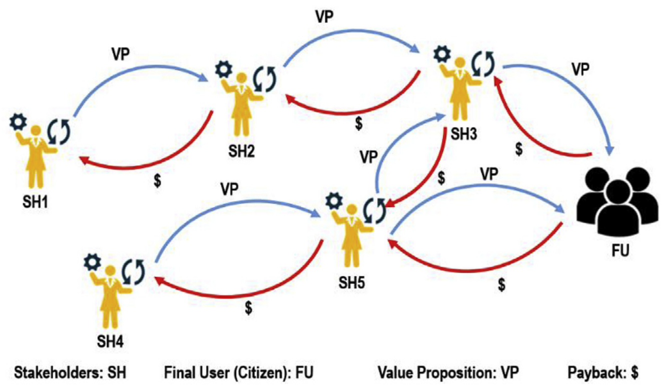

Fig. 1. Theoretical value creation ecosystem.

actor A to actor B (in blue in Fig. 1), which indicates the value that actor A creates for actor B, and another one from actor B to actor A (in red in Fig. 1), which shows the value that A captures from its relation with B (this would represent the payback). For cities, drawing the VCE of each intervention is a key activity for answering the following key questions: What are the activities needed to create value for the ultimate beneficiaries? Who are these ultimate beneficiaries? What actors/stakeholders are necessary to develop these activities? What are the values captured?

3.2. City Model Canvas

According to Section 2.2, all organizations, including municipalities, need to use business models to know and understand how they can organize their resources and activities to create and deliver value. City governments, to the best of the authors' knowledge, have just three methods for analyzing their particular business models. Walravens (2012) presents a framework that enables cities to evaluate whether they are really creating public value. The model is complex and it is more useful for an *ex post* assessment than for an *ex ante*, as our context requires. Díaz-Díaz et al. (2017) uses the Business Model Canvas (BMC) with a triple bottom line for designing and implementing a city business model. Except for the assessment of social and environmental impacts, the framework is the same used for private entities, and it is clear that the approach used by public authorities is far from identical to this. Finally, Timeus et al. (2019) present the City Model Canvas (CMC), which is based on the BMC, replacing several blocks of that canvas with others that are more closely related to public services and introducing a triple bottom line, as is done in Díaz-Díaz et al. (2017). Thus it can be seen as an evolution of Díaz-Díaz et al. (2017) framework and a real BMC adaptation for the public sector. City councils can use CMC (Fig. 2) to articulate how they expect to create and deliver value in an economically, environmentally and socially sustainable way through smart services. By using it when cities define strategies for their future services, public managers will be capable of assessing from a holistic perspective the net balance of their policies and actions. This tool emphasizes that the transition from a traditional city to a smart one should be based on solving environmental and social problems rather than just addressing economic challenges, which, obviously, also must be taken into account. This is important to ensure that smart services actually serve to alleviate a particular need of the population and are not just being implemented to follow a trend or satisfy corporate interests. CMC is composed of fourteen blocks (B), divided into four main areas: value proposition, delivering value, producing value, and the triple bottom line.

4. Results: case study

This section uses VCE and CMC to analyze the interventions that Nantes Métropole (France), Hamburg (Germany) and Helsinki (Finland) are developing as pilots under EU H2020 projects in order to identify the needs and challenges cities have to face in terms of governance when implementing building retrofitting projects.

4.1. Nantes Métropole's pilot intervention

Nantes Métropole's intervention consists of retrofitting residential building stock built at least 15 years ago. The municipality develops a local platform-web (i.e., principal channel) as a customer interface for the retrofitting of this stock, which is characterized by low energy efficiency and high energy consumption. In the case of multi-owner residential buildings, the intervention comprises insulation of façades and roofs of buildings with the integration of renewable energy services (RES). There are thermal solar panels with storage for domestic hot water, photovoltaic (PV) panels, air-cooler to an electrical storage. In addition, a power management system is installed to control the PV panels and the storage of the resulting energy. The buildings are connected to the high performance district heating based on renewable energy. Another action is the individual energy billing and an electrical "disappearance" used to reduce electrical consumption. In the case of individual houses, the retrofitting intervention comprises insulation of attics and walls, installation of smart thermostats and a hybrid solar thermal and PV system. Finally, the intervention deploys smart meters to enable the development of energy services to customers and the creation of new services through data gathering. Nantes Métropole aims to carry out these interventions with 3500 private dwellings, of which 1000 will benefit from funding from the municipality.

Fig. 3 shows the VCE of the Nantes Métropole intervention, of which the municipality acts as the retrofitting project promoter. Nantes Métropole uses the platform-web -managed by a private operator who develops the platform and does the operation and maintenance (O&P)- as the main channel to connect owners with retrofitting professionals (individuals, SMEs, housing operators, and energy, construction and digital services companies). Public authorities should develop their business around a model based on responsible growth to take on the major challenges of energy transition to a low-carbon economy. The platform-web acts as an interface for the promotion and marketing of full retrofitting packages and for funding/financing these packages. In particular, the platform-web has a space for information provided by energy retrofitting experts who attend and advise owners personally. Moreover, the platform-web offers a first retrofitting project approach without cost for the owners. Once the project is accepted, the owners work directly with retrofitting project/work suppliers.

Fig. 4 shows that the value proposition of the business model of Nantes Métropole is to retrofit the existing building stock of this city and its surroundings, in particular those dwellings built at least 15 years ago, in order to improve their energy performance through increased efficiency and use of renewables. The value proposition also emphasizes urban health and quality of life of residents. In particular, it focuses on the owners/tenants who can improve their quality of life through increasing the comfort level of their dwellings. In addition, the retrofitting intervention focuses on energy cost savings for households. With 13.7% of its population in the low-income category (Rodrigues and Pailloux, 2014), Nantes has particular interest in this community, and thus aims to retrofit 1000 low-income households, which will increase the comfort, energy savings and economic valuation of their dwellings.

The direct beneficiaries of the intervention are the owners and tenants of houses, apartments and condominiums of the 24 communes that are integrated in the metropolitan area of Nantes. This is an important program as it increases residential assets of low-income households. Delivering value of the business model for direct and indirect beneficiaries needs the buy-in of the owners and tenants. In the case of the owners, these can present concerns about financial matters.

