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Doctoral thesis

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Abstract

Building energy refurbishment reduces energy consumption by increasing energy efficiency through technical installations. The potential for saving energy is huge, as the building sector accounts for 40% of the total global energy consumption. At the same time, building energy refurbishment often requires different types of partners, such as government institutions, construction companies, financing companies, consulting companies, as well as citizens, to support the investment, construction, and management. To respond to this complexity, partnership models which receive different resources are required. Hence, the overall objective of the thesis is developing a suitable partnership model to promote the building refurbishment market in Norway, thereby reducing the energy consumption, with particular focus on Norway.

However, there is a lack of analyses and comparison studies among the various modes of partnerships, making it difficult to choose the appropriate one for a specific project, which is crucial to its success. Furthermore, there are many residential buildings have low levels of energy efficiency and require refurbishment, which is currently not being done. Therefore, understanding the barriers in building refurbishment for the residentials, investors, and public sectors is important. But there is little information concerning the barriers from each sector's perspective. Finally, there is a lack of analyses about how the existing partnership models promote the market, as well as a suitable partnership model to overcome the barriers in a specific context. In order to solve these problems, the thesis proposes three main research questions (RQ): 1) what are the existing multi-sector partnerships models being given attention by academia and in practice in the context of sustainable energy development, and what are their differences 2) what are the main barriers and solutions for conducting refurbishment from the perspective of people, private, and public sector 3) what is the most suitable partnership model to promote the market, and how to apply and improve it to be more practical to the market.

To answer the main objective and research questions, the research methods applied were literature review, interview, and workshop. The literature review was first conducted to summarize and analyze the history and status of multi-sector partnerships, which can provide a guide when choosing a suitable partnership model. Another review was conducted on the barriers for conducting refurbishment to figure out the barriers from the perspectives of people, private, and public. This can provide a more complete picture of the barriers. A third literature review was applied to figure out the current state of the existing business models in building refurbishment. Interviews were then conducted to verify the barriers found in the literature review, and find potential solutions based on empirical data. After a public-private-people partnership (PPPP) model was proposed to promote the refurbishment market, interviews were also conducted to determine the proposed model's ability to overcome the barriers. Finally, the feasibility of the PPPP model was discussed in a

workshop with representatives from each sector, and the model was improved to be more suitable for application using input from the participants.

Five main modes of multi-sector partnerships were identified, “multi-stakeholder partnership”, ‘public-private partnership’, ‘community-organizational partnerships’, ‘end-user-oriented partnerships’, and ‘public-private-people partnership’. Their differences are explained through four aspects, ‘factors affecting participation’, ‘relationship between participants’, ‘engagement strategy’, as well as ‘influence of participation’. The results of the literature review and the interviews for figuring out the barriers show that the main barriers are financial barriers, lack of information sharing and consulting, risk of not achieving desired benefits, limited resources, knowledge, experience, and lack of trust. Correspondingly, the potential solutions are financial support, an information sharing platform, and guarantees to cover the risks. In addition, the existing business models applied in the building refurbishment were identified and found to have limitations in terms of overcoming the barriers. The public-private-people partnership (PPPP) model was proposed, which has strong potential to overcome these barriers by dividing the high initial costs into more affordable sums, facilitating the information flow among different sectors, and having different resources, knowledge, and experiences from all three sectors to better handle the risks. At the same time, the interviews showed that most of the participants were interested in the PPPP model and would be able to provide the resources needed by the model. Finally, the detailed application of the PPPP model was explained with business model canvas, which developed through the workshop to be more suitable to the real market.

In the discussion section, areas of improvement of the different multi-sector partnership modes are regards as developing a systematic and effective way to classify the factors affecting participation into a structural system, exploring an efficient method to balance the power of different participants in the participation process, and finding an efficient means to make a collaborative agreement. Furthermore, how the PPPP model can overcome the barriers through a co-investment solution, information-sharing platforms, co-creation of the detailed application with PPPP were discussed. At the same time, the limitations of PPPP model, such as being highly time-consuming, the difficulty of engaging citizens, as well as the different communication levels were also mentioned.

A main contribution of the thesis is it identified and compared five modes of multi-sector partnerships, which is the first time in an urban development context. Another main contribution is identifying the barriers for building refurbishment from the angles of public, private, and people perspectives, which provides a fuller picture of the barriers. Most importantly, the thesis is the first to propose public-private-people partnership (PPPP) as a potential model to promote the building refurbishment market. For further study, it is recommended to study the PPPP model from the perspective of different countries. In particular, more information on the barriers and

potential solutions in other countries is needed. Finally, the PPPP model needs to be tested throughout the lifecycle of a real project.

Preface

This thesis is the completion of my three years (09.2018 - 08.2021) of research. The work has been conducted at the Norwegian University of Science and Technology, Faculty of Engineering, Department of Civil and Environmental Engineering, Research Group Building and Construction. My Ph.D. position has been financed by the Department of Civil and Environmental Engineering. The core papers are Paper 1, Paper 2, and Paper 3. In addition to the three core journal papers, one journal paper and two conference papers are the bases for this thesis.

The journey of this Ph.D. topic has been long and complex. As people pay more attention to energy issues, I also realize the importance of energy conservation. I hope my doctoral research should contribute a little to the development of mankind. Because of my bachelor's in architecture and master's degree in urban planning, I chose to research building energy refurbishment in urban areas, of which I have a deep understanding.

When I began studying the data, I found that there were many existing apartments in need of refurbishment. Furthermore, there was much research on figuring out the barriers to building refurbishment, and some of the proposed solutions, but without any systematic way of implementing them. This is possibly due to the barriers being complex and involving multiple disciplines, such as finance, architecture, management, and construction. Partnership models, on the other hand, are a systematic way to combine different resources and knowledge. My supervisors Alenka and Carmel thought it would be possible to use this to form a partnership with different sectors, in order to achieve balanced sustainable urban development. Hence, I started researching partnership models for building energy refurbishment.

I have many hopes for this work. I think it is the hope of all Ph.D. projects that they have a tangible impact on their field, and mine is no different. I hope that it does not stop here and continues to develop beyond the work I have conducted. I also hope that the industry can gain something from this research, particularly in the context of conducting sustainable building energy refurbishment. I hope that the PPPP model can jump out of my thesis and be applied in real life to promote refurbishment. I want this thesis to be a comma, not a full stop.

Acknowledgments

Although there is only one name on the front of this thesis, this project would have been impossible to complete without the help and support of many people over these three years. The research in this project would not have been possible without the cooperation of those I interviewed and the people participating in the workshop. So many people spent much of their valuable time being kind and patient, listening to my ideas and asking questions, providing valuable advice that helped form each step of this project.

I could not have brought this project to completion without the help and support of my supervisors, Alenka and Carmel. They were always there when help me with questions, brainstorm ideas, read my papers, and provide feedback. Thank you to my main supervisor, Alenka. Thank you for taking a chance on me and letting me fulfill my dream to finish a Ph.D. project. Your kindness, patience, and wisdom have left an impact on me that will never go away. You have encouraged me to take on new challenges, responsibilities and most importantly, always encouraged me to believe in my work. Thank you to my co-supervisor, Carmel. You always provided incredibly valuable, deep, and detailed feedback, and always pushed me hard to make me a better scholar.

There are also lots of colleagues who helped me a lot, Bradley, Dave, Zhiyong, Weizhi, Shabnam, Coline, Alla, and more. I was told some time ago that a Ph.D. can be a very lonely experience. I am happy to say that this was never something I ever experienced, as we were a wonderful little Ph.D. community. We have been our own comedians, guidance counselors, and family. We have laughed and cried. We have shared ideas, dreams, and even the odd disaster. We have supported each other's projects, attended each other's hearings and so much more. I will treasure it.

My wonderful family had an incalculable impact on this work, both before and during this project. I want to thank my boyfriend, David. He was supportive of me doing a Ph.D. He has had to tolerate me talking about PPPP and all of the grizzles that sometimes come with it. He has never once complained and possesses a level of understanding I do not possess. I have also valued his wonderful brain giving me advice and listening to my ideas. I could not have done it without you. I want to thank my mother and father, Liping and Ruyong. Throughout this project, they have listened to me, calmed me down, and taken interest in the work I have done. Your love and support have been a keystone of the project for me.

I also want to thank some friends near and far for their patience and support. Of particular mention is Yucheng, Shuaida, Haoge, Chuangxin, Gaohao. It is your encouragement that keeps me moving forward.

Appended papers

Paper I: Yan Xue, Alenka Temeljotov-Salaj, Atle Engebø, and Jardar Lohne, "Multi-sector partnerships in the urban development context: A scoping review," Journal of Cleaner Production, vol. 268. Elsevier Ltd, p. 122291, 20-Sep-2020.

Paper II: Yan Xue, Carmel M. Lindkvist, and Alenka Temeljotov-Salaj, "Barriers and potential solutions to the diffusion of solar photovoltaics from the public-private-people partnership perspective – Case study of Norway," Renewable and Sustainable Energy Reviews, vol. 137, p. 110636, Mar. 2021.

Paper III: Yan Xue, Alenka Temeljotov-Salaj, and Carmel M. Lindkvist, "Business model innovation through public-private-people partnerships for building energy refurbishment," submitted to Energy Research & Social Science journal.

Paper IV: Temeljotov Salaj, Alenka; Gohari, Savis; Senior, Coline; Xue, Yan; Lindkvist, Carmel Margaret. (2020) An interactive tool for citizens' involvement in the sustainable regeneration. Facilities. vol. 38 (11/12).

Paper V: Xue, Yan; Lindkvist, Carmel Margaret; Temeljotov Salaj, Alenka. (2019) Exploring the roles of facility management for liveable cities. Research Papers for the 18th EuroFM Research Symposium EFMC2019 12-15 June 2019 in Dublin, Ireland.

Paper VI: Yan Xue, Atle Engebø, Alenka Temeljotov-Salaj, and Jardar Lohne, Conceptual model for multi-sector participation from facility management perspective. Research Papers for the CIB Conference, June 2019 in Hongkong, China.

Declaration of Authorship

The thesis work is done by the thesis author and is the main author and responsible for the writing of papers, setting up a literature review, interviews, workshop, and analysis of the results for **Paper I**, **paper II**, and **paper III**, which are the core papers for the thesis. **Paper IV**, **paper V**, and **paper VI** are appended to the thesis. For **paper V** and **paper VI**, the author of this thesis had a major contribution in conducting the literature review, analysis of the results, and writing the papers. For **paper IV**, the author was a co-author and had a major contribution in writing the introduction section and discussed part of the results.

Four of the Papers (**I, II, IV, and V**) have been published before the thesis submission and the remaining Paper III has been submitted to the journal of Energy Research & Social Science.

The role of co-authors in the thesis and the appended papers is as follows:

 Carmel as co-supervisor and co-author provided inputs on designing research studies, analysis of the results and organizing of the workshop, reviewing, editing, and proofreading of **Papers II to V**.

 Alenka as the main supervisor and co-author contributed to discussions regarding the results obtained, provided scientific input from her expertise, quality control on the scientific content, and proofreading **Papers I to VI**.

 Atle and Jardar as co-authors in **Paper I and VI** guided the literature review process, supervised the structuring of the research work, and helped review and proofread the papers.

 Savis and Coline as co-authors of **Paper IV** designed the research method, provided inputs on the analysis, and wrote methods, results, discussion, and conclusion of the paper.

Contents

Figures

Tables

List of Abbreviations

RQ Research questions

FM Facility management

PPPP Public-private-people partnership

PPP Public-private partnerships

PV Photovoltaics

TPO Third party ownership

CS Community shared

FIT Feed-in tariffs

BIPV Building integrated photovoltaics

SCI Science Citation Index

SSCI Social Sciences Citation Index

EPC Energy performance contracting

1 Introduction

1.1 Background

Due to the high proportion of the total global energy used in the building sector, building refurbishments have been considered as an efficient approach to reduce energy consumption (Oregi, Hernandez, and Hernandez, 2017). Globally, the final energy consumption of the building sector doubled between 1971 and 2010, and the demand is predicted to grow significantly in the following decades. Buildings will therefore add substantial pressure on the primary energy supply, if further policy action is not taken at a global level to improve their efficiency. In Norway, energy consumption in buildings makes up about 40% of the total energy consumption, and about 47% of the existing residential buildings are more than 50 years old, according to Energy Analysis of the Norwegian Dwelling Stock (Thyholt *et al.*, 2009). Furthermore, scenario analysis has shown that there is great potential for energy saving through renovating these old residential buildings. For example, one analysis estimates that if all residential buildings built before 1990 were upgraded with 10 cm additional insulation in the walls, floors and ceilings, new windows, and improved air-tightness, the energy consumption would be reduced by approximately 12 TWh/year, which is a 25% reduction (Sartori, Jensen Wachenfeldt and Hestnes, 2009). According to this scenario analysis, residential buildings built before 1990 in Norway (about 80% of all the existing buildings) have the potential to be refurbished to reduce energy consumption in various degrees.

To conduct the building energy refurbishment, a wide range of knowledge and resources are needed from multiple fields, such as investment, design, construction, maintenance, consulting, etc. This often requires different types of partners from the public (government) sector, private (for-profit companies) sector, and people (residents) (Mah *et al.*, 2018). The public sector refers to policy-making departments and related institutions supported by the municipalities or the government (Perjo, Fredricsson and Costa, 2016). The private sector refers to private companies involved in building refurbishment projects, such as financing institutions, management companies, supply companies, and consulting companies, and the people refer to residents living in the buildings (Perjo, Fredricsson and Costa, 2016). To address this complexity in the refurbishment process, several researchers propose partnership models as an approach to facilitate cooperation and combine resources from different fields (Thabrew *et al.*, 2009; Robinson and Berkes, 2011).

The benefits of partnership models are demonstrated through achieving sustainable development from three perspectives. First, it can utilize various sectors' resources. In particular, public sectors typically have a better understanding of the existing regulations and have the power to make policies to support urban development (Morsink *et al.*, 2011). Meanwhile, private companies have a good understanding of the market (Kościelniak and Górka, 2016), and residents can provide knowledge about the building environment and their needs (Kahila-Tani *et al.*, 2019). Second, it

facilitates the information flow among different sectors, which results in new co-production of knowledge and forms shared value (Delannon *et al.*, 2016). Both results are crucial for decision-making in sustainable urban development. Finally, it can increase opportunities for urban renewal, as it allows the stakeholders to share the high initial costs of urban development projects, making them more affordable and reducing individual risk (Tang *et al.*, 2018).

Partnership models have also been researched by the urban facility management (FM) discipline (Lindkvist *et al.*, 2021). By definition, FM integrates the people, place and process within the built environment with the purpose of improving the quality of life of people (*ISO 41011:2017 - Facility management*, 2021). More specifically, the main goal of urban FM is to address the needs of the local community and achieve sustainable urban development (*ISO 41011:2017 - Facility management*, 2021). The approach to this is two-fold. First, the FM needs to understand not only the private and public sectors, but also the bottom-up initiatives for understanding the needs of citizens (Roberts, 2004). In fact, the participation of citizens is considered an indispensable part of sustainability as they can provide and discuss current issues and needs related to their living environment, which can lead to social sustainability through balancing community interests and creating shared value (Clarke *et al.*, 2019; Loh *et al.*, 2020; Yigitcanlar, Foth and Kamruzzaman, 2019). Second, urban FM needs to focus on connecting local communities with a multi-sector participation approach through informing, consulting, involving, collaborating, and empowering (Temeljotov Salaj *et al.*, 2020) (Temeljotov Salaj and Lindkvist, 2021). This is because urban sustainable development requires more collaboration and coordination across the different sectors with different knowledge, capacity and capability in response to climate change and resource constraints (Dixon *et al.*, 2014). Therefore, the thesis will attempt to develop a suitable partnership model to promote the building refurbishment in Norway, with attention to understanding the needs of different sectors, citizen engagement in the partnership model, and multi-sector participation approach.

1.2 Statement of the Problem

In the sustainable development areas, there exist different types of multi-sector partnerships, such as public-private partnerships, multi-stakeholder partnerships, and community-organizational partnerships. However, existing studies typically only focus on one kind of partnerships in their project (Liu *et al.* 2016; Young and Brans 2017; Knoeri *et al.*, 2016; Li *et al.*, 2018). There is a lack of analyses and comparison studies among the various modes of partnerships, which makes it difficult to choose an appropriate one for a specific project. In addition, some multi-sector partnership modes have not yet been widely applied, such as public-private-people partnerships and community-organizational partnerships (Ahmed and Ali, 2006; Knoeri *et al.*,

2016; Delannon *et al.*, 2016). Therefore, analyzing the strengths and weaknesses of these modes, as well as proposing improvements, is crucial for further study.

Before choosing a suitable partnership for building refurbishment, the barriers and needs for conducting the refurbishment should be identified. In addition, the different sectors have different concerns about the impact of refurbishment on society, economy, and the environment. The public sector mainly focuses on the achievement of energy goals, the efficiency of incentives, and social acceptance (Shuai *et al.*, 2019), while the private sector tends to focus on the profits, payback time, and risks (Gorjian *et al.*, 2019). The people mainly focus on the loan amount, payback time, as well as financial and environmental benefits (Qureshi, Ullah, and Arentsen, 2017). However, there is a lack of research that describe the barriers and needs from all three sectors, most of them only explain them from one or two sectors. Therefore, the barriers and needs for conducting building refurbishment in Norway to be explored from the perspective of the people, private, and public.

After identifying the main barriers and needs from the people, private, and public sectors, figuring out the corresponding solutions is crucial. However, there is little research on understanding the suggestions from all the three sectors (people, private, and public), most strategies are decided by the governmental sectors. The suggestions for how to overcome the barriers from different sectors are important, because each sector has different goals and concerns. Furthermore, the solutions they propose themselves have a higher potential to be used, as they are more familiar with the barriers.

This thesis aims to develop a suitable partnership model to overcome the identified barriers through their cooperation. In order to apply a partnership model, a business model is needed. A business model describes the rationale of how different sectors creates, delivers, and captures value from an efficient and systematic approach, which can guide the whole process with a specific strategy to conduct the refurbishment business (Osterwalder *et al.*, 2010). However, there is little research that summarizes existing business models for building refurbishment, analyzes advantages and disadvantages in terms of promoting the market or discusses which one is the most suitable business model for building refurbishment.

Furthermore, while many studies attempt to determine the barriers for conducting refurbishment and provide related solutions, most of them only provide suggestions on a theoretical level. Practical testing of the suggestions is limited, such as interviews for understanding the willingness to use, potential difficulties when being applied, potential resources to provide, as well as workshops with participants who have the empirical experience to discuss and improve the detailed application.

1.3 Objectives and Research questions

The overall objective of the thesis is to develop a suitable partnership model to promote the building refurbishment market, with the aim of reducing energy

consumption and achieving more sustainable and balanced development. About 47% of the existing residential buildings in Norway require refurbishment, which is currently not being done (Thyholt *et al.*, 2009). Therefore, building energy refurbishment has the potential to play a vital role in achieving the European Union's energy goals for 2050. In addition, building refurbishment has great potential to promote sustainable development from environmental, financial, and social aspects. It can reduce CO2 emissions from an environmental aspect, reduce electricity bills, maintenance costs, and achieve higher rent or sales prices from the financial aspect, as well as creating job opportunities, satisfying citizens' needs, and creating livable space from the social aspect.

Furthermore, this thesis will attempt to fill the knowledge gaps mentioned in the state of the problem section. For the lack of analyses and comparison studies among the various modes of partnerships, the thesis aims to determine the existing multi-sector partnership models, make a comparative analysis, and identify the most promising areas of improvement. For the shortage of research that explain the barriers and suggestions for overcoming the barriers from different sectors for conducting refurbishment, the thesis will explore the barriers and corresponding suggestions to overcome the barriers for conducting the building refurbishment from people, private, and public perspectives. For the short research on summarizing the existing business models for building refurbishment, this thesis will check the existing business models, analyzing advantages and disadvantages for promoting the market, as well as proposing the most suitable business model for building refurbishment. For the limitation of most research focus on figuring out barriers and provide suggestions from theoretical level, this thesis will check the suggestions from a more practical level, such as interviews with interviewees with deep experience and organize the workshop to test the possibility of the suggestions.

Therefore, this study has three main goals:

- To provide insight into the existing multi-sector partnership models, in order to provide information for choosing a suitable partnership model for building energy refurbishment in Norway.

- To better understand the barriers and propose corresponding solutions for conducting building refurbishment from the perspective of people, private, and public.

- To explore the existing partnership business models in building refurbishment, propose a suitable partnership model for building refurbishment in Norway, as well as test its feasibility and improve it to be more practical.

According to the main objective of the thesis, the aim is to tackle to following research questions:

RQ1: What are the existing multi-sector partnership models being given attention by academia and practice in the context of sustainable energy development, and what are their differences?

RQ2: What are the barriers and solutions for conducting the building refurbishment from the perspective of people, private, and public?

RQ3: What is the most suitable partnership model to promote the building refurbishment market in Norway, and how can be applied and improved to be more suitable in practice?

1.4 Scope of Research

This thesis considers mainly residential buildings with big potential for energy savings through building refurbishment, especially apartment residential buildings. The aim of choosing this type of building is to focus on the resident engagement in the partnership model for the refurbishment process. This type of building is difficult to deal with for refurbishment, as it requires the consent of many residents. However, it also provides a good opportunity to achieve more social sustainability through engaging the residents. In terms of scope for the participants of interviews and workshops, they come from both people, private, and public sectors. Different sectors have different concerns and resources, and the model with the most potential is chosen together by all three sectors.

1.5 Evolution of the project work

The thesis includes three main stages to answer the three research questions. They are identifying the main modes, focuses, and differences among multi-sector partnerships, figuring out the barriers from public, private, people perspectives through literature review and clarifying the results through interviews, as well as proposing a potential partnership model through interviews and improving it through workshop.

The first stage is the literature review for multi-sector partnership models, finally organized to paper I.

Paper I: Yan Xue, Alenka Temeljotov-Salaj, Atle Engebø, Jardar Lohne (2020) 'Multi-sector partnerships in the urban development context: A scoping review', Journal of Cleaner Production. Elsevier, p. 122291. doi: 10.1016/j.jclepro.2020.122291, https://doi.org/10.1016/j.jclepro.2020.122291

The goal of this paper is to identify the main modes, focuses, and differences among multi-sector partnerships, as well as analyzing the most promising areas of improvement in the existing partnership modes in the urban development context. The main research method is a scoping review. Five main modes of multi-sector partnerships were identified. These are 'multi-stakeholder partnership', 'public-private partnership', 'public-private-people partnership', 'community-organizational partnerships, and 'end-user-oriented partnership'. Most of them focus on four aspects,

namely ‘factors affecting participation’, ‘relationship between participants’, ‘engagement strategy’, as well as ‘influence of participation’. The differences of each model were explained, and their advantages and disadvantages were analyzed.

The literature review provides a basis for understanding the differences among these models and choosing a suitable partnership according to the characteristics of a project. In addition, the literature review provides directions for future research on developing the partnership model. These are: studying the factors affecting participation for building energy refurbishment in Norway, figuring out a suitable partnership model to engage different stakeholders and balance their power, as well as exploring the method to reach a collaborative agreement.

Building energy refurbishment is influenced by different stakeholders and their cooperation, and they can be classified into three sectors: public, private, and people (residents) (Mah *et al.*, 2018). Each sector has different concerns when conducting refurbishment. Hence, the second stage is figuring out the barriers and potential solutions both on a theoretical and practical level, from the perspective of people, private, and public sectors. Due to a large amount of possible energy refurbishment measures, we first use PV panel installations as an example for deep analysis of the main barriers and solutions on a theoretical level. The final results are shown in paper II.

Paper II: Y. Xue, C. M. Lindkvist, and A. Temeljotov-Salaj, “Barriers and potential solutions to the diffusion of solar photovoltaics from the public-private-people partnership perspective – Case study of Norway,” *Renewable and Sustainable Energy Reviews*, vol. 137, p. 110636, Mar. 2021.

The results show that the high initial costs of photovoltaics and limited information and awareness of the possible benefits are the main barriers for the people. For the private sector, limited funding and few pilot projects to learn from, as well as risk uncertainty are the main barriers. The main concern in the public sector is the low application of existing incentives. Public-private-people partnerships (PPPP) have a big potential to overcome these barriers by dividing the high initial costs into more affordable sums, facilitating the information flow among different sectors, and involving all three sectors to create new incentives. In addition, Norway is well-suited for PPPP, as the citizens pay much attention to sustainable development, and there is already close collaboration between the public and private sectors in the energy sector. Finally, three concrete solutions using PPPP are proposed: design a co-investment solution, provide information sharing platforms, and co-create new incentives.

To further verify the accuracy of the results of the barriers and potential solutions in an empirical setting, interviews were conducted with participants from the people, private and public sectors. In addition, the interviewees were asked about the feasibility from the following aspects: resources, channels, relationships among different sectors, etc. The main results are shown in 4.2.2. At the same time, the scope

was expanded from photovoltaics to the whole building energy refurbishment from empirical data.

The results of the interviews show that the barriers in Norway are very similar to those found during the literature review and can be classified into three main categories. They are financial problems, information sharing problems, and risk, and uncertainty problems. Furthermore, according to the interviewees, the solutions with the most potential are providing financial support for the initial cost, building an information platform, and promote cooperation between the three sectors to have access to more resources, which can make it easier to handle unforeseen risks. The results illustrate the value of co-creating a PPPP model for refurbishment in terms of solving the existing barriers and its potential to be applied in Norway.

A PPPP model has been considered has the potential to overcome the existing barriers from a theoretical level and been clarified by the interviewees with empirical experience. The third stage is developing the PPPP model to be more suitable for application in Norway. To apply the partnership model, a business model is needed. A business model describes the rationale of how the people, private, and public sectors create, deliver, and capture value from an efficient and systematic approach, which can guide the whole process with a specific strategy to conduct the refurbishment business (Osterwalder *et al.*, 2010). Hence, a novel PPPP business model is proposed and explained using the business model canvas. Then, a workshop with three different groups was organized to develop the PPPP business model to be more suitable to the real market. The results are shown in paper III.

Paper III: Yan Xue, Alenka Temeljotov-Salaj, and Carmel M. Lindkvist, "Business model innovation through public-private-people partnerships for building energy refurbishment," submitted to Energy Research & Social Science journal.

In this stage, a public-private-people partnership (PPPP) business model was proposed and explained using the business model canvas. At the same time, interviews were conducted which showed that the main support could be provided to an extent, and that most of the interviewees were interested in testing the PPPP model. Finally, 15 practitioners and academics participated in a focus group meeting and formed the expert panel. They discussed the detailed application of the model through the business model canvas. The result of the discussions was a revised PPPP business model canvas, modified according to the opinions and ideas of the participants.

1.6 Significance of the Work

With an increased emphasis on balancing social, economic, and environmentally sustainable development in building refurbishment, partnership models, especially with citizen engagement, have been gradually receiving more attention for their use in sustainable development (Xue *et al.*, 2020). This thesis identified and compared five modes of multi-sector partnerships, and determined gaps in the research of each mode, which can provide a basis for further study in this area.

At the same time, a better understanding of the barriers for the people, private, and public sectors and corresponding solutions is a crucial point of consideration. This thesis is the first one to identify them from different perspectives in the context of building refurbishment. The understanding will also result in possibilities to optimize work for further research from a wider perspective involving all three sectors.

Most importantly, the thesis proposed a potential partnership model to overcome the existing barriers for people, private, and public, explained its application in detail from theoretical aspects and developed it based on empirical experience from participants in the study. The combination of theory and practice gives it great potential to promote the building refurbishment market. If the PPPP business model can be used in countries and regions with similar barriers and backgrounds in building refurbishment, it could lead to a significant increase in the refurbishment market, which would contribute greatly to reducing carbon emissions from building sectors towards energy sustainable development.

Overall, the significance of this work is that it offers possibilities for people, private, and the public to co-invest, co-creation, and co-benefit the building refurbishment. It is more attractive to face the needs and demands of themselves with the cooperation resources from different sectors.

1.7 Thesis outline

This thesis is primarily centered around the topic of developing a partnership model for promoting the building energy refurbishment market and consists of three core journal papers. It has seven sections, in addition to the bibliography, appendices, and a preface. This first section introduces the background of the study, the aim of the research, research questions, evolution of the project work of the study, as well as thesis outline. Section 2 presents the theory and background related to the research on this thesis, including multi-sector partnerships, public-private-people partnerships, business model, business model canvas, as well as the background of partnership model applied in different countries. Section 3 discusses the research methodology, specifically the research process and the study design. The main methods used are literature reviews, interviews, and workshops. Section 4 presents the results, and Section 5 contains the discussion of the research. Sector 6 gives the conclusion of the study. Finally, major contributions of the thesis and further research are presented in section 7.

2 Theory

This section will introduce the theory and background behind the three research questions, which provide the basic information to conduct this research.

2.1 Theory related to RQ1

2.1.1 Multi-sector partnerships

Multi-sector partnerships are used to describe the participation of multiple sectors (institutions, agencies, individuals), who share resources towards a common goal in a specific project (Amadi and Abdullah, 2011). The partners must originate from at least two sectors, and the resources are generally financing, knowledge, and people (Pittz and Adler, 2016). Multi-sector partnerships have been built for decades, and their use have seen a large increase in recent years, mainly due to the increasing complexity and diversity in different types of areas (Pittz and Adler, 2016). The basic steps are making people aware of common concerns, choosing and engaging partners, as well as aligning and executing strategies (Warhurst, 2014). The partners are chosen according to the kinds of resources they can provide, as well as their values and interests in the project (Le Ber *et al.*, 2010). The decision-making usually comes from multiple sectors, both when forming the strategy and during execution (Erickson *et al.*, 2017).

Multi-sector partnerships can be used in a wide range of areas requiring cooperation using multiple resources. This thesis focuses on its use in urban development for deep analysis. For multi-sector partnerships, there exist some differences between the urban development area and other areas. First, the nature of the main goal varies. In other areas, multi-sector partnerships could be mainly focusing on business development, technological innovation, or health problems (Chachoua and Whelan, 2019; Bunn *et al.*, 2009; Rowe, 2018), whereas in urban development the main goal is to achieve a balanced development of social, economic and environmental sustainability (Nel, 2017; Foth and Adkinsor, 2005). Second, the scope of the involved sectors is different. More sectors are required in urban development compared to many other areas, due to its complexity and the wide range of knowledge and resources required (Fernandez-Anez *et al.*, 2018). The relevant sectors include urban planning institutions, urban development policy-making institutions, investors, developers, design companies, construction companies, maintenance companies, residents, and so on from the urban space to internal properties (Karatas and El-Rayes, 2015). Third, the involvement and decision-making processes are more difficult to achieve than in other areas due to the citizens' participation in multi-sector partnerships in urban development, which aims to promote social sustainability with a bottom-up approach (Li and de Jong, 2017). The main reasons include the citizens' lack of awareness, information, and related knowledge, whereas, in other areas, most partners are related stakeholders with related resources and knowledge (Swapan, 2016; Erickson *et al.*, 2017).

2.1.1.1 Multi-stakeholder partnership

Multi-stakeholder partnerships is one of the multi-sector partnership models, which was developed based on stakeholder theory introduced by Freeman in 1984. Freeman (1984) identified stakeholders as "any group or individual who can affect, or is affected by, the achievement of the organization's objectives". Therefore, the stakeholders include not only the investors, but also other groups related to the results. Freeman's theory stirred interest in multi-stakeholder partnerships research and orientation (Le Feuvre et al., 2016; Bowen et al., 2017; Bissonnette et al., 2018). The applicable sectors include the following groups: financial institutions, governments, municipalities, management companies, customers, employees, suppliers, environmental institutions, local communities, the media, and others.

2.1.1.2 Community-organizational partnerships

Community-organizational partnerships is another mode of multi-sector partnerships. This mode is used by one or more organizations in projects that are closely related to the community. A community commonly refers to a group of people, whether they are stakeholders, an interest group, or a group of citizens. First, the mode involves influential partners in the community. Then, the initial partners mobilize resources, attempt to improve relationships, promote cooperation, and ultimately achieve community engagement (Esmaeilpoorarabi *et al.*, 2020). Hence, the applicable sectors would commonly include stakeholders, interest groups, or groups of citizens in the same geographic location, with similar interests or within a small club.

2.1.1.3 End-user-oriented partnerships

The end-user-oriented partnership model is widely accepted that the main aspects of sustainable urban development, such as built environment, energy, climate, and urban green infrastructure, are determined by their end-users (Knoeri *et al.*, 2016; Wood *et al.*, 2016; Baldassarre *et al.*, 2017a). Consequently, there has been much research on the topic in recent years. The Legal Information Institute defines "end-user" as: "the person that receives and ultimately uses the good, service, or technology" (*U.S. Code § 8541 - Definitions*, 2019). In the urban development context, end-users typically refer to occupants, visitors, owners, and tenant organizations.

2.1.1.4 Public-private partnerships

Public-private partnerships (PPP), which was defined as " formal cooperation between enterprises, social leaders and local government officials to improve the city" by Perry Davis in 1986 (Davis, 2016). PPP projects are frequently organized by the public sectors, who invite private companies to collaborate through tendering. The public sectors comprise governments, municipalities, and institutions organized by these (Hodge and Greve, 2007), while participants from the private sector are mainly building contractors, planning companies, material providers, and management companies (Roehrich *et al.*, 2014). Most often, the main applicable sectors are government agencies and private-sector companies. The private partners mainly

participate in financing, planning, and managing the projects, while the public partners commonly focus on launching and monitoring the projects.

2.1.1.5 Public-private-people partnerships

The public-private-people partnerships (PPPP) is a direct extension of PPP, in which the citizens are also engaged (Ng *et al.*, 2013). The concept of public-private-people partnership is an emergent approach that highlights the needs for sustainable development through the involvement of public administration, private actors, and citizens in a joint process (Ng, Wong and Wong, 2013). "Public" means government departments, "private" refers to private for-profit enterprises, while "people" represent citizens (Marana, Labaka and Sarriegi, 2018). This public-private-people partnership process framework embraces bottom-up participative strategies, making citizen engagement visible for the co-creation for projects (Ng, Wong and Wong, 2013). It does not only fully utilize the advantages of each partner, but also creates a more open society through negotiation between different sectors.

Within PPPP, the role of the public sector is to supervise and guide the building refurbishment in an environmentally and socially sustainable direction, as well as to provide financial and political support (Perjo, Fredricsson and Costa, 2016). The tasks of the private sector are to execute the building refurbishment, including financing and organizing the projects, designing the refurbishment plans, and constructing and managing the renovated buildings (Marana, Labaka and Sarriegi, 2018). The roles of the people are to provide and discuss their needs and knowledge for refurbishment with the public and private sectors (Ahmed and Ali, 2006).

2.1.1.6 Basic differences among the partnership models with regards to the definition

Table 1 summarizes the basic characteristics between the five modes, listing the concept, author, participants, and the potential impact it can have on urban sustainable development. In the following, the detailed information will be analyzed individually.

Table 1: The basic characteristics of the five modes of multi-sector partnerships.

Modes	Concepts	Reference /year	Participants in urban context	Impact on urban sustainable development
Multi-stakeholder partnerships	Cooperation between any group or individual who can affect, or is affected by, the achievement of the organization's objectives	Freeman (1984)	Financial institutions, municipalities, management companies, customers, employees, suppliers, local communities, the media, and others	Potential to create financial, environmental, and social sustainable development depending on the project focus, through receiving multiple resources and reducing uncertainty and administrative overhead among stakeholders

Community-organizational partnerships	A group of people, whether they are stakeholders, an interest group, or a group of citizens in the same geographic location	Silberberg *et al.* (2011)	Stakeholders, interest groups, or groups of citizens in the same geographic location, with similar interests or within a small club	Creates mainly social sustainable development through balancing community interests and creating shared value
End-user-oriented partnerships	The person that receives and ultimately uses the good, service, or technology	*U.S. Code § 8541 - Definitions* (2019)	Occupants, visitors, owners, and tenants	Suitable for creating financial sustainable development through getting a good understanding of the consumers' desires and values
Public-private partnerships	Formal cooperation between enterprises and local government officials to improve the city	Davis (2016)	Government agencies and private-sector companies	Mainly creates financial and environment sustainable development through combining the political and financial resources from the public sector with the experience and expertise of the private sector
Public-private-people partnerships	A direct extension of public-private partnerships, it adds the "people" to supplement the missing links in the PPP process	Ahmed and Ali (2006)	Government agencies, private-sector companies, and citizens	It can create financial, social, and environment sustainable development through involving all resources from public, private, and people, as well as satisfying their needs

2.2 Background related to RQ2

Before choosing a suitable partnership model, the barriers and background should be identified. Because there are many different types of building refurbishment measures, only one measure is chosen at the initial stage to focus on the barriers.

2.2.1 Background of choosing solar photovoltaics in buildings as an example of the building energy refurbishment measures

The diffusion of solar photovoltaics (PV) is considered a potential method for achieving energy efficiency when conducting the refurbishment (Dubey, Jadhav and Zakirova, 2013). Research has shown that solar energy also has great potential in Norway. Specifically, a recent report found the energy output per square meter of solar in the South of Norway to be comparable to that of Germany (Zaitsev *et al.*, 2016). Furthermore, the cold climate is beneficial for solar energy production, as it prevents PV panels from overheating (Kawajiri, Oozeki and Genchi, 2011). Finally, Norway has a strong silicon industry, which is the main component in PV panels (Multiconsult and Viak Asplan, 2018). There has been a recent increase in installed PV capacity with these advantages, however, the cumulative installed solar photovoltaic capacity was 120 MW at the end of 2019, representing only 4.1% of the total electricity generation in Norway (PVPS Executive Committee Members, 2019). Hence, exploring the barriers to diffuse solar PV in Norway is valuable.

2.2.2 Partnership Models in PV leading countries

For choosing the suitable model, learning how other countries promote their market according to their specific background is crucial. The most used models can be classified into three main patterns based on the ownership aspect for solar PV, namely, the host-owned model, third-party ownership (TPO) model, and community shared (CS) model (Horváth and Szabó, 2018). The host-owned model is the most widely used pattern, where the owner of the building invests in, owns, and uses the generated electricity from the PV panel with support from government incentives (Horváth and Szabó, 2018). The TPO model is a type of private-people partnership, in which a third party (generally a private investment company or a private bank) invests in and owns the PV products, and the citizens pay a renting fee in return for electricity (Hong *et al.*, 2018). The CS model is a form of community partnership, which allows large groups of citizens to invest in solar PV as a community. The investors do not have to be building owners, but will have access to the generated energy as long as they invest in the project (Funkhouser *et al.*, 2015). There are two main types of CS models: crowdfunding and community solar. Crowdfunding is a type of financing model where a large number of people invest and get financial benefits from an organization (Lu, Chang and Lim, 2018). Community Solar is a model for indirectly purchasing energy by leasing or buying PV arrays in a solar plant, which allows multiple participants to directly get energy from the output from solar PV (Funkhouser *et al.*, 2015).

To learn from the PV leading countries, China, USA, Spain, and Sweden were chosen for deep analysis. This not only because they have higher installation capacity, but also because they can represent different social situations. Different measures should be applied according to their contextual background. An analysis has been made on solar PV related policies, financial models, driving sectors, and partnerships from the PV annual report in China (Lv *et al.*, 2018), the USA (Anderson, Feldman and Tinker, 2018), Spain (Donoso, 2018), and Sweden (Johan *et al.*, 2018) (see Table 2).

The policies for promoting solar PV in China include feed-in tariffs (FIT) and building-integrated photovoltaics (BIPV) incentives (Lv *et al.*, 2018). The main driving sector in China is the public sector, which promotes the solar market through FIT policies and organizes large national projects through public-private partnership (PPP) (Lv *et al.*, 2018). There is no main financial model according to the 2019 annual PV report, but the host-owned, TPO, and CS model exits to some extent (Zhang, 2016).

In the USA, there is a diverse mix of policies, including feed-in tariffs, feed-in premium, capital subsidies, green certificates, income tax credits, self-consumption, collective self-consumption, and virtual net-metering (Anderson, Feldman and Tinker, 2018). The driving sectors are both the public and private sectors (Strupeit and Palm, 2016). The incentives from the public sector, such as capital subsidies, feed-in tariffs, and green certificates have developed well since they were established (Anderson, Feldman and Tinker, 2018). Another main driver in the USA is the private sector,

which pushed the development of TPO and greatly promotes PV market development (Strupeit and Palm, 2016). Therefore, the main partnership in the USA is the people-private partnership. The people are also starting to play an important role in promoting the solar PV market through the CS model (Anderson, Feldman and Tinker, 2018).

Table 2: Policies, models, driving sectors, and partnerships for developing solar PV in China, USA, Spain, and Sweden.

Country	Main policies	Main financial models	Main driving sector (s)	Main partnership	References
China	Feed-in tariffs BIPV incentives	There is no main financial model according to the annual PV report in China, but the host-owned, third-party, and community shared model exist to some extent	Public	Public-private partnership	(Lv *et al.*, 2018)
USA	Feed-in tariffs Feed-in premium Capital subsidies Green certificates Income tax credits Self-consumption Collective self-consumption and virtual net- metering	Third-Party Ownership Leasing Community solar Crowdfunding	Private; Public	People-private partnership	(Anderson, Feldman and Tinker, 2018)
Spain	Self-consumption Collective self-consumption and virtual net-metering BIPV incentives Tax Exemption	Third-party ownership Crowdfunding Community solar	Public; People	Community partnership	(Donoso, 2018)
Sweden	Feed-in premium Capital subsidies Green certificates Income tax credits Self-consumption Collective self-consumption and virtual net-metering	Third-party ownership Renting Leasing Crowdfunding Community solar	Public; People	People-private partnership; Community partnership	(Johan *et al.*, 2018)

Spain had the largest annual solar PV installation in the EU in 2019. Their policies mainly aim to promote self-consumption, including the right to sell surplus electricity for at least market value, and no charges for self-consumed energy for installations producing less than 30kW. In addition, TPO of the PV facilities and collective self-consumption and virtual net-metering are allowed, and there are BIPV incentives and tax exemptions (Donoso, 2018). The main driving sectors are the public and people in the form of tendering auctions and a positive attitude towards self-consumption from the citizens (PVPS Executive Committee Members, 2019). This is because of the relatively low price on PV components and high solar irradiation, resulting in self-generated electricity being cheaper than standard electricity from the grid (PVPS

Executive Committee Members, 2019). Citizens can also achieve self-consumption with different models, such as TPO, crowdfunding, and community solar (Donoso, 2018). Community partnership is the main partnership form for solar PV in Spain.