Concerning the production of value of the city business model, and beyond the classic activities needed to deploy public services, in this

1. Mission achievement: What is the ultimate goal that the city seeks to achieve?

6. Key partnerships
Who can help the city deliver the proposed value to the beneficiaries? Who can access key resources that the city council does not have?

7. Key activities
What must the city council do to create and deliver the proposed value?

8. Key infrastructure & key resources
What key resources and infrastructures does the city council have to create and deliver the value? What is the regulatory framework required?

2. Value proposition
What specific benefits are created and what specific problems does the proposed service solve or alleviate?

4. Buy-in & support
Whose buy-in is needed in order to deploy the service (legal, policy, procurement, etc.)?

5. Deployment
How will the city solve the problems of the Value proposition specifically?

3. Beneficiaries
Who will directly benefit from the proposed services?

9. Budget costs
What costs will the creation and delivery of the proposed services entail?

10. Revenue streams
What sources of revenue for the city do the proposed services provide? What other sources of revenue does the city have?

11. Environmental cost
What negative environmental impacts can the proposed services cause?

12. Environmental benefits
What environmental benefits will the proposed services deliver?

13. Social risks
What are some of the potential social risks that the proposed service entails? Who is most vulnerable as a result?

14. Social benefits
What social benefits will the proposed services bring about? For whom will these benefits materialise?

Fig. 2. –Theoretical city model canvas (Timeus et al., 2019).

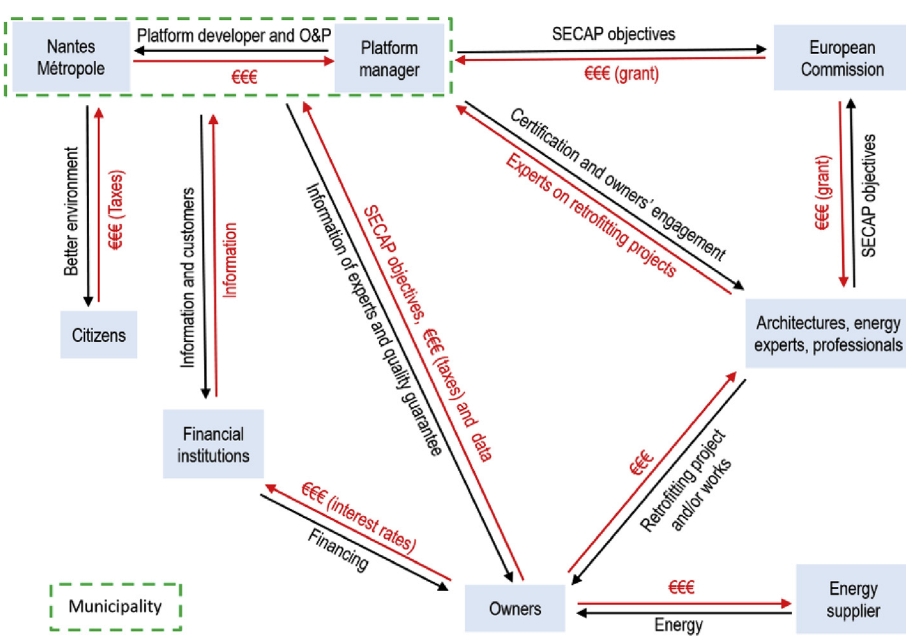

Fig. 3. VCE of Nantes Métropole retrofitting intervention.

Mission statement: To reduce the city's greenhouse emissions from buildings improving their energy efficiency and promoting renewable energies

Key Partnerships

- European Commission
- Architectures, energy experts, professionals (Individuals, SMEs, Habitat operators, Energy, Construction and Digital devices companies - IoT, Big data, Home solutions, etc.)
- Financial institutions
- Professional organizations in charge of the certification
- Housing operators

Key activities

- Public tender for the service (platform manager)
- Platform operation (maintenance, running, etc.)
- Owners' engagement campaigns and feedback
- Educational and training programs for citizens, technicians, operators, etc.
- Quality certification for professionals
- Evaluation and monitoring
- Owners and tenants competition to reduce its consumption to more than 8% (savings)

Key infrastructure and resources

- Public administration support
- Financing and funding schemes
- Nantes Métropole technicians *know how* to design the service
- Platform web
- Energy Data Lab service linked to the Urban Platform to evaluate services and create new energy ones

Value Proposition

1. To retrofit existing building stock of *Nantes Métropole*, in particular those dwellings built at least 15 years ago, in order to improve their energetic performance
2. To improve energy efficiency, reduce energy consumption and reduce of households energy bills (savings)
3. To produce and promote green energy
4. To increase and improve urban healthiness and quality of live of citizens through less fuel consumption and dwellings' comfort

Buy-in & support

- Owners' acceptance, mainly related to financial and funding concerns

Deployment

- Implementation of retrofitting actions: General retrofitting; Insulation of attics and walls; Smart thermostat: Solar thermal panels; Solar hybrid; Micro-wind turbines; Hybrid solar power system; Power management system; Smart meters

Beneficiaries

- Owners and tenants of houses and apartments built at least 15 years ago in *Nantes Métropole*

Budget costs

- Up to 70% of capex costs of retrofitting interventions
- Capex and Opex cost of the platform service
- Municipality funds

Revenue streams

- Private owners taxes (e.g. building and planning permits)
- HORIZON H2020 grants (short term)

Savings

- Reduction in municipal budget allocated for fuel poverty

Environmental costs

- Environmental impact in energy use during retrofitting works (short term)
- Rebound effect

Environmental benefits

- Less energy consumption (emissions of CO_2) of households because of an optimization and efficiency of retrofitted interventions
- Less air pollution
- Production of green energy

Social risks

- Possible increase of privacy concerns because of monitoring activities and data collection in private spaces
- Possible process of gentrification among cities because of an increase in prices of the building stock

Social benefits

- Increase of environmental awareness of citizens
- Improvement and increase of the smart social ecosystem development
- Better standards of social cohesion among citizens and improvement of their levels of quality of live
- Better urban healthiness that reduces health problems of citizens
- Energy poverty and reduce of energy bills
- Economic development: job creation, new business opportunities, companies' creation and development