Among the Nordic countries, Sweden, installed the most solar PV in 2019 (287MW), which is more than five times Norway's capacity (TaiyangNews, no date). The main driving sector is the public sector, which provides incentives in the form of feed-in premiums, capital subsidies, green certificates, income tax credits, and allowing for self-consumption and collective self-consumption (Johan *et al.*, 2018). In addition to the public sector, the people in Sweden have a high acceptance of solar PV. In an annual survey, 81 % of respondents wanted more investments in PV in Sweden (PVPS Executive Committee Members, 2019). Due to the positive attitude and existing policies, a wide range of financial models exist, such as host-owned model, TPO, crowdfunding, and community solar. The main partnerships in Sweden include private-people partnerships and community partnerships.

2.2.3 PV development in Norway

Policies and business models played a significant role in PV leading countries, however, they have been less successful in Norway. In Norway, the existing financial incentives, such as feed-in tariff and capital subsidies have been around for about 10 years, however, there has not been any significant increase before 2015 (see Figure 1). In addition, the financial model TPO has hardly been applied. This means that in addition to the policies, providing new suitable models to promote the market like the leading countries are needed to overcome the existing barriers.

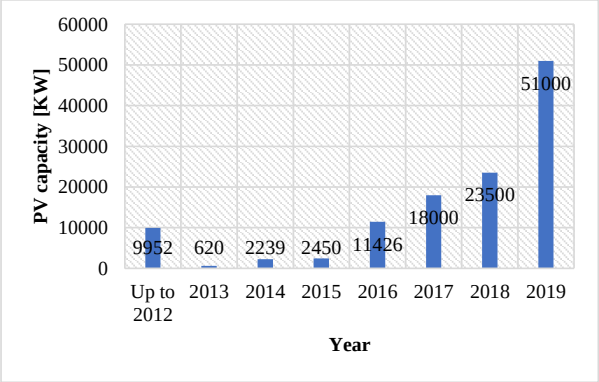

Figure 1: Yearly installed capacity from 2012 to 2019 for solar PV in Norway

(Source: IEA PV annual report for Norway)

In Norway, several attempts from different sectors have been made to encourage the development of solar PV. The main driving sector in Norway is the public with policies to promote solar PV, including electricity certificates, capital subsidies, and self-consumption. For the residential area, the public agency subsidizes up to 35 % of the installation costs for grid-connected residential PV systems at a rate of 10,000

NOK (1 NOK=0.11 USD) per installation and 1,250 NOK per installed kWp up to 15 kWp (International Energy Agency, 2018). Furthermore, self-consumption and the possibility of selling generated surplus electricity back to the grid are other types of incentives provided by the public sector (Holm, 2016). In the private sector, the silicon industry receives much attention (Unamba, 2016). The abundance of raw materials and cheap electricity from hydropower are the basic advantages to develop the silicon industry in Norway (Innovation Norway, 2018). From the investment aspect, some private financial institutions provide support mainly through the TPO to promote the diffusion of the PV system. However, few financial institutions are currently willing to invest (International Energy Agency, 2016). At the same time, some citizens are willing to invest in solar PV. According to an interview conducted by Winther, Westskog, and Sæle(Winther, Westskog and Sæle, 2018), these citizens include people who are interested in being both an investor and consumer for solar PV, have a desire to live in houses with modern technologies and functional automation, and wish to be environmentally friendly. To summarize, the people, private, and public sectors have the potential to invest in solar PV, however, the amount from each of them is limited. Thus, cooperation between all three sectors is needed.

2.3 Theory related to RQ3

To apply the partnership model, a business model is needed.

2.3.1 Business model

The concept of a business model has been explained by researchers from many different angles. Al-Debei and Avison (Al-Debei and Avison, 2010) consider a business model as a tool for conducting business concerning analyzing, designing, and applying a set of business strategies. A business model is also widely accepted as a way to describe the rationale of how an organization creates, delivers, and captures value (Osterwalder *et al.*, 2010). In addition, the development of new business models is regarded as an efficient method to promote the diffusion of sustainable development with existing technologies (Boons and Lüdeke-Freund, 2013).

2.3.2 Business model canvas

Although different types of definitions exist, the Business Model Canvas proposed by Osterwalder *et al* (Osterwalder *et al.*, 2010) has been widely applied for analyzing and designing business models by many researchers through a basic nine-block model (Moschetti and Brattebø, 2016), (Zhao, Hwang and Lu, 2018), (Hora *et al.*, 2016). The nine blocks are 1) key partners, 2) key resources, 3) key activities, 4) value propositions, 5) customer segments, 6) customer relationships, 7) channels, 8) cost structures, and 9) revenue streams. The nine blocks compose four pillars: infrastructure management, product, customer interface, and financial aspects (Figure 2).

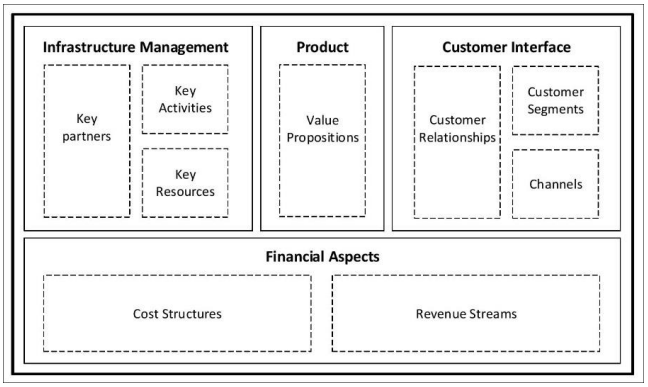

Figure 2: General business model canvas, adapted from (Gabriel and Kirkwood, 2016)

Infrastructure management consists of three blocks: key partners, key resources, and key activities. This pillar describes the partners, the human and physical resources they can offer, and the activities needed to deliver value to the consumers (Osterwalder, 2004), (Gabriel and Kirkwood, 2016). The value proposition is the only block in the product pillar, which is the core of the business model. It defines what types of value the stakeholders will provide to the consumers, and basically explores the customers' problems and needs (Osterwalder, 2004). The customer interface pillar comprises customer segments, channels, and customer relationships. This section defines the target consumers, the channels for communicating, distributing, and selling products or services, as well as establishing and maintaining relationships with consumers (Osterwalder *et al.*, 2010). The financial aspects pillar includes cost structure and revenue streams, which explain how the finances are spent and the return on revenue. (Leitão *et al.*, 2013).

In terms of building refurbishment, the business models have their specific characteristics. After analyzing the existing business models in the building renovation area, some examples are summarized in Table 3.

Table 3: Business Model Canvas explanation and examples in building refurbishment.

Main block	Explanation	Examples in the building refurbishment area	Reference
Key partners	Building refurbishment related participants	Original equipment manufacturers	(Bryant, Straker and Wrigley, 2018)
		Contractors/installers, Products/heating system suppliers, Financial institutions	(Mahapatra *et al.*, 2013)
Key resources	Human and physical resources provided by the building refurbishment stakeholders	Product/project manager, administration and marketing personnel, renovation employees and logistics, distribution network	(Mahapatra *et al.*, 2013)
		Financing	(Bertoldi, Rezessy and Vine, 2006)
Key activities	Activities for conducting the building refurbishment	Manufacturing, installation	(Nußholz *et al.*, 2020)
		Provide support to all partners to help develop awareness and new skills	(Ünal *et al.*, 2019)
		Marketing, building inspection, energy auditing;	(Bertoldi, 2018)

		Gaining approval from local authorities and applying for subsidies;	(Bertoldi, 2018)
		Project management;	(Bertoldi, 2018)
		Renovation work;	(Bertoldi, 2018)
		Post renovation information provision	(Bertoldi, 2018)
Value propositions	Solve building and building environment related problems and needs	Energy saving and efficient, low-cost of electricity	(Bryant, Straker and Wrigley, 2018)
		Functional and safe buildings with reduced environmental impact	(Nußholz *et al.*, 2020), (Würtenberger *et al.*, 2012)
		Indoor air quality, Thermal comfort	(Moschetti *et al.*, 2018)
Customer segments	Customers with different types of problems and needs	Individual building owners	(Bertoldi, Rezessy and Vine, 2006)
		End energy consumers	(Paiho *et al.*, 2015)
		Community owners	(Paiho *et al.*, 2015)
		Public and private building owners, and real estate	(Okkonen and Suhonen, 2010)
Customer relationships	Relationship between building owners and contractors or end-consumers and contractors	Dedicated personal assistance	(Mahapatra *et al.*, 2013)
		Mutual trust and confidence	(Moschetti and Brattebø, 2016)
		Related projects, business relationships	(Würtenberger *et al.*, 2012)
Channels	Create and use channels for information flow, build relationships between consumers and contractors, and products or services sale	Mass media and websites, personal contacts, local meetings	(Mahapatra *et al.*, 2013)
		Inside citizens who have already use the product	(Paiho *et al.*, 2015)
		Information change platform	(Richter, 2012)
Revenue streams	Revenue and cost savings	Energy (electricity, gas, heat) saving	(Bryant, Straker and Wrigley, 2018), (Garbuzova and Madlener, 2012)
		Payments to building developers	(Nußholz *et al.*, 2020)
		National innovation subsidy, free tax	(Puikkonen, 2010)
Cost structures	Costs of building refurbishment throughout the whole process	Operation & maintenance, R&D	(Bryant, Straker and Wrigley, 2018)
		Production and project management	(Nußholz *et al.*, 2020)
		Marketing, salaries, administration and support, travel, subcontracting	(Bertoldi, 2018)

The table explains the nine aspects of the business model canvas in the building refurbishment context, and the examples provide a direction for how to design the business model in building refurbishment projects.

This section introduced the basic theory behind existing partnership models, the applications of the partnership models in different countries, and the concept of a business model, which is a systematic way to apply the partnership model. With this knowledge of the theory related to the research questions, the thesis will explain how the three research questions been conducted through different methods in next section.

3 Methodology

3.1 Ethical Considerations

The interview subjects and participates in the workshop were taken care of adequately. All the interviewees and participants of the workshop were anonymized. The anonymity was crucial to make participants express with better credibility, and to achieve a better understanding without any worries about revealing potentially commercially sensitive data. The names of their companies were also anonymized, mentioning only the type of the company and their main roles in building refurbishment. None of the participants pulled out of the study when presented with how their answers would be published.

Before the interview and workshop, all the respondents were made aware of the nature of their involvement before the study took place. This included informing them that the interviews and workshops were being conducted for a Ph.D. research project, would be recorded, transcribed, and published in a peer-reviewed conference paper or peer-reviewed journal article. All transcripts, both typed and recorded, would be destroyed once the publication process was completed. After the interviews and workshops were completed, the typed transcripts were sent to the interviewees and the recordings destroyed, and a copy of the completed pre-publication article forwarded to them at a later date.

3.2. Research Design

This research used the methods literature review, interview, and workshop.

Research question 1: What are the existing multi-sector partnership models being given attention by academia and practice in the context of sustainable energy development, and what are their differences?

Applied method: Literature review

A literature review of the multi-sector partnership was conducted, aiming to summarize and analyze the history and status of multi-sector partnerships, which can provide guidance when choosing a suitable partnership model.

Research question 2: What are the barriers and solutions for conducting the building refurbishment from the perspective of people, private, and public?

Applied method: Literature review and interview

The literature review about the barriers for conducting refurbishment aimed to identify the barriers from the perspectives of people, private, and public. This can provide a fuller picture based on all three sectors. The scope was first narrowed to one building refurbishment measure, namely the installation of solar PV. There were two reasons for this; first, choosing a single measure can make people focus more on the barriers themselves, instead of focusing on the different measures for building refurbishment. Another reason is that solar PV has the potential to increase the energy supply in

Norway, but the installation of PV panels is limited. Hence, it was necessary to explore the barriers.

After identifying the barriers from a theoretical level, interviews were conducted. The scope was extended to the whole building refurbishment measures to include the common barriers, not just for PV panels. It aims to clarify the barriers identified in the literature review and figure out the potential solutions, as well as testing the possibility to apply the potential models with interviewees who have empirical experience. The interviews can provide narrative and explorative data that explain the barriers clearer and provide detailed suggestions on how to overcome the barriers and adjust the potential model. Furthermore, the interviews produce empirical data specific to the Norwegian context. Finally, according to the interview, the interviewees with resources and high interest in the proposed model can be identified, which can be chosen for the participants for the next stage workshops.

Research question 3: What is the most suitable partnership model to promote the building refurbishment market in Norway, and how can be applied and improved to be more suitable in practice?

Applied method: Literature review, interview, and workshop

Literature review: The existing business models for building refurbishment were identified through literature review and analysis.

Interview: To explore the feasibility of the PPPP model to overcome the barriers, interviews were conducted. At the interview stage, interviewees with rich experience and knowledge were asked about the value of applying the PPPP model, as well as suggestions on how to apply it.

Workshop: Workshops are good choices to test the feasibility of the proposed model, which are considered as an efficient approach for future-oriented study (Wu, 2013). Finally, a workshop with three groups discussed the PPPP business model and improved it to be more suitable for application based on empirical experience.

3.3 Weaknesses associated with this design

The methods applied in the thesis are literature review, interview, and workshops, and are all qualitative methods. This is due to the characteristics of model design and development. However, this leads to a lack of quantitative research. For example, the literature review was not a systematic review of all existing models but focused on the models receiving much attention academically and in practice, as well as figuring out potential areas of improvement. Furthermore, the barriers were identified from the people, private, and public through interviews, with the goal of understanding the detailed information from different sectors through narrative methods to ensure clear and understandable reasons behind the barriers. However, this leads to less quantitative data than methods such as surveys.

Another weakness is the sample size. Due to limited time, 45 interviews were conducted, and 15 people participated in the workshop. The participants in the study may not be representative of the general population, which may lead to a biased result. This weakness is somewhat remedied by including interviewees and participants in the workshop with empirical experience and deep knowledge from all building-related sectors.

3.4 The methods applied in each research question

3.4.1 Research question 1: What are the existing multi-sector partnership models being given attention by academia and practice in the context of sustainable energy development, and what are their differences?

Before undertaking the literature review, a basic guideline was set to ensure the correct direction of the review (see Table 4). The guideline limited the scope, sources, and required information. The scope contains timespan, access, and language, while sources are mainly from Science Direct, Web of Science, and Google Scholar. The required information refers to title, authors, keywords, aim, methodology, results, and recommendation for further study.

Table 4: A scoping review guideline.

Scope	**Sources**	**Required information**
• Timespan: Six months • Access to full-text • Articles in English	• Science Direct • Web of Science • Google Scholar	• Title, author(s), year of publication • Keywords • Aim of the study • Methodology • Results • Recommendation

The relevant studies were identified through a three-step process: The first step involves a structured search in academic databases, the second step uses the snowballing technique and explores the expanded keywords search and the third step narrows the research down to a controllable scope.

First, a structured search

According to the definition of multi-sector partnerships, the keywords “multi-sector partnerships”, “different institutions partnership”, and “multi agencies partnership” were used in the databases of *Web of Science*, *Science Direct* and *Google Scholar*. To limit the research field, relevant results also had to include the terms “urban ecosystem”, “urban development”, or “urban planning”. Furthermore, the year of publishing was limited to the last five years. Thus, the most important and cutting-edge research on this topic could be found. By studying the related articles, some modes related to multi-sector partnerships were identified, such as “stakeholder

partnership", "public participation", "community engagement", and "public-private partnership".

Second, expanded keywords and snowballing search

In order to identify articles that were not found by the structured approach described above, expanded keywords and snowballing searches (Wright and Stein, 2005) were conducted. The research scope was extended by using the newly identified modes of multi-sector partnerships as expanded keywords. At the same time, backward and forward citations tracking of these articles were conducted as a snowballing search.

Third, study selection

When implementing the two steps within the chosen databases, more than 4300 articles emerged. To identify the most relevant literature for the research, the following restrictions were applied:

- Studies before the year 2000 were excluded (important theoretical articles were not excluded). Based on this, relatively new challenges in the related fields could be found.
- Only articles in the *Science Citation Index (SCI)* and *Social Sciences Citation Index (SSCI)* journals were included (important theoretical articles were not excluded). This ensured that studies of relatively high academic value could be found. This step narrowed the study sample to 1300 articles.
- However, a study sample of 1300 articles was still perceived to be too unspecified for providing relevant answers to the research purpose. Therefore, a closer review of these studies was necessary. The titles were assessed, narrowing the number of articles down to 900. The sample was filtered down to 107 studies after assessing the keywords and abstracts.

The whole process is summarized in table 5.

Stage	Process	Number of the identified papers	Method
1. Initial structured search	Search for "multi-sector partnership", "different institutions participation partnership", "multi agencies participation partnership" AND "urban ecosystem", "urban development", and "urban planning"	96	Bibliometric
2. Expanded keywords search	Search for "stakeholder participation partnership", "public participation", "community engagement", and "public-private partnership" AND "urban ecosystem", "urban development", and "urban planning"	2130	Bibliometric
3. Snowballing	Snowballing search of the identified papers before	4300	Bibliometric
4. Filtering	Excluded studies before the year 2000	1300	Bibliometric
5. Specification	Qualitative assessment of title	900	Bibliometric + qualitative assessment of title

6. Selection	Qualitative assessment of title, keywords, and abstract	107	Bibliometric + qualitative assessment of title, keywords, and abstract

Table 5: The scoping process.

3.4.2 Research question 2: What are the barriers and solutions for conducting the building refurbishment from the perspective of people, private, and public?

3.4.2.1 Literature review on the barriers to installation of solar PV

A literature review was conducted to explore the main barriers to building energy refurbishment, using PV installation in Norway as an example. The relevant findings were identified through a three-step process: (1) structured search, (2) snowball-technique search, and (3) narrowing and summarization of the research. Keywords "barriers", "obstacles", "encumbrance" AND "photovoltaics", "solar energy", in Norway were used in the search. The initial search returned little information about the barriers to photovoltaics in Norway. The scope of the keywords was therefore extended to "PV", "photovoltaics panel", and "renewable energy", "solar energy" AND "Norway". The titles and abstracts of these papers were checked for a discussion about barriers. At the same time, a snowballing search (checking backward and forward citation tracking of identified articles (Streeton, Cooke and Campbell, 2004)) was conducted for each identified paper. The source data were mainly from Science Direct, Web of Science, Google Scholar, Scopus, ACM Digital Library, and IEEE Xplore. Information collected included the title, authors, keywords, aim, methodology, results, and recommendations for further study.

3.4.2.2 Interview to confirm the barriers from the literature review and extend the scope to all the building refurbishment measures

(1) The Role of the Researcher

There are three main roles of the researcher for the interviews. First, the researcher should have a good understanding of the answers from the interviewees. Second, although the answers can be drive by the interviewees, the researchers should drive the direction to the topic about the main barriers and solutions for building refurbishment. Third, the researcher needs to not only ensure the questions are answered, but also figure out how the answers will be developed to the highest possible degree.

There also have been a consideration of the bias. First, the knowledge of the researcher will have an influence on the data collection and analysis. Second, the interest of the researcher will also guide the direction of the answers, which may result in unintentionally neglecting other issues. This potential for bias is reduced by using the 'semi-structured' interview format, which also allows the interviewees to guide the directions on the main topic on barriers of the refurbishment market.

(2) Sampling

Interviewees were chosen from the people, private, and public sector, having satisfied some conditions. First, the interviewees from the public sector and private sector had to work in a field related to building refurbishment-related, to ensure a good understanding of the areas. Second, interviewees needed to have a good understanding and experience in the refurbishment market in Norway. This can make it possible to describe the data based on the real market.

The interviewees were found through three main channels. First, emails to familiar professional experts or researchers to ask about building energy refurbishment-related projects and persons, then getting the contact information. Second, contacting well-known building refurbishment companies, financial support institutions, related municipalities, and citizens, asking them for interviews. Third, finding interviewees through academic conferences related to building refurbishment. Furthermore, the study found new interviewees by adopting a snowballing method (Wright and Stein, 2005), asking existing participants about acquaintances interested in or working with building refurbishment. The process is shown in table 6.

Table 6: The interview process for figuring out the barriers for building refurbishment.

Stage	Time	Methods	Participants	Focus
Choosing the interviewees	1st August-30th October 2019	Email, online searching, conference	23	Choosing the refurbishment related citizens, private companies, and municipality
Figuring out the interviewees	1st November-30th December 2019	A snowballing method	51	Figure out the refurbishment related citizens, private companies, and municipality
Conducting the interview	1st January-30th April 2020	Interview	42	Barriers for public, private, and people to conduct the building refurbishment from the real context.

In the first stage for choosing potential interviewees, 23 respondents were identified through email, online searching, and conferences. After applying the snowballing method, a total of 51 respondents were found. Finally, 42 respondents satisfied the conditions.

(3) Interview questions

The study took the form of semi-structured interviews on an individual level. Each interview lasted for about 50minutes. Each of the interviewees was provided with an interview guide at least two days in advance, in order for them to prepare

appropriately. Before the interviewees answered the questions, some basic information was introduced to them, including the doctoral research topic, the potential energy saving when conducting the refurbishment, as well as information on the most used partnerships used in building refurbishment.

The interview guide was organized into the following topics:

- What are the barriers for public, private, and people to conduct the building energy refurbishment?
- What type of support is needed to overcome the barriers, and what type of support can you provide?
- what kinds of solutions have the potential to overcome the existing barriers?

(4) Data collection

All the respondents agreed to an appointment with the researcher to conduct the interview. All the interviews were conducted by video meeting. The majority were conducted during a three-month period. Each interview was initially recorded and transcribed in full within two weeks. The contents were all captured through a combination of recording and transcription. The transcripts were emailed to each of the interviewees with four weeks for tacit acceptance should they not respond to the email. After this date, the recording was destroyed.

(5) Analysis of the findings

After the completion of the interviews, the data analysis process began. The interviews were transcribed, and the answers summarized according to the questions and sector the participant belonged to. Due to restrictions of the academic paper format, not all the information could be included in the final publication. In order to make the best use of the space available, similar opinions were grouped together for analysis. Differing viewpoints which were considered important by the author were also given attention. This made it easier to find the information receiving the most attention and see if there were any substantial differences between different sectors.

Due to the qualitative nature of the data, many quotes were used in the publication and were paraphrased where appropriate. Where there was agreement amongst respondents, detailed summaries were given to ensure that such commonalities were understood by the reader.

(6) Limitations

Sampling: Although the sample was chosen based on strict criteria, which offers important possibilities for richer and higher quality data, this also introduces bias. In addition, the small sample size does negatively impact the validity of the data. A larger sample size of similar types of respondents would have made the results more generalizable. This would however be outside the scope of a doctoral thesis project, as

it is time-consuming to conduct semi-structured interviews with a large number of people.

Country Focus: The interviewees in this study mainly consisted of those based in Norway. The aim of this was to make interviewees provide empirical data according to their experiences from a specific context, since the context can vary greatly from each country. This can make the model have more potential to be applied to the real context in Norway, as the interviewees have a good understanding of the residents here. However, this will lead to a lack of an international view. The validity of this international perspective could have been improved with the inclusion of more countries.

Question form: The type of questions used can also be seen as a limitation. While a semi-structured narrative approach was used to provide a data set that could be investigated in a freer way, the lack of quantitative elements was a disadvantage. A degree of quantitative questioning would have offered possibilities for comparative data sets, while still ensuring that the intended topics were covered. Another limitation was the type of questions used. While attempts were made through drafting and feedback to ensure that questions were worded in a way that was easily understandable, some difficulties did occur. Some of these were due to challenges associated with some respondents speaking English as a second language, however, some were also terminologically based. This was particularly the case with respondents outside academia.

3.4.3 Research question 3: What is the most suitable partnership model to promote the building refurbishment market in Norway, and how can be applied and improved to be more suitable in practice?

3.4.3.1 literature review

To explore the most suitable partnership business model, the existing business models applied in the building refurbishment market were checked through a literature review. After they had been identified, the advantages and disadvantages were analyzed. At the same time, the most suitable model partnership business model was explored from the theoretical level to address the identified barriers for building refurbishment.

3.4.3.2 Interview

In the interviews for understanding the feasibility of the PPPP model, the role of the researcher, sampling, data collection, and analysis of the finding, and limitations are mostly the same as in the interviews for understanding the barriers in section 3.4.2.2.

There are some subtle differences. For the role of the researcher, there was more focus on figuring out the model with the most potential, as well as their feasibility. For selecting the sample for the private and public sectors, in addition to satisfying the conditions, namely working in a building refurbishment-related field and having a good understanding and experience in the refurbishment market in Norway, the

interviewees here also needed to have experience with the model design and application. Most of the interviewees also participated in the interview for the second research question. Finally, 36 interviews were conducted. The interview questions were:

- What do you think is the most suitable partnership model to overcome the main existing barriers for building refurbishment?
- Do you think it is feasible to apply the model?

For the data collection, the interviews were conducted, by video meeting. Most of the interviews were conducted in a period of three months, from 1st March to 30th June 2020. After the transcriptions were complete, the answers were analyzed and classified according to how the model can solve the existing barriers, its feasibility, and the barriers to applying it.

3.4.3.3 Workshop

After identifying the most suitable model from the interviews, a workshop was conducted to test its feasibility as well as improve it. The workshop has its advantages from the following aspects. First, workshops can gather opinions, knowledge, and needs from public sectors, private sectors, and residents, which provides the basic understanding. Second, during the process, participants in the workshop can expose potential problems earlier, which can embrace uncertainties and alternative futures (Nygrén, 2019). Finally, different stakeholders can express their opinions in the process, they can understand each other, negotiating the detailed application of the business model (Geissdoerfer, Bocken and Hultink, 2016).

The participants analyzed the feasibility of each aspect of the business model canvas and together decided which items to add or remove. Finally, a revised version of the originally proposed business model was created. The whole process is shown in table 7.

Table 7: The whole process of the workshop for discussing the PPPP business model.

Stage	Time	Methods	Participants	Focus
Figuring out the interviewees	1st August-30st October 2019	Email, online searching, conference	23	Figure out the refurbishment related citizens, private companies, and municipality
Figuring out the interviewees	1st November-30st December 2019	A snowballing method	51	Figure our the refurbishment related citizens, private companies, and municipality
Conducting the interview	1st January-30st April 2020	Interview	42	Barriers for public, private, and people to conduct the building refurbishment from the real context.

Propose a suitable model	1st May-30st June 2020	Data analysis	9	Propose a suitable model to overcome the identified barriers
Preparing the stage for workshop	1st August-30st August 2020	Meeting presentation	22	Presentations of the barriers from different sectors and the PPPP business model
Workshop	1st September -10st September 2020	Brainstorming	15	Brainstorming about how to overcome barriers
Workshop	11st September -20st September 2020	Present and discuss	15	Present and discuss the business models designed by everyone
Workshop	21st September -30st September 2020	Negotiating	15	Negotiating for the final application of the PPPP

(1) The Role of the Researcher

In the workshop, there were three main roles for the researcher. The first role is choosing the participants. The participants of the workshop are mainly the people who also participated in the interviews. After the interviews were conducted, the interviewees with rich empirical experience with building refurbishment and high interest were invited to participate in a workshop to discuss the feasibility and development of the proposed model. The participants were from the public sector, private sector, and residents.

The second role of the researcher is organizing a meeting to present some basic information before the workshop. The presentation described the needs and resources from different sectors and the information about how to design the business model. Understanding the needs and resources provided a basic focus for developing a suitable business model, and the business model information provided basic guidelines to design the PPPP business model.

The third role of the researcher is organizing the workshop, including coordinating the time, ensuring that each group is as balanced as possible with respect to participants from different sectors, and facilitating discussion along the main direction. Balancing the number of representatives from each sector is important to make each sector have an equal possibility to express their opinions.

(2) Sampling

Representatives from the public and private sectors had to work in a field related to building refurbishment and have a good understanding of the refurbishment market. In addition, the respondents must have a high interest in discussing the PPPP model in the workshop. At the same time, respondents with resources which quite related to the building refurbishment were also chosen.

Finally, participants of the workshop from the public sector included members of a municipal institution for promoting energy sustainable development, the Norwegian state housing bank, and the municipal government. The private sectors included representatives from property, construction, and design companies, as well as

engineering consulting companies, facility management companies, multiple stakeholder organization companies, and energy performance contracting (EPC) companies. They can provide expertise in multiple building refurbishment-related areas, and a mixture of experiences in Norway. The residents were mainly people living in apartment buildings, as the buildings have great potential for building energy refurbishment. They can provide information about the buildings and surrounding environment, as well as their needs.

(3) Case Selection

Karolinerveien community located 2 kilometers far away from the city center in Trondheim (a city in central Norway). The residential area is consisting of seven blocks, with a total of 45 privately owned apartments in each block (a total of 315 apartments). The blocks are built in 1967, which means that the buildings are quite old, and therefore a renovation of the blocks is needed. Although a minor renovation of the blocks has already been carried out, where, among other things, windows and facades were replaced in 1990. Despite this, there is a need for a more extensive renovation of the seven blocks. According to the report of NBBL (the Co-operative Housing Federation of Norway), the building in Karolinerveien has a big potential to save energy through building renovation. The related renovation contains facade rehabilitation with a new façade, insulation of exterior walls with wood wool, floor decks against the basement and roof are insulated, upgrading of balconies, replacement of windows and doors, new ventilation with recycling, new ventilation ducts, heat pump systems. They give a potential saving by different measures showed in Figure 3.

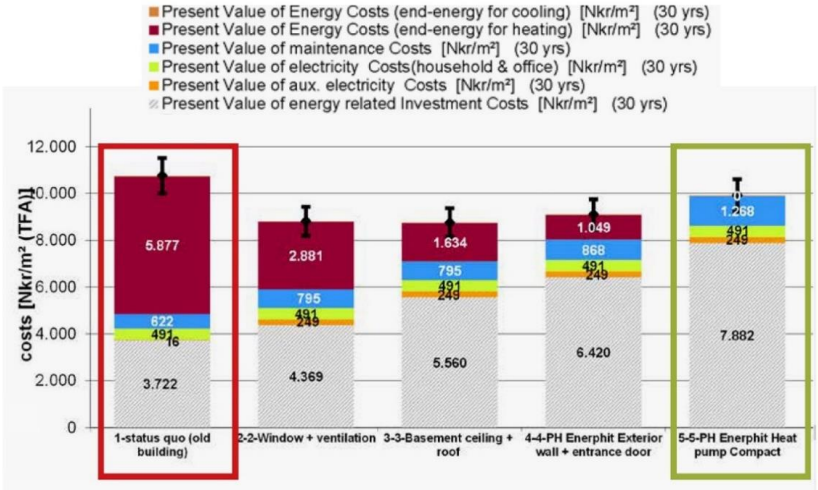

Figure 3: The potential energy saving for the Karolinerveien through different measures according to BJERG

However, there exist many barriers to invest in conducting the refurbishment. This thesis takes this case as an example to try to figure out whether the PPPP model has the potential to be applied in the community. The participants representing the people

sector were mainly from Karonlinerveien, and the workshop discussion will mainly focus on how to overcome the barriers and apply the PPPP in this case. With this case as background, the feasibility of the PPPP business model will be discussed and developed to be more suitable for use.

(4) The discussion about the PPPP business model canvas

The main instrument applied in the workshop is the PPPP business model canvas designed on a theoretical level (Table 8). During the workshop, there was no set speaking order, allowing participants to express their thoughts and ideas freely. At the same time, knowledge from different sectors was shared, which facilitated further discussion. Based on the needs and resources of each sector, participants provided their opinions on how to overcome the barriers, use the resources, and apply the PPPP business model. They analyzed the feasibility of each aspect of the business model canvas and together decided which element to add or remove. Finally, a revised version of the originally proposed business model was created.

Table 8: The originally proposed PPPP business model canvas for building energy refurbishment

Category	People	Private	Public	Reference
Key partners	Citizens with the right to conduct the building refurbishment	Financial private companies	Policy-making institutions	(Alberg Mosgaard, Kerndrup and Riisgaard, 2016), (Jensen *et al.*, 2018), (Jensen and Maslesa, 2015)
	Citizens with interest in investing in building refurbishment	Energy consulting and designing companies	Public financial support organizations	
		The operation, construction, and maintenance companies	Public research organizations	
Key resources	Consumer opinions	Investment capital	Policy consulting services	(Seyfang, 2010), (Stauch and Vuichard, 2019), (Liu *et al.*, 2015)
	Small investor opinions and investment capital	Construct, design, manage and maintain knowledge and experience	Investment capital and support	
	Citizens' needs			
Key activities	Preparation process to understand needs and necessary resources through surveys, interviews			(de Oliveira and Cortimiglia, 2017), (Mortensen, Heiselberg and Knudstrup, 2016), (Zheng *et al.*, 2019), (Osterwalder, 2004)
	Presentation process to understand the energy refurbishment measures and PPPP business model			
	Negotiation of the nine aspects of the business model canvas for detailed application through workshops with representatives from the public, private, and people			
	Apply the business model with co-investment, co-benefits, and risks sharing			
	Build an open innovation platform, different partners can share information and provide consulting			
Value propositions	Citizen oriented service such as mortgage scheme	Increase the service or product sales volume	Contributes to achieving the energy reduction goal by 2050	(Izvercianu, Șeran and Branea, 2014), (Dodoo, Gustavsson and Le Truong, 2018), (Fotino, Calabrese and Lettieri, 2018), (Ferreira,
	Energy saving, reduced electricity bill, comfortable living environment	More opportunities to interact with and build good relationships with local municipalities	Transition from relying on support from the government to a more self-sufficient model	

	Access to participate in decision-making	Opportunity to get professional recognition in the energy saving business	Almeida and Rodrigues, 2017), (Johansen and Emborg, 2018), (Zaborek and Mazur, 2019), (Almarri and Blackwell, 2014), (Ferreira, Almeida and Rodrigues, 2017), (Zaborek and Mazur, 2019), (Kohon, 2018)
Relationships	Personal assistance, co-investment, negotiation, as well as share benefits		(Lovrić and Lovrić, 2018), (Chrisman, 1989), (Vu, Phan and Le, 2018)
Channels	For raising awareness: educational programs, meetings, community events, surveys, web-based engagement, advertisements		(Zhang *et al.*, 2019), (Casais, Fernandes and Sarmento, 2020), (Haavik *et al.*, 2011), (Stamoulis, Kanellis and Martakos, 2002)
	For evaluating performance: online platform consulting		
	For negotiating the application of the PPPP business model: workshops		
Revenue streams	Lower electricity bill	Energy product sales	(Dodoo, Gustavsson and Le Truong, 2018), (Pacudan, 2018), (Pascuas, Paoletti and Lollini, 2017), (Drury *et al.*, 2012), (Streimikiene and Balezentis, 2019), (Pacudan, 2018)
	Revenue from feeding excess energy into the grid	Tax incentives	
	Potential increase in house value		
Cost structures	Build the relationship between different partners		(Xu *et al.*, 2017)
	Build the online platform for information sharing and consulting		
	Organize the workshop, survey, interview, and related activities		

(5) Data Collection

The data collection for this workshop study was conducted between 1st September and 30st September 2020. Eventually, 15 participants joined in the focus group meeting and formed the expert panel. The panel comprised of a wide spectrum of local construction professionals, with 3 from the public sector and government support organizations, 6 from the private sector, 6 from the residents.

The workshop was divided into three groups to gather as many as opinions from the participants, while facilitating discussion. All the groups took about 1 hour and 30 minutes, some participants also have a detailed discussion after the workshop to supply their opinions.

All of the workshop groups were recorded on Microsoft Teams and then transcribed in full. The transcripts were emailed to participants and the recordings destroyed if they did not raise an objection within four weeks

(6) Analysis of the Findings

The results of each group are negotiated to the agreements through discussion. The results already deleted some aspects which most participants think are not useful and left ideas they think are the most crucial points for the application. Groups of answers were arranged together, according to the nine aspects of the business model canvas, as well as the background of the sectors. This allowed for easier comparison and understanding of the differences. In the final publication, quotes were occasionally used to show the answers.

(7) Limitations

Although the participants have rich experience in the Norwegian context, the sample is relatively small, and cannot be considered generalizable. The developed business model can only be tested on a real case in Norway and countries with similar characteristics. The results are still considered to be important to developing the partnership model, which has the potential to promote the market.

This section explained why the methods literature review, interviews, and the workshop were chosen, how the research was conducted step by step, and the limitations of the research methods. In the following section, the result of each research question will be shown.

4 Results

4.1 Results to RQ1: What are the existing multi-sector partnerships models being given attention by academia and practice in the context of sustainable energy development, and what are their differences?

The question was answered in the **paper I**. Following the proposed research questions, the final sample of the literature review is comprised of 107 articles.

4.1.1 The existing partnership models for urban sustainable development

The literature review identified five main modes of multi-sector partnerships, namely:

- Multi-stakeholder partnerships
- Community-organizational partnerships
- End-user-oriented partnerships
- Public-private partnerships
- Public-private-people partnerships

The proportions of the main five modes of multi-sector partnerships in the research sample are shown in Figure 4. 'Multi-stakeholder partnerships' and 'community-organizational partnerships' both represent 32% of the sample, followed by 'end-user-oriented partnerships' with 19% and finally 'public-private partnerships' and 'public-private-people partnerships', which together represent 18%.

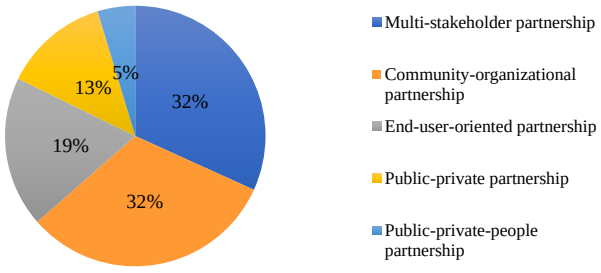

Figure 4: Percentages of different modes of multi-sector partnerships in the sample.

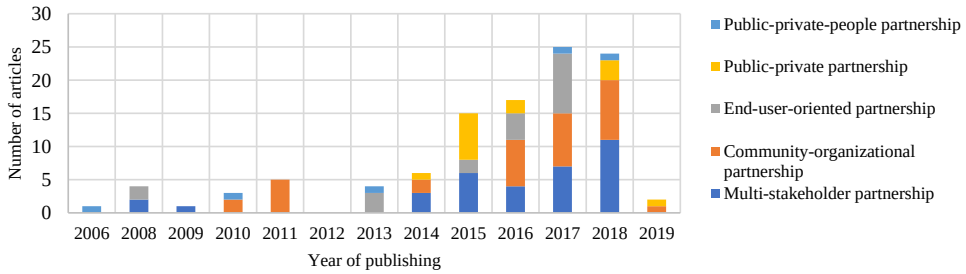

Figure 5: Publishing year of identified articles in the literature review.

Figure 5 shows the publishing year of the identified articles. By observing the number of research articles per year, it can be seen that the modes of multi-sector partnerships in urban sustainable development were not widely developed before 2014. After that, related studies steadily increase until 2018, which suggests that multi-sector partnerships are becoming an increasingly important approach for sustainable urban development. Only 2 articles from 2019 are in the sample, as the database search was conducted in early 2019.

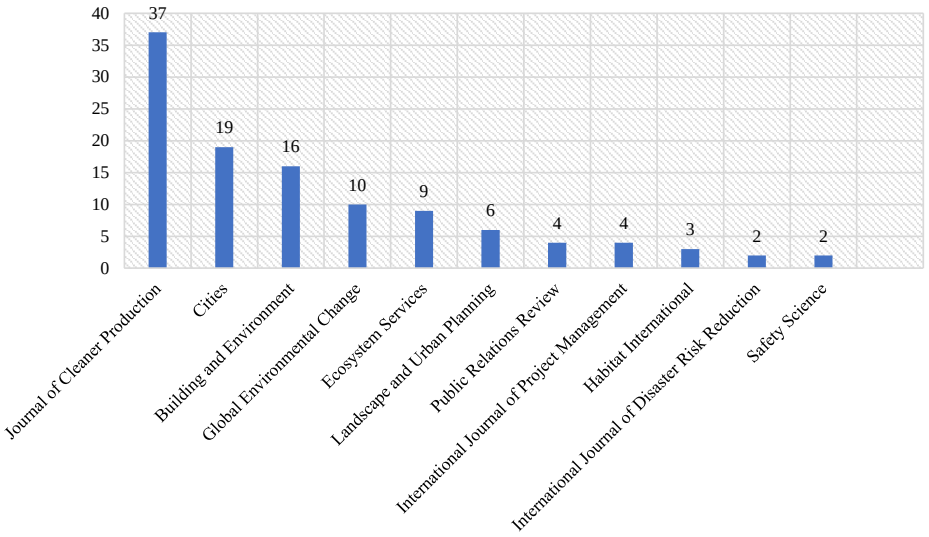

Figure 6: Publishing journals of sample papers in the literature review.

Figure 6 shows the publishing journals of the sample papers. From the figure, we can observe that 37 of the sample articles are published in *The Journal of Cleaner Production*, equaling 33% of the study sample. The journal was found valuable for the further exploration of related research, as it provided a means of identifying interrelated research. Results also show that other journals such as *Cities* and *Building and Environment* have high value for further study. *Cities* represents 16.9% and *Building and Environment* 14.2% of the study sample.

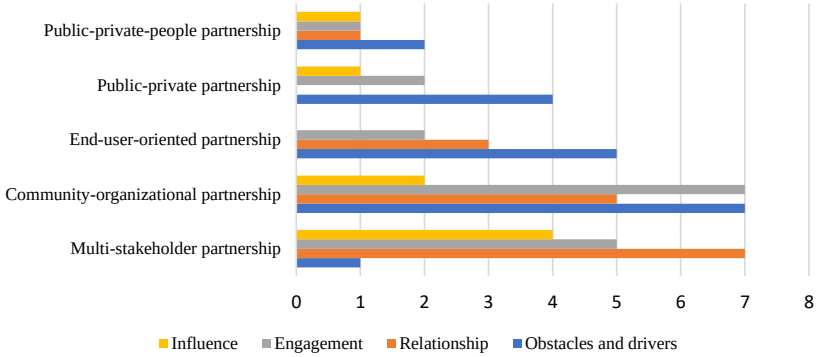

Figure 7: Research focus of articles in each mode.

Figure 7 shows the most frequently used keywords in the sample articles. 'Obstacles and drivers', 'engagement', 'relationship', and 'influence' are the most popular keywords and can help in determining the most important focus of the research.