Fig. 4. CMC of nantes métropole.

case, it is important to mention that Nantes Métropole has sponsored a competition among the owners/tenants in order to achieve a reduction of 8% in energy consumption in its "family with positive energy" challenge. Beyond the competition itself, this competitive activity is fundamental to engaging the owners and tenants and educating/training them about energy matters. One of the key resources where this model relies on is the platform-web mentioned earlier; this represents the principal channel of the business model, promoting professional engagement and coordinating owners, energy experts' info space, professionals and housing operators. Although a private company does the development, operation and maintenance of the platform, the municipality advises on its content. Furthermore, the platform-web offers owners the ability to conduct a self-evaluation of their dwellings as a first approach to identify existing strengths and weaknesses. In the case of the retrofitting actions, as mentioned in the introduction to this section, the intervention covers multiple, highly integrated measures. Nonetheless, the choice of these measures for the retrofitting package strongly depends on the individual owners' decision in the case of houses, and owners' agreement in the case of condominiums and apartment buildings. Obviously, other important elements are the financing and funding resources from Nantes Métropole, housing operators, state funding, or private institutions such as banks. The know-how of Nantes Métropole technicians is also key, given that it is they who design and implement the intervention.

Regarding the sustainability (triple bottom line) of the business model, as observed in Fig. 6, Nantes Métropole has different sources of revenue streams: the private owners' taxes, for example for building and planning permits, or EU grants (short term). Apart from these sources of revenue, the business model highlights savings in the municipal budget allocated to reduce the fuel poverty situation of households. From a traditional business market point of view, the revenue streams of the model are weak, particularly if we take into account the amount of the budget costs covered by public funding schemes -up to 70% of Capex costs of the retrofitting intervention in some cases. In this regard, business model sustainability depends heavily on the economic support of public administrations.

The model emphasizes energy cost savings (i.e., reduction in energy bills) for the owners, but these savings are estimated rather than guaranteed. Despite this, it is important to underline that Nantes Métropole helps to mitigate such risk through different actions such as identifying labeled retrofitting suppliers. These actions imply minimum standards to operate in order to achieve project objectives. According to the model, social and environmental benefits overcome the negative impacts.

According to these results, from a managerial point of view, it seems clear that the municipality is trying to offer an integrated solution through a one-stop-shop model. As Boza-Kiss and Bertoldi (2018) put it, Nantes-Métropole is transforming a weighty set of decisions and processes into a single and friendly entry. In this model, the savings achieved with the retrofitting are estimated rather than guaranteed, so the owners assume the whole risk of the intervention, according to their willingness to participate in it.

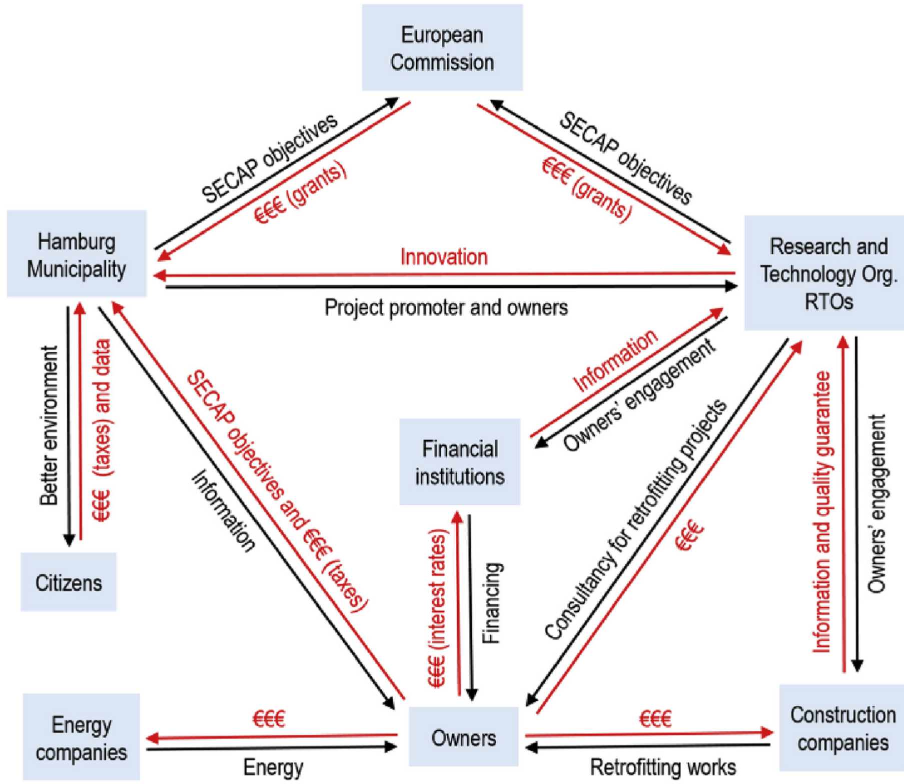

Fig. 5. VCE of Hamburg retrofitting intervention.

4.2. Hamburg's pilot intervention

Hamburg's intervention target consists of retrofitting 5000 dwellings in the city's Bergedorf district stock. Focusing on the objectives of energy refurbishment, energy efficiency and renewable energies, the intervention installs façade insulation and solar energy panels. In addition, it replaces insufficient heating facilities based on fossil fuels with renewable sources in order to become energy independent. Following these measures, some retrofitted buildings have smart home automation solutions, integrating both smart metering data and heating data. The owners control and monitor the connected heating facilities and thermostats, as well as electrical appliances (e.g., heaters, washing machines or roller shutters), via smart phones, PC/laptops or tablet computers, and they save energy with the support of such applications.