4.1.2 Differences between various modes of partnerships

The following section corresponds to the second research question, namely searching for differences between the various modes of partnerships. The differences among them will be explained through four main aspects. These are 'engagement', 'relationship', 'barriers and drivers' and 'influence', since they are the most frequently observed keywords in the articles (see Figure 4). At the same time, the theoretical background, corresponding applicable sectors, and methodology of each part will be explored.

4.1.2.1 Multi-stakeholder partnerships (n=34)

The first mode is multi-stakeholder partnerships, which was developed based on stakeholder theory introduced by Freeman in 1984. Freeman (1984) identified stakeholders as "any group or individual who can affect, or is affected by, the achievement of the organization's objectives". Therefore, the stakeholders include not only the investors, but also other groups related to the results. Freeman's theory stirred interest in multi-stakeholder partnerships research and orientation (Le Feuvre et al., 2016; Bowen et al., 2017; Bissonnette et al., 2018). The applicable sectors include the following groups: financial institutions, governments, municipalities, management companies, customers, employees, suppliers, environmental institutions, local communities, the media, and others. The research focuses on the papers on multi-stakeholder partnerships are shown in Table 9.

Table 9: Research focus on multi-stakeholder partnerships.

Research focus	Some criteria/ keywords	Main Methods	Main references	Weight (%)
Barriers and drivers	Obstacles, barriers, baffle, encumbrance, traverse	Data collection and analysis; focus groups	J. F. Bissonnette et al. (2018); Gan et al. (2018)	5.8%
Relationship	Relationship, relation, connection, hypotaxis, affect	Interviews; case studies; network approach; a Delphi approach; semi-structured interviews; matrix approach	Jung et al. (2015); Le Feuvre et al. (2016); Hein et al. (2017); Yang and Bentley (2017);de Chazal et al. (2008); Fernandez-Anez et al. (2018); Yang and Zou (2014)	35.3%

Engagement	Method, way, means of engagement, how to engage	Brainstorming; Q-methodology; interviews, surveys, focus groups; scenario analysis; life cycle assessment approach	Tyl et al. (2015); Alberg Mosgaard et al. (2016); Cousins (2017); Aoki (2018); Ferguson (2017);	29.4%
Influence	Influence, affect, effect, positive influence, value	Literature review; hypotheses; confirmatory factor analysis (SPSS); IBM SPSS statistic; quantitative method	Betts et al. (2015); Hongyang Li and Ng (2018); Thabrew et al. (2009); de Chazal et al.(2008); Wang et al. (2014);	29.4%

In the literature sample, 35% of the articles focus on the theoretical framework, with the intention of developing new conceptual methods of participation in urban development (Bissonnette *et al.*, 2018; Fernandez-Anez *et al.*, 2018; Aoki, 2018). Twenty-five percent of the papers use real case studies, relevant for their respective countries and regions (Jung *et al.*, 2015; Cousins, 2017; Aoki, 2018). Forty percent focus on the application of new methods of stakeholders' participation to urban ecosystem projects, such as the Delphi technique, Q-methodology, network approach and statistical analysis (Yang and Zou, 2014; Alberg Mosgaard *et al.*, 2016; Cousins, 2017; Li and Ng, 2018).

The *relationship* category represents the largest group with 12 papers (35.3%). Specifically, the papers explore the relationship between different stakeholders (de Chazal et al. 2008; Jung et al. 2015; Le Feuvre et al. 2016; Hein et al. 2017; Yang and Bentley 2017) and the relationship between organizers and stakeholders (Fernandez-Anez *et al.*, 2018). In this part, the problem of balancing the stakeholders' power and involvement received much attention in eight articles, through applying innovative models to real projects. At the same time, Hein (2017) attempted to balance the relationship between different stakeholders by analyzing the flow of power and value between them. Ten papers focus on the *engagement* aspect (29.4%), and are mainly concerned with methods of recruitment (Tyl et al. 2015; Alberg Mosgaard *et al.*, 2016; Cousins 2017; Aoki 2018). Several papers underline that the methods of engagement should be chosen according to the participants' values. The *influence* category also includes 10 papers. The studies from Betts *et al*. (2015), Li *et al.* (2018), and Li and S. T. Ng (2018) show that multi-stakeholder partnerships can promote a more sustainable urban development from a social, economic, or environmental aspect. Only two papers (5.8%) discuss the *barriers and drivers*.

4.1.2.2 Community-organizational partnerships (n=34)

Table 10: Research focus in community-organizational partnerships.

Research focus	Some criteria/ keywords	Main Methods	Main references	Weight (%)
Barriers and drivers	Obstacles, barriers, baffle, encumbrance, traverse, longstop, drivers, factors, opportunities	Case study, literature review, regression models, sale & lease-back model, contracting model	Fleiß et al. (2017); León-Fernández et al. (2018); Swapan (2016); Huifeng Li and de Jong (2017); Young and Brans (2017); Bottini (2018)	35.3%
Relationship	Interplay, interactions, effect on each other	Case study, literature review, scenario methods	Robinson and Berkes, (2011); Robinson and Berkes (2011); Boiral et al. (2019)	23.5%
Engagement	Method, way, means for engagement, how to engage	Case study, literature review, interpretive film-based approach, retrospective and real-time analysis	Delannon et al. (2016); Ranger et al. (2016); Gold, Muthuri, and Reiner (2018); Hu (2018)	29.4%
Influence	Influence, affect, effect, positive influence, value	Interviews, one-on-one discussions with relevant stakeholders, focused group discussions, documentary review	Kithiia and Dowling (2010); Robinson and Berkes (2011)	17.6%

Community-organizational partnerships is another mode of multi-sector partnerships. This mode is used by one or more organizations in projects that are closely related to the community. A community commonly refers to a group of people, whether they are stakeholders, an interest group, or a group of citizens. First, the mode involves influential partners in the community. Then, the initial partners mobilize resources, attempt to improve relationships, promote cooperation, and ultimately achieve community engagement (Esmaeilpoorarabi *et al.*, 2020). Hence, the applicable sectors would commonly include stakeholders, interest groups, or groups of citizens in the same geographic location, with similar interests or within a small club.

The research focus on community-organizational partnerships is shown in Table 4. The number of identified articles is the same as in multi-stakeholder partnerships. Twenty-three percent of the papers focus on the theoretical framework, while the remaining papers explore the development of community-organizational partnerships with real case studies. Because characteristics of communities vary greatly with different locations and different cultures, the related research is specific to different regions, such as Kenya (Kithiia and Dowling, 2010), Canada (Delannon *et al.*, 2016),

Mexico (Balslev Clausen and Gyimóthy, 2016), and China (Jiang *et al.*, 2013). The *barriers and drivers* category represents the largest category with 35.3%, while the *engagement* group accounts for 29.4%, followed by research on the *relationship* which represents 23.5%, and finally the *influence* category with 17.6%. The key objective of the research in this cluster is identifying the barriers and drivers and finding efficient methods of engaging the community in an urban ecosystem.

The sample suggests that the main *barriers and drivers* for community engagement are financial value and trust. Specifically, five articles emphasize the importance of financial value and three papers focus on the trust factor for engagement (Fleiß et al. , 2017; León-Fernández et al. , 2018; Swapan, 2016; Huifeng Li and de Jong, 2017). In addition to the financial value and trust, the geographical location and inclusiveness of decision-making were also considered important factors for engagement (Bottini, 2018; Young and Brans, 2017). In the *engagement* category, the main focus is on engagement approaches. Delannon *et al.* (2016) argued that information sharing, community consulting, corporate community joint initiatives, and community relations managers' participation are efficient methods of engagement. At the same time, Ranger *et al.* (2016) showed that knowledge sharing, social learning, and deep communication play crucial roles in the recruitment process. The *relationship* category consists of the interactions between the organization and the community and the interaction among different participants in the community. In particular, Robinson and Berkes (2011) proposed that multi-level participation is necessary to increase the interaction between the organization and the community, as the different levels have more potential to adapt to the real situation. Furthermore, social factors such as the level of authority, trust, and social support were shown to affect the interaction between participants (Boiral *et al.*, 2019). The *influence* group mainly focuses on the impact of community-organizational partnerships on urban ecosystem change. For example, Kithiia and Dowling (2010) used interviews, focused group discussions, and a climate report review to show that community-organizational partnerships can lead to reduced CO2 emissions.

4.1.2.3 End-user-oriented partnerships (n=20)

Table 11: Research focus on end-user-oriented partnerships.

Research focus	Some criteria/ keywords	Main Methods	Main references	Weight (%)
Barriers and drivers	Obstacles, barriers, baffle, encumbrance, traverse, longstop, drivers, factors, opportunities	Meta-analysis, literature review, snowball sampling, descriptive analysis	Beal et al. (2013); Knoeri et al. (2016); Nielsen et al. (2016); Bigerna et al. (2017)	45%
Relationship	Interplay, interactions, effect on each other	Game mode, case study	Qian et al. (2015); Heiskanen et al. (2013)	30%

Engagement	Method, way, means for engagement, how to engage	Design methodology, quantitative kano analysis, End-of-Life (EoL) scenarios	Baldassarre et al. (2017); Atlason et al. (2017)	20%
Influence	Influence, affect, effect, positive influence, value	Case study	Zimmerling et al. (2017)	5%

The third mode is the end-user-oriented partnerships. It is widely accepted that the main aspects of sustainable urban development, such as built environment, energy, climate, and urban green infrastructure, are determined by their end-users (Knoeri *et al.*, 2016; Wood *et al.*, 2016; Baldassarre *et al.*, 2017a). Consequently, there has been much research on the topic in recent years. The Legal Information Institute defines "end-user" as: "the person that receives and ultimately uses the good, service, or technology" (*U.S. Code § 8541 - Definitions*, 2019). In the urban development context, end-users typically refer to occupants, visitors, owners and tenant organizations.

Twenty articles were identified and classified according to the research focus given in Table 5. Eight papers focus on the theoretical framework, with literature review as the main method, while the remaining twelve papers conduct case studies to answer their questions. The table shows that the *barriers and drivers* category represents 45% of the papers, followed by the *relationship* and *engagement* groups which account for 30% and 20%, respectively. Only 5% of articles discuss the influence of end-user-oriented partnerships.

In the *barriers and drivers* category, financial means, knowledge sharing, and technologies used for communication represent the main factors for end-user-oriented partnerships (Beal *et al.*, 2013; Knoeri *et al.*, 2016; Nielsen *et al*., 2016; Bigerna *et al.*, 2017) The *relationship* category mainly focuses on the relationship between end-users and developers, as well as the relationship between end-users and practitioners (Qian *et al.*, 2015; Heiskanen *et al.*, 2013). The *engagement* category mainly explores strategies for joining different types of end-users. For example, Baldassarre et al. (2017) developed a framework for collecting information for making a value proposition, which is related to business models. One article discusses the *influence* of end-user-oriented partnerships. In a case study of three European firms, Zimmerling *et al.* (2017) claimed that constant end-user integration helps companies overcome risks, and brings new opportunities to the market.

4.1.2.4 Public-Private partnerships (n= 14)

Table 12: Research focus in public-private partnerships.

Research focus	Some criteria/ keywords	Main Methods	Main references	Weight (%)
Application	Institution, policy, incentives	Literature review, cross-case analysis, qualitative studies, multi-layered approach	Chou et al (2015); Zhang et al (2015); Liang et al. (2019); Almarri and Blackwell (2014)	57.1%
Barriers and drivers	Application, adoption, appliance	Systematic literature reviews, questionnaires, surveys	Osei-Kyei and Chan (2015); T. Liu et al. (2016).	14.3%
Risks	Risks, hazard	Statistical analysis	Keers and van Fenema (2018); De Schepperv et al. (2015)	28.6%

The fourth mode is the public-private partnerships (PPP), which was defined as " formal cooperation between enterprises, social leaders and local government officials to improve the city" by Perry Davis in 1986 (Davis, 2016). Most often, the main applicable sectors are government agencies and private-sector companies. The private partners mainly participate in financing, planning, and managing the projects, while the public partners commonly focus on launching and monitoring the projects.

Among the identified modes of multi-sector partnerships, PPP is the only one not directly involving citizens. However, according to Arnstein (1969), including the citizens in decision-making is crucial for attaining sustainable social development. Hence, only 14 articles concerning PPP projects were chosen. Table 6 shows the research focus on public-private partnerships. PPP papers are classified slightly differently than the other multi-sector partnerships modes: It is relatively mature, and engagement and barriers are no longer considered main issues. This is very different from the other modes, where citizen engagement is one of the main challenges. Instead, there is much more focus on the application of PPP and its risks.

Eight papers discuss the *application* of PPP, mainly focusing on governmental institutions and policies (Chou *et al*, 2015; Zhang *et al*, 2015). In addition, the negotiation between the public and private sectors has also received much attention (Almarri and Blackwell, 2014; Liang *et al*., 2019). Four of the papers focus on the risks related to PPP. The PPP projects generally require a high up-front investment, which makes risk assessment very important (Keers and van Fenema, 2018; De Schepper *et al.*, 2015). Two of the papers pay attention to the barriers and drivers of PPP. The factors with higher impact were considered to be benefits and risks sharing,

institutional support, community support, stable economic environment, and information sharing (Osei-Kyei and Chan, 2015; Liu *et al.*, 2016).

4.1.2.5 Public-Private-People Partnerships (n=5)

Table 13: Research focus in Public-Private-People partnership

Research focus	Some criteria/ keywords	Main Methods	References	Weight (%)
Barriers and drivers	Obstacles, barriers, baffle, encumbrance, traverse, longstop, drivers, factors, opportunities	Literature review, semi-structured questionnaires, observation	Marana, Labaka, and Sarriegi (2018); Ahmed and Ali (2006)	40%
Engagement	Method, way, means for engagement, how to engage	Literature review, case study	Ng et al. (2013)	20%
Relationship	Interplay, interactions, effect on each other	Data analysis and synthesis	Fontainha (2017)	20%
Influence	Influence, affect, effect, positive influence, value	Literature review, case study	Kuronen et al. (2010)	20%

The last mode of multi-sector partnerships is public-private-people partnerships. A direct extension of public-private partnerships, it adds the "people" to supplement the missing links in the PPP process (Ahmed and Ali, 2006). In this model, "public" means government departments, "private" refers to private for-profit enterprises, while "people" represent citizens. The participation of the people makes the existing cooperation more diverse and realistic, thus considering the social aspect, which brings it closer to the complexity of real urban ecosystems (Nunbogu *et al.*, 2018). In the process of participation, the roles of the public, private, and people are usually facilitators, providers, and end-users, respectively. Different participating entities provide assets or services according to their own characteristics.

After extensive searching, only five related articles were identified and classified by research focus, given in Table 7. Results show that the *barriers and drivers* and *engagement* groups account for 60%. Hence, the key objective of the research is to explore more efficient methods for improving the application of PPPP. In the sample, four papers develop a theoretical framework or model and one paper is a combination of a literature review and case studies.

Forty percent of the articles focus on the *barriers and drivers* for PPPP. Marana *et al.* (2018) developed a framework exploring the successful characteristics of public-private-people partnerships in the resilience-building process. Good relationships among partners, unobstructed information flow, and efficient methods for solving conflicts were considered as main drivers for PPPP. Conversely, the obstacles against

PPPP identified by Ahmed and Ali (2006) are the costs of facilitation, urban services, and feedback mechanisms by case studies. The *engagement* is another important aspect of PPPP that concerns ways of building an optimal process, involving all the partners at different stages. The *relationship* and *influence* accounts for a small percentage (Fontainha, 2017; Kuronen *et al.*, 2010).

4.2 Results to RQ2: What are the barriers and solutions for conducting the building refurbishment from the perspective of people, private, and public?

The barriers were first identified through the literature review, which focuses on the installation of solar PV as one of the building refurbishment measures. After identifying the barriers from a theoretical level, the research conducted the interviews to clarify the barriers and explore the potential solutions with interviewees with empirical experience. At the same time, the scope was extended to the whole building refurbishment measures to make sure the common characters. Therefore, the results of this research are shown in two parts.

4.2.1 Barriers for diffusion solar PV- as an example of a solution for refurbishment

There are many types of barriers before, during, and after the process of installing PV panels. This thesis focuses on the main non-technical barriers, which receive much attention from the majority of research on the diffusion of solar PV in residential areas in Norway. Table 14 shows an overview of the barriers, categorized according to sectors.

Table 14: Main barriers for people, private, and public sectors for installing solar PV.

Sector	Main barriers	Reference
People	High initial cost, as well as limited financial support	(Zaitsev *et al.*, 2016) (Multiconsult and Viak Asplan, 2018) (Sæle and Cherry, 2017) (Halvorsen *et al.*, 2011)(Kvalbein and Marstein, 2018)(Westskog *et al.*, 2018)
	Satisfaction with the current electricity system	(Sæle and Cherry, 2017) (Halvorsen *et al.*, 2011) (Hilsen, 2015)
	Limited information and awareness of the possible benefits	(Zaitsev *et al.*, 2016) (Multiconsult and Viak Asplan, 2018) (Sæle and Cherry, 2017) (Halvorsen *et al.*, 2011) (Westskog *et al.*, 2018) (Hilsen, 2015)
	Uncertainty	(Zaitsev *et al.*, 2016) (Sæle and Cherry, 2017) (Halvorsen *et al.*, 2011) (Westskog *et al.*, 2018)
Private	Limited access to capital	(Zaitsev *et al.*, 2016) (Multiconsult and Viak Asplan, 2018) (Westskog *et al.*, 2018) (Merlet and Ruud, 2014)
	Limited PV project examples	(Merlet and Ruud, 2014) (Solenergiklyngen, 2016)
	Uncertainty surrounding risks	(Zaitsev *et al.*, 2016) (Multiconsult and Viak Asplan, 2018) (Westskog

		et al., 2018) (Merlet and Ruud, 2014) (Solenergiklyngen, 2016) (Zaitsev *et al.*, 2016) (Multiconsult and Viak Asplan, 2018) (Merlet and Ruud, 2014)
	Lack of communication among different stakeholders	(Solenergiklyngen, 2016)
Public	Lack of efficient incentives	(Multiconsult and Viak Asplan, 2018) (Westskog *et al.*, 2018)

4.2.1.1 Barriers from the people's perspective

From the people's perspective, the barriers mainly come from four aspects, namely high initial cost, satisfaction with the current electricity system, limited information surrounding the possible benefits, and uncertainty.

(1) High initial cost, as well as limited financial support

In a survey on solar PV answered by 803 residents in Norway, 34.6% stated the high cost as the main barrier for diffusing solar PV (Sæle and Cherry, 2017). In Norway, the PV panel covered rooftop of a typical residential house can produce between 5-10 kW, while the current prices are about 15 NOK (1 NOK=0.11 USD) per W for grid-connected PV panels (Holm, 2016). This means that the typical investment for one house is about 75,000-150,000 NOK. The public support institution Enova covers 10-30% of the cost for citizens, however, they will still need to pay approximately 50,000-105,000 NOK for installing PVs on one house (International Energy Agency, 2018). Furthermore, since residents often already have a home mortgage (Holm, 2016), it is difficult for them to increase their loan amount according to their payback ability.

(2) Satisfaction with the current electricity system

Many residents in Norway are satisfied with the current price of electricity bills due to hydropower (Glachant, 2004), (*Norway's usually cheap energy as costly as Germany's in Q3-regulator - Reuters*, no date). In addition, hydropower is renewable and produces enough energy for the gross domestic electricity consumption (International Energy Agency, 2018), and some citizens believe that there is no need to invest in other types of energy (Hilsen, 2015). A study shows that 60% of the citizens have a very positive attitude towards hydropower while 35% have a somewhat positive attitude (Karlstrøm and Ryghaug, 2014). However, the main attitude towards solar PV is lack of interest, and 73% of the citizens would not consider installing PV panels (Sæle and Cherry, 2017). As more wind power plants have been installed in recent years, the attitude towards wind power in Norway has gradually worsened. According to a recent survey, 15 % were somewhat negative towards wind power, and 28 % were very negative (Norwegian Broadcasting Corporation, no date). This is because citizens think the windmills ruin the natural scenery and interferes with local wildlife (Norwegian Broadcasting Corporation, no date).

(3) Limited information and awareness

Many residents know little about the possible benefits of installing PV panels due to the limited number of PV projects and information sharing in Norway (Zaitsev *et al.*, 2016). Reliable information about financial costs and benefits, electricity output, related incentives, and potential benefits to the environment is not easy to find from Norwegian projects (Multiconsult and Viak Asplan, 2018), (Sæle and Cherry, 2017), (Halvorsen *et al.*, 2011), (Westskog *et al.*, 2018), (Hilsen, 2015). Furthermore, citizens lack information about the installation process, such as the suitability of the house and the length of time for the installation (Hilsen, 2015).

(4) Uncertainty

There are different types of uncertainty in the process of installing PV panels, which hinder the citizens' willingness to invest. First, residents are not sure about the energy output of PV in Norway, because the duration of sunshine is very short in the winter (Halvorsen *et al.*, 2011). Second, the development of PV panels is still in its early stages in Norway, which leads to uncertainty around the future policies and regulations on PV panels, as well as its long term benefits (Westskog *et al.*, 2018). Third, citizens worry about uncertainty and potential unforeseen costs in the process (Sæle and Cherry, 2017).

4.2.1.2 Barriers from the private sector's perspective

The solar PV private sector in this thesis includes PV developers, financial institutions, construction companies, consulting companies, and PV suppliers. These companies can have either one or several roles, such as construction, consulting, financing, developing, and providing energy products.

(5) Limited access to capital

The main problem for private companies is limited access to capital. Although there is some financial support from the public sector from state-owned enterprises like Enova, funding is still limited to 35% of the initial cost for installing solar PV (Energi 21, 2013). Furthermore, only a few financial institutions willing to invest in solar PV in Norway due to the high up-front investment and uncertainty around achieved electricity output (Merlet and Ruud, 2014). In addition, the long payback period (usually 25-30 years) discourages investors who look forward to getting money back as soon as possible, as the capital flow and risk guarantees are very important for businesses (Multiconsult and Viak Asplan, 2018).

(6) Limited pilot PV projects

The annual installed capacity for solar PV in Norway constitutes less than 0.25% of the global market (Klitkou and Coenen, 2013), with an installation of 23.5MW in 2018 (Westgaard, 2018). According to a report by Multiconsult, a Norwegian consulting firm, there are few pilot PV projects in the country to learn from (Merlet and Ruud, 2014). Limited projects lead to limited opportunities for the industry to learn and develop skills which means that projects are reliant on the expertise of a few

individuals may be expensive and difficult to access. Data on PV panel performance, project costs, and benefits gained from existing projects are the basic foundations needed before investing for private companies. However, the reality of limited projects to obtain in Norway leads to a large uncertainty (Unamba, 2016), as well as limited experience, knowledge, and solutions on PV development.

(7) Uncertainty surrounding risks

The uncertainty surrounding the risks of investing in solar PV mainly stems from three aspects. First, many investors, including those already involved in a PV project, are not sure how much electricity they will generate (Westskog *et al.*, 2018). Second, they are not sure about the payback and whether they can find solutions to deal with unforeseen events, such as lower electrical output than anticipated, throughout the whole process (Solenergiklyngen, 2016), (Azmi, Kohle and Imenes, 2013). Third, private companies are not sure how future policies will affect them because the PV market is still in its early stages in Norway, and the policies and regulations are still changing (Merlet and Ruud, 2014).

(8) Lack of communication among different stakeholders

Communication between different types of actors, such as financial institutions, construction companies, consulting companies, energy companies, skilled workers, and consumers, is required for the development of PV. The reason is that acceptance, understanding, and knowledge transfer are key factors to the diffusion of PV panels early on, which needs to be achieved through communication (Goldschmidt, Richter and Pfeil, 2019). However, most actors do not communicate enough and do not know how to transfer their knowledge efficiently (Merlet and Ruud, 2014). Furthermore, for projects with large volumes of information, lack of communication can lead to failure (Goldschmidt, Richter and Pfeil, 2019).

4.2.1.3 Barriers from the public sector's perspective

(9) Lack of efficient incentives

The Norwegian authorities lack efficient financial incentives to promote the PV market (Westskog *et al.*, 2018). The existing incentives include a capital subsidy for the initial cost, the right to self-consume, the right to revenues from excess PV electricity injected into the grid, an average loan rate of 3%, as well as a green certificate (Holm, 2016). However, the initial cost of about 50,000-10,5000 NOK is still high for residents even with the 10-30% capital subsidy. The average loan rate for PV is 3%, similar to the property loan interest, and the green certificate requires a minimum investment of NOK 15,000 (1,620 USD) in solar PV, which makes it difficult to get support for small systems (Holm, 2016). One reason for the low support is that there are conservative politicians with limited knowledge on solar PV, who are unwilling to invest in solar (Multiconsult and Viak Asplan, 2018).

The results show that many of the barriers of diffusing solar PV in Norway are general and somewhat applicable to many other countries as well, such as high initial cost, limited information and awareness of the possible benefits, uncertainty among people regarding the achieved output, limited access to capital, uncertainty surrounding risks, and lack of communication among different stakeholders. At the same time, there are barriers in Norway which differ from other countries, such as limited financial support policies and models, satisfaction with the current electricity output from hydropower, the uncertainty of the solar irradiation and energy output due to the latitude in Norway, limited pilot PV projects, and the controversy over whether to focus on hydropower or also develop solar energy in the public sector.

4.2.2 Barriers for building refurbishment through interviews

Demographic information for the 42 interviewees in this study is shown in Figure 8. They are referred to by numbers as #1, #2,#3, …#42, among which #1 to # 20 represent the residents, # 21 to #34 represent the private sector, and # 35 to # 42 represent the public sector.

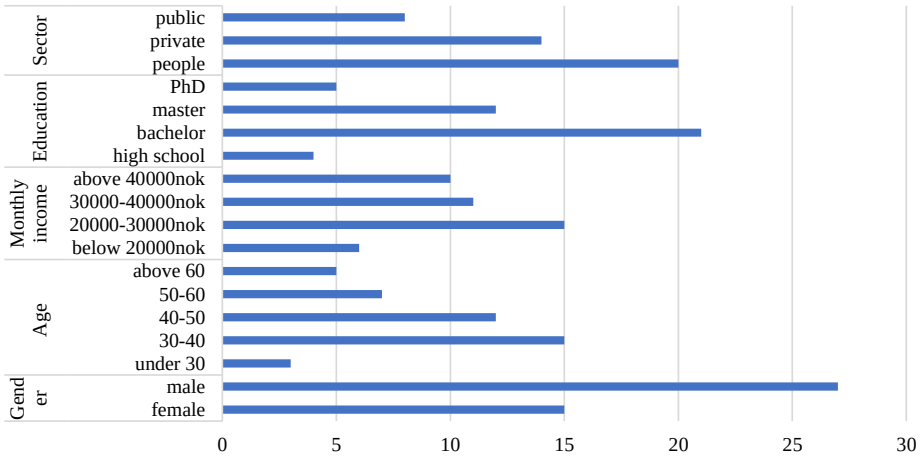

Figure 8: Information about the interviewees.

The people are the residents living in Karolinerveien, who have a good understanding of the building they live in. Their opinions for conducting the building refurbishment are quite crucial to consider. The private interviewees include multi-stakeholder organizing companies, engineering consulting, construction company, property company, facility management, EPC company, architecture company. The roles of the public interviewees are public support bank, public support energy institution, municipality.

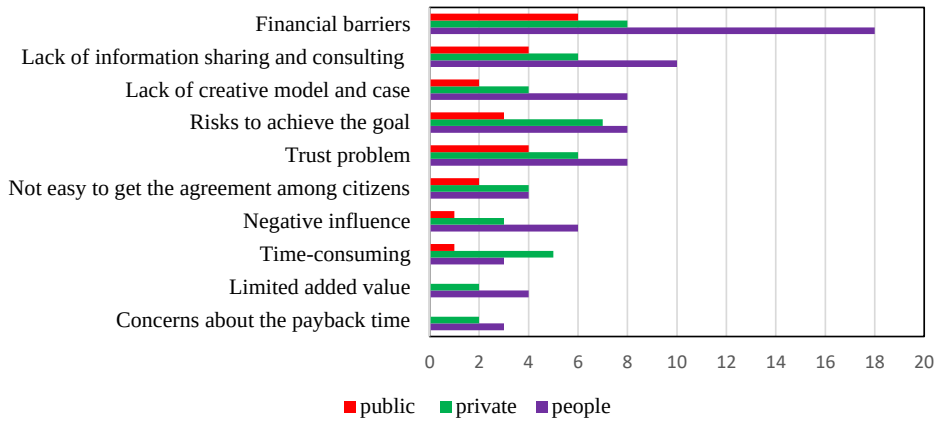

Figure 9: The barriers for conducting refurbishment from people, private, and public.

The results of the interviews are shown in Figure 9. The main concerns are financial barriers, lack of information sharing and consulting, risk of not achieving desired benefits, limited resources, knowledge, and experience, as well as lack of trust.

(1) Financial barriers

Eighteen people representing the residential perspective expressed financial concerns are the main barriers when investing in refurbishment, which can be classified into three categories. The first is lack of money to invest at the moment, and unwillingness to increase current loans. The second is difficulty applying for financial support from the public sector, which also is quite limited, and the third is that many prefer prioritizing spending elsewhere. As people #2 said *"I need make smart investments. If I invest in the building refurbishment, I cannot buy a new car or switch for a bigger apartment."*

Eight private company representatives had concerns primarily based on the financial barriers. Private #23 mentioned that their company is interested in investing in energy refurbishment, but that they lack the financing to do so. There are also private companies that believe the return on investment is too low, as #25 said *"We have invested in some building refurbishment, but most of them are official buildings, we are not investing in the residents' buildings, they're small and it's not easy to get the money back"*.

All the interviewees from the public sector think their main concern is low interest among residents to invest in building energy refurbishment, and that this is mainly due to financial barriers.

(2) Lack of information sharing and consulting

Ten people expressed that limited information and knowledge are key factors hindering them. For example, some citizens are worried about the regulations for refurbishment. Some also wanted more information about technical problems that may arise during the process.

Six private company representatives also believed lack of information to be a major problem. #27 mentioned that *"Because there is a lack of information sharing, different sectors do not know what resources they can get from the others, especially the residents do not know how to get support."* #28 added that *"There are barriers related to our ability to provide the people with good information, for example, which kind of refurbishment they should do, how to do it, and how much they can benefit"*.

Four representatives from the public sector believed there were barriers related to information-sharing. #36 pointed out that the building owners usually do not have enough knowledge about the buildings and business, and that they believe that it will take a lot of time to find the information needed.

(3) Risk of not achieving desired benefits

Eight people had concerns about the risk of not achieving the desired benefits, especially financial ones. First of all, the investment might not pay off and has a long payback period. Participant #5 expressed that: *"Selling the apartment might not be worth it for a while, because after I invest in the refurbishment, I cannot get a good return on investment in a short time."* Others pointed out that refurbishing might not be better than simply buying a new apartment. Participant #8 stated that *"There are a lot of things that need repairing in old buildings, it also takes a lot of time, and sometimes they are still not as comfortable compared to new houses"*. Furthermore, the value of the house might not increase to expected values after the energy refurbishment, and it is more difficult to sell when the loan attached to the building is high.

Four private companies mentioned this problem. It is not easy to achieve the energy goal from the construction aspect, and perhaps more importantly, it is not feasible to control the behavior of the residents for good energy performance. Participant #29 expressed that *"It is very difficult for us to promise a reduction when we need to control the way of living and action. People's behavior changes, and it is very difficult for us to make contracts with citizens for residential buildings".*

(4) Limited resources, knowledge, and experience

Eight residents, four representatives from the private sector, and two from the public sector believed the main barrier to be limited resources, knowledge, and experience.

Among the residents, People #12 and #15 expressed that they were interested in refurbishment but did not know how to get technical support from the public sector and did not have any related experience. From the private sector, Private #32 said that *"We want to test the new business model for energy sustainability, however, our main role is construction, we do not have the necessary connections with the bank, so it is difficult for us to invest"*.

(5) Lack of trust

Eight residents, six representatives from the private sector, and two from the public sector thought that one of the barriers was lack of trust. Some residents did not believe that the data from other cases were suitable for their cases. Participant #16 said: *"Sometimes I cannot believe that the data from other cases can also be applied to my apartment, I do not really trust the data from the providers, they just care about their profits"*. The sentiment was shared by participant #18, who said *"I am not so trusting of the advertisements because I am worried they will cheat me. I would like to hear from people I know".*

There are also other barriers, such as concerns about the payback time, limited added value, time spent on the refurbishment, possible negative side effects, and difficulty getting an agreement among the citizens. However, these were mentioned by only a few of the interviewees, and the thesis will focus on solving the main barriers.

4.2.3 Potential solutions to overcome these barriers from the interviewee perspective

(1) Financial support

For the people, 70% of the interviewees expressed they want to get financial support, and most of them believed this to be a crucial element for them to decide whether to invest in the building refurbishment. 2# said, *"I think the most important factor is the financial support. As long as it is worthwhile it deserves and I can afford it, I will invest in the refurbishment"*. 5# mentioned that *"different types of financial support are good, such as lower interest, higher subsidies, grants, soft loans, or tax incentives"*. For the private, 50% of the interviewees thought that financial support from the public was needed, *"financial support is a big issue, if we can get financial support from the public sector, we could try the new partnership model"*.

(2) Information sharing and consulting platform

40% of the interviewees representing people believed that information sharing and consulting platforms would be useful. As 3# mentioned, *"I think the information sharing and consulting platform is useful because there are many things about refurbishment, I have little knowledge and experience in"*. Some residents also thought that information sharing offline would be needed, 6# mentioned *"I don't think the online consulting is useful for some older people, I think you should make sure the*

information is accessible to everyone". 8# also said *"Professional consulting is quite important. It is better if I can receive consulting for my apartment through a platform from an expert"*. For the private, 11# and 13# thought that information sharing was the basis for cooperation among different sectors for refurbishment. 11# mentioned that *"sharing and openness in the projects are the basic characteristics for cooperation"*. 13# added that *"We need to work with people with knowledge, which means they should better have basic information about refurbishment"*.

(3) Guarantee

For the people, 40% of the interviewees wanted a risk guarantee to overcome the risk barriers. 2# expressed "*It should ensure that I can get the estimated energy savings, if they do not achieve the goal, they should give compensation."*. 5# also regarded the guarantee as the main needed support to promote the market, *"If the outcome of energy savings does not reach the set goal, the government should pay the difference so that the consumer does not lose money"*. Furthermore, 7# also mentioned that co-investing with public and private can be a form of guarantee. *"I think the bidding process from the public sector can find big companies, with a good reputation, skilled people, and large amounts of resources, I would be more likely to believe them"*. For the private, 11# mentioned that *"Commitment is also very important to ensure the cooperation"*.

(4) New partnership models

From the private perspective, 57.1% of the interviewees believed that new partnership model is needed to adapt to the developing refurbishment market. Because there are limited resources, knowledge, and experience for people and private sectors, the partnership model can increase access to these resources by pooling them together from all three sectors. At the same time, there is sometimes a lack of trust among the people and private sectors. By forming a partnership, information is shared, which can lead to increased trust between them. The multi-sector partnership business model is a systematic way to conduct the refurbishment and can solve the barriers through receiving financial support from different sectors, sharing information among the related sectors, and making use of resources and experiences from different sectors.

4.3 Results to RQ3: What is the most suitable partnership model to promote the building refurbishment market in Norway, and how can be applied and improved to be more suitable in practice?

Before choosing the most suitable partnership business model, the existing models applied in the building refurbishment were identified, and their advantages and disadvantages analyzed.

4.3.1 The existing business models for building energy refurbishment

(1) Host-owned business model

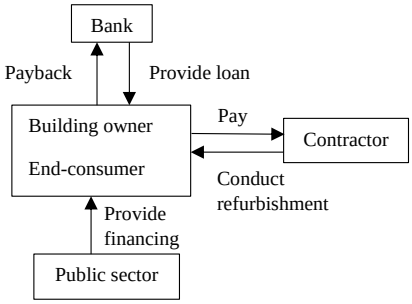

Figure 10: Figure 10 Host-owned business model.

The most widely used model is the host-owned business model, where the initial cost is paid for mainly by the host, shown in Figure 10. Projects using this model are often strongly dependent on public funding, which typically covers 20%-40% (Karlsson and Lindkvist, 2013), and even then, the initial cost of refurbishment remains high. Furthermore, refurbishment services such as design, construction, and materials are typically supplied by separate providers, which requires the building owners to spend a lot of time and effort on communication and coordination (Moschetti and Brattebø, 2016).

(2) Energy Performance Contracting

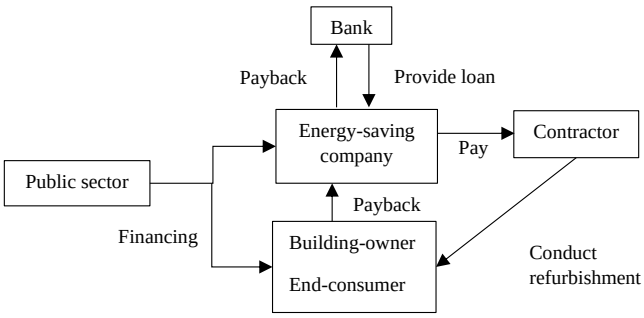

Figure 11: Energy performance contracting (EPC) business model.

Figure 11 shows the energy performance contracting (EPC) business model, where the energy-saving companies finance the initial investment and design and pay a contractor to conduct the energy refurbishment. The payback from the building owners is then based on the attained energy performance (Bleyl-Androschin, 2010) (Moschetti and Brattebø, 2016). The EPC business model is not used as often as the host-owned residential building model and most companies only apply this model for private and public-owned buildings. EPC models tend to be driven by energy-saving companies and typically have better access to financial capital than the host-owned

model. Energy-saving companies usually provide energy-related services through long-term contracts (Bertoldi, 2018). The risk of investing in energy refurbishments is reduced for building owners because they pay for the attained energy performance. However, the energy-saving companies usually cannot receive the predicted payback because the predicted energy performance does not match the actual energy performance. This is often due to changes to building design during the construction stage or the impact of the user's behavior on the energy load not being captured during lifecycle assessment (Fouquet *et al.*, 2014) (Soroye and Nilsson, 2010). Hence, there is a low interest by energy-saving companies to invest in residential refurbishment in Norway.

(3) Community shared business model

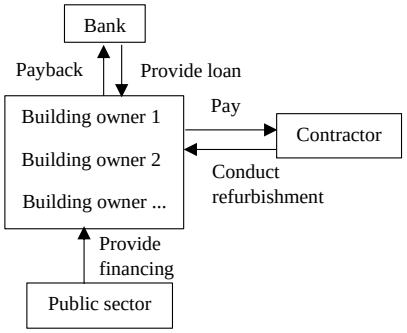

Figure 12: Community shared business model.

In the community shared business model (Figure 12), the investment is mainly financed by a large number of citizens (Stauch and Vuichard, 2019). They form a community group, who co-invests in a project and shares the benefits. They can also get financial support from the public sector and loans from financial institutions as a group. There are only a few cases of the model being applied for building refurbishment, as it is still in the early stages of development, and most cases are for building-integrated solar energy (Ebers Broughel and Hampl, 2018). In the community shared model, the residents are important actors, as they not only invest in the project but also provide the needs and information about problems related to the building environment. However, it is not easy to engage the citizens, and there are other barriers such as lack of industrial resources and connections, issues of trust among citizens, and limited skills in community engagement (Gordon *et al.*, 2013).

The main three existing business models have limited application for investment into residential refurbishment, yet, they contain qualities that appear positive towards business model innovation. The innovation direction of the new business model includes sharing the financial risks of investment across public and private sectors with residential owners. In addition, knowledge from these different sectors can be combined on how to do quality energy refurbishment that is important for reducing

carbon emissions in existing residential buildings. However, there is little research on the barriers in building refurbishment from the perspective of the different sectors, and knowledge is sparse about the willingness of these sectors to work together to invest in an energy-efficient refurbishment.

4.3.2 The potential of the PPPP model

With the proposed solutions, such as financial support, information sharing platform, and some guarantees to overcome the risks, the PPPP business model seems to have greater potential to solve the current barriers than the existing business models.

For the financial problems, the host-owned model has limited potential. Many householders are not willing to invest in energy because of the high initial cost and low electricity prices in Norway (Sæle and Cherry, 2017). Although they can get some financial support from the public sector to cover 20-30% of the costs, the cost is still very high (Holm, 2016). The TPO model can solve the high initial cost problem, however, relying on the private sector in Norway is not as suitable as in USA (Holm, 2016). This is because lower profitability due to cheap hydropower, and long payback times make it risky for third-party companies to invest in energy (Merlet and Ruud, 2014). The CS model has the potential to overcome the barriers by gathering funds from multiple citizens. However, it is difficult to promote the market at this moment, as most citizens have little awareness and information about the benefits of investing in building energy refurbishment (Westskog *et al.*, 2018). The PPPP has the potential to solve financial problems by combining the resources of all three sectors. It allows the public sector, private sector, and people to divide the high initial costs into more affordable sums (Sihombing *et al.*, 2018). This way, it can attract private sectors in two directions. First, the high initial cost is divided among the three sectors, which will reduce the individual risks for the private sector (Sihombing *et al.*, 2018). Second, projects organized by the public sector are often easier to be convinced, because the public sector has the potential to reduce the risks through policymaking and guarantees (Takashima, Yagi and Takamori, 2010). After the investment from both public and private sectors, the remaining amount should be low enough for the citizens to invest in. Finally, by involving all three sectors, the financial support measures from the public sector can be accurately tailored according to the needs of the private companies and citizens, which increases the likelihood that they will be used (de Jong, Neulen and Jansma, 2019).

The second main problem is information sharing. The host-owned model does little to spread awareness about available policies and incentives, and the building owners need to find the information by themselves. The third party in the TPO model can take the role of an educator to help citizens understand the benefits. However, the third party is often regarded as an “outsider” and often needs to first establish trust to lend credibility to their information (Lambright, Mischen and Laramee, 2010). The CS model can play a good role in sharing information and transfer knowledge among residents, which allows them to identify the potential benefits and reduce concerns

about risk. However, the information is only from the citizens' aspect, as they do not have the same expertise and ability to adapt to unforeseen events as the public and private sectors (Stauch and Vuichard, 2019). The PPPP has great potential for information sharing, as it facilitates the information flow across different sectors, which can improve both the knowledge of PV and the relationship between the different sectors (Maraña, Labaka and Sarriegi, 2020). The information from all the three sectors can give a complete picture of building refurbishment. In particular, governments typically have a better understanding of the existing regulations and have the power to make policies to support sustainable energy-related projects (Ng, Wong and Wong, 2013). Meanwhile, private companies have a good understanding of the market and can provide expertise in refurbishment. Finally, the citizens can provide knowledge about the building situation and their needs, and share new information with their communities (Torvinen and Ulkuniemi, 2016).

The third main barrier is risks and uncertainty. The host-owned model has the highest risks among all the models, as the building owners themselves have to fund the main portion of the high initial costs. In the process, any differences between predicted and actual output are their responsibility (Thakur and Chakraborty, 2019). In the TPO model, citizens pay a renting fee to the third party, who take the main risks for the citizens and take responsibility for maintenance. However, this only shifts the risks from the people to the private sector (Kollins, Speer and Cory, 2009). In the Norwegian context, there are already limited pilot cases and related data to study from and limited guarantees from the public sector, which further exacerbate the risk. The CS model can reduce the risks for each individual, but not reduce the total risk of the investment (Funkhouser *et al.*, 2015). The PPPP can reduce the risk for each stakeholder by dividing the costs between the three sectors. More importantly, it can also reduce the overall risks by allowing participants to make better-informed decisions based on knowledge from different sectors (Masonta, Kliks and Mzyece, 2017). The cooperation of the three sectors has a better ability to overcome unforeseen events in the installation process, because each sector has different types of experiences and resources, leading to better flexibility than only one or two sectors (Marana, Labaka and Sarriegi, 2018).

The fourth and fifth main barriers are the limited resources, knowledge, and experiences, and lack of trust problems. The existing models can only combine the resources with one or two sectors, the PPPP can receive the resources from people, private, and public sectors. The whole process of refurbishment requires resources from all three sectors. Furthermore, the cooperation among them can increase the trust with shared information, risks, and benefits.

4.3.3 PPPP business model for building energy refurbishment proposed

Based on the main barriers of conducting building energy refurbishment, the limitations of existing business models, and the information about business models and energy refurbishment, this thesis proposes a public-private-people partnership (PPPP) business model. The PPPP business model provides a new way to conduct

energy refurbishment through a deep cooperation between the public, private, and people illustrated in figure 13.

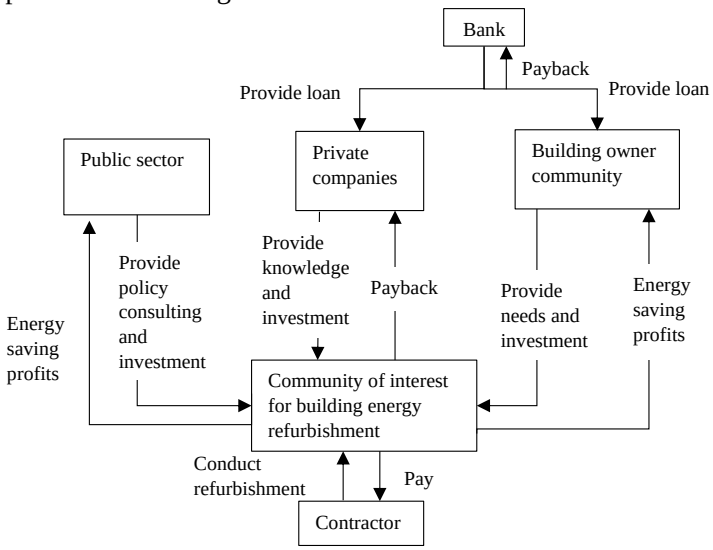

Figure 13: PPPP Business model.

In this model, the public sector, private sector, and the householder community compose a community of interest for building energy refurbishment. First, all partners share their needs, resources, information, and data about the building refurbishment from the different sectors' perspectives. Specifically, the public sector provides political consulting and investment, the private sector provides investment and construction experience and knowledge, and the residents provide needs and investment. The different sectors then negotiate the details around the application of the refurbishment, including the investment ratio, value propositions, communication channels, capital flow, etc. Then the community of interest co-invests, and the construction companies conduct the refurbishment. After the building is finished and can start saving energy, the public sector, the private sector, and residents will share the profits and risks according to the initial investment and the agreement between them. In the model, the co-investment and shared benefits lead the different partners as a community of interest, which has the potential to motivate an effective use of resources from different sectors. The different sectors each have multiple roles as investors, designers, and consumers, which can promote correspondence between supply and demand (Chen and Tseng, 2007), (Ciasullo *et al.*, 2016). At the same time, risk-sharing reduces the individual risks for each investor, not only because more investors divide the risks, but also because the cooperation across sectors increases pooled resources and knowledge, which enhances the ability to handle unforeseen events.

After the basic idea of the PPPP business model is proposed, the nine basic aspects of the Business Model Canvas will be explained in detail, namely, key partners, key resources, key activities, value propositions, relationship, channels, customer segments, revenue streams, and cost structures, as shown in Table 15. The business model canvas provides a basic method to apply the PPPP business model. For each case, however, the details surrounding the application of the model should be decided by three sectors according to the specific context.

Table 15: The PPPP business model canvas for building energy refurbishment.

Category	People	Private	Public	Reference
Key partners	Citizens with the right to conduct the building refurbishment	Financial private companies	Policy-making institutions	(Alberg Mosgaard, Kerndrup and Riisgaard, 2016), (Jensen *et al.*, 2018), (Jensen and Maslesa, 2015)
	Citizens with interest in investing in building refurbishment	Energy consulting and designing companies	Public financial support organizations	
		The operation, construction, and maintenance companies	Public research organizations	
Key resources	Consumer opinions	Investment capital	Policy consulting services	(Seyfang, 2010), (Stauch and Vuichard, 2019), (Liu *et al.*, 2015)
	Small investor opinions and investment capital	Construct, design, manage and maintain knowledge and experience	Investment capital and support	
	Citizens' needs			
Key activities	Preparation process to understand needs and necessary resources through surveys, interviews			(de Oliveira and Cortimiglia, 2017), (Mortensen, Heiselberg and Knudstrup, 2016), (Zheng *et al.*, 2019), (Li *et al.*, 2020), (Osterwalder, 2004)
	Presentation process to understand the energy refurbishment measures and PPPP business model			
	Negotiation of the nine aspects of the business model canvas for detailed application through workshops with representatives from the public, private, and people			
	Apply the business model with co-investment, co-benefits, and risks sharing			
	Build an open innovation platform, different partners can share information and provide consulting			
Value propositions	Efficient information updating and easy access to related consultants			(Izvercianu, Şeran and Branea, 2014), (Dodoo, Gustavsson and Le Truong, 2018), (Fotino, Calabrese and Lettieri, 2018), (Ferreira, Almeida and Rodrigues, 2017), (Johansen and Emborg, 2018), (Zaborek and Mazur, 2019), (Almarri and Blackwell, 2014), (Ferreira, Almeida and Rodrigues, 2017), (Zaborek and Mazur,
	Create safer, more competitive, innovative, and environmentally friendly energy production			
	Solve the barrier of high initial cost and limited capital			
	Risks are shared among different partners			
	Citizen oriented service such as mortgage scheme	Increase the service or product sales volume	Contributes to achieving the energy reduction goal by 2050	
	Energy saving, reduced electricity bill, comfortable living environment	More opportunities to interact with and build good relationships with local municipalities	Transition from relying on support from the government to a more self-sufficient model	
	Access to participate in decision-making	Opportunity to get professional recognition in the energy saving business		

		2019), (Kohon, 2018)
Relationships	Personal assistance, co-investment, co-negotiation, as well we co-benefit	(Lovrić and Lovrić, 2018), (Chrisman , 1989), (Vu, Phan and Le, 2018)
Channels	For raising awareness: educational programs, meetings, community events, surveys, web-based engagement, advertisements	(Zhang *et al.*, 2019), (Casais, Fernandes and Sarmento, 2020), (Haavik *et al.*, 2011), (Stamoulis, Kanellis and Martakos, 2002)
	For evaluating performance: online platform consulting and real case data analyses	
	For negotiating the application of the PPPP business model: workshops	
Revenue streams	Lower electricity bill Revenue from feeding excess energy into the grid Potential increase in house value	Energy product sales Tax incentives	(Dodoo, Gustavsson and Le Truong, 2018), (Pacudan, 2018), (Pascuas, Paoletti and Lollini, 2017), (Drury *et al.*, 2012), (Streimikiene and Balezentis, 2019), (Pacudan, 2018)
Cost structures	Build the relationship between different partners	(Xu *et al.*, 2017)
	Build the online platform for information sharing and consulting	
	Organize the workshop, survey, interview, and related activities	

(1) Key actors and customers

Key actors in the business model contain partners from three sectors, “public”, “private”, and “people”. In the building refurbishment field, the public sector includes building-related policy- making institutions and publicly supported financial and research organizations (Alberg Mosgaard, Kerndrup and Riisgaard, 2016). The private sector contains private financial institutions, energy suppliers, energy consulting companies, building energy refurbishment companies, as well as construction and maintenance companies (Jensen *et al.*, 2018). The people comprise the residents with the right to make changes to their buildings and citizens with interest in investing in building refurbishment (Jensen and Maslesa, 2015). The public, private, and people sectors form a community of interest, which share benefits and risks with collective knowledge and resources. In this business model, the key partners are also customers, tailoring the end-product according to their needs.

(2) Key resources

Correspondingly, the key resources mainly come from the public, private, and people sectors. The resources from the “people” sector are consumers’ and small investors’ willingness to pay, and the citizens’ needs (Seyfang, 2010), (Yildiz, 2014), (Liu *et al.*, 2015). Specifically, people can state what they are willing to pay for in the building

refurbishment as consumers, what their financial and environmental goals are when participating as small investors, as well as the needs of the living environment and buildings as residents (Seyfang, 2010), (Yildiz, 2014), (Liu *et al.*, 2015). The private sectors can provide different kinds of services and products for the energy efficiency of a building or a block. Specifically, financial institutions provide investment capital, building contractors, energy suppliers, architects, engineers, consultant companies to provide relevant resources and experiences for building energy refurbishment. The cooperation aims to engage in building energy efficiency companies to participate together, which can lead to increased flexibility and efficiency (Alberg Mosgaard, Kerndrup and Riisgaard, 2016). The public sectors mainly provide financial and political incentives (Yang *et al.*, 2019). The financial support can be in the form of grants, subsidies, tax incentives, and energy certificates (Karlsson and Lindkvist, 2013). The political incentives can be building energy performance certification systems and flexible building regulatory measures (Baek and Park, 2012).

(3) Main activities

The main activities consist of preparation, presentation, and negotiation processes, as well as providing an information-sharing platform (de Oliveira and Cortimiglia, 2017). The first step is the preparation process, which includes surveys and interviews with representatives from the public, private, and people conducted by the research group. The aim of this step is to understand the needs of the partners and the resources they can provide, which can help ensure that supply meets real needs (Mortensen, Heiselberg and Knudstrup, 2016). The main questions for the people are: "for what kinds of services or products are you willing to pay", and "what are the barriers for you to invest in building energy efficiency projects" (März, 2018). The main topics for the private sector are discussing the barriers for them to invest in a building renovation, scenarios for the investment and payback approach, and understanding what they care about the most (Li *et al.*, 2020). For the public, being informed about the main barriers for people and private is important, as well as discussing what types of corresponding resources they can provide. The second step is the presentation process for understanding the fundamentals of the project, including energy refurbishment measures, the PPPP business model, and the needs and resources of different sectors. The third step is to arrange workshops and negotiate the nine aspects of the business model canvas, and to work out the details for applying the model from a public-private-people partnership perspective (Osterwalder, 2004). Finally, the partners will apply the business model as negotiated, and co-invest, share risks and gain co-benefits as a community of interest.

At the same time, designing a platform for different stakeholders to participate together is also one of the crucial activities (Nadeem *et al.*, 2020). On the platform, the partners can share information and data on building energy efficiency (Rasch, 2019), seek consulting and provide services, and provide suggestions for the application of the business model (Laczko *et al.*, 2019).

(4) Value propositions

A value proposition defines the specific value gained for the public, private, and people in this model. The value mainly comes from the information-sharing platform and the negotiation and co-investment process of the business model. Specifically, the information-sharing platform with different partners can lead to reliable and up-to-date information and easy access to relevant consultants (Gammelgaard, Andersen and Figueroa, 2017). In addition, the negotiation process, which includes partners with a variety of backgrounds, has the potential to create safer and more competitive, innovative, and environmentally friendly energy production, while also considering balanced social, economic, and environmental sustainability (Kruger *et al.*, 2018). Finally, the co-investment process can solve the barriers of high initial cost and limited capital for building refurbishment projects, because it not only divides the high cost into affordable amount with the public, private, and people sharing, but also enables access to capital from different sides (Ebers Broughel and Hampl, 2018), which has the potential to promote building refurbishment (Kudo, 2016).

In addition to the common values gained by all sectors, each sector gains different values in the refurbishment process. For the citizens, the energy level of the building will improve through refurbishment, which paired with suitable consumer behaviors leads to a reduced electricity bill (Dodoo, Gustavsson and Le Truong, 2018). Furthermore, the citizens can not only provide the needs from their perspective but also directly participate in decision-making (Fotino, Calabrese and Lettieri, 2018). Private companies, such as energy refurbishment contractors and energy suppliers, can increase the services or product sales volume through cooperation with consumers (Zaborek and Mazur, 2019). In addition, after cooperating with the public sector, private companies will have opportunities to build good relationships with local municipalities, which can have a positive effect on future cooperation (Zou *et al.*, 2014). Furthermore, if the energy efficiency goal is reached, the private companies will not only get related benefits but also get professional recognition for energy saving, which can be a form of commercial branding (Anagnostopoulos, Arcipowska and Mariottini, 2915). For governments or municipalities, the cooperation will promote building energy refurbishment projects, which will help achieve the EU's energy reduction goal by 2050 (European Commission, 2012). At the same time, the model can transform the characteristics of building renovation from relying mainly on government grants and subsidies to self-sufficient with investors (Brown, Hall and Davis, 2019).

(5) Relationships between different stakeholders

In the PPPP business model, there are opportunities for different types of relationships to be promoted among the public, private, and people during each process, particularly through discussion and consulting (Romero and Molina, 2011). The main relationships contain personal assistance, co-investment, co-negotiation, as well we

co-benefit. Among these relationships, some characteristics of relationships are required. For example, relationships with mutual commitment and trust are crucial to sharing benefits and risks (Romero and Molina, 2011). Commitments from different sectors are needed, which means they will make efforts to focus on the long-term goal as well as solve short-term problems (Marana, Labaka and Sarriegi, 2018). Mutual trust is the basic element to build relationships between sectors, which refers to the shared belief in and reliability of others while participating in the business model. The contracts act as insurance for the different partners, which can clarify the benefits and risks are shared, as well as solve disputes.

(6) Channels

Channels are designed for conducting the business model and include channels for information sharing, problem consulting, business model discussion, and product sales (Mahapatra *et al.*, 2013). To conduct these steps, social media, website, workshop, public event, meetings, advertisements, and surveys are considered efficient methods (Mlecnik, 2015).

Channels are used before, during, and after the co-design of the business model. For raising awareness of building energy efficiency, the main channels can be educational programs, meetings, community events, surveys, web-based engagement, and advertisements (Paiho *et al.*, 2015). To help the partners evaluate the value of investing in building energy projects, the main channels can be online consulting and real case data analysis. To negotiate the application of the business model for building energy efficiency, the main channel is workshops (Nenonen and Storbacka, 2010).

(7) Revenue streams

For different partners, the main revenue streams are different. For citizens, the revenue comes mainly from four aspects. First, in the form of cost savings from the reduced electricity bill, which can come from either higher levels of energy efficiency in the building, or electricity generated from for example solar power (Dodoo, Gustavsson and Le Truong, 2018). Second, when the newly produced energy is sufficient for daily life consumption, any excess energy can be sold back to the grid (Pacudan, 2018). Third, the municipalities award a monetary bonus when the energy performance is good (Kabak *et al.*, 2014). On the other hand, if the energy performance is bad, the energy-saving companies need to pay a penalty. Fourth, when the energy level of the building improves, its market value will increase (Fuerst *et al.*, 2016).

For the private sectors, the revenue streams mainly come from three sources: first, the revenue from the increased sales volume of products and services related to building refurbishment, as the negotiation of products with consumers can increase the sales volume since the refurbishment is designed based on the consumers' needs (Enz and Lambert, 2012); second, financial incentives from the public sector for promoting

building refurbishments, such as grants, subsidies, soft loans, and tax reductions (Karlsson and Lindkvist, 2013).

For the public sector, they cannot get revenue directly but can promote building energy projects, which can lead to long-term energy efficiency (Streimikiene and Balezentis, 2019). At the same time, they can get more energy on the grid from the extra energy output (Pacudan, 2018).

(8) Cost structures

The main costs are those for conducting building refurbishment and for applying the PPPP business model. To apply the new business model, there are costs from three aspects: building the relationship between the different partners; building the online platform for information sharing and consulting, and finally; organizing workshops, surveys, interviews, and related activities. The PPPP community of interest will need to pay the costs as negotiated.

4.3.4 The feasibility of the PPPP model

4.3.4.1 Providing necessary support measures

According to the analysis earlier, the PPPP model has the most potential to receive resources from different sectors to overcome the existing barriers. Whether the sectors could provide the support needed is crucial to the model. The interviews showed that the main support could be provided to an extent.

(1) Financial support

Among the public sector, all the interviewed public sectors believed they could provide the necessary financial support. 18# mentioned, *"Our bank is a government institution, its main goal is to support housing and to increase the quality of the house, guiding the insurance quality of the housing, and providing financial support for refurbishment"*. 19# said *"We can provide different kinds of financial support, such as lower interest, higher subsidies, grants, soft loans, or tax incentives. Each year, we allocate NOK 250 million to refurbishment measures in private households"*. 20# stated that *"Projects in commercial real estate can receive from 15-60% support depending on the degree of innovation and the size of the applicant"*. 27% of the private companies showed a willingness to co-invest but thought that the financing was limited.

(2) Information sharing

Nearly all the interviewees from both private and public sectors mentioned that they could provide consulting for the cooperation. Private 11# said, *"we can make the plans for the residents, tell them what to do. Creating an online platform for information sharing and consulting is possible for us"*. Public 19# mentioned, *"We want to assist building owners. We, therefore, have good dialogue with both the large,*

strategic building owners and the smaller building owners who submit applications to us. We can provide information meetings and consulting every year where everyone can attend. In addition, we conduct many one-on-one meetings with building owners, consultants, architects and planning authorities each year, as well as information about regulations and incentives".

(3) Guarantees

Interviewees mentioned that it not easy to receive direct financial guarantees, however, there are other types of guarantees. For example, by including public sectors and large companies with a good reputation, powerful resources, knowledge, and experiences, it can make the project seem less risky for the people.

4.3.4.2 Willingness to participate

After proposing the PPPP business model, the participants were also asked about their willingness to test the model with a real project. They could choose between highly interest, somewhat interested, and low interest.

(1) High interest

All the interviewees from the public sector expressed high interest in testing the new PPPP model. As 19# said, *"For the public sector, the interest for building energy refurbishment is growing, because of the growing interest for green environments"*. 18# also mentioned *"We have interested, as it has the possibility to get financial support from different sectors. The banks can provide the loans, and the insurance companies and other financial institutions can contribute financially"*.

60 % of the interviewees from the private sector expressed high interest in co-investing in building energy refurbishment. 11# expressed *"We are focusing on the cooperation of different sectors for sustainable development, we would like to try new business model"*.

70% of the interviewees from the people expressed high interest, because they can receive financial support, have the access to information sharing and consulting, and have the access to resources from other sectors. 3# mentioned *"New partnership models can receive the resources from different sectors, we have more opportunities to combine resources and overcome the barriers, and we would like to try the model"*.

(2) Somewhat interested

42.8% of the interviewees from the private sector stated that they were interested, however, there were some key factors to consider. 12# was concerned about the risks associated with piloting the PPPP model, as it has not previously been applied for building refurbishment in Norway. 13# was also interested but expressed concerns about limited financing for testing new models, "*We are interested, but we do not have the necessary resources. For example, we do not have close relationships with many banks*".

20% of the people said it would depend on their financial situation, and that they might not want to spend time on discussions with the public and private sectors, as some of them thought that they had limited knowledge to provide useful suggestions.

(3) Low interest

15% of the private expressed low interest. 14# said that "*We are a construction company. We have not invested in building refurbishment before"*. 17# mentioned that *"It is not easy, as we are not allowed to gather the information for the electricity, which we need to measure the achieved energy efficiency"*. 10% of the people also had low interest in participating. They did not care about conducting refurbishment and were satisfied with their current situation.

4.3.5 The PPPP business model canvas developed in a workshop

After the PPPP business model was proposed and introduced to the participants of the interview about barriers, 20 of them believed that the PPPP business model had a high value in terms of solving the existing barriers, and expressed interest in developing the model. Eventually, 15 practitioners and academics participated in a focus group meeting and formed the expert panel. The panel was comprised of a wide spectrum of refurbishment professionals, with 3 participants from the public sector and government support organizations, 6 from the private sector, 6 from the residents.

Table 16: The background of the participants in the workshop.

Group	Participants	Sector	Background	Gender
1	Public #1	public	public support institution	male
	Private #1	private	property company	male
	Private #2	private	consulting company	male
	People #1	people	residents	female
	People #2	people	residents	female
2	Public #2	public	public support bank	male
	Private #3	private	multi-stakeholder organizing companies	male
	Private #4	private	construction company	male
	People #3	people	residents	male
	People #4	people	residents	male
3	Public #3	public	municipality	female
	Private #4	private	consulting company	male
	Private #5	private	facility management	male
	People #4	people	residents	female
	People #5	people	residents	female

To develop the PPPP model, the participants discussed the detailed application of the model through the business model canvas. The result of the discussions was a revised PPPP business model canvas, modified according to the opinions and ideas of the

participants (Table 17). The main changes to the original model are described in the following.

Table 17: The revised PPPP business model canvas for building energy refurbishment.

Category	People	Private	Public
Key partners	Community board	Facility management companies	Public support energy institutions
	Citizens (with interest and without interest) in building refurbishment	Consulting, design, operation, construction, and maintenance companies	
Key resources	Opinion	Investment capital	Policy consulting services
	Investment capital	Knowledge and experience	Investment capital and support
		Information sharing	Information sharing
Key activities	Dialog with citizen board		
	Understand barriers and necessary resources from different sectors		
	Convince people		
	Build an open innovation platform, different partners can share information and provide consulting		
	Presentation process to understand the energy refurbishment measures and PPPP business model		
	Negotiation of the nine aspects of the business model canvas for detailed application through workshops with representatives from the public, private, and people		
Value proposition	Financial supports	More opportunities to interact with and build good relationships with local municipalities	Contributes to achieving the energy reduction goal by 2050
	Energy-saving and comfortable living environment	Increase the product sales volume	Social sustainability
	Efficient information updating and easy access to related consultants		
Relationships	Information sharing, co-investment, as well as co-benefit		
Channels	For raising awareness: (1) meeting (2) documents from experts (3) familiar people (4) good example show		
	For evaluating value: (1) technical report (2) consulting (3) meeting.		
Revenue streams	Lower electricity bill	Energy products or services sales	
	Revenue from feeding excess energy into the grid		
	Potential increase in house value		
Cost structures	Build the relationship between different partners		
	Build the online platform for information sharing and consulting		

(1) Key partners

For the people, the citizen board is regarded as a necessary key partner, because they can share relevant information with the residents in the building, collect their opinions, and represent them in decision-making processes. In addition, it was argued that both residents with and without interest in investing should be encouraged to participate in this model. As private #3 mentioned, *"it is better to add citizens who are not interested in investment, then we can know the practical obstacles we have in such a project".* As for key partners from the private sector, facility management companies for building energy sustainable buildings are considered useful, because

facility management companies can play really important roles for the building refurbishment, such as financing, building relationships with the public, and knowledge sharing. The consulting, design, construction, and maintenance companies are needed because they have good experience with building refurbishment. From the public sector, the public support energy institutions are necessary, because they can make or influence policies to a certain degree, create strategies, and provide financial support.

(2) Key resources

The public can provide consulting services on existing policies and can create new policies and regulations for building refurbishment. Public #1 said, *"Now we have quite strict energy regulations when building the new house, but there are no rules when you refurbish older houses, this is an opportunity to create the regulations with people and private"*. They can also provide information and consulting to answer the questions from the residents. All participants from the public sector also expressed willingness to provide financial support, as long as the refurbishment could improve energy efficiency. The private can provide information sharing and consulting, financial support, and knowledge and experience. Almost all the private sectors can provide related knowledge and experiences for the cooperation. Most private companies mentioned that they would not provide financial support, as they thought the money should come from the public sector and green banks, and only a small part of private companies would consider contributing with a limited amount. The key resources from the people are information about their needs and financial investment. Private #5 thought that the opinions of people were quite important to consider and that engaging people was crucial. Participants were also worried that it would be difficult to get financial investment from the residents. Private 3# mentioned: *"The refurbishment will obviously increase the common costs, it might be a crucial question about their economy"*.

(3) Key activities

The main activities include understanding the barriers and resources from different sectors, presenting the findings, engaging people, building an open innovation platform, and conducting workshops. Determining the barriers and the resources of the different sectors before the co-creation process is crucial, which can give a better understanding of how to use the resources to satisfy the needs. For understanding the barriers of people, public #3 mentioned: *"a starting activity should be a dialog with the citizen board, so they can be facilitators to the communities"*. People #3 also believed that convincing people of the value of the investment was an important activity. In addition, information can be provided by building an open innovation platform, where different partners can share information and provide consulting. People #4 thought a presentation would be needed to explain the costs, benefits, and business model canvas, *"the presentation part could be more involving, if you did*

some statistical analysis and presented the numbers, then you would get people's attention much easier". The final activity was for the partners to discuss the detailed application of the PPPP model in a workshop.

(4) Value proposition

The value for the people includes financing support, energy-saving, getting a comfortable living environment, and easy access to updated information and related consultants. The co-investment in the PPPP business model can solve the financial barriers by dividing the financial investment between different sectors, and energy-saving lead to lower electricity bills and a higher energy rating for the building. Another value for the citizens is getting a more comfortable living environment, such as heating, stillness, spaciousness, and low electricity use. People #4 thought that frequently updated information and easy access to related consultants were important, *"It will save lots of time checking different knowledge from different places, in the PPPP model, we can easily access to this information"*. The value for the private sector mainly comes from building relations with people and the public sector and increasing the product sales volume. Building relations is important for private companies, as it can lead to more contracts with the government and residents. Private #5 mentioned that *"People are more willing to buy the apartment, which is developed through the cooperation of the public and private sector, as the public sector always receives more trust, leading to a higher profit for the private"*. The value for the public sector is to get closer to achieving their energy goals as well as social sustainability. Public #2 also pointed out that *"the refurbishment can create jobs, which is good for the community. By giving people more contracts, they create more work, which generates more taxes, which is good for the entire the community"*.

(5) Relationship

All the participants agreed that the PPPP cooperation can promote building relationships between the sectors. The types of relationships include information sharing, co-investment, and benefits sharing. Information sharing between private and people can involving residents, as private #4 said *"If the private sector works for the people to present themselves as green developers and give information related to the refurbishment, the residents will more willing to cooperate with the private"*. Information sharing between the private and public sectors can promote more opportunities for cooperation. Private #6 also expressed that *"if the public can share information about the municipality plans, we can have very clear goals and measures on sustainability and promote cooperation"*. Private #3 and people #4 both expressed that co-investment is the core relationship for the model. The co-investment relationship leads to the benefit-sharing relationship and using the model, all three sectors can benefit. For people, it is easier to get relevant information and financial support from the public with cooperation. Public 3# mentioned *"we want to assist all the building owners. We can hold several information meetings for people. In*

addition, we conduct many one-on-one meetings with building owners, consultants, architects and planning authorities each year to try to provide help". For the private sector, private #1 believed the relationship between private and public could be quite useful and expressed that a good relationship with the public would likely get them more contracts. For the public, they can get social sustainability, the cooperation can create more job opportunities, which increases the tax revenues and is good for the community.

(6) Channel

The channels for raising awareness are meetings, documents from experts, acquaintances, and demonstrations of good examples. People #2, #4, #5 thought the meetings were an especially important channel. They mentioned that *"the meeting with many people is a good idea. Meeting means there are many people participate, there should be some institutions we can believe. At the same time, when many people have the meeting together, all the residents can think about the potential benefits and risks, we can also discuss that, which makes it clearer"*. On the other hand, People #3 and #6 believed that presenting documents from experts was the best way, because they could just focus on the data they were interested in, without it requiring a lot of knowledge and time to understand. People #1, #2, #4 stated that if people they knew had successfully conducted the refurbishment, they would be more interested in doing it themselves. Private #1, #2, #5 believed that showing good examples of past projects could be an effective method. Private #1 mentioned, *"we need show residents good examples and show what happened in each example and the scenarios, give them ideas about how can we learn from this case and how the lessons can be applied in our cases."*.

For evaluating the value of the refurbishment, the main channels are technical reports, consulting, and meetings. People #2, #3, #4, #6 expressed that a technical report could help them evaluate the value of investing in refurbishment, as #6 mentioned: *"If you make a detailed calculation of the expected investment and profit in a technical report, I can see more clearly what I am investing in"*. People #1 and #5 thought the consulting platform would be useful. While meetings and reports can provide a general overview, consulting is needed for case-specific problems. In addition, people can seek help from experts on the platform that they trust.

(7) Revenue streams

For the people, the revenue can come from lower electricity bills, revenue from selling excess energy into the grid, and a potential increase in the value of the apartment. The first and direct revenue is the decline of the energy cost, which leads to the lower electricity bill. Another revenue from selling excess energy back to the grid or to the neighbor, as people 4# mentioned *"I will add the PV panel for energy refurbishment, we have really big roofs, we could actually get enough energy, if we can sell the extra energy to the grid or the neighbor, I will get more money"*. There were also

participants who mentioned that the increased high energy performance would increase the value of the apartment.

For the private, the main revenue comes from the sales of energy products or services during the project. In addition, discussions with the consumers can improve customer relations and give a better understanding of their needs, which in turn could increase the sales volume even further. The public sector cannot get revenue directly but can promote building energy projects, which can lead to long-term energy efficiency.

(8) Cost structures

In addition to the costs of the building energy refurbishment itself, the main costs come from building the information-sharing platform and building the relationship between the different sectors. Private #3, public #2 believed that getting the consulting work done would cost a lot of money, because it would require many experts within a wide range of subjects, as private #3 mentioned: *"the most costly one is to get all consulting work done, due to there being different sectors that need to prepare all the related project documentation"*. Private #2 and private #4 expressed that building relationships also would require a lot of money and time and is sometimes not easy.

In this section, five modes of multi-sector partnerships were identified and compared, the main barriers and potential solutions for building energy refurbishment were explored through a literature review and interviews, and an innovative public-private-people partnership model was proposed on a theoretical and practical level. These results will be discussed in the following section.

5 Discussion

This section is designed to answer the main aim of the thesis about developing a suitable partnership model to promote the building refurbishment market in Norway, by discussing the main findings related to each research question.

5.1 Discussion to RQ1: What are the existing multi-sector partnership models being given attention by academia and practice in the context of sustainable energy development, and what are their differences?

For the research question1, there are three sub questions, which will be discussed in the follow.

5.1.1 What is the current status of multi-sector partnerships research in urban development?

Five modes of multi-sector partnerships were identified. The current status of each mode is different.

The multi-stakeholder partnerships category has the largest proportion of the selected papers and employs a more diverse set of methods than the other categories, such as the Delphi technique, Q-methodology, network approach, and regression analysis model. One possible reason for its success is that stakeholders are more willing to participate than other participants since they are often directly affected financially by the outcome of the project. Furthermore, there are more opportunities to conduct practical case studies. Finally, cooperation and balancing of power are somewhat easier than for example PPPP, as everyone has a voice in the decision-making process.

Although community-organizational partnerships is a new concept in the urban development area, the results show that there is much ongoing research. However, the fact that the research mainly focuses on barriers and drivers of engagement indicates that the current level of community participation is not high enough or has not yet achieved effective participation and desired goals.

End-user partnerships group in urban development has begun to receive attention in recent years, however, it is still in its early stages. Research is largely problem-oriented, focusing on identifying barriers to engaging the participants.

Public-private partnerships category is developing well and has a wide range of applications internationally. Different areas such as risk management, relationship management, financial viabilities, and procurement have been explored by researchers worldwide since the late 1990s. In the total sample, only 12.5% of the articles are about PPP projects, however, this is not due to limited research, but to the fact that this pays more attention to the common citizens' participation.

The last form of multi-sector partnerships is public-private-people partnerships (PPPP). Only five related articles were found in all the domains in the database, of which only two articles included case studies. This is not surprising since it is quite

difficult to include people in the PPP models. Government departments can provide corresponding institutional guarantees and enforcement rights, and the private companies can provide investment capital and operational management experience, but citizens have neither the authority nor the money, making it difficult for them to have an equal position. Moreover, ordinary citizens rarely have enough knowledge to participate in the discussions, and often fail to provide effective strategies. It seems that both the theory and the application of this mode are underdeveloped.

5.1.2 What are the differences between the various modes of partnerships?

Although all the modes are forms of multi-sector partnerships, there are differences in several aspects. First, the applicable sectors vary. Multi-stakeholder partnerships category is arguably the most general mode. Unlike the other modes, it does not require participants to have a specific background such as public and private sectors but includes any participants who can affect or be affected by the achievement of objectives in the project. Projects based on multi-stakeholder partnerships generally aim to benefit the stakeholders themselves. On the other hand, community-organizational partnerships and PPPPs are often formed to create value for mainly the citizens. The applicable sectors for community-organizational partnerships commonly include organizations, stakeholder communities, interest groups, or citizen groups in the same geographic location. For PPPP, the applicable sectors are more focused on the resources and differences between the public and private sectors, as well as the opinions of the citizens. End-user-oriented partnerships also emphasize the opinions of citizens; however, the goal is commonly to make them prosumers. The applicable sectors are the organizers and the people that ultimately use the good, service, or technology. In the public-private partnerships (PPP) model, the main applicable sectors are government agencies and private-sector companies. Unlike the other partnerships modes, it does not include the citizens, which sometimes leads to missing the actual need of the citizens.

Second, the level of maturity among the modes is different, which in turn leads to a different research focus. The main research focus for multi-stakeholder partnerships is the relationship between stakeholders, representing 41.2% of the studies in this category. Among these, the majority focuses on how to balance the power of the different stakeholders. This is a sign of maturity, as it has moved beyond problems surrounding barriers and engagement. The research on community-organizational partnerships focuses on mainly the barriers and drivers of community engagement, closely followed by engagement approaches. Furthermore, the results show that financial value and trust are the main factors affecting community engagement. Most papers explore the characteristics of community engagement with case-studies from different regions, due to the cultures in communities being highly dependent on the location. For end-user-oriented partnerships, most papers try to identify factors that affect end-user participation. The results show that financial compensation, knowledge exchange, and technologies used for communicating are the most

important factors in the participation process, with formal and informal information exchange being crucial as well. For the PPP mode, most of the research is centered on policymaking, rather than problems surrounding engagement. Therefore, at present, the projects in the relevant fields are mostly policy-oriented and the related research mostly discusses how to avoid risks and create benefits. PPPP is the least developed; since the term was introduced in 2006, only five research papers have been written on the topic. Existing papers mainly focus on developing theoretical frameworks. There are some theoretical participation strategies, but since there are few corresponding cases, their effectiveness cannot be fully proven.

Third, the modes are suitable for different situations. For projects with a clear objective and where the participants have already been determined, multi-stakeholder partnerships are effective. If the project puts more emphasis on the opinion of the community and a willing suitable organization can be found, the community-organizational partnerships will be a good choice. For projects that aim to create new products or services, the end-user-oriented partnerships should be considered. Projects organized by the public sector can use PPP or PPPP to increase its total resources and reduce risk.

Finally, each method has clear advantages and disadvantages. The biggest advantage of stakeholder partnerships is its maturity and efficiency. However, in an urban sustainable development perspective, there is little emphasis on social sustainability. Community-organizational partnership's main advantage is that a neighborhood community usually shares the same geographical location, which means that they likely have a shared culture and set of values. This facilitates the balancing of their interests and the creation of shared value. Second, the proximity between participants within the community makes it easier to arrange meetings and workshops. However, the engagement process has a lot of barriers, due to a lack of willingness to participate among citizens. End-user-oriented partnerships typically get a good understanding of the consumers' desires and value, however, similarly to community-organizational partnerships, engaging citizens is a big challenge. The PPP has the potential for social welfare and economic benefits, however, by excluding the citizens from the decision-making process, they may not capture the real needs of the citizens. The PPPP has the potential to solve all the previous problems, however, no good method exists.

5.1.3 What are the most promising areas of improvement for the existing modes?

All five modes of multi-sector partnerships share some common problems related to partner relationship, engagement, barriers and drivers, and influence. Identification of barriers and drivers factors can provide a better direction for the engagement strategy. The relationships between different stakeholders play an important role in the final decision-making process. The efficiency of the engagement strategy can lead to the

successful application of the modes, and the influence and effects of the methods can help to determine which modes to choose in projects.

First, the relationship between participants is a general issue, as various sectors generally have different power in the decision-making process, which can lead to disagreement and discontent among the participants. Particularly, the power of citizens tends to be quite low in PPPP and end-user-oriented partnerships, which in turn leads to low levels of engagement. However, thus far there are no methods in existing research to efficiently balance their power. Although some studies are starting to explore the appropriate sequencing and combining of participation by the various sectors, which are designed to balance the power among them, the results are not very clear. There are also papers which suggest that close relationships are efficient for making agreements, but do not mention how to build them. Furthermore, researchers are exploring the relationships between different sectors, but the micro-level classification is missing, such as relationships concerning economic rights and resource sharing. To increase the citizens' participation, as well as improving their role in decision-making, it is clear that further research is needed on managing relationships in multi-sector partnerships.

Second, an efficient approach to engage different sectors is a premise to form multi-sector partnerships. Some researchers discuss various modes of recruitment, from coercive to voluntary ones, and the respective types of participants. However, they do not mention how to combine modes of recruitment with specific sectors, which needs to be further explored. In addition, an approach to make an agreement between participants is key in the engagement process of multi-sector partnerships, as different sectors regularly have different opinions and priorities. Some methods, for example, the Delphi technique, can be used to obtain the collective opinion of the participants in a well-structured and academically rigorous process. However, the path to reach this agreement is quite a time and energy-consuming. For further study, more efficient methods to reach an agreement are needed.

Third, for determining barriers and drivers, the Q-methodology is used to reveal different social perspectives, attitudes, and understandings during the participation process. It is an efficient way to find the factors which affect the willingness of participants. However, investigation reveals there is no systematic and effective way to systematically classify these factors, as well as determining their relative importance.

Finally, with regard to the influence of multi-sector partnerships, the results show that multi-sector partnerships can promote sustainable urban development from social, economic, and environmental aspects. However, most studies only measure the effect at the end of the process, without addressing the influence of the participants in the different stages. Further research in this area may improve understanding of the strengths and weaknesses at each stage of the process.

In addition, there are some specific problems in each mode. For the multi-stakeholder partnerships, its methods are relatively mature and efficient, and in theory, everyone who can affect or have been affected by the objectives of the project is included. However, in real cases, the stakeholders usually do not include all affected parties, especially the citizens, which leads to less value gained in terms of social sustainability. The issue of citizens' engagement should be emphasized in future research.

For community-organizational partnerships, the main issue is engagement. As financial value and trust are considered the most important factors, research on business models could potentially solve the problem. As for trust, more efficient approaches are needed for improving trust between partners. While several theoretical frameworks for engagement strategies exist, they still need to be put into practice to determine their efficiency.

For the end-user-oriented partnerships, the most important factors for participation are financial value, knowledge exchange and use of technology for communication. The development of business models that bring more immediate value to the end-user, as well as digital tools that common citizens can adopt are two possible solutions. Moreover, the interaction between end-users and organizers needs both formal and informal methods, which means that both formal documents and informal communication should be designed.

For public-private partnerships, it has developed well in terms of the application and providing risk guarantees. However, as it does not consider the real needs of citizens, its directly top-down approach may not have the competitive strength for the increasingly complex urban development. Involving the citizens to share benefits and risks will further study, which easier to achieve social acceptance.

PPPP is a good concept that can get support through policies made by the public sector, financial and operational support from the private sector, and an accurate portrayal of the needs of citizens. However, it is still underdeveloped. For further development of this mode, the barriers should first be identified, an efficient engagement method is needed, and a cooperation model should be designed.

5.2 Discussion to RQ2: What are the barriers and solutions for conducting the building refurbishment from the perspective of people, private, and public?

After the literature review and interviews, the main barriers and potential solutions are identified.

5.2.1 The main barriers

According to the literature review, the main barriers can be classified into three categories, financial barriers, information sharing and consulting barriers, and uncertainty about the risks guarantees. To further clarify the main barriers, 42 deeply

semi-structured interviews were conducted. According to the results of the deeply discussion with interviewees, the main barriers can be categorized as 1) financial barriers, 2) information sharing and consulting barriers,3) risk of not achieving desired benefits, 4) limited resources, knowledge, and experience, 5) lack of trust. The results of the interview clarified the barriers from the literature review for the financial problems, information sharing and consulting problems, and concerns of risks guarantees (Baek and Park, 2012) (Sesana and Salvalai, 2018) (Moschetti and Brattebø, 2016). Furthermore, the interview also identified two main barriers limited resources, knowledge, and experience and lack of trust.

The financial barriers, information sharing barriers, and uncertainty of the risks account for most of the answers, and these three barriers were mentioned by all the sectors. This result provides a clear direction for which barriers should be the main focus. Furthermore, the barriers identified from different perspectives, which make people have a detailed understanding of the barriers from different sectors, for example, the financial problems from a different perspective are different. The financial barriers for people are it adds the life burden for increase the loan, concerns about not get the money back maybe when selling the apartment, the financial barriers for the private sectors are concerns about the residents' behavior are not easy to control to ensure the energy saving to get invest money back, while the financial concerns for the public are that they provide lots of financial support, but people do not know how to apply with correct way. These detailed barriers can provide a deep analysis of the barriers and can provide an adapted model.

5.2.2 Potential solutions

According to the interviewees, the potential solutions to overcome these barriers can be financial support, information sharing and consulting platform, and cooperation among the people, private, and people to face the risks with different resources, knowledge, and experiences. The PPPP model has the potential to overcome the barriers by combining these solutions in a systematic method.