Fig. 5 shows the VCE of the Hamburg intervention. The municipality acts as the retrofitting project promoter, and the main partner in Hamburg's value chain is a local Research and Technology Organization (RTO) that embodies an interface between public administration and investors and civil society. The RTO's roles in the intervention are: 1) engaging the owners for retrofitting their apartments, 2) providing a first approach to the retrofitting project of the owners through a staff of architects and energy experts, and 3) following the retrofitting projects. This situation is predicated upon the RTO being seen by the owners as a customer interface. The RTO's commercial activity for engagement is crucial because a high percentage of owners are hesitant to retrofit their apartments. The strategies to engage the owners are: 1) a direct approach using their own workforce, consisting in a "door knocking" activity to identify and contact the owners; and 2) indirect access through other organizations, such as the energy suppliers, which carry out information campaigns to inform and connect the owners to the RTO at a district level. The RTO also receives inquiries from owners interested in retrofitting their apartments. RTO offers an initial consultation through in-house energy experts. If owners are interested in developing the retrofitting project, RTO acts as a main channel to connect them with architecture and energy experts who will work directly with the owners if the project is finally developed. In fact, owners usually make multiple contracts with separate suppliers. The RTO also informs owners about financing institutions, such as the *Hamburgische Investitions-und Förderbank* (IFB Hamburg), national banks or the Home bank.

According to the CMC of Hamburg (Fig. 6), the value proposition of this city is to retrofit the existing building stock of the Bergedorf district in the city of Hamburg through the implementation of energy refurbishment, energy efficiency and renewable energies. The current energy demand of this area is 49,284 MWh/yr and the project plans to reduce it to 23,686 MWh/yr, thus reducing energy consumption to less than 50% of the current level. Moreover, the municipality plans to have 30,000 m^2 suited for PVs that could generate 20% of the electricity, and 34,000 m^2 suited for solar thermal energy that could generate 30% of the heating demand. Clearly, the implementation improves energy efficiency and reduces consumption of fossil fuel energies. Furthermore, the owners can control and monitor their energy consumption in real time. This is a key aspect, because it can significantly increase their awareness of energy matters.

The direct beneficiaries of the intervention are the owners/tenants of apartments in the city of Hamburg's Bergedorf district. There are different types of ownership: single property ownerships and multi-property ownerships. Among the multi-property owners there are some housing associations which operate at below-market rental prices to offer affordable rents to low-income families. In fact, the delivery aspect of this city model emphasizes how important the owner is. Owners' engagement represents the bottleneck of the value chain, as owners are hesitant to assume the up-front costs of the retrofitting intervention. Furthermore, the different types of property ownership make the situation very complex.

For this reason, in the case of Hamburg, a campaign centered on owners' engagement and feedback represents one of the main activities of the business model. In addition, the intervention tracks and evaluates its actions in order to validate them and analyze their impact. In addition, the scale-up of the intervention to the whole city must include

Mission statement: To reduce the city's greenhouse emissions from building through promoting and enhancing renewables energies and savings

Key Partnerships	Key activities / Key infrastructure and resources	Value Proposition	Buy-in & support / Deployment	Beneficiaries
• European Commission • Architectures, energy experts, retrofitting professionals • Construction companies • Research and Technology Organizations (RTOs) • Financial institutions	**Key activities** • Owners' engagement acceptance campaigns and feedback • Educational and training programs for citizens, technicians, operators, etc. • Evaluation and monitoring **Key infrastructure and resources** • Public administration support • Financing and funding schemes • Urban Platform of Hamburg connected through integration of DTGA Smart City Ecosystem	1. To retrofit 1% of existing buildings stock of Bergedorf district in order to implement energetic refurbishment, energy efficiency and renewables energies 2. To improve energy efficiency, reduce energy consumption of fossil fuel and reduce energy bills of households 3. To produce green energy 4. To increase and improve urban healthiness and quality of live of citizens 5. To increase citizens' awareness	**Buy-in & support** • Political buy-in • Owners' acceptance, mainly related to the financial concerns **Deployment** • Implementation of retrofitting actions: Façade insulation and solar energy panels, renewable sources for heating, photovoltaics for electricity; smart home solutions; and smart heating islands with wind turbines, hybrid PVs, solar thermal and heat pumps altogether in combination with smart home solutions	• Owners/tenants of apartments (5000 apartments of 500 buildings in *Bergedorf* district).

Budget costs	Revenue streams
• No significant budget cost for the intervention	• HORIZON H2020: mySMARTLife (EU grant – short term)
Environmental costs	**Environmental benefits**
• Environmental impact in energy use during retrofitting works (short term) • Rebound effect	• Less energy consumption (emissions of CO_2 per m^2) of households because of an optimization and efficiency of retrofitted interventions • Production of green energy
Social risks	**Social benefits**
• Possible increase of privacy concerns because of monitoring activities and data collection in private spaces • Possible process of gentrification in *Bergedorg* district because of an increase in prices of the housing stock	• Increase of environmental awareness of citizens • Improvement and increase of the smart social ecosystem development • Better standards of social cohesion among citizens and improvement of their levels of quality of live • Better urban healthiness that reduces health problems of citizens • Reduce of digital divide (access to network and usage of IoT) • Energy poverty • Reduce of energy bills • Economic development: job creation, new business opportunities, company's creation and development, etc.

Fig. 6. CMC of Hamburg municipality.

educational and training programs for residents, technicians, operators, energy experts, and others. Regarding key resources and infrastructures, there are no public funding schemes from the municipality. However, in the case of scaling up or possible replications, funding will be needed in order to engage owners. Financial institutions have agreed to participate in low-interest financing schemes so that the access to money is quite affordable as an incentive for the owners, but the problem is that they have to cover all up-front costs of the intervention. In addition to these key resources linked to funding and financing, another important infrastructure is the connection to the Urban Platform.

Regarding financial sustainability, as observed in Fig. 7, the municipality has just one type of revenue stream: the EU grants. Hamburg's model does not charge owners with taxes, for example for building and planning permits, and does not count savings from municipal budget allocated to reduce the fuel poverty situation of households since there is not a clear target from the retrofitting intervention. Another possible source of revenue that Hamburg is considering for future steps could be fees from the Urban Platform services related to information and data in retrofitting for private retrofitting suppliers (professionals, SMEs, Energy companies, etc.). At the moment, the Urban Platform is conceived as an open source and operates under an open data concept, so Hamburg does not consider these services provided by the Urban Platform as a source of revenue. With regard to the budget costs, Hamburg bears no significant direct costs because the owners pay for the retrofitting intervention. The municipality does not offer funds linked to this intervention. From a traditional business market point of view, the business model is not weak for the city of Hamburg. In fact, in this model, it is the owners who assume all the risk of the intervention regarding financial and energy savings aspects, because these are not guaranteed. According to the model, social and environmental benefits overcome the negative impacts.

The results presented in this subsection show that the Hamburg municipality is developing its retrofitting strategy through a traditional scheme, where it is important to note the intervention of the RTO acting as a customer interface, which represents a clear evolution, as a first step on its transition to the one-stop-shop model.

4.3. Helsinki's pilot intervention

Helsinki's retrofitting intervention targets residential construction space composed of building blocks -some of them run by housing associations-built in the 1970s and 80s in the areas of Merihaka and Vilhonvuori. Almost half of the total building stock of the city dates from these years and represents a vast amount of the building stock that needs energy refurbishment. The objective of the intervention is to develop an energy refurbishment model to replicate for the entire building stock that needs to be retrofitted in the area, in particular 1323 apartments (34 buildings). The energy refurbishment model focuses on improved energy performance through smart home management. In particular, the retrofitting intervention installs renewable energy source (RES) production and smart controls. The apartments are equipped with a system that includes smart thermostats connected to the district heating system through Internet of Things (IoT) and cloud-based intelligence to load balance the network, and smart management of

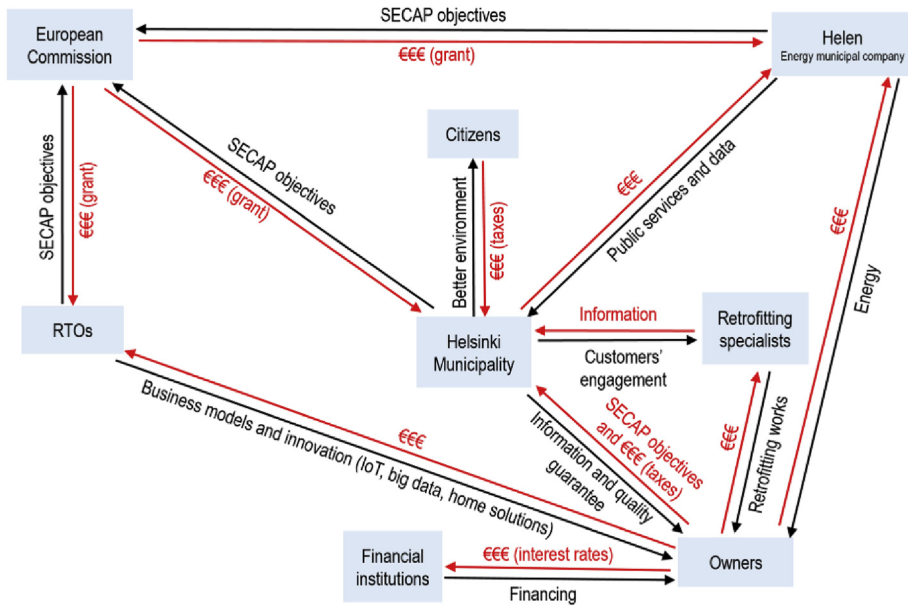

Fig. 7. VCE of Helsinki retrofitting intervention.

electricity consumption.

Fig. 7 shows the VCE of the Helsinki intervention. The municipality acts as the retrofitting project promoter: In collaboration with Helen (the wholly city-owned producer and distributor of Helsinki's heating, electricity, and cooling) and local RTOs, it works in the development of a business model for the intervention and its scale-up. The RTOs, in this case, are organizations that carry out research and innovation activities for the needs of industry and knowledge-based society. They are strongly engaged in smart and energy-efficient transformation of building stock, offering, in particular, digital devices (IoT technologies and big data management) for controlling, automation and energy savings to the owners. The municipality uses this stakeholder structure to produce value for the owners, residents and the city itself. Regarding the owners, as key stakeholders and decision-makers for the success of the intervention, the smart monitoring systems for their apartments allow them to realize significant economic savings in heating and electricity bills. The role of the owners/citizens as decision makers is important because it responds to the public-private-people partnership (4 P), a framework defined by the cooperation that occurs among these three types of actors in working towards shared objectives.

The municipality acts as an interface with regard to owners. The owners have to pay for the intervention and the contractual relation is directly done with retrofitting supplier companies. This is a challenging situation since the owners have to cover the whole cost of the intervention. However, the Helsinki model puts a high emphasis on monitoring all intervention actions to guarantee savings as well as environmental benefits. Currently, the housing association that runs some of these buildings splits heating cost equally among the owners/tenants, an arrangement that does not allow any type of incentive for an individual apartment to lower its heating costs. With the intervention, the owners/tenants are able to have information and control over their own energy consumption and savings.

The Helsinki city model for the building retrofitting interventions (Fig. 8) has as a value proposition the improvement of energy performance and energy efficiency through retrofitting measures based on smart controls in existing apartments of building blocks built between 1960 and 1980. Helsinki aims to implement and speed up the uptake of RES models in building blocks through solar panels. For this purpose, the municipality is studying different business models of RES production focusing on how to obtain revenue from roof renting or selling. The municipality estimates that interventions can reduce energy demand by around 30%, from 19,318 MWh/yr to 13,523 MWh/yr.

The direct beneficiaries of the intervention are the owners, housing associations and tenants of apartments in Merihaka and Vilhonvuori. They are actively engaged in the design and functionality of some intervention measures, such as the smart management of electricity consumption. This question is important given that direct beneficiaries become key stakeholders in co-creation services. Additionally, Helsinki has ongoing discussion groups with citizens at the neighborhood or district level related to the development of areas, and retrofitting is one of the themes frequently discussed. In this regard, municipality policy decisions incorporate citizens' debates, arguments and opinions from these ongoing discussions.