First, a co-investment solution with PPPP can potentially solve financial barriers. To solve the problem of financial-related problems, the basic idea is to expand the existing funding options by reducing the high initial cost to an affordable amount with the three sectors. This thesis proposes a co-investment solution based on PPPP, with investors from the people, private and public sectors to promote a larger market. The benefit of including the public sector to co-invest are added investment capital and access to related resources from the public sector. In the long term, if the market grows, the public sector can shift governmental funds from subsidizing solar energy to investing in projects (Liberman, 2012). The inclusion of different types of private companies will reduce the investment pressure for the people and public sectors, and they can provide their operational experience on installation, management, making contracts for investing and sharing, problem-solving, and consulting (Cedrick and

Long, 2017). Finally, the benefits of involving the people are significant, as it considers the citizens' opinions with a bottom-up approach for social sustainability (Li and de Jong, 2017). Besides, citizens' investment in building energy refurbishment represents a potentially huge market (Creamer *et al.*, 2018). As more people participate in this form of co-investment, it will also naturally promote greater diffusion of building refurbishment. Overall, including investors from all three sectors has the potential to solve the financial problem.

Second, the PPPP-based information-sharing platforms can solve information-related problems. To solve the barrier of limited information and awareness of the possible benefits, information-sharing platforms with knowledge from the public, private, and people can help citizens obtain and understand information (Janssen and Estevez, 2013). The information should pertain to the financial costs and benefits, electricity output, related incentives, and potential benefits to the local and global environment (Palm and Eriksson, 2018). Information about financial support and incentives can be provided by the public sector, while knowledge about the financial costs and benefits, and expected output can provide by the private sector (Lo, Wang and Huang, 2013). The consumers' needs, feedback, and questions can provide by the people. Unlike the barrier regarding limited information and awareness of the possible benefits, the barrier of uncertainty mainly refers to people who already have some interest and understanding of building refurbishment, but are unsure whether and how to implement it (Westskog *et al.*, 2018). Therefore, they need a platform for asking specific questions to different sectors, where they can get reliable answers from the relevant sectors. Consultants from public and private sectors, who have the relevant knowledge about policies and experience can then clear up any confusion from the citizens.

Third, co-investing with different sectors can reduce the uncertainty surrounding risks for the private sector. A wider base of knowledge and the ability to pool the resources from multiple sectors, can make the partners better equipped to handle unforeseen events during the project (Yang and Zou, 2014). In addition, co-create the detailed application through PPPP that can solve the barriers regarding the uncertainty of risks to some degree. The co-creation with the opinions of the public, private, and people has been regarded as an efficient approach to consider the needs of different sectors on specific issues.

Fourth, the public-private-people partnership business model can benefit from crucial resources of building retrofit from the public, private, and people, such as the legislative and financial support from the public sector, and experience in design, construction, and management from private companies. The residents living in the buildings can provide investment and information about their needs (Ng, Wong and Wong, 2013).

Fifth, the PPPP model can increase trust among different sectors. When the cooperation built among the people, private, and public, the different sectors will

share the information and data related to the project, the benefits and risks will be shared, which will increase the trust.

Finally, PPPP has the potential to promote sustainable development through sharing information and negotiating the interests of the different sectors to promote a balanced social, environmental, and financial development (Booth and Richardson, 2001). In the existing models, there is rarely negotiation between the three sectors. The citizens essentially need to make larger investments with higher risks to have a meaningful impact on decision-making.

5.3 Discussion to RQ3: What is the most suitable partnership model to promote the building refurbishment market in Norway, and how can be applied and improved to be more suitable in practice?

5.3.1 From the theoretical level

The public-private-people partnerships with the cooperation of people, private, and public sectors, was considered as the most suitable partnership model to promote building refurbishment market. First, participants in the PPPP business model have the most diverse background with citizens, energy-related private company clusters, and government-related institutions, compared to other existing models that only contain one or two of the sectors (public, private, and people). This means that the new cooperation will have the most varied types of resources and knowledge. Second, it can solve the main barriers to energy efficiency in buildings, such as the high initial cost of investment, limited awareness and information sharing, and lack of risk guarantees. Specifically, the PPPP model allows the different sectors to share the high costs, while the negotiation process and information sharing platform improves awareness and creates a deep understanding of building energy efficiency. The different backgrounds of the partners increase their ability to tackle unforeseen events, due to their different knowledge and resources (Sihombing *et al.*, 2018) (Barile and Saviano, 2015) (Fontainha *et al.*, 2017). In comparison, the host-owned and third-party ownership models do not have a strong role in disseminating information about building refurbishment. The community sharing model emphasizes the opinion of the citizens, but with limited support from the public and private sectors. Third, the PPPP business model has the potential to satisfy the needs of the people, private, and the public to a great extent, compared to existing models which often only satisfy one or two of them. It allows the citizens to achieve energy saving and a comfortable environment, and access to decision-making. For the private sector, the model increases capital access through co-investment and reduces individual risk by sharing it between the partners. The public sector benefits through long-term sustainable urban development and by coming closer to achieving the EU's energy goal. Fourth, the new business model will lead to deep citizen participation in decision-making compared to other models. It allows people to provide their needs, access to data and information from the private and public sectors, and to participate in negotiating the application of the business model, which is not the case for the other models. This deep citizen

engagement also has the potential to increase the voice of citizens in decision-making processes and to promote further participation (Romero and Molina, 2011).

5.3.2 From the empirical level

After the PPPP model was proposed on a theoretical level, the feasibility was tested through the interviews with participants who had empirical experience, mainly through three aspects. First, they were asked about the potential of the PPPP model in overcoming the existing barriers. Almost all the interviewees believed that the PPPP model was better than existing ones regarding access to knowledge, information sharing, and the ability to handle unforeseen events. Second, the interviewees mentioned that crucial resources, such as information sharing support and financial support could be provided by the public and private sectors. Third, when asked about their willingness to test the model in practice, most of the interviewees expressed interest. The three main questions of the interviews suggest that applying the PPPP model is feasible.

To further test the feasibility and develop the PPPP business model canvas, a workshop was organized. The process involved many stakeholders with different backgrounds. All the participates expressed their opinions, and gave detailed explanations to others, which resulted in participants gaining a deeper and wider understanding with knowledge from different sectors

The participants developed the PPPP model mainly through discussing the nice aspects in the business model canvas. For the key partners, the citizen board was added, which makes the model more efficient than just including the citizens as partners, because the citizen board can inform the residents, collect the opinions from the residents, and help the residents understand the benefits and information through the same communication level. At the decision-making stage, the citizen board can make the decision to present the citizens instead of talking to a large number of citizens to waste time. The facility management companies add in the partners, which increased the potential for cooperation. Because the facility management companies generally have good relationships with public, private, and people, which can be the link among all the sectors. At the same time, the private financing companies deleted the partners, which changed the investment roles, this means all the cooperation-related private companies can co-invest in the project, not just the financing companies can invest. For the key resources, the private and public sectors both mentioned that they can provide information sharing and consulting, this is crucial to solving the barriers for residents, which increases the potential to overcome the barriers. For the key activities, convince people were added and underlined, which can increase the involvement of the citizens. For the value proposition, for the people, the most crucial value is getting the financial support from the private and public instead of the services, the financial is the most important element people care about, which makes people more clear about the focus when cooperation. The job opportunities added to the value, which provides a new added value for the community, the new value can attract more partners, which means increase the partners. The transition

from relying on support from the government to a more self-sufficient model is deleted, expressed that the transition requires all aspects in the life, not just the refurbishment, the refurbishment does not have that many functions. For the relationship, the personal assistance was instead by information sharing, because the public, private, and people all can share the information, not just provide information to one sector. This changeable means the PPPP model is the cooperation among people, private, and public, people have the equal voice and status with private and people, instead of just getting the assistance. Equality is the basis for cooperation. For the channels, there are some changes to make people more believable. The familiar people and good examples show instead of the surveys and advertisements, the technical report also added. The newly developed PPPP business model canvas can more suitable to the market, according to the analysis before.

At the same time, there may exist some opposite functions for the developed PPPP business model canvas. For the partners, residents without interest added in the workshop, it is hard to involve them and they may just give random answers because they have no interest. At the same time, their attitude may cause a negative influence on other partners. Furthermore, private financing companies were deleted in the key partners, which make reduce the partners who can be the main investors, maybe leading to the insufficient initial investment. For the value proposition, the citizen-oriented service was deleted, which means the PPPP business model will just focus on the existing barriers if citizens have other needs, which will be ignored. For the channel, the relatively not believable channels, such as surveys and advertisements are deleted, but this channel can be applied for more widely scope to attract the partners than the familiar people and good example show.

The developed PPPP business model canvas is likely more suitable to the market because the participants have a good understanding of the market than the theoretical level.

However, the PPPP business model has its weaknesses. First, it will be a large investment to use a new business model that engages many different partners. The main costs will be the costs of building relationships between public, private, and people through meetings and workshops, for building the online platform for information sharing and consulting, and for organizing different types of activities, such as surveys and interviews. In addition, more research on suitable strategies is required, which is also time-consuming. Second, there are many barriers to conducting the PPPP business model. The first barrier is engaging the citizens. According to existing cases with citizen participation, it is quite difficult to engage citizens, due to the financial risks, low voice, and low levels of trust towards outsiders (Hartley and Wood, 2005). The second barrier is the communication barriers due to the different levels of knowledge in each sector (Mauser *et al.*, 2013). To communicate and participate in discussions, a basic understanding of the topic is needed amongst all partners. The third barrier is the time it takes to reach an agreement for all partners

during the process of co-designing and co-implementation of the new business model (Ng, Wong and Wong, 2013). There are many aspects that need to be discussed and negotiated, as the participants likely have different goals and concerns.

Even though, the PPPP model still has the opportunities to be developed. In recent years, many different types of partnerships involving citizens, such as community engagement, multi-stakeholder partnership, and public-private-people partnership, have been gradually receiving more attention for their use in sustainable development (Xue *et al.*, 2020). Therefore, PPPP has the potential to get more attention than the existing models. Furthermore, increasing levels of internet informatization can make online communication and consult from different sectors more efficient (Viglia, Pera and Bigné, 2018), which is important to promote the relationship building of PPPP. Finally, the awareness of balanced development of financial, environmental, and social development under the building refurbishment, will promote the cooperation of different sectors. There will be some social or institutional resistance to change, but it is expected that the political and economic environment will make more favorable conditions for PPPP in the future due to climate needs.

5.3.3 The potential for application in Norway

Norway has the potential to conduct pilot projects using the PPPP model. First of all, many stakeholders in the energy sector such as research groups, private companies, and municipalities in Norway collaborate through energy clusters (Norwegian Innovation Clusters, no date). There are some projects of collaborative energy projects, for example, the +CityxChange project, which explores suitable co-creation approaches to achieve efficient innovative energy systems with joint partners, including public bodies, industries and private businesses, research and academia, and citizens (Ahlers *et al.*, 2019). Furthermore, PPPP is already present in the energy sector, most notably through the prosumer scheme offered by the Norwegian Energy Regulatory Authority (The Norwegian Water Resources and Energy Directorate, 2020). It is a set of regulations supporting cooperation between people, private industry and public sectors, by allowing owners of small installations to sell surplus energy to private energy companies (The Norwegian Water Resources and Energy Directorate, no date).

Second, although the resources from one sector is limited, PPPP can gather the resources of three sectors in Norway. From the people's perspective, the citizens in Norway are likely to engage in PPPP for renewable energy. According to a country ranking of public environmental concern conducted by Franzen and Vogl (Franzen and Vogl, 2013), Norwegians pay much attention to sustainable environmental development, this is particularly exemplified in the electric car industry in Norway which has the most electric cars per capita in the world (Aasness and Odeck, 2015). Ironically, this has the potential to put stress on the district power grid and if these trends for electric cars continue, there is a need to identify alternative energy sources to avoid blackouts. The desire for a green identity can also attract residents to conduct

the building refurbishment, as it may be seen as a symbol of being modern and progressive, similar to the electric car. The environmentally friendly lifestyle was considered the main driver for households who installed PV panels based on an interview conducted by Winther, Westskog, and Sæle (Winther, Westskog and Sæle, 2018).

There are supports for building refurbishment in the public and private sectors as well. In the public sector, Enova introduced up to 35% support for a range of energy-efficient technologies for households. The private sector can support the PPPP by providing resources, as well as knowledge and experience from abundant experts and consultants on building refurbishment. There are also close relationships among different types of private companies. One example is Multiconsult, a consulting company with about 300 experts in the building energy sector that provides consulting and design services in Norway.

To summarize, it was found that in the partnership among different partnership models, the PPPP can get support through policies made by the public sector, financial and operational support from the private sector, and an accurate portrayal of the needs of citizens. However, it is still underdeveloped. The main identified barriers were categorized as 1) financial barriers, 2) information sharing and consulting barriers,3) risk of not achieving desired benefits. The results suggest that the PPPP has significant potential to overcome these barriers by dividing the high initial costs into more affordable sums, facilitating the information flow among different sectors, and having different resources, knowledge, and experiences from all three sectors to better handle the risks. In the following, the main conclusion of the thesis will be given.

6 Conclusions

This section is designed to answer the main conclusions related to the three research questions, which aims to develop a suitable partnership model to promote the building refurbishment market in Norway.

6.1 Conclusions to RQ1: What are the existing multi-sector partnerships models being given attention by academia and practice in the context of sustainable energy development, and what are their differences?

The thesis conducted a scoping review on multi-sector partnerships in the urban development area, to answer the following sub research questions:

- What is the current status of multi-sector partnerships research in the urban development context?
- What are the differences between the various modes of partnerships?
- What are the most promising areas of improvement for the existing modes?

Three steps were conducted to determine the sample papers: structured searching, expanded keywords and snowballing search, and filtering selection. Finally, 107 papers were selected, which were used for analyzing the research questions.

The results show that multi-sector partnerships can be classified into five modes, namely multi-stakeholder partnerships, community-organizational partnerships, end-user-oriented partnerships, public-private partnerships, and public-private-people partnerships. According to existing research, multi-stakeholder partnerships established itself early and has developed to a relatively mature level with many types of innovation approaches. Community-organizational partnerships is a newer concept in the urban development area, but there is much ongoing research in the field. End-user partnerships in urban development has begun to receive attention in recent years, however, it is still in its early stages. Public-private partnerships is developing well and has a wide range of applications internationally. Public-private-people partnerships is underdeveloped in both theory and application.

Although the five modes of multi-sector partnerships all focus on the success of multiple participation for sustainable urban development, several aspects differ. First, the applicable sectors vary according to the partners in each method. Second, the level of maturity among the modes is different, which in turn leads to a different research focus. Third, the modes are suitable for different situations. Finally, each method has clear advantages and disadvantages. A more detailed description is given in the discussion section.

Areas of improvement have also been identified for each of the modes. Research shows that multi-stakeholder partnerships rarely include citizens, which can lead to reduced end-user value and fewer benefits in terms of social sustainability. This can

be improved by emphasizing the citizens' role in multi-stakeholder partnerships in future research. The main issue in community-organizational partnerships is engagement, for which the most important factors are financial value and trust. Research on new business models can improve the financial value aspect, whereas more efficient methods are needed for establishing trust. End-user-oriented partnerships also struggle with the engagement of citizens, with the main factors being financial value, exchange of knowledge and choice of technology for communication. The development of better methods of communication, both formal and informal, are needed. Public-private partnerships' top-down approach sometimes makes it difficult to capture the real needs of citizens. A possible solution is including citizens in the decision-making process, i.e. public-private-people partnerships. However, PPPP is currently underdeveloped in both theory and application; its barriers need to be fully identified, and efficient engagement approach is needed, and a cooperation model should be designed.

Finally, there are some limitations to this research. First, the scoping approach is less rigorous than a systematic review, as its main purpose is to identify the research gaps. Second, it only identifies articles written after the year 2000, as its purpose is to find the latest research questions, but the content of the selected materials could be incomplete. Third, only articles written in English from acknowledged journals were included.

6.2 Conclusions to RQ2: What are the barriers and solutions for conducting the building refurbishment from the perspective of people, private, and public?

This thesis is the first to classify the barriers for diffusing solar PV in Norway from the perspective of the people, private, and public sectors. The barriers were explored through a literature review, which identified nine main barriers. For the people, these are (1) high initial cost, as well as limited financial support; (2) satisfaction with the current electricity system; (3) limited information and awareness of the possible benefits; (4) uncertainty, while the main barriers for the private sector are (5) limited access to capital; (6) limited pilot PV projects; (7) uncertainty surrounding risks; and (8) lack of communication among different stakeholders. The main concern for the public sector is (9) the lack of efficient incentives. According to the analysis, they can be classified into three main problems: financial problems, information sharing problems, and concern about the risks.

To clarify the results of the literature review, the interviews for identifying the barriers for conducting building energy refurbishment were conducted. The main barriers are (1) financial barriers (2) limited information (3) risks about the achievement (4) limited resources, knowledge, and experience (5) lack of trust. These barriers can clarify the results from the literature review and provide clear directions for what should be focused on.

After the barriers were identified, the potential solutions also asked the interviewees. The results show the potential solutions are co-investment, information-sharing platforms, and co-creation of the model with PPPP to overcome the financial, information sharing, and risks barriers separately. A co-investment solution with investors from the people, private and public sectors can receive as much as an initial investment due to the co-investment can reduce the high initial cost to an affordable amount. Furthermore, co-investment and co-creation with different sectors can reduce the uncertainty surrounding risks through receiving different resources to face unforeseen results. The PPPP-based information-sharing platforms can solve information related problems through sharing the information from people, private, and public perspectives.

6.3 Conclusions to RQ3: What is the most suitable partnership model to promote the building refurbishment market in Norway, and how can be applied and improved to be more suitable in practice?

Three existing business models for building refurbishment were identified, they are the host-owned model, the EPC business model, and the community shared model. The current development state of the existing models, advantages, and disadvantages of the existing models were analyzed. The results show they have limitations and still little potential to overcome the existing main barriers to promote the building refurbishment market.

After analyzing the main barriers and potential solutions, this thesis proposed a novel Public-private-people partnership (PPPP) business model for building refurbishment. The PPPP has a big potential to overcome these barriers by dividing the high initial costs into more affordable sums, facilitating the information flow among different sectors, and involving all three sectors to receive different resources, knowledge, and experiences to face the risks. In addition, the different main focuses of the public, private, and people sectors can promote a balanced development of financial, environmental, and social values. Finally, the involvement of people not only considers the residents' opinions with a bottom-up approach for social sustainability but also lets them access the final decision-making, which has the potential to balance the power of different sectors.

In addition, the feasibility of the PPPP model has been supported by the results of the interviews. The interviewees illustrate the potential value of the PPPP model to overcome the existing barriers. At the same time, crucial resources, such as information sharing support and financial support can be provided by the public and private sectors. Furthermore, most of the interviewees have an interest in participating in the PPPP model.

To further develop the PPPP model to be more practical to the market, participants with rich knowledge and deep experience in the refurbishment market organized a

workshop, discussed the PPPP business model canvas and further developed it. The final results are explained through the business model canvas from nine basic blocks:

(1) Partners. Community board (people), residents with and without interest in refurbishment, developers, public support energy institutions.

(2) Resources. From the public, the key resources are: policy consulting services and co-create new regulations, information sharing and consulting, financial support. From the private, they can provide information sharing and consulting, financial support, knowledge and experiences. From the people, the resources are opinions and financial investment.

(3) Main activities. According to the final decision, the main activities include dialog with the community board, understand the barriers and sources needed from different sectors, convince people, presentation, and workshop.

(4) Value proposition. The value for people includes: financing support, energy-saving, get comfortable living environment, and citizen-oriented services. The value for the private sector mainly from getting cooperation opportunities and profit. The value for the public sector is to achieve the energy goal and social value.

(5) Relationships. All the participants agree that the PPPP cooperation can promote building relationship with each other: information sharing, co-investment, and co-benefit.

(6) Channels. Channels for raising awareness are meetings, documents from experts, familiar people, and good examples show. According to interviewees, there are three main channels for evaluating the refurbishment, they are technical report, consulting, and meeting.

(7) Customer. The customer comes from public, private, and people sectors who are related to or interested in energy efficiency in buildings.

(8) Revenue. For the people, the revenue can come from lower electricity bills, revenue from feeding excess energy into the grid, and the potential increased price of the apartment.

(9) Cost. In addition to the cost of the building energy refurbishment itself, the main cost comes from building the consulting platform and building the relationship between different sectors.

7 Major Contributions and Further Research

There is a huge potential to save energy through building energy refurbishment, however, this is not been done with a large scale. This thesis identified the barriers from the perspective of different sectors and proposed a PPPP partnership model to solve these barriers. The model was tested through interviews and workshops, where it showed great potential for application. If applied successfully, the model has great potential to promote the energy refurbishment market and significantly reduce energy consumption in the building sector.

7.1 Major contributions

One of the main contributions in this thesis is that it identified and compared five modes of multi-sector partnerships, which is the first time in an urban development context. It fills the gaps in existing research in the field, namely a lack of analyses and comparison studies among the various modes of multi-sector partnerships. This can provide information for choosing an appropriate mode for a specific project, which is a crucial factor to its success. Furthermore, the explanation of the history, current state, and limitations of these modes determined gaps in the research of each mode, which can direct further study in this area.

Another main contribution is that the thesis for the first time identified the barriers for building refurbishment from the angle of public, private, and people, which provides a full picture of the barriers. This is important because all three sectors play a significant role in building refurbishment. It extended existing research which only focused on the barriers from one or two of the sectors. Furthermore, the identified barriers were studied and substantiated on a practical level through semi-structured interviews. The people, private, and public sector explained the barriers in the interviews gave a detailed description, which helps to give a deeper understanding of the problems. In addition, the comprehensive analysis of the results from both the interview and literature review provides a clear direction for further research, by highlighting the barriers related to financing, information sharing, and risks.

The thesis aims to overcome these barriers through using a multi-sector partnership model, which can receive different kinds of resources and knowledge from multiple sectors to overcome the barriers. A significant contribution in this thesis is being the first one to analyze the three existing main business models applied in building refurbishment and compare the advantages and disadvantages between them. The results illustrate that all of them have their limitations in promoting the building refurbishment market. The thesis is also the first to analyze the driving sector, financial models, and main forms of partnership in multiple countries, such as the USA, China, Sweden, and Denmark and discuss whether they are suitable in Norway.

The most important contribution of this thesis is the proposal of the public-private-people partnership (PPPP) as a potential model to promote the building refurbishment market, based on the identified barriers and solutions, as well as the analysis of the

differences among different partnership models. Furthermore, it proposed corresponding solutions to the barriers using the PPPP model, by dividing the high initial costs into more affordable sums, facilitating the information flow among different sectors, and involving all three sectors to receive different resources, knowledge, and experiences to better handle unforeseen events.

In addition, the feasibility of the proposed PPPP model was substantiated through a practical approach utilizing interviews and a workshop. The PPPP business model canvas was designed and developed using both theoretical knowledge, and empirical experience from the participants. This gives it better potential for solving the barriers and of being applied, which will lead to a better building refurbishment market, lower CO2 emissions and sustainable energy development.

Finally, the PPPP model has three contributions to urban facility management (FM). First, the PPPP business model is designed according to the needs of the people, private, and public sectors, which realizes the goal of urban FM to understand the needs of the local community and address them. Second, the PPPP business model combines the knowledge and experience from different sectors and has great potential to achieve sustainable building energy development, which aligns with FM's goal to get different resources to achieve sustainable cities. Third, the PPPP model promotes an increased motivation and deep engagement for people to participate in co-creation projects, which is also a focus of urban FM.

7.2 Further research

For further study, the barriers and needs for refurbishment from people, private, public can be identified from different countries to get a larger sample, in order to find the common traits of the barriers. This can make the solutions applicable for a wider scope. At the same time, it is important to note the differences in order to properly tailor the details of the PPPP model to each country. At the same time, the interviewees figuring process can be more digitally, which has the possibility to save time and engage more participants.

In addition, more research is needed in other countries on the feasibility of the PPPP model, the potential resources that can be received from each sector, and methods to achieve cooperation. It is suggested to add participants with a more comprehensive background in the building refurbishment market.

Finally, the PPPP model needs to be tested in a full-length project. The feasibility of the PPPP model is different in different stages of a project. In addition, there are aspects that need to be paid attention to and improved when applying the PPPP model. First, for engaging participates, different approaches, such as door-to-door explanation, digital tools, community meetings should be tested to determine the most efficient method. At the same time, the engaging approaches for people, private, and public should be tested separately, due to their different characteristics. Second, for building trust among all the participants, more approaches can be tested, such as

contract guarantees and political support. Third, the decision-making process with different sectors is usually time-consuming. More approaches, such as the Delphi technique, Analytic Hierarchy Process are recommended to be tested with the PPPP model to figure out the most efficient method. In particular, there should be a focus on how to empower the residents to achieve a balanced decision-making process among the people, private, and public.

8 Reference

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Appendix

Table of contents

Paper I

Journal of Cleaner Production 268 (2020) 122291

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Review

Multi-sector partnerships in the urban development context: A scoping review

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ABSTRACT

The existing research on urban development has gradually changed from policy-led management to multi-sector participation in co-design, aiming to create a more livable urban ecosystem. The goal of this paper is to identify the main modes, focuses, and differences among multi-sector partnerships, as well as analyzing the most promising areas of improvement in the existing partnerships modes in the urban development context. The main research method is a scoping review. Five main modes of multi-sector partnerships were identified. These are 'multi-stakeholder partnership', 'public-private partnership', 'public-private-people partnership', 'community-organizational partnerships, and 'end-user-oriented partnership'. Most of them focus on four aspects, namely 'factors affecting participation', 'relationship between participants', 'engagement strategy', as well as 'influence of participation'. The analysis revealed three main areas of improvement: Developing a systematic and effective way to classify the factors affecting participation into a structural system, exploring an efficient method to balance the power of different participants in the participation process, and finding an efficient means to reach a collaborative agreement for different partners.

Contents

Abbreviations: PPP, Public-private partnerships; PPPP, Public-private-people partnerships; SEI, sustainable end-user innovation.

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1. Introduction

Urban planning research emphasizes sustainable development, which aims to improve the quality of citizen well-being and environmental health in a complex urban ecosystem by considering the social, economic and environmental aspects (Panagopoulos et al., 2016; Carmichael et al., 2019). The sustainable development of the environment is typically concerned with natural green areas, urban ecological landscapes, climate change, and levels of pollution (Okeke and Ifeoma, 2019), while sustainable economic development pays attention to job positions, affordability, and welfare for citizens (Yan et al., 2018). Sustainable social development focuses on urbanization rate, urban density, safety, accessibility, availability, and equity (Li et al., 2019). The different aspects include, but are not limited to, these factors.

However, in many large cities, urbanization has had a gradual negative influence on sustainable development, such as reduced air quality, rising house prices, and limited access to natural areas. To cope with the complex challenges and respond to the uncertainty of urban development, a wide range of knowledge and resources are needed from multiple fields. Furthermore, this knowledge and resources often require different types of partners, such as governments, private companies, and citizens, to support the investment, construction, and management of related projects. To respond to this complexity, as well as multiple sciences in the urban developing process, several researchers propose multi-sector partnerships as an efficient approach, which can facilitate cooperation and combine resources from different fields (Thabrew et al., 2009; Robinson and Berkes, 2011).

Multi-sector partnerships are used to describe the participation of multiple sectors (institutions, agencies, individuals), who share resources towards a common goal in a specific project (Amadi and Abdullah, 2011). The partners must originate from at least two sectors, and the resources are generally financing, knowledge, and people (Pittz and Adler, 2016). Multi-sector partnerships have been built for decades, and their use have seen a large increase in recent years, mainly due to the increasing complexity and diversity in different types of areas (Pittz and Adler, 2016). The basic steps are making people aware of common concerns, choosing and engaging partners, as well as aligning and executing strategies (Warhurst, 2014). The partners are chosen according to the kinds of resources they can provide, as well as their values and interests in the project (Le Ber et al., 2010). The decision-making usually comes from multiple sectors, both when forming the strategy and during execution (Erickson et al., 2017).

Multi-sector partnerships can be used in a wide range of areas requiring cooperation using multiple resources. This paper focuses on its use in urban development for deep analysis. For multi-sector partnerships, there exist some differences between the urban development area and other areas. First, the nature of the main goal varies. In other areas, multi-sector partnerships could be mainly focusing on business development, technological innovation, or health problems (Chachoua and Whelan, 2019; Bunn et al., 2009; Rowe, 2018), whereas in urban development the main goal is to achieve a balanced development of social, economic and environmental sustainability (Nel, 2017; Foth and Adkinsor, 2005). Second, the scope of the involved sectors is different. More sectors are required in urban development compared to many other areas, due to its complexity and the wide range of knowledge and resources required (Fernandez-Anez et al., 2018). The relevant sectors include urban planning institutions, urban development policy-making institutions, investors, developers, design companies, construction companies, maintenance companies, residents, and so on from the urban space to internal properties (Karatas and El-Rayes, 2015). Third, the involvement and decision-making processes are more difficult to achieve than in other areas due to the citizens' participation in multi-sector partnerships in urban development, which aims to promote social sustainability with a bottom-up approach (Li and de Jong, 2017). The main reasons include the citizens' lack of awareness, information, and related knowledge, whereas, in other areas, most partners are related stakeholders with related resources and knowledge (Swapan, 2016; Erickson et al., 2017).

According to existing studies, the benefits of multi-sector partnerships are demonstrated through achieving sustainable urban development from three perspectives. First, it can utilize various sectors' resources. In particular, governments typically have a better understanding of the existing regulations and have the power to make policies to support urban development (Morsink et al., 2011). Meanwhile, private companies have a good understanding of the market (Kościelniak and Górka, 2016), and residents can provide knowledge about the building environment and their needs (Kahila-Tani et al., 2019). Second, it facilitates the information flow among different sectors, which results in new co-production of knowledge and forms shared value (Delannon et al., 2016). Both results are crucial for sustainable urban development decision-making. Finally, it can increase opportunities for urban renewal, as it allows the stakeholders to share the high costs of urban development projects, making them more affordable and reducing individual risk (Tang et al., 2018).

In the urban development process, the related sectors refer to urban planning institutes, architecture designing companies, financing institutions, building material providers, construction companies, refurbishment consulting companies, policy-making departments, management companies, and the residents (Alberg Mosgaard et al., 2016). Choosing the most suitable partnerships with the relevant sectors is crucial. However, there is a lack of summaries of the typical modes concerning choice of sectors for a multi-sector partnership, as well as analyses and comparative studies among the various modes of partnerships, which makes it difficult to choose an appropriate one for a specific project (Liu et al. 2016; Young and Brans, 2017; Knoeri et al., 2016; Li et al., 2018). To solve this gap, this paper will identify the main modes of multi-sector partnerships, and provide analysis concerning their applicable sectors, level of maturity, suitable situations, as well as advantages and disadvantages.

In addition, some multi-sector partnership modes which consider the citizens' participation have not yet been widely applied in the urban development area (Ahmed and Ali, 2006; Knoeri et al., 2016; Delannon et al., 2016). In fact, the participation of citizens is considered an indispensable part of urban

sustainability as they can provide and discuss current issues and needs related to their living environment, which can lead to social sustainability through balancing community interests and creating shared value (Clarke et al., 2019; Loh et al., 2020; Yigitcanlar et al., 2019). Therefore, analyzing the strengths and weaknesses of these modes, as well as proposing improvements, is crucial for the further development of urban planning.

The objective of this study is to explore the main modes of multi-sector partnerships, to analyze the current state, limitations, differences of these modes in details, as well as finding the most promising areas of improvements. This will be done through reviewing the relevant theories and applications of multi-sector partnerships in the urban development context.

The research questions this paper proposes are:

1. What is the current status of multi-sector partnerships research in the urban development context?
2. What are the differences between the various modes of partnerships?
3. What are the most promising areas for improvement in the existing modes?

The remainder of the article is organized as follows: Section 1 demonstrates the definition, characteristics, and importance of multi-sector partnerships for sustainable urban development and the current state of the existing research, and presents the research questions; Section 2 describes the research methodology; Section 3 presents the results of the review; Section 4 discusses the results based on the three research questions; Section 5 concludes the review.

2. Research methodology

This study adopted a scoping review methodology, with the aim of summarizing and analyzing the history and status of multi-sector partnerships in the urban development context, as well as indicating existing main modes and identifying the differences between them. Furthermore, the most promising areas for improvement were identified by comprehensively searching and analyzing existing research.

Before undertaking the scoping review, a basic guideline was set to ensure the correct direction of the review (see Table 1). The guideline limited the scope, sources, and the information to collect on each article. The scope contains timespan, access, and language, while sources are mainly from Science Direct, Web of Science, Google Scholar, Scopus, ACM Digital Library, and IEEE Xplore. The collected information refers to the title, authors, keywords, aim, methodology, results, and recommendation for further study.

The relevant studies were identified through a three-step process: The first step involves a structured search in academic databases, the second step uses the snowballing technique and explores the expanded keywords search and the third step narrows the research down to a controllable scope.

2.1. ***First,*** *a structured search*

First, according to the definition of multi-sector partnerships, the keywords “multi-sector partnerships”, “different institutions partnership”, and “multi agencies partnership” were used in the databases of *Web of Science*, *Science Direct, Google Scholar, Scopus, ACM Digital Library, and IEEE Xplore*. In addition, some newer innovative partnership models use different terminologies, such as co-design, co-creation, institutions, triple/quadruple helix innovation models, and living labs. These keywords were also used for conducting the literature review. To limit the research field, relevant results also had to include the terms “urban ecosystem”, “urban development”, or “urban planning”. Furthermore, the year of publishing was limited to the last five years. This limitation was only applied in the first step for exploring the most important and cutting-edge research on this topic.

2.2. ***Second****, expanded keywords and snowballing search*

To identify articles that were not found by the structured approach described above, expanded keywords and snowballing search (Wright and Stein, 2005) were conducted. The research scope was extended by using the newly identified modes, such as “multi-stakeholder partnership”, “public participation”, “community engagement”, “public-private partnership”, “end-user-oriented partnerships” and “public-private-people-partnerships” of multi-sector partnerships as expanded keywords. At the same time, backward and forward citations tracking of these articles were conducted as a snowballing search.

2.3. ***Third****, study selection*

When implementing the two steps within the chosen databases, more than 4300 articles emerged. To identify the most relevant literature for the research, the following restrictions were applied:

- Studies before the year 2000 were excluded (important theoretical articles were not excluded). Based on this, relatively new challenges in the related fields could be found.
- Only articles in the *Science Citation Index (SCI)* and *Social Sciences Citation Index (SSCI)* journals were included (important theoretical articles were not excluded). This ensured that studies of relatively high academic value could be found. This step narrowed the study sample to 1300 articles.
- However, a study sample of 1300 articles was still perceived to be too unspecified for providing relevant answers to the research purpose. Therefore, a closer review of these studies was necessary. The titles were assessed, narrowing the number of articles down to 900. The sample was filtered down to 113 studies after assessing the keywords and abstracts.

The scoping process is summarized in Table 2.

Table 1
A scoping review guideline.

Scope	Sources	Collected information
• The Timespan for conducting the review: Six months • Access to the full text • English language	• Science Direct • Web of Science • Google Scholar • Scopus • ACM Digital Library • IEEE Xplore	• Title, author(s), year of publication • Keywords • Aim of the study • Methodology • Results • Recommendation

Table 2
The scoping process.

Stage	Process	Number of the identified papers	Method
1. Initial structured search	Search for "multi-sector partnership", "different institutions participation partnership", "multi agencies participation partnership" AND "urban ecosystem", "urban development", and "urban planning"	96	Bibliometric
2. Expanded keywords search	Search for "stakeholder participation partnership", "public participation", "community engagement", and "public-private partnership" AND "urban ecosystem", "urban development", and "urban planning"	2130	Bibliometric
3. Snowballing	A snowballing search of the identified papers before	4300	Bibliometric
4. Filtering	Excluded studies before the year 2000	1300	Bibliometric
5. Specification	Qualitative assessment of title	900	Bibliometric + qualitative assessment of title
6. Selection	Qualitative assessment of title, keywords, and abstract	113	Bibliometric + qualitative assessment of title, keywords, and abstract

3. Results

Following the proposed research questions, the final sample is comprised of 113 articles.

3.1. The current status of multi-sector partnerships

The literature review identified five main modes of multi-sector partnerships, namely:

- Multi-stakeholder partnerships
- Community-organizational partnerships
- End-user-oriented partnerships
- Public-private partnerships
- Public-private-people partnerships

The proportions of the main five modes of multi-sector partnerships in the research sample are shown in Fig. 1. 'Multi-stakeholder partnerships' and 'community-organizational partnerships' both represent 30% of the sample, followed by 'end-user-oriented partnerships' with 18% and finally 'public-private partnerships' and 'public-private-people partnerships', which together represent 22%.

Fig. 2 shows the publishing year of the identified articles. By observing the number of research articles per year, it can be seen that the modes of multi-sector partnerships in urban sustainable development were not widely developed before 2014. After that, related studies steadily increase until 2018, which suggests that multi-sector partnerships are becoming an increasingly important approach for sustainable urban development. Only 3 articles from 2019 are in the sample, as the database search was conducted in early 2019.

Fig. 3 shows the publishing journals of the sample papers. From the figure, we can observe that 37 of the sample articles are published in *The Journal of Cleaner Production*, equaling 33% of the study sample. The journal was found valuable for the further exploration of related research, as it provided a means of identifying interrelated research. Results also show that other journals such as *Cities* and *Building and Environment* have high value for further study. *Cities* represents 17% and *Building and Environment* 14% of the study sample.

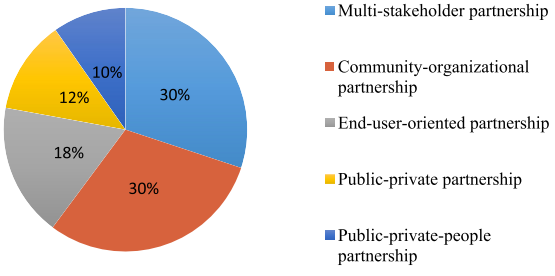

Fig. 1. Percentages of different modes of multi-sector partnerships in the sample.

Fig. 4 shows the most frequently used keywords in the sample articles. 'Obstacles and drivers', 'engagement', 'relationship', and 'influence' are the most popular keywords and can help in determining the most important focus of the research. The 'Obstacles and drivers' refers to the barriers and drivers to apply the modes, 'engagement' focuses on how to engage related sector to participate in the partnership modes, 'relationship' emphasizes the relationship between different sectors, and the influence refers to the impact on the urban sustainable development. In the following, the identified five modes will be analyzed concerning the differences between these modes in terms of these four aspects.

3.2. Differences between various modes of partnerships

The following section corresponds to the second research question, namely searching for differences between the various modes of partnerships. The differences among them will be explained through four main aspects. These are 'engagement', 'relationship', 'barriers and drivers' and 'influence', since they are the most frequently observed keywords in the articles (see Fig. 4). At the same time, the theoretical background, corresponding applicable sectors, and methodology of each part will be explored.

Table 3 summarizes the basic characteristics between the five modes concerning the concept, author, participants, and the potential impact it can have on the urban sustainable development. In the following, the detailed information will be analyzed individually.

3.2.1. Multi-stakeholder partnerships ($n = 34$)

The first mode is multi-stakeholder partnerships, which was developed based on stakeholder theory introduced by Freeman et al. (1984), who identified stakeholders as "any group or individual who can affect, or is affected by, the achievement of the organization's objectives". Therefore, the stakeholders include not only the investors but also other groups related to the results. Freeman's theory stirred interest in multi-stakeholder partnerships research and orientation (Le Feuvre et al., 2016; Bowen et al., 2017; Bissonnette et al., 2018). The applicable sectors include the following groups: financial institutions, governments, municipalities, management companies, customers, employees, suppliers,

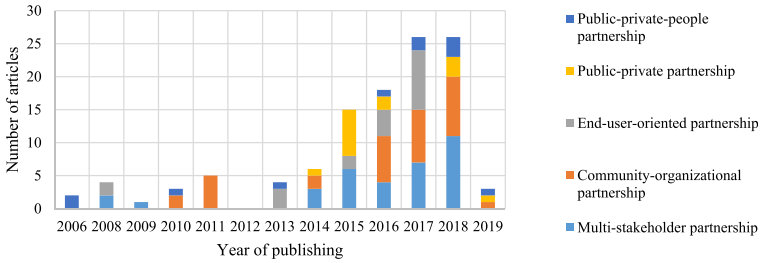

Fig. 2. Publishing year of identified articles.

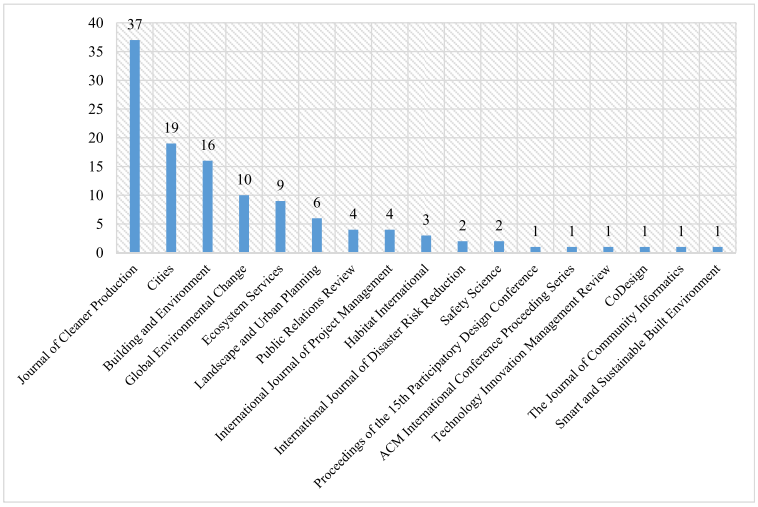

Fig. 3. Publishing journals of sample papers.

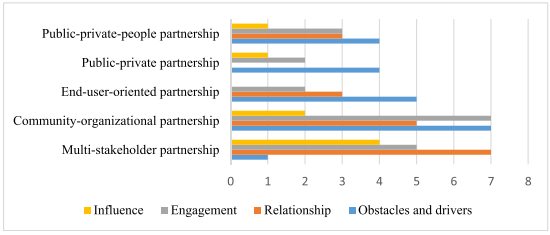

Fig. 4. Research focus of articles in each mode.

environmental institutions, local communities, the media, and others. The research focuses on the papers on multi-stakeholder partnerships are shown in Table 4.