Helsinki does not need to face large-scale renovations since most of its U-values are already relatively good when compared to European building averages. For example, since 1970, the city's standard for bindings is two-layer window, and the high U-value is 0,25 W/m^2K in floors and walls, whereas in Prague it is 0,45 W/m^2K in floors and in Barcelona it is 0,73 W/m^2K in walls and floors (Boermans and Petersdorff, 2007). This represents an important cost-cutting for the intervention. This factor is key for the buy-in and support of owners, who cover the whole retrofitting cost and assume the risk rather than sharing it with other stakeholders. In addition, the Helsinki approach highlights the 3D model for data visualizing, which includes educational and training programs for citizens, involvement of technicians and operators to explain the know-how, and monitoring and evaluation of the interventions.

Regarding the key resources and infrastructures, the business model entails: the uptake of new sensor infrastructure; the basis for the participation and interaction model; the Carbon Neutral Helsinki 2035 action plan that integrates 143 strategic actions, one of which is the energy renaissance program; and the Helsinki internal development plan. Other important aspects are the public administration support to set up the conditions for the retrofitting intervention, and the municipality technicians' expertise to design and establish the requirements of the retrofitting actions for future replications.

Finally, in terms of the first row of the triple bottom line (i.e., the economic one), Helsinki, like Hamburg, does not have to cover any significant direct costs for developing this intervention. The municipality has different sources of revenue streams: the private owners' taxes, for example building and planning permits; possible grants based on the value of tons of CO_2 avoided; or EU grants. Another possible

Mission statement: To reduce the city's greenhouse emissions from buildings improving their energy performance

Key Partnerships	Key activities	Value Proposition	Buy-in & support	Beneficiaries
• European Commission • Owners • Retrofitting specialists • Research and Technology Organizations (RTOs) • Financial institutions • Helen (energy municipal company)	• Public tender design for the service • Owners' engagement campaigns and feedback – neighborhood meetings • 3D (VTT data) • Educational and training programs for citizens, technicians, operators, energy experts • Evaluation and monitoring **Key infrastructure and resources** • Municipal administration support • Financing and funding schemes • Helsinki's technicians *know how* to design the service • Urban Platform of Helsinki • Up-take of new sensoring infrastructure • Participation and interaction model • Carbon neutral Helsinki 2035 action plan • Energy renaissance programme • Helen development plan	1. To retrofit existing apartments built in the 1960-1980s, in order to refurbish them and improve their energetic performance 2. To improve energy efficiency, reduce energy consumption and reduce of households energy bills 3. To produce green energy 4. To increase and improve urban healthiness and quality of live of citizens 5. To increase CleanTech businesses	• Political buy-in • Owners' acceptance, mainly related to the financial concerns • Tenants acceptance, mainly related to rental increase **Deployment** • Implementation of retrofitting actions: Smart home management; smart thermostats and smart management of electricity consumption; and RES production	• Owners and tenants of apartments built in the 1960-1980s, approximaly 1323 dwellings (34 buildings) in Merihaka and Vilhonvuori.

Budget costs	Revenue streams
• No significant budget cost for the project	• HORIZON H2020 grants (short term) **Savings:** • Reduction in municipal budget allocated for fuel poverty

Environmental costs	Environmental benefits
• Environmental impact in energy use during retrofitting works (short term) • Rebound effect	• Less energy consumption (emissions of CO2) of households because of energy performance • Production of green energy

Social risks	Social benefits
• Possible increase of privacy concerns by citizens because of monitoring activities and data collection in private spaces • Possible process of gentrification among cities because of an increase in prices of the building stock	• Increase of environmental awareness of citizens • Improvement and increase of the smart social ecosystem development • Better standards of social cohesion among citizens and improvement of their levels of quality of live • Better urban healthiness that reduces health problems of citizens • Reduce of digital divide (access to network and usage of IoT) • Energy poverty • Economic development: job creation, new business opportunities, company's creation and development, etc.

Fig. 8. CMC of Helsinky municipality.

revenue, which Helsinki is considering for future steps, could be fees from the Urban Platform services related to information and data on retrofitting for private suppliers (professionals, SMEs, Energy companies, etc.). However, as is the case in Hamburg, the Urban Platform is conceived as an open source and operates under an open data concept, so the city does not count on it for the time being as a source of revenue. According to the model, social and environmental benefits overcome the negative impacts.

Helsinki, like Nantes Métropole, is guiding its retrofitting project through the one-stop-shop model. Interventions based on smart controls need a great deal of coordination, which, according to Boza-Kiss and Bertoldi (2018), is guaranteed with a customer-centered service building bridges between owners and suppliers. In this case, although the intervention focuses on certain savings through monitoring and evaluation activities, the model does not use savings as a payback to finance retrofitting up-front costs, which are paid completely by owners.

5. Discussion

5.1. General analysis

The three models try to improve the energy efficiency of buildings through multiple measures with a common emphasis on energy cost savings and highlighting urban health and quality of life. The business models for Nantes Métropole and Hamburg correspond to a comprehensive residential retrofitting, whereas Helsinki focuses its retrofitting actions on energy performance because its building stock does not need large-scale renovations.

The value chain of the projected interventions represents a public–private structure. The European Commission and individual municipalities, representing the public sector, promote the interventions; while private sector, such as architects, energy experts, energy companies, construction companies and digital devices, are the suppliers. In general, the composition of stakeholders is quite similar among the business models, and it represents the traditional value chain of the sector, with the exception of involving digital device suppliers (IoT, Big data, Smart home solutions, etc.). One of the main differences among the models is that Helsinki incorporates the owners as stakeholders. In order to engage and include them, Helsinki does a public-private-people partnership (4 P) that aims to provide a framework where mechanisms to address concerns are embedded at different stages of the production and delivery process (Ng et al., 2013). This model incorporates the owners in the process through ongoing and regular discussion groups at a neighborhood/district level. The implementation of 4 P models has already yielded very good results, especially in the Nordic countries such as Finland. A very good example is given in Kuronen et al. (2010), where 4 P provided 75% lower CO_2 emissions than the business-as-usual scenario.

The essence of the value propositions of the business models for the three cities' retrofitting interventions are also quite similar, as are the benefits that are expected. In general terms, all three value propositions mention the two main traditional benefits related to the energy efficiency improvement in buildings: reduction in energy demand and consumption, and energy cost savings for citizens. In fact, as stated in Section 4, Hamburg aims to reduce its demand by 50% and Helsinki by 30% in the interventions areas, which is a path forward to becoming neutral cities. The value propositions also emphasize other important advantages such as the improvement of urban health and quality of life for residents, which implies improved comfort, health, jobs, and the like.

In geographical terms, Hamburg and Helsinki focus the interventions in specific districts of their cities (i.e., Bergedorf and Merihaka/Vilhonvuori, respectively), while Nantes focuses on its whole region, making it much more difficult to establish a clear target in terms of energy consumption. Likewise, having a highly dispersed intervention could result in a potential low-carbon gentrification—a pattern in which energy refurbishments in specific neighborhoods lead to an increase of rental and sales prices, and thus a displacement of residents (Wolff and Weber, 2017; Knuth, 2019).

The type of ownership is important in terms of engagement. Helsinki deals with single ownerships and housing associations, while Nantes Métropole and Hamburg also include multi-property ownership. Usually it is easier to engage individuals with single or multiple property ownerships than housing associations, because the former operate under market rental prices, while the latter operate below-market rental prices but offering affordable rents. The three models highlight the owners' buy-in as a key element to achieving the aim of the interventions. Taking into account that the average cost for retrofitting a dwelling is around 150 to 170 €/m^2 (Kuusk and Kalamees, 2016), it seems obvious that owners' buy-in is mainly related to high up-front costs (Ciulla et al., 2016; and Regnier et al., 2018). However, the transaction costs (Achtnicht and Madlenet, 2014), fear about risk (Webber et al., 2015; and International Energy Agency, 2017), or absence of comprehensive financing systems aligned with the needs (BPIE, 2015) are also important barriers. Additionally, the net present value of these projects is likely to be negative (Mikulić et al., 2016). Public funds, subsidies or other forms of financial support lower the costs of retrofitting works and thus make them more attractive to owners' investment (Achtnicht and Madlener, 2014).

In terms of key activities, the cities identify two main areas beyond owner's engagement: educational and training programs for citizens, and also for technicians and/or operators; and the monitoring and evaluation of activities. The quantification of indicators from economic, environmental and social points of view is unavoidable to validate the viability of retrofitting (Moschetti and Brattebo, 2016). Moreover, the monitoring and evaluation show evidence of direct and indirect impacts that can make the investment in retrofitting attractive (Webber et al., 2015), as well as providing evidence that can be shown to new potential customers.

Regarding key resources and infrastructures, for all three cases, public administration support is fundamental, creating the conditions to scale-up the interventions. Public administration support involves different levels, from local to regional, national, and supranational. These levels have to be aligned in order to develop legal and regulatory frameworks creating fiscal incentives. Concerning infrastructures, our three cities identified the need to link and analyze the data provided by the interventions to the cities' Urban Platforms or concrete data analysis departments. This data infrastructure could help to offer better services to citizens and, of course, make decisions based on reliable and accurate information (Achtnicht and Madlener, 2014).

Finally, the sustainability of the business models focuses on the triple bottom line: cost/revenue, environmental cost/benefits, and social risks/benefits. For the first element, cost/revenue, the business model from Nantes Métropole is the only one that presents high budget costs. It covers up to 70% of Capex costs of retrofitting intervention for specific households' profiles, related to low income. According to Washan et al. (2014), retrofitting programs led and financed by public authorities, in addition to reducing the level of fuel poverty, would deliver a return of 3,20€ in increased GDP and 1.25€ in taxes per each euro invested by governments. As observed, from a classical economic point of view, the Hamburg and Helsinki models are much more balanced than the Nantes because they do not offer any financing scheme.

In terms of environmental costs/benefits, retrofitting activities have a high potential towards a low carbon economy. From the benefits aspect, the business models highlight less energy consumption of households due to optimization and efficiency of the retrofitting interventions and the production of green energy. These benefits are clearly higher than the costs, related to the intensive energy use during retrofitting works (short term) and the possible rebound effect, based on Jevon's paradox. This negative effect has to be accurately controlled through education, training, monitoring and evaluation activities.

Concerning social risks and benefits, the third layer of the triple bottom line, our three models coincide on the benefits, which will be much more evident in the scale-up than in the pilot interventions. The pilot interventions will increase the environmental awareness of owners and citizens about their health, levels of quality of life, and energy poverty -concretely for low-income dwellings. The retrofitting interventions have a direct positive impact on offering living comfort, air quality and safety (Webber et al., 2015; Brown, 2018; and Day et al., 2018). One of the most important benefits is economic development, which brings about creation of unskilled, skilled and professional jobs, new business opportunities, and attractiveness for investment. Another is the reduction of public budget in concrete areas such as fuel poverty or healthcare, since retrofitting projects tend to improve the health of residents over time -especially that of children, people with chronic health problems, and vulnerable groups in general (Maidment et al., 2014).

5.2. Scale-up strategy

Beyond their pilot projects, the main objective of cities is to define a clear strategy to surmount many of the obstacles existing today that prevent the take-up of energy efficiency measures in buildings. The results obtained in Section 4 and the analysis carried out in Subsection 5.1 have been key to identifying the principal aspects/activities of building retrofitting, which could be divided into two main phases. The first of these is for the intervention to be clearly led and developed by cities' governments, and the second entails the strong collaboration of their citizens. Fig. 9 presents the set of activities and its timeline sequence.

In the first phase:

1 Municipalities should offer a clear and efficient customer interface that takes responsibility for the entire retrofitting project, facilitating the owners' daily management from the beginning of the project through its completion.
2 The city council should launch information and training campaigns with the objective of explaining to citizens what benefits and risks these projects present. In addition, the municipality should inform them about the opportunities (economic and technical resources) offered by public administrations.
3 Municipalities and other public administrations should promote through specific regulatory frameworks and fiscal initiatives the Energy Performance Contract (EPC), applied by Energy Saving Companies (ESCOs), where savings are guaranteed. In this contract, the lender captures energy savings and credits them back to property owners based on historic consumption levels (Boza-Kiss et al., 2017).
4 Municipalities should create a precise stakeholders map, identifying all the actors that could participate in retrofitting projects. This list should classify experts, companies, research and technology organizations, social agents, and other public administrations such as regional or state governments.
5 Municipalities should identify those building that are potential targets for retrofitting interventions developing a general diagnosis.