In the literature sample, 35% of the articles focus on the theoretical framework, intending to develop new conceptual methods of participation in urban development (Bissonnette et al., 2018; Fernandez-Anez et al., 2018; Aoki, 2018). Twenty-five percent of the papers use real case studies, relevant for their respective countries and regions (Jung et al., 2015; Cousins, 2017; Aoki, 2018). Forty percent focus on the application of new methods of stakeholders' participation to urban ecosystem projects, such as the Delphi technique, Q-methodology, network approach and statistical analysis (Yang and Zou, 2014; Alberg Mosgaard et al., 2016; Cousins, 2017; Li and Ng, 2018).

The *relationship* category represents the largest group with 12 papers (35.3%). Specifically, the papers explore the relationship between different stakeholders (de Chazal et al., 2008; Jung et al., 2015; Le Feuvre et al., 2016; Hein et al., 2017; Yang and Bentley, 2017) and the relationship between organizers and stakeholders (Fernandez-Anez et al., 2018). In this part, the problem of balancing the stakeholders' power and involvement received much attention in eight articles, through applying innovative models to real projects. Specifically, Yang and Bentley (2017) proposed a theoretical model for moving away from a sender-centered pattern through power, legitimacy and urgency aspects, to better balance the relationship. Furthermore, an integrated model combining politics, knowledge, economy and social aspects with a set of internal and external factors were proposed by Fernandez-Anez and Fernández-Güell. At the same time, Hein (2017) attempted to balance the relationship between different stakeholders by analyzing the flow of power and value between them. The remaining four articles discuss the impact of behavior and interactions on the relationship of different stakeholders. For example, Le Feuvre et al. (2016) proposed that the stakeholders' cooperation will be affected by the attitude and behavior of different participants.

Ten papers focus on the *engagement* aspect (29.4%) and are

Table 3
The basic characteristics of the five modes of multi-sector partnerships.

Modes	Concepts	Reference/year	Participants in urban context	Impact on urban sustainable development
Multi-stakeholder partnerships	Cooperation between any group or individual who can affect, or is affected by, the achievement of the organization's objectives	Freeman et al. (1984)	Financial institutions, municipalities, management companies, customers, employees, suppliers, local communities, the media, and others	Potential to create financial, environmental, and social sustainable development depending on the project focus, through receiving multiple resources and reducing uncertainty and administrative overhead among stakeholders
Community-organizational partnerships	A group of people, whether they are stakeholders, an interest group, or a group of citizens in the same geographic location	Silberberg et al. (2011)	Stakeholders, interest groups, or groups of citizens in the same geographic location, with similar interests or within a small club	Creates mainly social sustainable development through balancing community interests and creating shared value
End-user-oriented partnerships	The person that receives and ultimately uses the good, service, or technology	*U.S. Code § 8541 - Definitions* (2019)	Occupants, visitors, owners, and tenants	Suitable for creating financial sustainable development through getting a good understanding of the consumers' desires and values
Public-private partnerships	Formal cooperation between enterprises and local government officials to improve the city	Davis (2016)	Government agencies and private-sector companies	Mainly creates financial and environment sustainable development through combining the political and financial resources from the public sector with the experience and expertise of the private sector
Public-private-people partnerships	A direct extension of public-private partnerships, it adds the "people" to supplement the missing links in the PPP process	Ahmed and Ali (2006)	Government agencies, private-sector companies, and citizens	It can create financial, social, and environment sustainable development through involving all resources from public, private, and people, as well as satisfying their needs

mainly concerned with methods of recruitment (Tyl et al., 2015; Alberg Mosgaard et al., 2016; Cousins, 2017; Aoki, 2018). Several papers underline that the methods of engagement should be chosen according to the participants' values. Specifically, Tyl et al. (2015) highlight different ways of engaging stakeholders by analyzing their values. Based on this, the drivers for participating in a cooperation process have been explored by Ferguson et al. (2017) through statistical analysis. From this, he suggests suitable recruitment methods based on the partners' values, which can be used as guidance in real projects. The way stakeholders form preferences and perspectives is the focus of the article by Cousins (2017), who explained how the circumstances, feelings, and awareness can affect the performance of the Q-methodology. Recently, a theoretical framework for tailoring methods of recruitment to the different types of participants has been provided (Aoki, 2018). Two articles explore dynamic involvement in the participation process. Alberg Mosgaard et al. (2016) analyzed how the participants' education, overall ability, and interest in urban development were linked to their level of engagement in a building renovation process.

The *influence* category also includes 10 papers. Betts et al. (2015) used quantitative confirmatory factor analysis to demonstrate that multi-stakeholder partnerships can improve the environment. Stakeholders' influence is also quantitatively analyzed by Li et al. (2018) in the context of the architectural, engineering and construction industry. The results show that there was more social acceptance of the building public space when created by multiple partners. In addition, three other evaluation methods are used in separate articles. Thabrew et al. (2009) recommended applying the life cycle assessment to guide the decision in urban planning. de Chazal et al. (2008) discussed how different values affect the results with respect to financial and environmental aspects through a matrix approach. Finally, Li and Ng (2018) studied the influence of various stakeholder groups, using the Delphi approach to quantify the impact of sustainability. The results show that multi-stakeholder partnerships can promote a more sustainable urban development from a social, economic, or environmental aspect, but the emphasis is different in different cases.

Only two papers (5.8%) discuss the *barriers and drivers*. Bissonnette et al. (2018) suggest that prioritizing engagement can improve the efficiency of cooperation at an early stage. In addition, limited standards in the participation process make it difficult for stakeholders with less power to impact the decision-making process (Gan et al., 2018).

With respect to methodology, the most commonly used methods in existing studies are literature reviews, case studies, and statistical analyses. Recent multi-stakeholder articles use novel approaches such as the Delphi technique, Q-methodology, and network approach. The Delphi technique is a statistical method for quantifying subjective evaluation. A large number of people score their personal subjective preferences, and the average value is used as the result (Hallowell, 2009; Chim-Miki and Batista-Canino, 2018). Q-methodology explores the viewpoints of people with different opinions. The result of the method is a sum of these opinions aggregated in a structured way (Buchel and Frantzeskaki, 2015). The last method is the stakeholder network approach, which is grounded in social exchange and resource dependence theory. It emphasizes the dynamic interaction among multiple stakeholders instead of the relationship between only two stakeholders (Sciarelli and Tani, 2013).

3.2.2. *Community-organizational partnerships (n = 34)*

Community-organizational partnerships is another mode of multi-sector partnerships. This mode is used by one or more

Table 4
Research focuses on multi-stakeholder partnerships.

Research focus	Some criteria/keywords	Main Methods	Main references	Weight (%)
Barriers and drivers	Obstacles, barriers, baffle, encumbrance, traverse	Data collection and analysis; focus groups	Bissonnette et al. (2018); Gan et al. (2018)	5.8%
Relationship	Relationship, relation, connection, hypotaxis, affect	Interviews; case studies; network approach; a Delphi approach; semi-structured interviews; matrix approach	Jung et al. (2015); Le Feuvre et al. (2016); Hein et al. (2017); Yang and Bentley (2017); de Chazal et al. (2008); Fernandez-Anez et al. (2018); Yang and Zou (2014)	35.3%
Engagement	Method, way, means of engagement, how to engage	Brainstorming; Q-methodology; interviews, surveys, focus groups; scenario analysis; life cycle assessment approach	Tyl et al. (2015); Alberg Mosgaard et al. (2016); Cousins (2017); Aoki (2018); Ferguson et al. (2017)	29.4%
Influence	Influence, affect, effect, positive influence, value	Literature review; hypotheses; confirmatory factor analysis (SPSS); IBM SPSS statistic; quantitative method	Betts et al. (2015); Li and Ng (2018); Thabrew et al. (2009); de Chazal et al.(2008); Wang et al. (2014)	29.4%

organizations in projects that are closely related to the community. A community commonly refers to a group of people, whether they are stakeholders, an interest group, or a group of citizens. First, the mode involves influential partners in the community. Then, the initial partners mobilize resources, attempt to improve relationships, promote cooperation, and ultimately achieve community engagement (Esmaeilpoorarabi et al., 2020). Hence, the applicable sectors would commonly include stakeholders, interest groups, or groups of citizens in the same geographic location, with similar interests or within a small club.

The research focus on community-organizational partnerships is shown in Table 5. The number of identified articles is the same as in multi-stakeholder partnerships. Twenty-three percent of the papers focus on the theoretical framework, while the remaining papers explore the development of community-organizational partnerships with real case studies.

The *barriers and drivers* category represents the largest category with 35.3%, while the *engagement* group accounts for 29.4%, followed by research on the *relationship* which represents 23.5%, and finally the *influence* category with 17.6%. The key objective of the research in this cluster is identifying the barriers and drivers and finding efficient methods of engaging the community in an urban ecosystem.

The sample suggests that the main barriers and drivers for community engagement are financial value and trust. Specifically, five articles emphasize the importance of financial value and three papers focus on the trust factor for engagement. Looking at sale & lease-back and contracting models, Fleiß et al. (2017) claim that monetary and not moral value makes the most important impact on citizen participation. Furthermore, Swapan (2016) claimed that awareness and trust are the main factors for engaging, based on a field survey focusing on social, political and psychological factors. Li and de Jong (2017) argued that distrust is the main barrier for community engagement, by examining the actual performance of citizen participation in eco-city development cases. In addition to the financial value and trust, the geographical location and inclusiveness of decision-making were also considered important factors for engagement. For example, Bottini (2018) explored the factors affecting community participation in the built environment through questionnaires and regression analysis and found the geographical location to be the most important factor. Finally, Young and Brans (2017) analyzed a case study of a sustainable energy community and proposed that inclusiveness in decision-making and co-ownership are the most important factors in community engagement.

In the *engagement* category, the main focus is on engagement approaches. Delannon et al. (2016) compared the community engagement strategies of 17 companies. They argued that information sharing, community consulting, corporate community joint initiatives, and community relations managers' participation are efficient methods of engagement. At the same time, Ranger et al. (2016) attempted to include the community voices through an interpretive-deliberative-democratic approach. The results showed that knowledge sharing, social learning, and deep communication play crucial roles in the recruitment process. Furthermore, Gold et al. (2018) used system dynamics modeling and real-time analysis for developing a model of collective action for community involvement. In addition, Hu (2018) focused on the role of scientists in the community and their degree of involvement in scientific communication.

The *relationship* category consists of the interactions between the organization and the community and the interaction among different participants in the community. In particular, Robinson and Berkes (2011) proposed that multi-level participation is necessary to increase the interaction between the organization and the community, as the different levels have more potential to adapt to the real situation. Furthermore, social factors such as the level of authority, trust, and social support were shown to affect the interaction between participants (Boiral et al., 2019).

The *influence* group mainly focuses on the impact of community-organizational partnerships on urban ecosystem change. For example, Kithiia and Dowling (2010) used interviews, focused group discussions, and a climate report review to show that community-organizational partnerships can lead to reduced CO2 emissions. Similarly, Robinson and Berkes (2011) used a case study to demonstrate how community-organizational partnerships can increase the adaptive capacity of an ecosystem.

For this mode, the most widely used methods are regression analysis models (Bottini, 2018) and business models (Fleiß et al., 2017), combined with case studies and literature reviews. Regression analysis is a way of mathematically determining the importance of each variable. Namely, which factors matter the most, which ones can be ignored, how they interact with each other and their corresponding uncertainty (Iserbyt et al., 2015). The business model typically focuses on the value proposition, activities design, and profits acquisition (Madsen, 2019). The sustainable business model is designing the business model according to the needs of the community, which can attract multiple citizens to participate (Bocken et al., 2019).

3.2.3. End-user-oriented partnerships ($n = 20$)

The third mode is the end-user-oriented partnerships. It is widely accepted that the main aspects of sustainable urban development, such as built environment, energy, climate, and

Table 5
Research focuses on community-organizational partnerships.

Research focus	Some criteria/keywords	Main Methods	Main references	Weight (%)
Barriers and drivers	Obstacles, barriers, baffle, encumbrance,traverse, longstop, drivers, factors, opportunities	Case study, literature review, regression models, sale & lease-back model, contracting model	Fleiß et al. (2017); León-Fernández et al. (2018); Swapan (2016); Li and de Jong (2017); Young and Brans (2017); Bottini (2018)	35.3%
Relationship	Interplay, interactions, effect on each other	Case study, literature review, scenario methods	Robinson and Berkes (2011); Robinson and Berkes (2011); Boiral et al. (2019)	23.5%
Engagement	Method, way, means for engagement, how to engage	Case study, literature review, interpretive film-based approach, retrospective, and real-time analysis	Delannon et al. (2016); Ranger et al. (2016); Gold et al. (2018); Hu (2018)	29.4%
Influence	Influence, affect, effect, positive influence, value	Interviews, one-on-one discussions with relevant stakeholders, focused group discussions, documentary review	Kithiia and Dowling (2010); Robinson and Berkes (2011)	17.6%

urban green infrastructure, are determined by their end-users (Knoeri et al., 2016; Wood et al., 2016; Baldassarre et al., 2017a). Consequently, there has been much research on the topic in recent years. The Legal Information Institute defines "end-user" as: "the person that receives and ultimately uses the good, service, or technology" (*U.S. Code § 8541 - Definitions*, 2019). In the urban development context, end-users typically refer to occupants, visitors, owners and tenant organizations.

Twenty articles were identified and classified according to the research focus given in Table 6. Eight papers focus on the theoretical framework, with literature review as the main method, while the remaining twelve papers conduct case studies to answer their questions. The table shows that the *barriers and drivers* category represents 45% of the papers, followed by the *relationship* and *engagement* groups which account for 30% and 20%, respectively. Only 5% of articles discuss the influence of end-user-oriented partnerships.

In the *barriers and drivers* category, financial means, knowledge sharing, and technologies used for communication represent the main factors for end-user-oriented partnerships. Specifically, Beal et al. (2013) performed a series of tests and claimed that a range of variables can affect the participation of end-users, including age, income, and education. Based on this, Knoeri et al. (2016) proposed that the key drivers are financial benefits, business structure, and communication technology through analyzing the performance of participants. Furthermore, Nielsen et al. (2016) defined the concept of sustainable end-user innovation (SEI), whereby innovation is mainly end-user driven. They further proposed a set of policies to accommodate better SEI, emphasizing that creating platforms for knowledge sharing is an important factor. In a separate paper, Bigerna et al. (2017) suggested technologies play an important role in the end-users' participation through a meta-analysis.

The *relationship* category mainly focuses on the relationship between end-users and developers, as well as the relationship between end-users and practitioners. The relationship between the developers and end-users is studied by Qian et al. (2015), who used a tree game to express how the dynamic relationship developed in different scenarios. Heiskanen et al. (2013) claimed that there is a shortage of approaches for formal and informal interaction between end-users and practitioners.

The *engagement* category mainly explores strategies for joining different types of end-users. For example, Baldassarre et al. (2017a) developed a framework for collecting information for making a value proposition, which is related to business models. Furthermore, the method of door-to-door interviews was tested for promoting end-users participation in three scenarios by Atlason et al. (2017).

One article discusses the *influence* of end-user-oriented partnerships. In a case study of three European firms, Zimmerling et al. (2017) claimed that constant end-user integration helps companies overcome risks, and brings new opportunities to the market.

In this part, the most commonly used methods are meta-analysis, business model and tree game model. A meta-analysis is a survey in which the results of past studies are combined and analyzed as if they were one study. A business model describes the whole process of conducting business, which mainly contains a value proposition, value transfer, and value acquisition (Geissdoerfer et al., 2017). Business models are applied in this part due to the end-user value being a crucial factor for participation. The tree game model visualizes the decisions and expresses each decision point and decision outcome (Huang et al., 2018).

3.2.4. Public-private partnerships ($n = 14$)

The fourth mode is the public-private partnerships (PPP), which was defined as "formal cooperation between enterprises, social leaders and local government officials to improve the city" by Perry Davis in 1986 (Davis, 2016). Most often, the main applicable sectors are government agencies and private-sector companies. The private partners mainly participate in financing, planning, and managing the projects, while the public partners commonly focus on launching and monitoring the projects.

Among the identified modes of multi-sector partnerships, PPP is the only one not directly involving citizens. However, according to Arnstein (1969), including the citizens in decision-making is crucial for attaining sustainable social development. Hence, only 14 articles concerning PPP projects were chosen. Table 7 shows the research focus on public-private partnerships.

PPP papers are classified slightly differently than the other multi-sector partnerships modes: It is relatively mature, and engagement and barriers are no longer considered main issues. This is very different from the other modes, where citizen engagement is one of the main challenges. Instead, there is much more focus on the application of PPP and its risks.

Eight papers discuss the *application* of PPP, mainly focusing on governmental institutions and policies. For example, Chou et al. (2015) developed sustainable PPP policy guidelines through a strategic governance model, which is designed for increasing adaptability in the event of a global financial crisis. At the same time, Zhang et al. (2015) verified the institutional analysis and its implications in a Chinese context, and argue that good policies can lead to healthy PPP promotion. In addition, the negotiation between the public and private sectors has also received much attention (Almarri and Blackwell, 2014; Liang et al., 2019). Liang et al. (2019) proposed building a game model based on the initial negotiation process, which can be used to guide the renegotiation process.

Four of the papers focus on the risks related to PPP. Projects using PPP generally require a high up-front investment, which

Table 6
Research focuses on end-user-oriented partnerships.

Research focus	Some criteria/keywords	Main Methods	Main references	Weight (%)
Barriers and drivers	Obstacles, barriers, baffle, encumbrance, traverse, drivers, factors, opportunities	Meta-analysis, literature review, snowball sampling, descriptive analysis	Beal et al. (2013); Knoeri et al. (2016); Nielsen et al. (2016); Bigerna et al. (2017)	45%
Relationship	Interplay, interactions, effect on each other	Game mode, case study	Qian et al. (2015); Heiskanen et al. (2013)	30%
Engagement	Method, way, means for engagement, how to engage	Design methodology, quantitative kano analysis, End-of-Life scenarios	Baldassarre et al. (2017a); Atlason et al. (2017)	20%
Influence	Influence, affect, effect, value	Case study	Zimmerling et al. (2017)	5%

makes risk assessment very important. Risk realization and risk evaluation in the process of cooperation between public and private were examined by Keers and van Fenema (2018) through cross-case analysis, qualitative studies and a multi-layered approach. The results show that investing in the cooperation structure before formal partnerships can reduce the risks. Furthermore, De Schepper et al. (2015) claimed that efficient risk management, improved methodology, and knowledge management should be the aim of further studies after conducting a literature review of PPP.

Two of the papers pay attention to the barriers and drivers of PPP. The factors with higher impact were considered to be benefits and risks sharing, institutional support, community support, stable economic environment, and information sharing (Osei-Kyei and Chan, 2015; Liu et al., 2016).

Literature reviews, case studies, the multi-layered approach, and statistical methods are the main methods used. The multi-layered method contains multiple levels, with each level including different indicators, and the combination of different levels forming a complex relationship (Li et al., 2018). The statistical approach is based on a large amount of data and analyzes the relationship between different types of data, as well as pointing out further trends.

3.2.5. *Public-private-people partnerships (n = 11)*

The last mode of multi-sector partnerships is public-private-people partnerships (PPPP). A direct extension of PPP, it adds the "people" to supplement the missing links in the PPP process (Ahmed and Ali, 2006). In this model, "public" means government departments, "private" refers to private for-profit enterprises, while "people" represent citizens. The participation of the people makes the existing cooperation more diverse and realistic, thus considering the social aspect, which brings it closer to the complexity of real urban ecosystems (Nunbogu et al., 2018). In the process of participation, the roles of the public, private, and people are usually facilitators, providers, and end-users, respectively. Different participating entities provide assets or services according to their own characteristics.

After extensive searching, eleven related articles were identified and classified by research focus, given in Table 8. Results show that the *barriers and drivers* and *engagement* groups together account for 63%. Hence, the key objective of the research is to explore more efficient methods for improving the application of PPPP. The main methods used in this part are literature reviews, semi-structured questionnaires, and case studies.

36% of the articles focus on the *barriers and drivers* for PPPP. Marana et al. (2018) developed a framework exploring the successful characteristics of PPPP in the resilience-building process. Good relationships among partners, unobstructed information flow, and efficient methods for solving conflicts were considered as main drivers for PPPP. Conversely, the obstacles identified by Ahmed and Ali (2006) are the costs of facilitation, urban services, and feedback mechanisms by case studies. Lodato and DiSalvo (2018) argue that institutions can produce constraints and barriers for the application of PPPP. Shortly after, Foth and Turner (2019) proposed a conceptual framework aiming to transfer the policy-oriented institutions to more community active institutions.

The *engagement* is another important aspect of PPPP that concerns ways of building an optimal process, involving all the partners at different stages. Ng et al. (2013) visualized the participation process to understand the conflict points and the different needs of the partners. Hughes et al. (2018) try to foster digital participation and informal learning among public, private, and people through social living labs. The main participatory methods included sharing information and experience, co-creation, and co-evaluation around different social concerns. Baccarne et al. (2016) applied a quintuple helix model to explore the innovative methods for applying PPPP through urban living labs, which have been considered a method to work with ad hoc collectives, lowering the barriers for collaboration.

A study on *relationship* structures of PPPP was conducted by Fontainha et al. (2017) using multiple research methods, such as literature review, data collection, and data interpretation. A visual representation of relationship structures was presented through vertical/horizontal and centralized/decentralized aspects. Foth and Adkinsor (2005) developed and tested a new ethnography research method for understanding the value of citizens engaging in social networks. Based on this, Foth (2017) analyzed the maturity of the relationship between citizens and governments through a critical review approach. The results were categorized into four classes, namely, people as residents, consumers, participants, and co-creators.

Table 7
Research focuses on public-private partnerships.

Research focus	Some criteria/keywords	Main Methods	Main references	Weight (%)
Application	Institution, policy, incentives	Literature review, cross-case analysis, qualitative studies, multi-layered approach	Chou et al. (2015); Zhang et al. (2015); Liang et al. (2019); Almarri and Blackwell (2014)	57.1%
Barriers and drivers	Application, adoption, appliance	Systematic literature reviews, questionnaires, surveys	Osei-Kyei and Chan (2015); T. Liu et al. (2016).	14.3%
Risks	Risks, hazard	Statistical analysis	Keers and van Fenema (2018); De Schepperv et al. (2015)	28.6%

Kuronen et al. (2010) examined the *influence* of PPPP by investigating the possibility of applying PPPP. In a case study, the application of PPPP was shown to be able to reduce CO2 emissions by 75% through new system design and newly proposed solution by applying knowledge from three sectors.

4. Discussion

This section discusses the results of this study following the three research questions proposed in the introduction.

4.1. What is the current status of multi-sector partnerships research in urban development?

Five modes of multi-sector partnerships were identified. The current status of each mode is different. The multi-stakeholder partnerships category has the largest proportion of the selected papers and employs a more diverse set of methods than the other categories, such as the Delphi technique, Q-methodology, network approach, and regression analysis model. One possible reason for its success is that stakeholders are more willing to participate than other participants since they are often directly affected financially by the outcome of the project. Furthermore, there are more opportunities to conduct practical case studies. Finally, cooperation and balancing of power are somewhat easier than for example PPPP, as everyone has a voice in the decision-making process.

Although community-organizational partnerships is a new concept in the urban development area, the results show that there is much ongoing research. However, the fact that the research mainly focuses on barriers and drivers of engagement indicates that the current level of community participation is not high enough or has not yet achieved effective participation and desired goals.

End-user partnerships group in urban development has begun to receive attention in recent years, however, it is still in its early stages. Research is largely problem-oriented, focusing on identifying barriers for engaging the participants.

Public-private partnerships category is developing well and has a wide range of applications internationally. Different areas such as risk management, relationship management, financial viabilities, and procurement have been explored by researchers worldwide since the late 1990s. In the total sample, only 12.5% of the articles are about PPP projects, however, this is not due to limited research, but to the fact that this paper pays more attention to the common citizens' participation.

The last form of multi-sector partnerships is public-private-people partnerships (PPPP). Eleven related articles were found in all the domains in the database. This is not surprising since it is quite difficult to include people in the PPP models. Government departments can provide corresponding institutional guarantees and enforcement rights, and the private companies can provide investment capital and operational management experience, but citizens have neither the authority nor the money, making it difficult for them to have an equal position. Moreover, ordinary citizens rarely have enough knowledge to participate in the discussions, and often fail to provide effective strategies. It seems that both the theory and the application of this mode are underdeveloped.

4.2. What are the differences between the various modes of partnerships?

Although all the modes are forms of multi-sector partnerships, there are differences in several aspects. First, the applicable sectors vary. The multi-stakeholder partnerships category is arguably the most general mode. Unlike the other modes, it does not require participants to have a specific background such as public and private sectors but includes any participants who can affect or be affected by the achievement of objectives in the project. Projects based on multi-stakeholder partnerships generally aim to benefit the stakeholders themselves. On the other hand, community-organizational partnerships and PPPP are often formed to create value for mainly the citizens. The applicable sectors for community-organizational partnerships commonly include organizations, stakeholder communities, interest groups, or citizen groups in the same geographic location. For PPPP, the applicable sectors are more focused on the resources and differences between the public and private sectors, as well as the opinions of the citizens. End-user-oriented partnerships also emphasize the opinions of citizens; however, the goal is commonly to make them prosumers. The applicable sectors are the organizers and the people that ultimately use the good, service, or technology. In the public-private partnerships (PPP) model, the main applicable sectors are government agencies and private-sector companies. Unlike the other partnership modes, it does not include the citizens, which sometimes leads to missing the actual need of the citizens.

Second, the level of maturity among the modes is different, which in turn leads to a different research focus. The main research focus for multi-stakeholder partnerships is the relationship between stakeholders, representing 41.2% of the studies in this category. Among these, the majority focuses on how to balance the power of the different stakeholders. This is a sign of maturity, as it has moved beyond problems surrounding barriers and engagement. The research on community-organizational partnerships focuses on mainly the barriers and drivers of community engagement, closely followed by engagement approaches. Furthermore, the results show that financial value and trust are the main factors affecting community engagement. Most papers explore the characteristics of community engagement with case-studies from different regions, due to the cultures in communities being highly dependent on the location. For end-user-oriented partnerships, most papers try to identify factors that affect end-user participation. The results show that financial compensation, knowledge exchange, and technologies used for communicating are the most

Table 8
Research focuses on Public-Private-People partnership.

Research focus	Some criteria/keywords	Main Methods	References	Weight (%)
Barriers and drivers	Obstacles, barriers, baffle, encumbrance, traverse, longstop, drivers, factors, opportunities	Literature review, semi-structured questionnaires, observation	Marana et al. (2018); Ahmed and Ali (2006); Lodato and DiSalvo (2018); Foth and Turner (2019)	36%
Engagement	Method, way, means for engagement, how to engage	Literature review, case study	Ng et al. (2013); Baccarne et al. (2016); Huybrechts et al. (2017)	27%
Relationship	Interplay, interactions, effect on each other	Data analysis and synthesis	Fontainha (2017); Foth and Adkinsor (2005); Foth (2017)	27%
Influence	Influence, affect,effect, positive influence, value	Literature review, case study	Kuronen et al. (2010)	9%

important factors in the participation process, with formal and informal information exchange being crucial as well. For the PPP mode, most of the research is centered on policymaking, rather than problems surrounding engagement. Therefore, at present, the projects in the relevant fields are mostly policy-oriented and the related research mostly discusses how to avoid risks and create benefits. PPPP is the least developed; since the term was introduced in 2006, only eleven research papers have been written on the topic. Existing papers mainly focus on developing theoretical frameworks. There are some theoretical participation strategies, but since there are few corresponding cases, their effectiveness cannot be fully proven.

Third, the modes are suitable for different situations. For projects with a clear objective and where the participants have already been determined, multi-stakeholder partnerships are effective. If the project puts more emphasis on the opinion of the community and a willing suitable organization can be found, the community-organizational partnerships will be a good choice. For projects that aim to create new products or services, the end-user-oriented partnerships should be considered. Projects organized by the public sector can use PPP or PPPP to increase its total resources and reduce risk.

Finally, each method has clear advantages and disadvantages. The biggest advantage of stakeholder partnerships is its maturity and efficiency. However, in an urban sustainable development perspective, there is little emphasis on social sustainability. Community-organizational partnership's main advantage is that a neighborhood community usually shares the same geographical location, which means that they likely have a shared culture and set of values. This facilitates the balancing of their interests and the creation of shared value. Second, the proximity between participants within the community makes it easier to arrange meetings and workshops. However, the engagement process has a lot of barriers, due to a lack of willingness to participate among citizens. End-user-oriented partnerships typically get a good understanding of the consumers' desires and value, however, similarly to community-organizational partnerships, engaging citizens is a big challenge. The PPP has the potential for social welfare and economic benefits, however, by excluding the citizens from the decision-making process, they may not capture the real needs of the citizens. The PPPP has the potential to solve all the previous problems, however, no good method exists.

4.3. What are the most promising areas of improvements for the existing modes?

All five modes of multi-sector partnerships share some common problems related to partner relationship, engagement, barriers and drivers, and influence. Identification of barriers and driving factors can provide a better direction for the engagement strategy. The relationships between different stakeholders play an important role in the final decision-making process. The efficiency of the engagement strategy can lead to the successful application of the modes, and the influence and effects of the methods can help to determine which modes to choose in projects.

First, the relationship between participants is a general issue, as various sectors generally have different power in the decision-making process, which can lead to disagreement and discontent among the participants. Particularly, the power of citizens tends to be quite low in PPPP and end-user-oriented partnerships, which in turn leads to low levels of engagement. However, thus far there are no methods in existing research to efficiently balance their power. Although some studies are starting to explore the appropriate sequencing and combining of participation by the various sectors, which are designed to balance the power among them, the results are not very clear. There are also papers which suggest that close relationships are efficient for making agreements, but do not mention how to build them. Furthermore, researchers are exploring the relationships between different sectors, but the micro-level classification is missing, such as relationships concerning economic rights and resource sharing. To increase the citizens' participation, as well as improving their role in decision-making, it is clear that further research is needed on managing relationships in multi-sector partnerships.

Second, an efficient approach to engage different sectors is a premise to form multi-sector partnerships. Some researchers discuss various modes of recruitment, from coercive to voluntary ones, and the respective types of participants. However, they do not mention how to combine modes of recruitment with specific sectors, which needs to be further explored. In addition, an approach to make an agreement between participants is key in the engagement process of multi-sector partnerships, as different sectors regularly have different opinions and priorities. Some methods, for example, the Delphi technique, can be used to obtain the collective opinion of the participants in a well-structured and academically rigorous process. However, the path to reach this agreement is quite a time and energy-consuming. For further study, more efficient methods to reach an agreement are needed.

Third, for determining barriers and drivers, the Q-methodology is used to reveal different social perspectives, attitudes, and understandings during the participation process. It is an efficient way to find the factors which affect the willingness of participants. However, investigation reveals that there is no effective way to systematically classify these factors, as well as determine their relative importance.

Finally, with regard to the influence of multi-sector partnerships, the results show that multi-sector partnerships can promote sustainable urban development from social, economic, and environmental aspects. However, most studies only measure the effect at the end of the process, without addressing the influence of the participants in the different stages. Further research in this area may improve understanding of the strengths and weaknesses at each stage of the process.

In addition, there are some specific problems in each mode. For the multi-stakeholder partnerships, its methods are relatively mature and efficient, and in theory, everyone who can affect or have been affected by the objectives of the project are included. However, in real cases, the stakeholders usually do not include all affected parties, especially the citizens, which leads to less value gained in terms of social sustainability. The issue of citizens' engagement should be emphasized in future research.

For community-organizational partnerships, the main issue is engagement. As financial value and trust are considered the most important factors, research on business models could potentially solve the problem. As for trust, more efficient approaches are needed for improving trust between partners. While several theoretical frameworks for engagement strategies exist, they still need to be put into practice to determine their efficiency.

For the end-user-oriented partnerships, the most important factors for participation are financial value, knowledge exchange and use of technology for communication. The development of business models that bring more immediate value to the end-user, as well as digital tools that common citizens can adopt are two possible solutions. Moreover, the interaction between end-users and organizers needs both formal and informal methods, which means that both formal documents and informal communication should be designed.

The PPP has developed well in terms of the application and providing risk guarantees. However, as it does not consider the real needs of citizens, its direct top-down approach may not have the

competitive strength for the increasingly complex urban development. Involving the citizens to share benefits and risks will need further study, in order to achieve higher social acceptance.

PPPP is a good concept that can get support through policies made by the public sector, financial and operational support from the private sector, and an accurate portrayal of the needs of citizens. However, it is still underdeveloped. For further development of this mode, the barriers should first be identified, an efficient engagement method is needed, and a cooperation model should be designed.

5. Conclusion

To cope with the complex challenges and respond to the uncertainty of urban development, multi-sector partnerships, which can facilitate cooperation and combine resources from different fields, are regarded as an efficient approach. The paper conducted a scoping review on multi-sector partnerships in the urban development area, to answer the following research questions:

1. What is the current status of multi-sector partnerships research in the urban development context?
2. What are the differences between the various modes of partnerships?
3. What are the most promising areas for improvement in the existing modes?

Three steps were conducted to determine the sample papers: structured searching, expanded keywords and snowballing search, and filtering selection. Finally, 113 papers were selected, which were used for analyzing the research questions.

The results show that multi-sector partnerships can be classified into five modes, namely multi-stakeholder partnerships, community-organizational partnerships, end-user-oriented partnerships, public-private partnerships, and public-private-people partnerships. According to existing research, multi-stakeholder partnerships established itself early and has developed to a relatively mature level with many types of innovative approaches. Community-organizational partnerships is a newer concept in the urban development area, but there is much ongoing research in the field. End-user partnerships in urban development has begun to receive attention in recent years, however, it is still in its early stages. Public-private partnerships is developing well and has a wide range of applications internationally. Public-private-people partnerships is underdeveloped in both theory and application.

Although the five modes of multi-sector partnerships all focus on the success of multiple participation for sustainable urban development, several aspects differ. First, the applicable sectors vary according to the partners in each method. Second, the level of maturity among the modes is different, which in turn leads to a different research focus. Third, the modes are suitable for different situations. Finally, each method has clear advantages and disadvantages. A more detailed description is given in the discussion section.

Areas for improvement have also been identified for each of the modes. Research shows that multi-stakeholder partnerships rarely include citizens, which can lead to reduced end-user value and fewer benefits in terms of social sustainability. This can be improved by emphasizing the citizens' role in multi-stakeholder partnerships in future research. The main issue in community-organizational partnerships is engagement, for which the most important factors are financial value and trust. Research on new business models can improve the financial value aspect, whereas more efficient methods are needed for establishing trust. End-user-oriented partnerships also struggle with the engagement of citizens, with the main factors being financial value, exchange of knowledge and choice of technology for communication. The development of better methods of communication, both formal and informal, are needed. Public-private partnerships' top-down approach sometimes makes it difficult to capture the real needs of citizens. A possible solution is including citizens in the decision-making process, i.e. public-private-people partnerships. However, PPPP is currently underdeveloped in both theory and application; its barriers need to be fully identified, and an efficient engagement approach is needed, and a cooperation model should be designed.

Finally, there are some limitations to this research. First, the scoping approach is less rigorous than a systematic review, as its main purpose is to identify the research gaps. Second, it only identifies articles written after the year 2000, as its purpose is to find the latest research questions, but the content of the selected materials could be incomplete. Third, only articles written in English from acknowledged journals were included.

In summary, three main contributions were made for the multi-sector partnerships for sustainable urban development. First, this paper identified and compared five modes of multi-sector partnerships, which is the first time in an urban development context. Second, the paper explained the history, current state, and limitations of these modes. Third and most importantly, it determined gaps in the research of each mode, which can direct further study in this area.

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Barriers and potential solutions to the diffusion of solar photovoltaics from the public-private-people partnership perspective – Case study of Norway

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ABSTRACT

Norway is a major renewable energy developer in Europe, mainly through its development of hydropower. Research has shown that solar energy also has potential in Norway, however, the cumulative installed photovoltaic capacity was only 120 MW at the end of 2019, representing 4.1% of the total electricity generation. Hence, this paper aims to investigate the main barriers to diffusing photovoltaics for residential buildings from the public sector, private sector, and the people's perspectives in Norway. Furthermore, it analyzes solar development, policies, and models in different countries, and proposes a potential model and solutions to overcome barriers. The results show that the high initial costs of photovoltaics and limited information and awareness of the possible benefits are the main barriers for the people. For the private sector, limited funding and few pilot projects to learn from, as well as risk uncertainty are the main barriers. The main concern in the public sector is the low application of existing incentives. Public-private-people partnerships (PPPP) have a big potential to overcome these barriers by dividing the high initial costs into more affordable sums, facilitating the information flow among different sectors, and involving all three sectors to create new incentives. In addition, Norway is well-suited for PPPP, as the citizens pay much attention to sustainable development, and there is already a close collaboration between the public and private sectors in the energy sector. Finally, three concrete solutions using PPPP are proposed: design a co-investment solution, provide information sharing platforms, and create new incentives.

1. Introduction

The diffusion of solar photovoltaics (PV) is considered a potential method for achieving energy efficiency, environmental sustainability, and socio-economic development [1]. According to the PV annual report conducted by the International Energy Agency (IEA) [2], the yearly installed PV capacity has increased significantly in recent years. The global annual PV capacity installed in 2019 was at least 114.9 GW, which led to the cumulative installed PV capacity increasing to 627 GW [3].

Countries such as Brazil, Canada, and Sweden, have a strong dependence on hydropower, accounting for 70%, 62%, and 42% of their total energy production, respectively, while having a mixed energy production [4–6]. Norway has a strong hydropower industry, with a higher dependence than other countries, that produces energy equal to 93% of the country's energy generation in the form of low-cost and clean electricity. Still, there are many advantages to developing solar energy. The first reason for developing solar is seasonal variations in demand. During the winter, when demand is high, electricity from hydropower alone is not enough to cover the whole domestic consumption in Norway, and importing energy becomes necessary [7]. In 2018, Norway imported 8 340 GWh of electricity [7], generated mainly from oil, gas, and coal [8]. By investing in PV, this can be replaced with clean renewable energy, reducing CO2 emissions globally. At the same time, Norwegian citizens need to pay a higher electricity price in dry seasons when generated hydroelectric energy is low [9,10]. Data shows that the cost of electricity from solar PV is lower than buying electricity from the grid. Assuming a lifespan for PV panels of 30 years, the average cost of the generated electricity in southern Norway is 0.69 NOK/kWh [11]. Although hydropower by itself is considerably cheaper (0.48 NOK/kWh

Abbreviations: PV, photovoltaics; BIPV, building-integrated photovoltaics; PPP, public-private partnership; PPPP, public-private-people partnerships; TPO, third-party ownership; CS, community shared; IEA, International Energy Agency; GW, gigawatts (10^9 W); MW, megawatts (10^6 W).

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in 2018), buying electricity from the grid cost on average 1.15 NOK/kWh in 2018, due to grid fees and governmental taxes [12]. The second reason is to secure a more stable energy production by becoming less dependent on a single source of energy. In fact, the past two years have seen a decline in the output from hydropower, due to the lower rainfall and colder winters, which limit the energy supplies [9]. Uncertainty around hydropower output has been addressed in Brazil, for example, by developing multiple kinds of non-hydroelectric energy including solar energy [4]. Third, due to environmental and aesthetic concerns, many Norwegians are against installing new hydropower stations [13]. Canada has started to develop other nonhydroelectric energy after realizing the environmental and social issues caused by hydropower projects, such as disruption of fish migration and habitat loss for several species [14].

In addition, research has shown that solar energy also has great potential in Norway. Specifically, a recent report found the energy output per square meter of solar in the South of Norway to be comparable to that of Germany [15]. Furthermore, the cold climate is beneficial for solar energy production, as it prevents PV panels from overheating [16]. Finally, Norway has a strong silicon industry, which is the main component in PV panels [17]. There has been a recent increase in installed PV capacity with these advantages, however, the cumulative installed solar photovoltaic capacity was 120 MW at the end of 2019, representing only 4.1% of the total electricity generation in Norway [18]. Hence, exploring the barriers to diffuse solar PV in Norway is valuable.

The adoption of solar PV is influenced by different stakeholders and their cooperation. In the solar PV market, the main stakeholders are energy-related government departments, financing institutions, solar PV suppliers, consulting companies, skilled workers, and end-consumers [19]. These can be classified into three sectors: public (institution), private (commerce), and people (residents) [20]. The public sector refers to policy-making departments and related institutions supported by the municipalities or the government [21]. The private sector refers to private companies involved in solar projects, such as financing institutions, management companies, supplier companies, and consulting companies [22]. The people refer to end-consumers [22]. Fig. 1 shows the public sector, private sector, and people visually.

The different sectors have different concerns about the impact of solar PV on the society, economy, and environment. The public sector mainly focuses on the achievement of energy goals, the efficiency of PV incentives, and social acceptance for PV [23], while the private sector tends to focus on the profits, payback time, and risks [24]. The people mainly focus on the loan amount, payback time, as well as financial and environmental benefits [25]. Therefore, the barriers for diffusing solar in Norway will be explored from the perspective of the people, public, and private sectors.

In addition, using a suitable form of partnership is a potential method to overcome the barriers for diffusing solar PV [26]. Specifically, partnerships between different sectors can utilize various sectors' resources [27]. Furthermore, they facilitate the information flow among different sectors, which results in new co-production of PV knowledge and forms shared value [28]. Finally, it can increase opportunities for PV projects, as it allows partners to share the high costs, making them more affordable and reducing individual risk [29].

Partnerships have been applied to promote solar PV in several countries successfully. Specifically, China employs public-private partnerships in the form of the government providing financial support to large private organizations, which greatly promotes the PV market [30]. USA does this through the third-party ownership (TPO) model [31], while Spain has seen an increase in solar PV installation through community partnerships, particularly crowdfunding and community solar models [32]. In the following, detailed information about the partnerships and models in different countries will be introduced and analyzed, and a potential model for Norway will be proposed.

Therefore, this paper aims to: analyze the solar PV development, policies and models in different countries; explore the main barriers for the diffusion of solar photovoltaics in the people, private, and public sectors in Norway; analyze and discuss a potential model in Norway compared with the existing models, such as host-owned, third-party, and community shared models; describe the potential solutions to the identified barriers according to the Norwegian context.