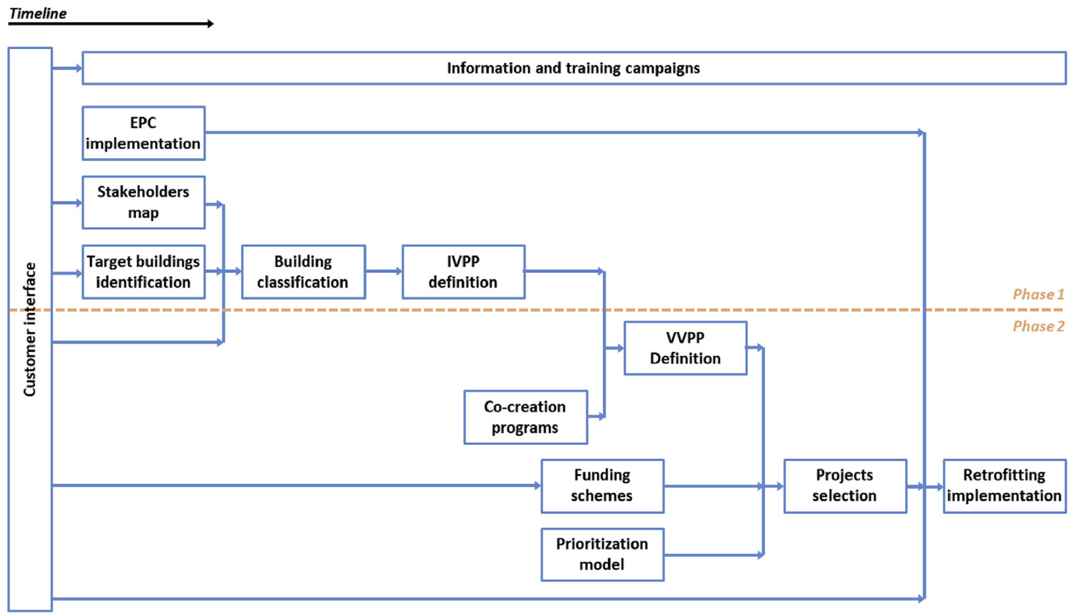

Fig. 9. Retrofitting scale-up general strategy.

Cities' governments should have a broad knowledge of the state of their housing stock.

6 As an essential part of activity 5, municipalities should categorize each building according its owners' socioeconomic status and its architectural (structural) features. These two factors will be key to defining possible interventions.
7 Finally, municipalities and retrofitting experts should define for each potential target building an Ideal Value Proposition Project (IVPP).

In the second phase:

8 Municipalities should develop different co-creation programs for involving citizens in cities' strategy definition. These programs are understood as an intimate form of cooperation and can significantly increase citizens' satisfaction.
9 Taking into account the IVPP, and thanks to co-creation programs, owners, municipalities, and construction companies, working in a public-private-people partnership framework, should define a Viable Value Proposition Project (VVPP) which owners trust and feel comfortable with.
10 Once the different VVPP are defined, municipalities should develop a decision-making methodology for prioritizing and selecting those that they consider strategic for the development of a sustainable city in term of social inclusion, environmental protection and economic viability.
11 Municipalities should offer financing and funding schemes for owners, according to their limited resources and capacities. These schemes are key to de-risk investments and to engage those owners who are willing to retrofit their apartments but lack the resources to do so; concretely this refers to low-income households that cannot afford high up-front costs and long payback periods, or housing associations that offer affordable rental prices.
12 Final project selection and deployment.

6. Conclusions

The analysis presented in this paper serves to reach the following general conclusions: Municipalities need to develop business models to guide their transition from a traditional city to a sustainable one, if they want to promote social inclusion, environmental protection and financial viability. Value Creation Ecosystem (VCE) and City Model Canvas (CMC) are crucial tools for rigorously identifying what cities need in order to create, capture and deliver public value to their residents in a smart and sustainable manner. These two business tools offer the possibility to categorize key aspects in a simple and clear manner in order to implement strategies to scale-up and replicate the interventions in building retrofitting. The comparison of these aspects among lighthouse cities, although it should be taken carefully, allows recognizing common patterns that will surely be fundamental for other cities. Our study of the three cities' interventions shows that the benefits of these actions are greater than the cost of producing them. The interventions cannot be just analyzed in monetary terms, and for this reason the CMC incorporates a triple bottom line. The environmental and social benefits clearly overcome the risks. The results can contribute to a variety of benefits: reducing public budget allocations in other areas such as fuel poverty, engaging citizens, and attracting private investment, among others. Overall, the role of cities is fundamental to the promotion and enlargement of an adequate ecosystem to reach sustainability goals.

The main conclusions in terms just of building retrofitting projects in European cities are the following: The bottleneck for the retrofitting of residential building stock is owner engagement. There are different types of barriers (economic, technical, social and political), but among them the high up-front costs, the security of payback periods of energy efficiency retrofitting projects and the customer experience are key elements that discourage owners. In order to engage owners, the analysis of the three cities' business models has revealed interesting ideas. One of the principal ways to tackle the barriers is the concept of customer interface. The analysis of the VCEs shows the importance of this concept for citizen engagement as well as for the production and delivery of the value of each intervention. Owners must have the customer interface as the main contact point, which is managed just by one organization which offers them the promotion and marketing of retrofitting, the comprehensive project with energy retrofitting experts, and the facilitation of funding and financing schemes. In this regard, the municipality plays an essential role in promoting and organizing activities to inform owners about the process of retrofitting and about companies that offer integrated energy and financing packages. The strategies for the scale-up and replication of the intervention in cities should consider the evolution of their business models towards the ESCO model, which offers, among other aspects, risk sharing schemes and guaranteed savings. In order to increase the retrofitting rate of residential buildings, the public administration could offer funding schemes. This funding is important as an engagement strategy, especially for low-income property owners and residents. Finally, cities should highlight that it is key to include the owners (customers) in the decision-making processes of building retrofitting strategies and interventions, as Helsinki does through utilizing the 4 P approach.

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