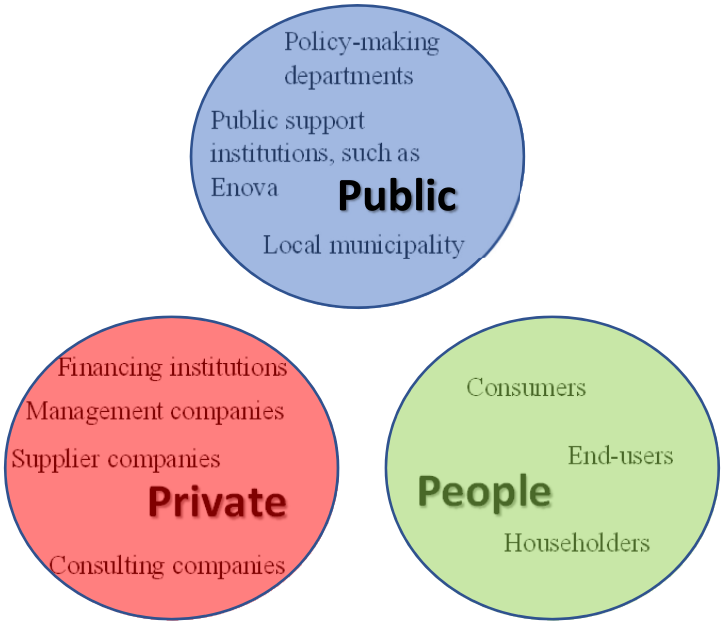

Fig. 1. Public sector, private sector, and people in the context of solar PV.

2. Background

2.1. Global trends of solar PV

The data in this paragraph concerning the global solar PV development are mainly from the Snapshot of Global PV Markets 2020 report [3]. According to the report, 114.9 GW of solar PV was installed globally in 2019, which led to a total cumulative installed capacity for PV of 627 GW. China remained the leader with 30.1 GW installed in 2019, followed by the European Union installing close to 16 GW. The largest contributors among them are Spain (4.4 GW) and Germany (3.9 GW). The US installed 13.3 GW, followed by India with 9.9 GW and Japan with 7 GW [3]. The annual installed capacity in Norway was 51 MW in 2019 [33], compared to other Nordic countries, for example, 287 MW in Sweden [34]. Installations of solar PV in Norway are comparatively low on a global and Scandinavian scale for Solar PV.

2.2. Policies and models in PV leading countries

Before analyzing the policies and models for developing solar PV in different countries, the general economic policies and models for diffusion solar PV will be introduced. The policies mainly include feed-in tariff (FIT), feed-in premium (above market price), green certificates, income tax credits, tax exemptions, self-consumption, collective self-consumption and virtual net metering, and building-integrated photovoltaics (BIPV) incentives [32,35,36]. The main models can be classified into three main patterns based on the ownership aspect for solar PV, namely, host-owned model, TPO model, and community shared (CS) model [37]. The host-owned model is the most widely used pattern, where the owner of the building invests in, owns, and uses the generated electricity from the PV panel with support from government incentives [37]. The TPO model is a type of private-people partnership, in which a third party (generally a private investment company or a private bank) invests in and owns the PV products, and the citizens pay a renting fee in return for electricity [31]. The CS model is a form of community partnership, which allows large groups of citizens to invest in solar PV as a community. The investors do not have to be building owners, but will have access to the generated energy as long as they invest in the project [38]. There are two main types of CS models: crowdfunding and community solar. Crowdfunding is a type of financing model where a large number of people invest and get financial benefits from an organization [39]. Community Solar is a model for indirectly purchasing energy by leasing or buying PV arrays in a solar plant, which allows multiple participants to directly get energy from the output from solar PV [38].

To learn from the PV leading countries, China, USA, Spain, and Sweden were chosen for deep analysis. This not only because they have higher installation capacity, but also because they can represent different social situations. Different measures should be applied according to their contextual background. An analysis has been made on solar PV related policies, financial models, driving sectors, and partnerships from the PV annual report in China [40], USA [35], Spain [32], and Sweden [36] (see Table 1).

The policies for promoting solar PV in China include feed-in tariffs (FIT) and BIPV incentives [40]. The main driving sector in China is the public sector, which promotes the solar market through FIT policies and organize large national projects through public-private partnership (PPP) [40]. There is no main financial model according to the 2019 annual PV report, but the host-owned, TPO, and CS model exits to some extent [41].

In USA, there are a diverse mix of policies, including feed-in tariffs, feed-in premium, capital subsidies, green certificates, income tax credits, self-consumption, collective self-consumption, and virtual net-metering [35]. The driving sectors are both the public and private sectors [42]. The incentives from the public sector, such as capital subsidies, feed-in tariffs, and green certificates have developed well since they were established [35]. Another main driver in USA is the private sector, which pushed the development of TPO and greatly promotes PV market development [42]. Therefore, the main partnership in USA is the people-private partnership. The people are also starting to play an important role in promoting the solar PV market through the CS model [35].

Spain had the largest annual solar PV installation in the EU in 2019. Their policies mainly aim to promote self-consumption, including the right to sell surplus electricity for at least market value, and no charges for self-consumed energy for installations producing less than 30 kW. In addition, TPO of the PV facilities and collective self-consumption and virtual net-metering are allowed, and there are BIPV incentives and tax exemptions [32]. The main driving sectors are the public and people in the form of tendering auctions and a positive attitude towards self-consumption from the citizens [18]. This is because of the relatively low price on PV components and high solar irradiation, resulting in self-generated electricity being cheaper than standard electricity from

Table 1
Policies, models, driving sectors, and partnerships for developing solar PV in China, USA, Spain, and Sweden.

Country	Main policies	Main financial models	Main driving sector (s)	Main partnership	References
China	Feed-in tariffs BIPV incentives	There is no main financial model according to the annual PV report in China, but the host-owned, third-party, and community shared model exist to some extent	Public	Public-private partnership	[40]
USA	Feed-in tariffs Feed-in premium Capital subsidies Green certificates Income tax credits Self-consumption Collective self-consumption and virtual net- metering	Third-Party Ownership Leasing Community solar Crowdfunding	Private; Public	People-private partnership	[35]
Spain	Self-consumption Collective self-consumption and virtual net-metering BIPV incentives Tax Exemption	Third-party ownership Crowdfunding Community solar	Public; People	Community partnership	[32]
Sweden	Feed-in premium Capital subsidies Green certificates Income tax credits Self-consumption Collective self-consumption and virtual net-metering	Third-party ownership Renting Leasing Crowdfunding Community solar	Public; People	People-private partnership; Community partnership	[36]

the grid [18]. Citizens can also achieve self-consumption with different models, such as TPO, crowdfunding, and community solar [32]. Community partnership is the main partnership form for solar PV in Spain.

Among the Nordic countries, Sweden, installed the most solar PV in 2019 (287 MW), which is more than five times Norway's capacity [34]. The main driving sector is the public sector, which provides incentives in the form of feed-in premiums, capital subsidies, green certificates, income tax credits, allow for self-consumption and collective self-consumption [36]. In addition to the public sector, the people in Sweden have a good acceptance of solar PV. In an annual survey, 81% of respondents wanted more investments in PV in Sweden [18]. Due to the positive attitude and existing policies, a wide range of financial models exists, such as host-owned model, TPO, crowdfunding, and community solar. The main partnerships in Sweden include private-people partnerships and community partnerships.

2.3. The Norwegian context

Norway is a major renewable energy developer in Europe. Renewable energy sources include hydro, wind, and solar power. In 2019, hydropower generated 135 TWh electricity, representing 93.4% of the Norwegian electricity production, while wind power and solar power only represented 2.5% and 4.1%, respectively [43].

Although there is no clear goal to diffuse PV in Norway [44], the annual installed capacity of solar PV has increased every year from 2012 to 2019 (see Fig. 2). Continued decline in prices of PV components and rising prices on hydropower due to lower rainfall, as well as more attention to solar energy led to an increase in 2018–2019 [45]. However, the total installed capacity was still only 120 MW in 2019.

Policies and business models played a significant role in PV leading countries, however, they have been less successful in Norway. Specifically, in China, the total annual installed capacity increased by 306% in 2013 and increased by 200% in 2014 compared to the previous year, due to a series of efficient incentives, such as direct financial subsidies, explicit monetary rewards, and feed-in tariffs [46,47]. In the US, the installed capacity increased from 753 MWp in 2008–51,738 MWp in 2017 gradually through various kinds of incentives, such as feed-in tariffs, capital subsidies, green certificates, income tax credits, as well as the different kinds of business models, such as TPO, community solar, and crowdfunding [35]. In Spain, the increase in installed capacity was quite big in 2019 due to the tender auctions approved in 2017 for accomplishing the de-carbonization compromises with the European Union [18]. Sweden installed the most solar PV among the Nordic countries in 2019 (287 MW) using policies and different kinds of financial models, such as TPO, renting, leasing, crowdfunding, and community solar [34]. In Norway, the existing financial incentives, such as feed-in tariff and capital subsidies have been around for about 10 years, however, there has not been any significant increase before 2015 (see Fig. 2). And the financial model TPO has hardly applied. There has been a rapid growth in solar deployment recently, mainly due to the decreasing costs of PV components and the higher electricity price of hydropower [48]. This means that in addition to the policies, providing new suitable models to promote the market like the leading countries are needed to overcome the existing barriers.

There are two main contextual factors that hinder the diffusion of solar energy in Norway, which are different from other countries. The first is the abundance of hydropower, which has a lower levelized cost of energy (LCOE) than solar in Norway. The data in the remainder of this paragraph is from the Renewable Power Generation Costs in 2019 report conducted by IRENA [49]. Between 2010 and 2019, the global LCOE of solar PV fell by 82% to USD 0.068/kWh in 2019, mainly thanks to the 90% decline in the prices of PV panels and supporting systems. However, the LCOE of solar PV is still higher than hydropower, whose LCOE increased from USD 0.037/kWh in 2010 to USD 0.047/kWh in 2019. Another available resource in Norway is wind power, and over the past ten years, the cost of onshore wind power has decreased by 40% to USD 0.053/kWh, which is lower than for solar PV.

The second obstacle is the high latitude and relatively low solar intensity. This leads to less motivation for citizens to invest in solar energy, limited pilot PV projects in the private sector, and controversy in the public sector over whether to focus on hydropower or to develop solar. The average daily solar irradiation in Norway is 2.46 kWh/m^2 [50], compared to 3.2 kWh/m^2 in Germany [51]. It is only 0.1 to 0.35 kWh/m^2 during winter months, however, during summer it is between 4.0 and 5.5 kWh/m^2 [50]. The average daily solar irradiation map of Norway for January and July is show in Fig. 3 [50]. In some southern parts of the country, the solar irradiation can reach more than 5.5 kWh/m^2 during the summer, which makes it not only possible but also

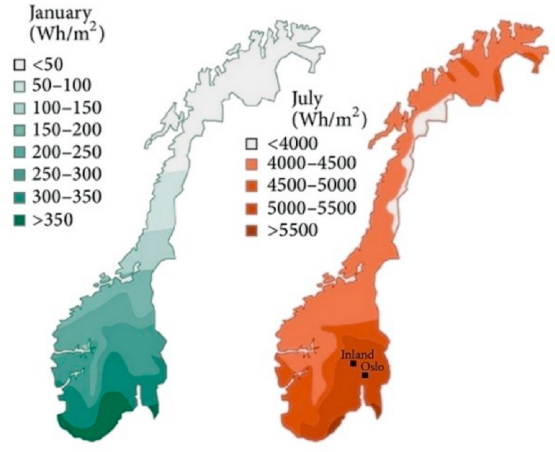

Fig. 2. Yearly installed capacity from 2012 to 2019 for solar PV in Norway. (Source: IEA PV annual report for Norway)

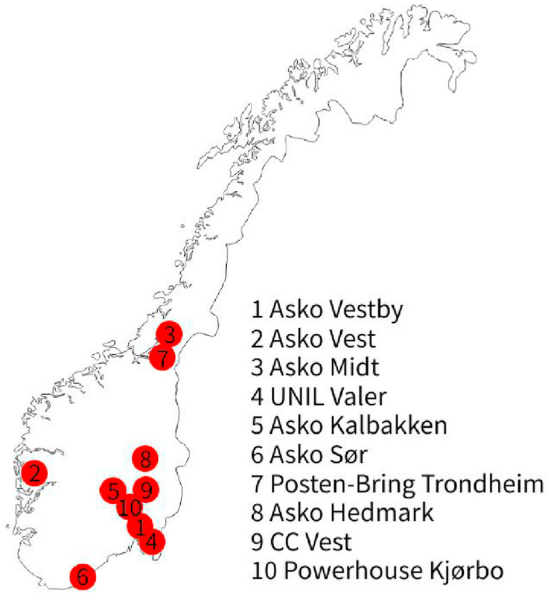

Fig. 3. Average daily solar irradiation map of Norway in January and July [50].

profitable to develop solar energy [50]. Fig. 4 shows the location of the ten PV plants in Norway with the highest installed capacity in 2017 [52]. As can be seen in Fig. 4, the plants are all located in areas with relatively high solar irradiation. According to an experiment conducted by Midtgard [53], an area of 50 × 50 km^2 in southern Norway covered with solar PV could match the current energy production from hydropower, which is at 120 TWh. The experiment also shows that the average monthly energy yield in the four seasons is 7.6 kWh/m^2, 13.1 kWh/m^2, 10.6 kWh/m^2, and 3.5 kWh/m^2 respectively for a multi-crystalline silicon PV model.

Several attempts from different sectors have been made to encourage the development of solar PV. The main driving sector in Norway is the public with policies to promote solar PV, including electricity certificates, capital subsidies, and self-consumption. The public sector issues electricity certificates to stimulate electricity generation from renewable energy sources [44]. However, it is not suitable for small scale projects and residential areas, due to high registration fees. For the residential area, the public agency Enova SF subsidizes up to 35% of the installation costs for grid-connected residential PV systems at a rate of 10,000 NOK (1 NOK = 0.11 USD) per installation and 1250 NOK per installed kWp up to 15 kWp [44]. Enova is a government-owned institution in Norway, whose role is to explore new sources of clean energy to ensure a more secure energy supply, reduce greenhouse gas emissions, and develop new materials and technologies [54]. Every year, Enova invests more than 2 billion NOK in solutions for sustainable development in Norway [55]. Furthermore, self-consumption and the possibility of selling generated surplus electricity back to the grid are other types of incentives provided by the public sector [56]. In addition, the Research Council of Norway funded about 83 million NOK (~9.1 million USD) in solar-related R&D projects in 2018, mostly in PV [56].

In the private sector, the silicon industry receives much attention [57]. The abundance of raw materials and cheap electricity from hydropower are the basic advantages to develop the silicon industry in Norway [58]. From the investment aspect, some private financial institutions provide support mainly through the TPO to promote the diffusion of the PV system. However, few financial institutions are currently willing to invest [59].

At the same time, some citizens are willing to invest in solar PV. According to an interview conducted by Winther, Westskog, and Sæle [60], these citizens include people who are interested in being both an investor and consumer for solar PV, have a desire to live in houses with modern technologies and functional automation, and wish to be environmentally friendly.

3. Method

First, a scoping review was conducted to explore the main barriers to the diffusion of solar photovoltaics in Norway. The relevant findings were identified through a three-step process: (1) structured search, (2) snowball-technique search, and (3) narrowing and summarization of the research. Keywords “barriers”, “obstacles”, “encumbrance” AND “photovoltaics”, “solar energy”, in Norway were used in the search. The initial search returned little information about the barriers to photovoltaics in Norway. The scope of the keywords was therefore extended to “PV”, “photovoltaics panel”, and “renewable energy”, “solar energy” AND “Norway”. The titles and abstracts of these papers were checked for a discussion about barriers. At the same time, a snowballing search (checking backward and forward citation tracking of identified articles [61]) was conducted for each identified paper. The source data were mainly from Science Direct, Web of Science, Google Scholar, Scopus, ACM Digital Library, and IEEE Xplore. Information collected included the title, authors, keywords, aim, methodology, results, and recommendations for further study.

Second, data analysis. The adoption of solar PV is influenced by different sectors and their cooperation. The different sectors have different concerns about the impact of solar PV on the society, economy, and environment. Therefore, the barriers for diffusing solar in Norway were classified from the people, public, and private perspectives. At the same time, the barriers that were found could be classified into three groups: (1) financial problems; (2) information sharing problems; (3) risk and uncertainty problems. This was used for the following analysis of the potential model.

Third, the IEA’s annual reports on PV development were studied to determine the leading countries in terms of PV installation. In order to understand how they had promoted the development of solar PV, information about their strategies, such as policies, financial models, driving sector(s), as well as partnership forms, were studied. Here, China, USA, Spain, and Sweden were chosen for deep analysis, not only because of their high installation capacity, but also because they can represent different social situations. The analysis, combined with knowledge about the Norwegian context, were then used to propose a potential model for Norway.

The ability of public-private-people partnerships (PPPP) to overcome the identified barriers was then compared to that of existing business models, such as the host-owned model, third party ownership model, and community shared model. The feasibility of applying the PPPP model in Norway was also analyzed. Finally, three concrete solutions to the identified barriers were proposed based on the PPPP model.

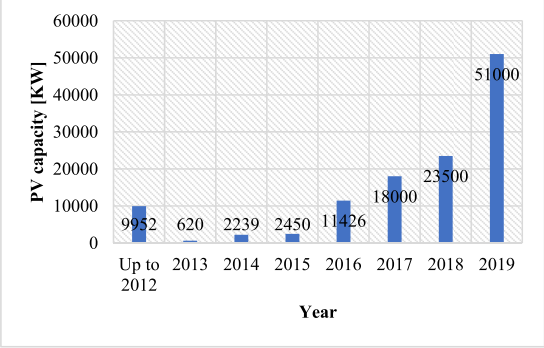

Fig. 4. Locations of ten largest solar PV plants in Norway.

4. Results

There are many types of barriers before, during, and after the process for installing PV panels. This paper focuses on the main non-technical barriers, which receive much attention from the majority of research on the diffusion of solar PV in residential areas in Norway. Table 2 shows an overview of the barriers, categorized according to sectors.

Table 2
Main barriers for people, private, and public sectors.

Sector	Main barriers	Reference
People	High initial cost, as well as limited financial support	[15,17,62–65]
	Satisfaction with the current electricity system	[62,63,66]
	Limited information and awareness of the possible benefits	[15,17,62,63,65,66]
	Uncertainty	[15,62,63,65]
Private	Limited access to capital	[15,17,65,67]
	Limited PV project examples	[67,68]
	Uncertainty surrounding risks	[15,17,65,67,68]
	Lack of communication among different stakeholders	[15,17,67,68]
Public	Lack of efficient incentives	[17,65]

4.1. Barriers from the people's perspective

From the people's perspective, the barriers mainly come from four aspects, namely high initial cost, satisfaction with the current electricity system, limited information surrounding the possible benefits, and uncertainty.

(1) High initial cost, as well as limited financial support

In a survey on solar PV answered by 803 residents in Norway, 34.6% stated the high cost as the main barrier for diffusing solar PV [62]. In Norway, the PV panel covered rooftop of a typical residential house can produce between 5 and 10 kW, while the current prices are about 15 NOK (1 NOK = 0.11 USD) per W for grid-connected PV panels [56]. This means that the typical investment for one house is about 75,000–150, 000 NOK. The public support institution Enova covers 10–30% of the cost for citizens, however, they will still need to pay approximately 50, 000–105,000 NOK for installing PVs on one house [44]. Furthermore, since residents often already have a home mortgage [56], it is difficult for them to increase their loan amount according to their payback ability.

(2) Satisfaction with the current electricity system

Many residents in Norway are satisfied with the current price of electricity bills due to hydropower [69,70]. In addition, hydropower is renewable and produces enough energy for the gross domestic electricity consumption [44], and some citizens believe that there is no need to invest in other types of energy [66]. A study shows that 60% of the citizens have a very positive attitude towards hydropower while 35% have a somewhat positive attitude [71]. However, the main attitude towards solar PV is lack of interest, and 73% of the citizens would not consider installing PV panels [62]. As more wind power plants have been installed in recent years, the attitude towards wind power in Norway has gradually worsened. According to a recent survey, 15% were somewhat negative towards wind power, and 28% were very negative [72]. This is because citizens think the windmills ruin the natural scenery and interferes with local wildlife [72].

(3) Limited information and awareness

Many residents know little about the possible benefits of installing PV panels due to the limited number of PV projects and information sharing in Norway [15]. Reliable information about financial costs and benefits, electricity output, related incentives, and potential benefits to the environment is not easy to find from Norwegian projects [17,62,63, 65,66]. Furthermore, citizens lack information about the installation process, such as the suitability of the house and the length of time for the installation [66].

(4) Uncertainty

There are different types of uncertainty in the process of installing PV panels, which hinder the citizens' willingness to invest. First, residents are not sure about the energy output of PV in Norway, because the duration of sunshine is very short in the winter [63]. Second, the development of PV panels is still in its early stages in Norway, which leads to uncertainty around the future policies and regulations on PV panels, as well as its long term benefits [65]. Third, citizens worry about uncertainty and potential unforeseen costs in the process [62].

4.2. Barriers from the private sector's perspective

The solar PV private sector in this paper includes PV developers, financial institutions, construction companies, consulting companies, and PV suppliers. These companies can have either one or several roles, such as construction, consulting, financing, developing, and providing energy products.

(5) Limited access to capital

The main problem for private companies is limited access to capital. Although there is some financial support from the public sector from state-owned enterprises like Enova, funding is still limited to 35% of the initial cost for installing solar PV [73]. Furthermore, only a few financial institutions willing to invest in solar PV in Norway due to the high up-front investment and uncertainty around achieved electricity output [67]. In addition, the long payback period (usually 25–30 years) discourages investors who look forward to getting money back as soon as possible, as the capital flow and risk guarantees are very important for businesses [17].

(6) Limited pilot PV projects

The annual installed capacity for solar PV in Norway constitutes less than 0.25% of the global market [74], with an installation of 23.5 MW in 2018 [75]. According to a report by Multiconsult, a Norwegian consulting firm, there are few pilot PV projects in the country to learn from Ref. [67]. Limited projects lead to limited opportunities for the industry to learn and develop skills which means that projects are reliant on the expertise of a few individuals may be expensive and difficult to access. Data on PV panel performance, project costs, and benefits gained from existing projects are the basic foundations needed before investing for private companies. However, the reality of limited projects to obtain in Norway leads to a large uncertainty [57], as well as limited experience, knowledge, and solutions on PV development.

(7) Uncertainty surrounding risks

The uncertainty surrounding the risks of investing in solar PV mainly stems from three aspects. First, many investors, including those already involved in a PV project, are not sure how much electricity they will generate [65]. Second, they are not sure about the payback and whether they can find solutions to deal with unforeseen events, such as lower electrical output than anticipated, throughout the whole process [68, 76]. Third, private companies are not sure how future policies will affect them because the PV market is still in its early stages in Norway, and the policies and regulations are still changing [67].

(8) Lack of communication among different stakeholders

Communication between different types of actors, such as financial institutions, construction companies, consulting companies, energy companies, skilled workers, and consumers, is required for the development of PV. The reason is that acceptance, understanding, and knowledge transfer are key factors to the diffusion of PV panels early on, which needs to be achieved through communication [77]. However, most actors do not communicate enough and do not know how to transfer their knowledge efficiently [67]. Furthermore, for projects with large volumes of information, lack of communication can lead to failure [77].

4.3. Barriers from the public sector's perspective

(9) Lack of efficient incentives

The Norwegian authorities lack efficient financial incentives to promote the PV market [65]. The existing incentives include a capital subsidy for the initial cost, the right to self-consume, the right to revenues from excess PV electricity injected into the grid, an average loan rate of 3%, as well as a green certificate [56]. However, the initial cost of about 50,000–10,5000 NOK is still high for residents even with the

10–30% capital subsidy. The average loan rate for PV is 3%, similar to the property loan interest, and the green certificate requires a minimum investment of NOK 15,000 (1620 USD) in solar PV, which makes it difficult to get support for small systems [56]. One reason for the low support is that there are conservative politicians with limited knowledge on solar PV, who are unwilling to invest in solar [17].

The results show that many of the barriers of diffusing solar PV in Norway are general and somewhat applicable to many other countries as well, such as high initial cost, limited information and awareness of the possible benefits, uncertainty among people regarding the achieved output, limited access to capital, uncertainty surrounding risks, and lack of communication among different stakeholders. At the same time, there are barriers in Norway which differ from other countries, such as limited financial support policies and models, satisfaction with the current electricity output from hydropower, the uncertainty of the solar irradiation and energy output due to the latitude in Norway, limited pilot PV projects, and the controversy over whether to focus on hydropower or also develop solar energy in the public sector.

5. Discussion

5.1. Potential model in Norway

In this section, the potential of PPPP to overcome the barriers in Norway will be analyzed and compared with the host-owned model, TPO, and CS model.

The above-identified barriers can be classified into three aspects: (1) financial problems, such as high initial cost as well as limited financial support and limited access to capital; (2) information sharing problems, such as limited information and awareness of the possible benefits, low awareness about the solar irradiation and energy output, and lack of communication among different stakeholders; (3) risk and uncertainty problems, such as the risk of extra costs of the PV system from maintenance, risk of misprediction of the actual output, uncertainty of payback time, and changing policies.

For the financial problems, the host-owned model has limited potential. Many householders are not willing to invest in PV because of the high initial cost and low electricity prices in Norway [62]. Although they can get some financial support from the public sector to cover 20–30% of the costs, the cost is still very high [56]. Primarily relying on public financial support as in China is not as applicable in Norway. The controversy over whether to focus on hydropower or to develop solar energy in the public sector makes it unlikely that Norway will invest large amounts in solar PV [71]. The TPO model can solve the high initial cost problem, however, relying on the private sector in Norway is not as suitable as in USA [56]. This is because few pilot cases, lower profitability due to cheap hydropower, and long payback times make it risky for third party companies to invest in solar PV [67]. The CS model has the potential to overcome the barriers by gathering funds from multiple citizens. However, it is difficult to promote the market at this moment, as most citizens have little awareness and information about the benefits of solar PV [65]. The PPPP has the potential to solve the financial problems by combining the resources of all three sectors. It allows the public sector, private sector, and people to divide the high initial costs into more affordable sums [78]. This way, it can attract private sectors through two directions. First, the high initial cost is divided among the three sectors, which will reduce the individual risks for the private sector [78]. Second, projects organized by the public sector are often easier to be convinced, because the public sector has the potential to reduce the risks through policymaking and guarantees [79]. After the investment from both public and private sectors, the remaining amount should be low enough for the citizens to invest in. Finally, by involving all three sectors, the financial support measures from the public sector can be accurately tailored according to the needs of the private companies and citizens, which increases the likelihood that they will be used [80].

The second main problem is about information sharing. The host-owned model does little to spread awareness about available policies and incentives, and the building owners need to find the information by themselves. The third party in the TPO model can take the role of an educator to help citizens understand the benefits. However, the third party is often regarded as an "outsider" and often needs to first establish a trust to lend credibility to their information [81]. The CS model can play a good role in sharing information and transfer knowledge among residents, which allows them to identify the potential benefits and reduce concerns about risk. However, the information is only from the citizens' aspect, as they do not have the same expertise and ability to adapt to unforeseen events as the public and private sectors [82]. The PPPP has great potential for information sharing, as it facilitates the information flow across different sectors, which can improve both the knowledge of PV and the relationship between the different sectors [83]. The information from all the three sectors can give a complete picture for diffusing solar PV. In particular, governments typically have a better understanding of the existing regulations and have the power to make policies to support sustainable energy-related projects [84]. Meanwhile, private companies have a good understanding of the market and can provide expertise in solar PV. Finally, the citizens can provide knowledge about the building situation and their needs, and share new information with their communities [85].

The third main barrier is about risks and uncertainty. The host-owned model has the highest risks among all the models, as the building owners themselves have to fund the main portion of the high initial costs. In the process, any differences between predicted and actual output are their responsibility [86]. In the TPO model, citizens pay a renting fee to the third party, who take the main risks for the citizens and take responsibility for maintenance. However, this only shifts the risks from the people to the private sector [87]. In the Norwegian context, there are already limited pilot cases and related data to study from and limited guarantees from the public sector, which further exacerbate the risk. The CS model can reduce the risks for each individual, but not reduce the total risk of the investment [38]. The PPPP can reduce the risk for each stakeholder by dividing the costs between the three sectors. More importantly, it can also reduce the overall risks by allowing participants to make better-informed decisions based on knowledge from different sectors [88]. The cooperation of three sectors has a better ability to overcome unforeseen events in the installation process, because each sector has different types of experiences and resources, leading to better flexibility than only one or two sectors [89].

In addition to the three main patterns of business models, there are also some advanced innovative business models for the diffusion of solar PV. These models each have the potential to solve one of the existing problems, however, they have limited ability to solve multiple problems compared with PPPP. For example, a new business model was proposed to combine the investment mode and sales mode, as well as designing an interactive consultation service module between supply and demand [90]. An experiment was conducted, which showed that it can enhance the information sharing through consulting services, further promote the local consumption and increase the investors' benefits [90]. However, it is not enough to promote the solar market in Norway at the moment, because it has limited ability to solve the financial problems and risk and uncertainty problems in Norway. Another type of innovative business model emphasizes a revenue-sharing mechanism to promote solar installation [91]. It allows the consumers to get profits directly through transferring the surplus energy to their neighborhood instead of the grid. Its modes include transferring energy between businesses, from businesses to consumers, and between consumers [90]. The sharing between consumers can have the potential to achieve a self-sufficient energy community and reduce the energy loss to the grid [29]. However, it cannot solve the problems related to high initial cost and risks in Norway at this moment.

In addition, Norway has the potential to apply the PPPP. First of all, many stakeholders in the energy sector such as research groups, private companies, and municipalities in Norway collaborate through energy

clusters [92]. For instance, the Norwegian Solar Energy Cluster is a solar energy support company consisting of more than 80 industrial partners, major R&D institutions and regional, and national public partners [93]. There are some projects of collaborative energy projects, for example, the +CityxChange project, which explores suitable co-creation approaches to achieve efficient innovative energy systems with joint partners, including public bodies, industries and private businesses, research and academia, and citizens [94]. Furthermore, PPPP is already present in the energy sector, most notably through the prosumer scheme offered by the Norwegian Energy Regulatory Authority [95]. It is a set of regulations supporting cooperation between people, private industry and public sectors, by allowing owners of small installations to sell surplus energy to private energy companies [96].

Second, although the resources from one sector is limited, PPPP can gather the resources of three sectors in Norway. From the people's perspective, the citizens in Norway are likely to engage in PPPP for renewable energy. According to a country ranking of public environmental concern conducted by Franzen and Vogl [97], Norwegians pay much attention to sustainable environmental development, this is particularly exemplified in the electric car industry in Norway which has the most electric cars per capita in the world [98]. Ironically, this has the potential to put stress on the district power grid and if these trends for electric cars continue, there is a need to identify alternative energy sources to avoid blackouts. Solar energy is a viable renewable energy solution as it allows flexibility in supplying to the grid or the household. The desire for a green identity can also attract residents to install solar PV, as it may be seen as a symbol of being modern and progressive, similar to the electric car. The environmentally friendly lifestyle was considered the main driver for households who installed PV panels based on an interview conducted by Winther, Westskog, and Sæle [60]. In addition, according to a survey on the willingness to install PV panels, 56.1% of the survey participants stated that they cared about the electricity bills [62]. In other words, the long-term cost savings for electricity may make people consider installing PV panels.

There are supports for solar PV in the public and private sectors as well. In the public sector, Enova introduced up to 35% support for a range of energy-efficient technologies for households including solar PV. According to a report by Enova in 2008, municipalities are willing to provide support for new approaches that have the potential to promote the diffusion of sustainable energy [99]. The private sector can support the PPPP by providing resources through Norway's strong silicon industry and cheap electricity from hydropower, as well as knowledge and experience from abundant experts and consultants on solar energy. There are also close relationships among different types of private companies. One example is Multiconsult, a consulting company with about 300 experts in the renewable energy sector that provides consulting and design services in Norway.

5.2. Potential solutions with PPPP in Norway

From the perspective of PPPP, the barriers were analyzed, and potential solutions were proposed for the three sectors. Table 3 presents potential solutions for the barriers, and how each group can contribute to a PPPP.

5.2.1. Co-investment with PPPP

A co-investment solution with PPPP can potentially solve financial barriers. Specifically, it can solve the barriers for (1) high initial cost, as well as limited financial support for the people sector; (5) limited access to capital for the private sector; and (7) uncertainty surrounding risks for the private sector.

To solve the problem of (1) the high initial cost for residents and (5) limited access to capital for investors, the basic idea is to expand the existing funding options by reducing the high initial cost to an affordable amount with the three sectors.

This paper proposes a co-investment solution based on PPPP, with investors from the people, private and public sectors to promote a larger PV market. The benefit of including the public sector to co-invest are added investment capital and access to related resources from the public sector. In the long term, if the market for solar PV grows, the public sector can shift governmental funds from subsidizing solar energy to investing in projects [100]. The inclusion of different types of private companies will reduce the investment pressure for the people and public sectors, and they can provide their operational experience on installation, management, making contracts for investing and sharing, problem-solving, and consulting [30]. Finally, the benefits of involving the people are significant, as it considers the citizens' opinions with a bottom-up approach for social sustainability [101]. Besides, citizens' investment for solar PV represents a potentially huge market [102]. As more people participate in this form of co-investment, it will also

Table 3
Potential solutions to identified barriers from a PPPP perspective.

Sector	Main barriers	Potential solutions	What the public sector can do	What the private sector can do	What the people can do
People Private Private	(1) High initial cost, as well as limited financial support (5) Limited access to capital (7) Uncertainty surrounding risks	Develop a co-investment solution with people, private, and public sectors	Organize a platform to gather investors from different sectors; Create co-investment supporting policies; Co-invest with the people and private sectors	Provide information about co-investment, such as benefits and risks; Make suitable contracts for benefits and risks sharing for co-investing; Co-invest in PV projects	Co-invest with private and public sectors; understand co-investment
People People Private	(3) Limited information and awareness of the possible benefits (4) Uncertainty (8) Lack of communication among different stakeholders	Knowledge and data sharing platforms across public, private, and people sectors	Provide platforms for different sectors to get information on PV; Provide information and consulting about available policies; Provide risk guarantees	Provide online information and consulting about solar PV from financial, operational, and managerial aspects; Participate in offline platforms for communicating among different sectors, such as meetings, workshops, and presentations	Involvement in different types of platforms, get information about solar PV; Consult with related sectors for specific PV problems; Communicate with other sectors from the citizens' perspective
Public	(9) Lack of efficient incentives	Design new incentives for solar PV with public, private, and people	Design new support incentives with other sectors according to market needs; Support and testing of new incentives	Design new incentives with other sectors; Provide opinions about desired incentives from a private perspective	Design new incentives with other sectors; Provide recommendations on incentives from a people perspective
Private	(6) Limited pilot PV projects	Encourage the disclosure of existing PV projects information on a platform	Support the development of pilot projects; Share real data from PV projects and their social and environmental impact	Share data on the financial aspect of PV projects; Provide analysis the performance of the existing projects	Provide detailed feedback when involved in PV projects

naturally promote greater diffusion of solar PV. Overall, including investors from all three sectors has the potential to solve the high initial cost problem.

In addition, co-investing with different sectors can reduce the (7) uncertainty surrounding risks for the private sector. A wider base of knowledge and the ability to pool the resources from multiple sectors, can make the partners better equipped to handle unforeseen events during the project [103]. Furthermore, the different sectors can share risks [104].

Aside from solving barriers (1), (5), and (7), the people can get financial and environmental benefits from solar PV through investing affordably and can receive policy support from the public sector and operational experience from the private sector. The private sector can attract co-investors not only from the public sector but also from general residents, which can alleviate the problems surrounding the capital shortage [78]. It can also benefit from the public policies, and possibly provide PV installation services for residents. For the public sector, if the shared model is developed well, they are more likely to achieve their energy goals for 2050 and can help the solar PV industry become more self-sufficient, instead of strongly dependent on the public sector as it is today [100].

5.2.2. Information-sharing platforms with PPPP

The second PPPP-based solution is to design different types of information-sharing platforms both online and offline. The participation of the public, private, and people is required, as knowledge is needed from each group. These platforms can solve the barriers for (3) limited information and awareness of the possible benefits for the people; (4) uncertainty for the people; and (8) lack of communication between different stakeholders for the private sector.

To solve the barrier of (3) limited information and awareness of the possible benefits, an online information-sharing platform with knowledge from the public, private, and people can help citizens obtain and understand information about solar PV [105]. The information should pertain to the financial costs and benefits, electricity output, related incentives, and potential benefits to the local and global environment [106]. Information about financial support and incentives should come from the public sector, while knowledge about the financial costs and benefits, and expected output of solar PV should come from the private sector [107]. The consumers' needs, feedback, and questions should come from the people. With the online information-sharing platform, citizens can easily obtain information on solar PV from reliable sources.

Unlike the barrier regarding limited information and awareness of the possible benefits, (4) the barrier of uncertainty mainly refers to people who already have some interest and understanding of solar PV, but are unsure whether and how to implement it [65]. Therefore, they need a platform for asking specific questions to different sectors, where they can get reliable answers from the relevant sectors.

For barrier (8) lack of communication between different stakeholders in the private sector, the online platform is not enough. Other offline activities to promote the communications among different stakeholders are needed as well. Meetings, workshops, advertisements, and surveys are potential channels to enhance the communication to share the information on PV [108]. Consultants from public and private sectors, who have the relevant knowledge about policies and experience can then clear up any confusion from the citizens.

5.2.3. Creation of new incentive policies with PPPP

The third potential solution is to create new incentives through PPPP that can solve the barriers regarding (7) uncertainty of risks and (9) lack of efficient incentives and policies.

According to these barriers, new incentives and support measures from the public sector are expected to be issued. Furthermore, new incentives should include some risk guarantees, which can ensure that investors will not lose too much. A guarantee can boost sales and increase the confidence of customers, for example, performance guarantee and fixed feed-in tariff [109,110]. In addition, the incentives need to better match the needs of the people and private sectors.

To overcome the barriers, the creation of incentives with the opinions of the public, private and people has been regarded as an efficient approach to consider the needs of different sectors on specific issues [111]. The benefits of creating incentives with PPPP for PV projects can be seen from three aspects. First, it can help the public sector better understand the specific barriers and needs of the private and people sectors [112]. Second, the public sector can evaluate the advantages and disadvantages of new incentives from the perspectives of the participants [113]. Third, incentives designed with PPPP are more likely to get wide support and adopted by the private and people sectors in practice [114].

5.2.4. Co-investment and information-sharing platform with PPPP

Two barriers remain unresolved, namely (2) satisfaction with the current electricity system and (6) limited pilot PV projects. To overcome (6) limited pilot PV projects, co-investment and an information-sharing platform with PPPP are both required. The co-investment will increase opportunities for pilot PV projects, which upon completion can act as proof of viability for future investors. The information-sharing platform will facilitate a comprehensive understanding of the project efficiently. The information should include the financial aspect of PV projects and performance analyses from the private sector, an analysis on the social and environmental impact from the public sector, as well as detailed feedback from people involved in the project.

For barrier (2) satisfaction with the current electricity system, when all the other barriers have been overcome, the benefits of the solar PV will be widely accepted by the public, private, and people, and this will no longer be a barrier.

There are currently no examples of using PPPP to overcome barriers for diffusion solar PV specifically, but there are examples of using it to solve problems similar to the identified barriers related to information sharing. For example, in a case study by Kuronen [115], the application of PPPP was shown to be able to reduce CO2 emissions from residential development by 75% through new system design and newly proposed solutions, by applying knowledge from three sectors and utilize various sectors' resources. The process also gave all the participates a good understanding of the project through information sharing.

6. Conclusion

Research has shown that solar energy has great potential in Norway due to its suitable cold climate, strong silicon industry, and potential energy output from PV in southern parts of the country comparable to that of Germany. However, the cumulative installed solar photovoltaic capacity is still small, and most people in Norway pay little attention to solar PV. This paper highlights the importance of developing solar energy in Norway to meet the electricity demand during winter, provide a more secure supply of energy by diversifying the energy mix, and to protect existing ecosystems which are threatened by the more pervasive hydropower generation.

The adoption of solar PV is influenced by different stakeholders and their cooperation. The different sectors have different concerns about the impact of solar PV on the society, economy, and environment. This paper is the first to classify the barriers for diffusing the solar PV in Norway from the perspective of the people, private, and public sectors. The barriers were explored through a literature review, which identified nine main barriers. For the people, these are (1) high initial cost, as well as limited financial support; (2) satisfaction with the current electricity system; (3) limited information and awareness of the possible benefits; (4) uncertainty, while the main barriers for the private sector are (5) limited access to capital; (6) limited pilot PV projects; (7) uncertainty surrounding risks; and (8) lack of communication among different stakeholders. The main concern for the public sector is (9) lack of efficient incentives.

To explore the potential models to develop solar PV in Norway, the solar PV development, main policies and financial models in different PV leading countries were explained. This paper is the first to analyze the driving sector, financial models, and main form of partnership for the diffusion of solar PV in multiple countries and discuss whether they are suitable in Norway. It was found that the host-owned model, which relies on the public sector, is not an applicable approach in Norway due to the limited support from the public sector. The TPO model is also not feasible, because investment in PV is not as widely accepted in the private sector in Norway due to limited examples of pilot PV projects and limited access to capital for solar PV projects. Finally, the community shared (CS) model is also not suitable for promoting the solar market. The main reason is low acceptance among citizens to invest in solar energy due to limited financial support from the public, satisfaction with the current electricity from hydropower, and uncertainty about the achieved energy output.

After analyzing the identified barriers and the current context in Norway, the public-private-people partnership (PPPP) is proposed to be a partnership form with great potential to promote the PV market. The barriers can be classified into three categories: financial problems, information access and sharing problems, and problems associated with risks. PPPP has a big potential to overcome these barriers, by dividing the high initial costs into more affordable sums, facilitating the information flow among different sectors, and overcome unforeseen events with different types of experience and resources. In addition, Norway is well-suited for the PPPP, as stakeholders in the energy sector such as research groups, private companies, and municipalities in Norway almost always operate as joint groups. Furthermore, citizens in Norway pay much attention to sustainable development and the environment. Finally, there is support for solar PV in the public and private sectors.

To solve the barriers, three concrete measures using PPPP were proposed: a co-investment solution, information sharing platforms, and design for new incentives with PPPP. The co-investment solution with PPPP can solve the barriers for: (1) high initial cost, as well as not enough financial support for the people; (5) limited access to capital for the private sector; and (7) uncertainty of risks for the private sector. Information sharing platforms with PPPP can solve the barriers for: (3) limited information and awareness of the possible benefits among the people; (4) uncertainty in the people sector; and (8) lack of communication among different stakeholders in the private sector. Design for new incentives with PPPP can solve the barriers for (7) uncertainty surrounding risks and (9) lack of efficient incentives.

However, there are also some arguments against developing solar PV with PPPP. First, it will require large amounts of time and energy to organize the different stakeholders on a common platform, as well as persuade them to participate, especially the citizens. According to existing cases with citizens participation, it is quite difficult to engage citizens, due to the financial risks, little decision-making power, and low levels of trust towards outsiders. Second, it will take considerable time to make agreements for sharing the benefits and risks with different stakeholders. Third, there are currently no examples of using PPPP for solar PV, meaning that there will likely be some unforeseen problems. Finally, the communication between the sectors is also challenging, due to the different levels of knowledge in each sector.

With the exploration of suitable policies, models, and partnerships in Norway, PPPP has the potential to overcome existing barriers. Although the solar PV installation capacity is not high at this moment, it likely to grow with increasing awareness and opportunities in the solar market in Norway.

This study has potential limitations. There are currently limited existing resources on solar PV projects, barriers for the diffusion of solar PV, as well as analyses of partnerships for diffusing solar PV in Norway, which may lead to a biased result. Furthermore, while the application of PPPP has been proven to have the potential to make use of more resources, achieve good information sharing and solve the high initial cost problems, there are few real case studies, and its efficiency needs to be further verified. Finally, this paper only discusses the non-technical barriers for the diffusion of solar PV in Norway, which may lead to an incomplete analysis of how to promote solar development.

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Credit author statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Paper III

This paper is awaiting publication and is not included in NTNU Open

Paper IV

An interactive tool for citizens' involvement in the sustainable regeneration

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Abstract

Purpose – The purpose of this paper is to test possibilities of real participation in FM field in response to the energy sustainable demand by using new technologies for better communication. It is acknowledged that the technological innovation is a necessary condition to make a city sustainable, though the challenge is not primarily on technology but on service transformation and improvement. Improving service quality requires the participatory and synergetic processes that attract an extra attention to the social and management aspects of urban planning.

Design/methodology/approach – This is an evidence-based research, which shows how FM can extent its impact on the build environment and society by bringing the socio-physiological aspect and the community in the central of the planning and design process.

Findings – An "urban" facility manager, through integration of multiple disciplines in a human-centre approach, can become the enabler and implementer of sustainable urban ecosystem, i.e. balancing social, economic and environmental pillars. This requires central involvement of FM in the planning and decision-making processes; therefore, its role and impact should be enlarged and better communicated. The enlargement of the FM's role initially requires an effective communication with people, whose behavioural

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change are prerequisite for the sustainability transition. The communication between FM and people should be interactive and iterative, in which they both define problems/needs and co-create the relevant solutions.

Research limitations/implications – This paper depicts an evidence-based FM practice, in which the website as an interactive tool is co-designed by the "facility management" students and the citizens to contribute to the real citizen participation in an effective communication process.

Originality/value – The high value for both, citizens and facility manager, is co-created information platform for upgrading the sustainability level and well-being in the communities. The tool is seen as an important starting contribution for the Paris climate agreement, and as a step toward human-centric-oriented urban sustainable regenerating project.

Keywords Facilities management, Urban areas, Communication, Citizens' involvement, Interactive tool, Sustainable regeneration

Paper type General review

1. Introduction

The expansion of cities has faced a variety of challenges, indicating a loss of basic functionalities to be a liveable place, such as human health and well-being concerns and inadequate, deteriorating and aging infrastructures (Nam and Pardo, 2011). The urbanization process and urban activities generate environmental impacts both within and beyond city boundaries. Smart City' is a new approach, which aims at operating cities in an innovative way to solve the tangled and wicked problems inherited in the rapid urbanization. To explore the effective implementation of the Smart City in response to the challenges of sustainable socio-economic and urban development, global competitiveness and improved quality of life, the literature has already spotlighted the technological aspects. However, the social and political aspects of sharing different resources, governing co-development processes and fostering knowledge flows within innovation projects are still limited. Bai *et al.* (2010) argue that urban policy can play an important role in shaping and changing the regional, national and global linkages of cities. Therefore, coordination of policies across spatial scales, organizational practices and multi-levels of governance can foster innovation in cities (Nam and Pardo, 2011). A poor coordination, fragmentation, overlap and/or conflict between policies can undermine sustainable development, rather than facilitating it. However, the integration and coordination between policies are not easy because temporal, spatial and institutional aspects of policies are mismatching (Gohari *et al.*, 2020). The European Green Deal lays out the European Commission (2019) strategy to implement the United Nation's 2030 Agenda and sustainable development goals. Parts of this strategy include a "renovation wave" of public and private buildings and the enforcement of the legislation in relation to the energy performance of buildings, as well as examining initiatives that combine societal pull and technology push in local communities to work towards a sustainable future (Kristl *et al.*, 2019). This paper argues that ambition of cities to prepare for the future by means of smart sustainable technology and efficient use of resources in the continued urbanization first and foremost requires enhanced citizen participation. However, how exactly the real citizen participation can be established and, more specifically, which types of citizen participation we should aim at are still under the question (Williems *et al.*, 2017).

This paper calls for the contribution of facility management (FM) to improvement of the quality of life for the citizens by stimulating and facilitating their synergistic participation in innovation processes. FM integrates people, place, process and technology to ensure the functionality of the built environment; FM is the interface between an organisation, its employees and physical space (Donald, 1994). FM is defined as the one that can influence the efficiency, productivity and economies of societies, communities and organizations, as well

as the manner in which individuals interact with the built environment (ISO, 2017). Thereby, it can affect the health, well-being and quality of life of the societies and population.

The current practices of FM are mainly translated into the office, higher education, hospital and retail sectors (Price, 2004; Boge *et al.*, 2018). This paper highlights the underlying potential for FM to act in a wider urban context. To retain FM's relevance as a profession and strengthen and maintain its role and impact, in the first place, FM should be seen in the broader urban context (Alexander, 1994). The understanding of FM's leverage should be extended beyond the impact on individual organisations and buildings to recognize the full contribution that facilities make to the local economy and community. In addition, its policies and strategies should take more account of the factors of community and the public interest (Alexander and Brown, 2006). However, in an era in which governments and communities are demanding "more community", there are limited conceptual and practical tools for assessing the social outcomes of facilities (Alexander and Brown, 2006).

FM, as a people-based discipline, is seen as a vehicle for providing the opportunity for involvement of the communities in the co-design process. Therefore, current knowledge areas of FM (EN-15221-4) on strategic, tactical and operational level need to be enlarged with urban planning, data modelling, public – private – people partnerships (PPPP), financial and multi-criterion optimization models, social infrastructure in dynamic development, forecasting methods, demographic models, communication methods, spatial statistical methods and visualisation methods (Xue *et al.*, 2019a; Salaj *et al.*, 2011). Focusing on engaging citizens in formal and informal networks and groups for climate mitigation and adaptation, responds to the importance of social strategies to achieve behavioural changes (Salaj *et al.*, 2018). Participating in climate groups and networks takes advantage of social norms, status, cooperation and competition. This may lead people to copy attitudes, behaviour and concrete measures (Hauge, 2007). The motivational and socio-psychological theories are important for raising the willingness to change behaviour (Grum *et al.*, 2013; Kobal-Grum, 2018). The combination of different mechanisms are relevant to addresses different social groups in the neighbourhoods or urban areas (Hauge, 2007).

In the model (Figure 1), the impact of the primarly stakeholders (state/central gov., municipality/municipal government and FM) in materializng the real citizen participation is evaluated by the last five stages of citizens participation of Arnstein (1969), namely, inform, consult, involve, collaborate and empower (Xue *et al.*, 2019a, 2019b).

As it is shown in Figure 1, the impact of the central government (the state) is focused on the information, with a potential to extend to the consultation stage. The impact of the

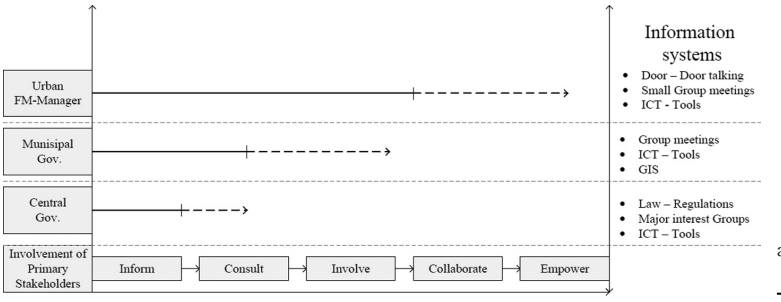

Figure 1.
Comparison of main actors' contribution to citizens' participation

municipal government starts with information and consultation, but can elaborate to the involvemnet stage. Our argument is that the nature of the urban FM allows the full achievement of the participation. Their task to deliver services to the citizens, business companies, and public institutions, requires FM to have an effective collaboration with these partners. Although their systematic technical knowledge is an essential element for the partnership, without an effective communication skill and full understanding of the social aspect of their task achieving sustainable built environment is impractical. Facility managers' day-to-day interactions with their partners provide an opportunity, particularly in relation to the citizens, to have closer contacts and improve mutual understanding about the sustainable challenges and solutions, thereby building the trustful relationship. Still, the current FM system has been unsuccessful to put the collaboration and empowerment stages of the participation into practice.

The recent approach in the FM field is to develop new models, systems and tools to put sustainable development at the heart of planning and decision-making, changing the way people think and behave to create a sustainable culture (Putnam, 2001). This will help to achieve the positive social outcomes, such as community identity, sense of belonging, respect, trust and mutual understanding. Due to cost-efficient and multimedia-rich interaction opportunities offered by the internet and the existence of online communities, various internet-based tools are created and designed to enable people to actively participate and engage in co-creation activities. Thus, virtual co-creation has become a desired goal of creating social value and improving the overall success of FM. By this way, people are invited to actively participate in the creation of new tools, in generating and evaluating new ideas while discussing and improving optional solution details. People can select or individualize the preferred virtual prototype, testing and experiencing the new features by running simulations and demanding information about or just using the tool (Fuller *et al.*, 2009). In a virtual environment, people can communicate their knowledge through an electronic interface with no direct personal contact. Since they do not get immediate personal feedback, there is a need to find a way to enable and motivate people to continue their active role and participation.

In addition, the challenge is how to create appropriate incentives to motivate people to freely share their knowledge with FM and how to create and apply tools to capture customers' tacit and explicit knowledge in a virtual setting (Hemetsberger and Godula, 2007). On the other hand, while several studies explore the impact of tools and technologies on effective problem solving (Thomke and von Hippel, 2002), or saving people's time and money (Dahan and Hauser, 2002), little research exists on the impact of these virtual tools on people' experiences. Fuller *et al.* (2009) did research on the way, in which internet-based tools and technologies contribute to people's empowerment and individual experience. Their results revealed the importance of IT tool support as a trigger of consumers' experienced empowerment and enjoyment. In addition, they figured out that consumers' sense of control and self-determination depends on possessing a domain-specific knowledge and creativity-relevant processing skills.

However, their result indicates the contribution of virtual tools to the people's participation and empowerment; they include only a rather small number of consumers, who possess specific creative or technical skills. This challenges the mass democracy and inclusiveness. In addition, consumer' empowerment, a sense of self-efficacy and enjoyment, does not result from their actual strength of influence on product policy. To make them feel empowered and enjoy co-creating new products or tools together with FM or other actors is especially important in this study. Besides, FM can build on the smartness through the knowledge they have within established services such as workspace management,

maintenance management and energy management by scaling up their skills from singular organisation/building vision to a city vision (Lindkvist *et al.*, 2019).

In the next section, we will give a short description of the refurbishment of the Karolinerveien neighbourhood in Trondheim, which aimed at designing a virtual interactive tool, in which the residents can engage and involve in the co-design and co-creation processes.

1.1 Karolinerveien case of sustainable regeneration

The Co-operative Housing Federation of Norway (NBBL) has decided to take actions towards the Paris Agreement to contribute to the constructions of high environmental standards. The focus is on the existing stock of buildings that have high energy consumption and poor performances. One of the cases is a sustainable regeneration of the area Karolinerveien, which consists of seven apartments buildings from 1967 (Figure 2). The responsible housing cooperative company is TOBB. Within the implementation process, the executive facility manager, faced the residents' resistance for renovation.

The issue was consulted by the Department of Civil and Environmental Engineering at the Norwegian University of Science and Technology (NTNU), who assumed the lack of communication with the residents as the main problem. NTNU organized a four-week workshop to investigate how the urban FM can bring the residents back to the process. The task given to the students from ESTIC (School of Civil Engineering) from Caen was to co-design an interactive tool to solve the communication problem and the lack of citizen participation in the refurbishment of the Karolinerveien as a technological innovation in accordance with Errichiello and Marasco (2014) statement. The role that FM can play in regeneration has been recognised in East Manchester through the creation of an FM Academy to provide skills training and enterprise support, driven by community demand and supported by research and development (Williems *et al.*, 2017).

Source: Google (June 12, 2019); www.google.com/maps/place/Karolinerveien,±7021±Trondheim

Figure 2.
Karolinerveien, Trondheim

2. Methodology and results

The methods used are survey, interviews, active participation and co-design. Figure 3 shows the interconnection between the methods and data sequentially.

Step1 – Survey: students used the results of the survey, which was collected from 100 participants, to identify the citizen's need for the refurbishment process. The results were two main things:

(1) The bad quality of indoor environment, including the high humidity level, bad ventilation and drafts from the windows and doors, causes acoustic disturbance; and

(2) The majority of the residents are young, between 25 and 35 years old (real estate agency).

Based on these two important facts, students used their technical backgrounds to find relevant solutions for possible upgrades such as an improved ventilation system, replacing windows and adding an extra layer of insulation. Considering the age of the community, they came up with an idea to design a digital tool with a playful interface, creating a website as visualization, communication and co-creation tool together with some technical 3-D modelling solution.

Realizing such technical solution would challenge making the real participation ambition into practice (Arnstein, 1969). Students realized that they and FM do not know how their tool would lead to the real citizen's contribution towards a sustainable refurbishment/regeneration. While they are not in a direct dialogue with people, their vision/solution is simply based on the available data, rather than the real facts.

Step 2 – Action research/fieldwork: to ask the resident's opinion about their needs and problems, students started with their fieldwork in Karolinersveien, trying to initiate contact. The language was a barrier for (international) students to communicate with Norwegian residents. Through a use of creative action research techniques (posting pictures, maps, messages, key words, questions, etc. on the walls in Karolierveien) they initiated the dialogue, presented themselves and their project and asked questions about people's opinion (Figure 4).

However, only few residents were willing to have a dialogue with students due to the lack of time, which can also explain about the lack of motivation for participation. Thus, the students needed to manage the second challenge, finding out how they should attract, motivate and increase citizens' curiosity to participate in design process and use the designed tool. They needed to collect citizen's ideas and listen to their voices. In such

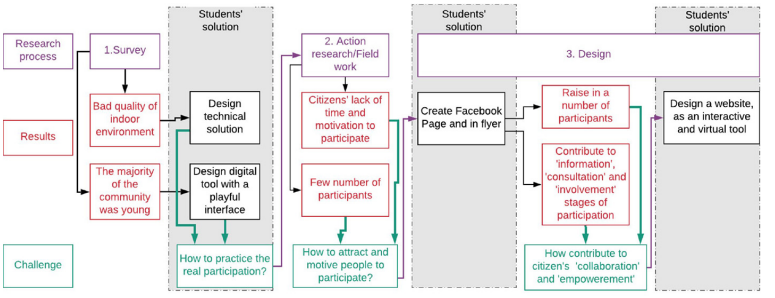

Figure 3.
Progress development of a design process

Source: Authors (2019)

Figure 4.
Prepared material

environment, where the time was scarce, students could not "inform", "consult" and "involve" citizens at one and the same time (Figure 1).

Step 3 – Design: opening a Facebook page as an informative and interactive digital platform could manage all the above challenges. To attract the citizen's attention and willingness to use the Facebook page, they came up with an inspiring name "La oss samskape Karolinerveien sammen" (let us co-create Karolinerveien together). To inform the citizens about the Facebook page, they created a business card and flyer (Figure 5), in which they provided the contact info. This new idea has resulted in a raise of the participants' number.

Statements below show some of the students' reflection on this participatory process:

> Taking the results of the field trips into consideration, we went back to reflect on our initial ideas and suggestions for improvement. We dropped some of our suggestions as they did not match the residents' needs! We decided to refocus on what they had expressed as a problem. We experienced that people reacted less defensively when the idea comes from themselves, rather than we impose the suggestion. This has also helped them to feel more comfortable to open up their daily life experiences.

> One thing we noticed, being familiar with the Norwegian culture is that people tend to «renovate» their home quite regularly, which often results in hiding signs of deterioration for a short period of time until the paint cracks again. This could also explain why people would be more reluctant to take actions towards refurbishment as they don't see the problem and therefore the need for it.

During Step 3 (design), students managed to meet the three stages of the participation ladder (Arnstein, 1969). To ensure the last two stages, namely, "collaboration" and "empowerment", they needed to design a tool, which would not be limited to their temporary presence in the workshop. They needed to safeguard the longitudinal across the life of facilities and vertically amongst all the players involved in cycles of planning, design, management and use of facilities that assure the long-term impact of their interactive tool. An effective interaction tool that enables people to actively engage in virtual co-creation needed to allow a realistic understanding and enhance people's creative articulation. Before people could make competent contributions, they needed an understanding of the innovation problem to be solved. This requires citizens to iteratively inform about their

Figure 5.
Facebook invitation

Source: Authors (2019)

problems and needs and to co-create solutions and be informed/aware about the technical and sustainable aspects and challenges of their apartments, buildings and neighbourhood. This would also enable people to play different roles in the co-design process. In the ideation phase, they can serve as a resource, and the interactive multimedia tools, virtual brainstorming, or virtual focus groups can support the users/residents in creating new ideas. In the design and development phase, they can assume that the role of co-creators and tools, such as Web-based conjoint analysis, virtual user design, internet-based design competitions and tool kits, allows them to express their preferences and design their own products. In the test and launch phase, IT tools such as virtual concept testing can help to provide valuable feedback on products (Nam and Prado, 2011).

To collect the resident's inputs regarding their problems and needs in an interactive and participatory way, the students created a website, www.blimedoss.com/ for "et bedre boliv" (*join us in a better place to live*). The name/logo also includes BIM (building information modelling) and OSS (our sustainable society). This interactive website consists of three main visualization and informative parts:

(1) 3-D model of the present situation of the neighbourhood is a simple BIM and Google map, which allows the people to get more sense of the neighbourhood. It is mainly used as an attractive tool to encourage people to participate in mini-game and learning tool (Figure 6).

(2) Mini-game "Pick your Picto", which is designed for collecting the real problems, is divided in two parts. First, the people can find the typology of their apartments among five existing alternatives. Then, they are asked to pick the pictogram, which illustrates their problem (drafts, cold, smell, noise, etc [. . .]) and drag it to the exact place (Figure 7). They also have an option to give additional idea, suggestion or more details.

(3) Learning tool "Click and Learn" aims at improving the technical and sustainable knowledge of people, enabling them to collaborate in "co-solution making" (Figure 8). Thereby we are empowering them for the co-design process and co-creation of their own neighbourhood. It invites people to explore the picture of the building and the outdoor environment with a possibility to click on specific elements, such as facade, windows and playground and gain information about both the present situation and possibilities for future upgrades and benefits. By this way, citizens can be both users and sources of data, fuelling open data platforms (Williems *et al.*, 2017).

In the end, the students presented the designed model, an interactive website, to NBBL and NTNU to examine the practicality of the tool and discuss the possibilities for the future improvement. It was agreed that the next step should include the building information modelling technology to facilitate interoperability and cooperation between professionals. This would become even more interesting and idealistic to involve people in the further co-design of the website. It is a new way of sharing information and coordinating everyone's behaviours towards a more sustainable development.

Besides, more tools, including some financial and real estate value information, could be valuable for citizens. From the financial aspect, citizens' participation can increase opportunities for urban renewal, as it allows a large of citizens to share the high costs of urban development projects, making them more affordable and reducing individual risk. Citizens can not only make contributions to liveable environment around them but also get financial benefits as co-investors. Furthermore, the citizens can provide and discuss related needs for making new business model for projects, which will lead to a social sustainability through balancing the community interests.

3. Conclusions

This paper aimed at testing possibilities of real participation in FM field in response to the energy sustainable demand in an evidence-based practice. This was shown by a mutual

Source: Authors (2019)

Figure 6.
BIM model of Karolinerveien

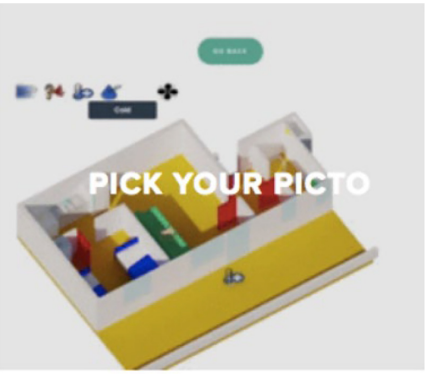

Figure 7.
Mini game

Source: Authors (2019)

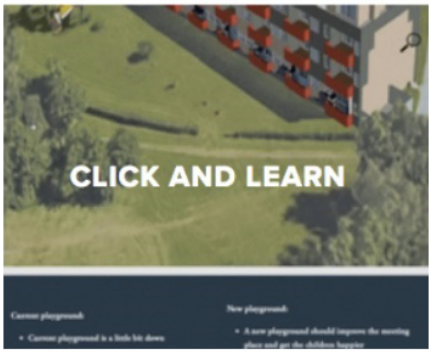

Figure 8.
Learning tool

Source: Authors (2019)

partnership of the university, the co-operative housing federation and FM to provide a platform for the co-design of virtual tool together with the residents in the future. We have shown that there is a possibility to reach the initial stages of the participation ladder: informing, consulting and involving people. But, to really "collaborate" and "empower" citizens, we need a stronger interactive tool, which can safeguard their long-term participation.

The literature review shows that there is a risk that a co-design of an interactive tool leads to the exclusion of those, who do not have a required specific knowledge and creativity. However, our practice has proved that it is possible to ensure a real inclusiveness and complete democracy by involving and informing users/citizens before starting the

process of co-design. In addition, co-design process should not be something to be done once, it should be continued. The website designed in the case of Karolinerveien can ensure such ambitions. This requires a stronger collaborative network, in which FM, academia, citizens, decision-makers and other stakeholders share knowledge, skills and responsibilities and expand their impact and commitment in assuring the sustainability in the built and urban environment.

We also witnessed that the involvement of students, as the future professionals and decision-makers, in such evidence-based researches was crucial. This workshop gave them the opportunity to learn and experience the challenges and requirements of the real citizen participation in the sustainability practices. The open-minded, passionate, creative and responsive characteristics of students/young researchers are something that can be learned for a success of similar co-design processes was very fruitful.

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Paper V

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Paper VI

Conceptual model for multi-sector participation from facility management perspective

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Abstract

Purpose: The purpose is to develop a conceptual model for multi-sector participation that use shared value principles for community, users and commercial actors in urban settlements, considering the facility managers as the main enablers in the model. The background for the project is the recognition that there is a clear correlation between the design of the built environment, individuals' quality of life, the community's social structure and business development. Extensive research shows that the development of urban areas must be linked more closely to an understanding of the development of participation models for different stakeholders to enhance sustainability orientation and reduce inequality and lack of inclusion. Lack of understanding of this context leads to cities and towns as in far less than desirable capabilities to create shared value for the residents, the business world and society as a whole.

Design/methodology/approach: The research is a literature review from the fields of facility management, urban design, economy, business models, social security, technology and ethics.

Findings: The model of urban value ecosystem is based on an open governance model, active community involvement and new business orientation to share the value with citizens. Within the process of creating the urban ecosystem, and changes toward healthier and more sustainable environment, the role and complexity of facility manager is important to explore, as the main facilitator of changes. Here, the urban facility manager is seen in accordance as the one to initiate and support the changes for better interaction with the built environment, and toward enabling the health, well-being and quality of life of the world´s societies and population through services it manages and delivers.

Implications: The value is to see the benefits of facility management to provide a platform for community engagement (employees in companies, residents in residential places, owners of the flats in buildings, and users of public buildings), modify forms of management (more proactive role for FM in the urban context) and initiate new services for FM. The last should be oriented toward social responsibility, giving a better understanding of the societal effect of using collective impact as an objective of city development.

Keywords: urban value ecosystem; facility management; social sustainability

1. Introduction

The urban ecosystem approach includes elements which interactions are affected by the natural environment, culture, personal behavior, politics, economics and social organizations (Threlfall 2018). Dizdaroglu (2015) mentioned three main aspects, identified in urban ecosystems: 1) natural environment; 2) building physical environment; and 3) socio-economic environment, all of them multidisciplinary in their nature. The complexity and simplicity of the urban ecosystem is that it is flexible and can quickly adapt to changes of one or more systems .

On basis of this understanding, urban ecosystem researchers have paid more attention to shared value for neighbourhoods to balance and integrate different systems like environmental system, social ecosystem and ecological system in the urban context. Shared value definition is taken over Porter and Kramer (2011) as a new way of management strategy for companies to find business opportunities in social problems, to build the models around social good and create real change on important social problems. Correspondingly, many different kinds of different partnership patterns have arisen, such as stakeholder participation, community engagement, end-user consultation, and public-private-people partnership. There are, however, many kinds of barriers for applying such models, which were mentioned by Lovrić and Lovrić (2018), such as a lack of: 1) ability to design innovative methods to enable efficient multi-participation of all stakeholders; 2) agencies or persons with a systematic knowledge of urban planning, data modelling, value capture, finance, communication and spatial statistical methods; 3) close relationships among different stakeholders

Facility management (FM) is an integrated approach to operating, maintaining, improving and adapting the buildings and infrastructure of an organization in order to create an environment that strongly supports the primary objectives of that organization (Atkin and Brooks, 2015, p. 3). FM encompasses multiple disciplines to ensure functionality, comfort, safety, and efficiency of the built environment by integrating people, place, process and technology (ISO, 2017). Alexander and Brown, (2006) discussed the benefits for extending facilities management from individual organisation and building to local economies and communities. Considering insights gathered from the literature review constituting the point of departure for the research presented in this paper, using the capacity of FM-providers in order to create a sustainable urban ecosystem (Urban FM) seems like a promising solution. Urban FM is the extension of FM from one building onto the neighborhood level, and understand and enable to achieve sustainable development by combining people, places, and processes in urban areas. It is quite similar to urban ecosystem from the sustainable development to urban area, as well as integrating the environment, buildings, and social-economic aspects.

Even though facility managers do not always have similar titles, they share common roles within their respective organizations. These roles include: occupancy and human factors; operations and maintenance; sustainability; facility information and technology management; risk management; communication; performance and quality; leadership and strategy; real estate; project management; finance and business (Meng 2014). From the roles of facility managers, we can find that they have a quite systematic knowledge concerning the building structure that they are responsible for operating and maintain. This seems, actually, to permit addressing the second barrier. At the same time, as an organizer, the facility managers can build a close relationship with citizens, business companies, and public institutions. Hence, they are easier to be connectors between different partners, creating for a instance a partnership network for stakeholders. Furthermore, due to the systematic knowledge, they are the most likely to design the creative methods for efficient multi-participation.

Therefore, the aim of the paper is to develop a conceptual model for multi-sectors participation that use shared value principals for community, users and commercial actors-over time in urban settlements. Specifically, two research questions will be addressed in this article:

1. What are the key dimensions necessary for multi-sector participation process?
2. To what extent can FM be used as a tool for implementation of multi-sector participation process?

2. Research Methodology

This research searched for a way of defining an urban value ecosystem model from a facility management perspective. The research consisted of two stages. Firstly, a scoping literature review was carried out. Secondly, existing models/ framework were analysed and broken down into thematic elements. The result from the research is a proposed model for an urban value ecosystem. Thus, this is a conceptual paper. The paper emphasis is on integration and proposing new relationships among

concepts. Thus, the purpose is to develop logical and complete arguments for associations rather than testing them empirically (Gibson & Goldberg, 2015).

In management sciences, a model is typically understood as being a representation or an abstraction of an object or a real-world phenomenon (Cook and Russell, 1977). Such a model can then be used to highlight and explain phenomena in a real-world context. The purpose of proposing a model for urban value ecosystem is to provide a framework for further investigation of cause-and-effect relationships. In addition, theory-building within this field of research has so far been relatively weak, and the proposed model is an attempt to advance this field of study by enabling the analytic highlighting of crucial elements.

The literature review process followed the framework proposed by Arksey and O'Malley (2005). This framework consists of the following stages: identifying the research question, identifying relevant studies, study selection, charting the data, and collating, summarizing and reporting the results. The keywords selected was based around "urban value ecosystem"; "facility management"; "social sustainability" as well as associated concepts such as "stakeholder management". The searches were conducted using Google Scholar, ASCE Journals and ScienceDirect. Furthermore, a total of 26 studies on shared urban value ecosystem were identified. From the studies identified, the analysis focused on extracting definitions and descriptions surrounding urban value ecosystem. The search is summarised in Table 1.

Table 1: Published articles in scientific journals related to urban ecosystem

Journals	**Keywords used**	**Themes investigated**
Urban ecosystem	urban ecosystem, multi-sectormulti-sector participation participation, sustainable urban development, social sustainability, urban planning, partnership, relationship network, stakeholders, citizen engagement, facility management, shared value	urban ecosystem
Cities		sustainable urban development
Journal of cleaner production		sustainable urban development
Society & natural resources		social sustainability
Ecology and society		social sustainability
Landscape and urban planning		urban ecosystem
Facilities		facility management
Journal für Facility Management		facility management
Journal of Facilities Management		facility management
Project management		shared value

The methodology as an entity was conceptual. However, the analytical element was empirical in nature but restricted to workshops with an expert group including all authors of the papers. The examination of the existing urban value ecosystem literature during the workshops was restricted to analysing, scrutinising, and the discussion of the three relevant and important models. The workshops were not a mean of data collection, but a step implemented in the thematic analysis to ensure reliability and validity in the study. The group met to discuss the progress of the scoping review, as well as to discuss how to interpret the result from the scoping review. The analysis employed a thematic approach in which the sources identified in the scoping review was examined to identify themes. In the workshop, the central sources were scanned to develop a set of thematic categories. According to Meredith (1993), conceptual research is conducted as a theory-building effort. Thus, the literature review shows that the emerging field of urban value ecosystem has a need for theory-building research.

Furthermore, Meredith (1993) states that the development of a conceptual model may be conducted through three different approaches: conceptual description, taxonomies- and typologies, or philosophical conceptualization. This research took form as a conceptual description, meaning that the search is primarily descriptive in its modelling of the phenomena. The analytical technique used to analyse the material might be described as a thematic analysis as according to (Saunders et al., 2016; Byrne, 2017). By using the thematic analysis method, key elements from the literature was extracted

and then used to develop a well-structured model. The purpose of the thematic analysis was both the organisation of conceptual development and indexing of the identified materials to present the developed conceptual model (Byrne, 2017). The model represents these elements but does not represent a theory that is empirically tested.

3. Theoretical Framework

The aim of the analysis is, firstly, mapping the related concepts and existing participation models in the urban planning domain through a literature review. Secondly, the ambition is to improve the current model from the facility management perspective.

3.1 Related Concepts

Urban ecosystem

An urban ecosystem can be defined as any ecological system located within a city or other densely settled environments (Dizdaroglu 2015). It consists of biological components and physical components. In the urban context, the biological components include human populations, their demographic characteristics, their institutional structures, and corresponding social and economic features. At the same time, the physical components comprises buildings, urban transportation, landscape, and energy use. Urban ecosystems are determined by complex factors, such as natural environment, culture, personal behavior, politics, economics and social organizations (Kremer et al. 2016).

The emerging science of urban ecology, a sub-discipline of ecology that examines the interactions between organisms and the human-dominated ecosystems in which they reside, may provide additional solutions to urban environmental problems (Grimm and Redman 2004). Ecological knowledge progression lays the foundation for better practices on urban ecosystem management, in response to the increasing need of urban areas to develop and implement plans to increase their sustainability and resilience, and ultimately, the human well-being of urban dwellers (Donoghue and Sturtevant 2007).

Shared value

Creating shared value is a strategy for developing the future market while also strengthening economies, the marketplace, communities, and corporate coffers (Riahi et al. 2017). To develop an integrated, holistic and ecological strategy for urban ecosystem that can balance all various interests in an area. Such approaches require the decision maker to consider a field based on a systemic point of view as a viable system of systemic components while focusing on the net outcomes of relationships (Fotino, Calabrese, and Lettieri 2018). The term ‘shared values’ has often been used to refer to guiding principles and normative values that are shared by groups or communities or to refer to cultural values more generally (Kenter et al. 2015). Adner and Kapoor (2010) discussed shared values as synonymous with what he also called ‘public values’: “goals or intentions the individual ascribes to the group or community of which he is a member; they are his because he believes and argues they should be ours; he pursues them not as an individual but as one of us”. The term ‘social values’ has also been used in diverse ways.

Multi-sector participation

With the development of paying attention to interdisciplinary problem solving, various methods for multi-sector participation pattern gradually appeared, such as stakeholder participation, community engagement, end-user consultation, and public-private-people partnership. Stakeholder participation was identified as “any group or individual who can affect, or is affected by, the achievement of the organization's objectives” by Freeman. By the 1990s, stakeholder definition and classification became more sophisticated, focusing on various criteria through which the importance of stakeholders to a given organization could be ascertained (Le Feuvre et al. 2016). In general, community participation refers to almost everything that signifies peoples' involvement (Swapan 2016). This public-private people

partnerships (P4) process framework embraces the bottom-up participative strategies which bring the public engagement clearly visible for infrastructure planning and policy making (Ng, Wong, and Wong 2013).

Facility management

Facility management (or facilities management or FM) is a professional management discipline focused upon the efficient and effective delivery of support services for the organizations that it serves (Eltringham 2017). The FM focus on supporting 'people' is reflected from different FM standards. The European standard CEN 15221 defines FM as 'integration of processes within an organization to maintain and develop the agreed services, which support and improve the effectiveness of its primary activities' (CEN, 2006). International FM Association (Mohammed, Nor, and Baung Alias 2014) defines FM as 'a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process, and technology'. ISO 41011:2017 FM Vocabulary defines FM as 'function, which integrates people, place, and process within the built environment with the purpose of improving the quality of life of people and the productivity of the core businesses. Based on this, a new standard, ISO/FIDIS 41001:2018 FM-Management- Requirements, gives an updated definition: 'FM integrates multiple disciplines to have an influence on the efficiency, productivity and economies of societies, communities, and organizations as well as the manner in which individuals interact with the built environment. FM affects the health, well-being, and quality of life of the world´s societies and population through services, manages and delivers.' Professional FM as an interdisciplinary business function has the objective of coordinate demand and supply of facilities and services within public and private organizations (Eltringham 2017).

3.2 Participation Models

Arnstein (1969), who put forward three different degrees of participation, firstly proposed citizen participation theory. They are non-participation with the lowest degree of participation, tokenism with medium level of engagement and citizen power with a higher level of participation. There are eight different ways to participate, and they are ranked from low to high depending on the level of participation (figure 1).

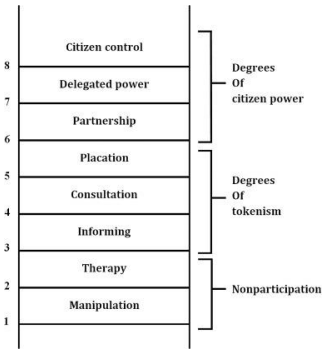

Figure 1: Arnstein (1969): A ladder of citizen participation.

On this basis, different scholars have improved the original model in different aspects. Glass (1979) designed a new model, which focus the relationship between objectives of participation degree and corresponding techniques. However, these traditional techniques like neighborhood meetings, agency information meeting and public hearings often time-consuming and fails to solve complex participation processes in modern society (figure 2).

	Objectives			
Technique categories	Information exchange	Education / Support building	Decision-making supplement	Representational input
	Unstructured	Structured	Active process	Passive process
Techniques	1. Drop-in centers 2. Neighborhood meetings 3. Agency information meetings 4. Public hearings	1. Citizen advisory committees 2. Citizen review boards 3. Citizen task forces	1. Nominal group process 2. Analysis of judgement 3. Value analysis	1. Citizen survey 2. Delphi process
	Administrative perspective		Citizen perspective	
	Purposes			

Figure 2: Glass (1979): the objectives, techniques, and purposes of citizen participation

Cooper, Bryer, and Meek (2006) provided five dimensions of different stakeholders' engagement (Figure 3).

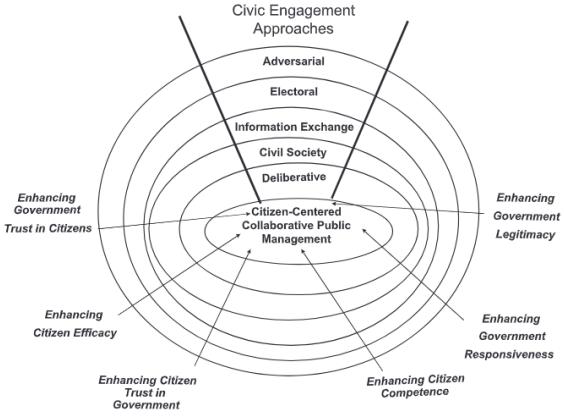

Figure 3: Cooper (2006) : Conceptual Model of Approaches to Civic Engagement

The five dimensions are: 1) who is involved; 2) Who initiates community engagement; 3) Why are they involved; 4) Where does the engagement take place; 5) How are they involved. At the same time, they put forward a conceptual model of approaches to civic engagement. They suggested that six variables need to be maximized in order to achieve a well-functioning collaborative public management: government trust in citizens, citizen efficacy, citizen trust in government, citizen competence, government responsiveness, and government legitimacy (Cooper, Bryer, and Meek 2006). Although they put forward a new perspective based on previous theories, they did not propose specific evaluation criteria, so it is difficult to actually apply them.

4. Results

The main objective is to provide a concept for multi-sector participation, which has people and environment as the main driving forces and urban facility manager as the main enabler and implementer. In order to meet this, we focus on innovative processes of FM professionalism extended from the building to the urban space. Related concepts are examined within urban ecosystem as a goal for sustainable neighbourhoods, socio-economic aspects with value orientation, and multi-sector participation for fully stakeholders engagement. After mapping the relevant theories of urban ecosystem, shared value and facility management, as well as the models of participation (figures 1-3), a conceptual

participation model was proposed for shared value urban ecosystem (figure 4). In the model, five main involvement patterns were put forward, sorted according to the level of participation from low to high. Usually, the informing and consulting steps can be done in a central government. Legal guidance, major interest group participation are the main methods, the main electronic web application here is Facebook. Furthermore, the involving step can be conducted at a municipal government level. Group meetings, ICT tools, and GIS can be used here. The applying of GIS here means participation in a wider geographical area. However, collaborating and empowering are rarely present in the current management system. In this new model, the two steps (collaborate and empower) can be initiated and conducted by the urban facility managers. Because of the good relationship with citizens, business companies, and government, as well as systematic knowledge, the urban facility managers can complete cooperation and empowerment very effectively. The door-to-door talking, small group meetings and ICT tools will be used in the process. A door-to-door talking means that managers and all participants will have closer contact and mutual understanding. Small group meetings mean more closely related persons involved in the project, which is very conducive to decision making. ICT tools used here for getting more information and make smarter decisions.

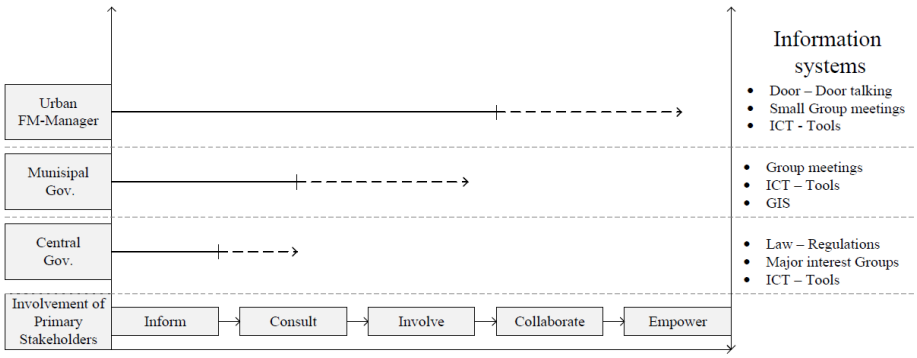

Figure 4: A conceptual model for multi-sector participation from facility management perspective

5. Discussion & Conclusion

In this paper, the research team tried to address two questions:'What are the key dimensions necessary for multi-sector participation process' and 'To what extent can FM be used as a tool for implementation of multi-sector participation process'.

In the paper, it is found that three key dimensions are quite important in the multi-sector participation process, and in each dimension, urban facility managers can play a new role.

First, involvement degree of stakeholders. A ladder of eight degrees of participation was firstly proposed by (Arnstein 1969). Manipulation and therapy belong to non-participation, so we eliminated these two items and focused on the high level of participation. Placation is not necessary in many cases. Citizen control is quite hard to totally achieve in this era, so we replace it with empower. Hence, the combine of informing, consulting, involving, collaborating and empowering in the process for shared value is a key characteristic. As we can see in current participation system, the informing and consulting steps can be done in a central government, the involving step can conduct in a municipal government level, and the collaborating and empower is rarely present in the current management system. Through the analyzing of roles of urban facility manager, it found that they have a good relationship with citizens, business companies, and government, as well as systematic knowledge (Mohammed, Nor, and Baung Alias 2014). Therefore, if the urban facility managers are added to the whole management system, it will be easier to achieve the high partnership of all the stakeholders. From an economic point of view,

the cultivation of urban facility managers may consume some funds in the early stage. However, the engagement of urban facility managers can deepen participation of the whole stakeholders in urban ecosystem, which means a more balanced social, economic and environmental benefits.

Second, the techniques of multi-sectors participation. In order to achieve different participation goals, the corresponding participation technology is one way to achieve the goal. For information exchange, drop-in centers, neighborhood meetings, agency information meetings, and public hearings are put forward. However, people in the department of drop-in centers usually not have enough interests if the participation projects have no effect on them. Hence, if we just focus on the major interests group, it will get more information that is efficient. At the same time, such meetings are usually time-consuming and it may be hard to gather all participants together due to the different arrangements of different persons. Therefore, ICT tools are quite efficient to obtain information from all the stakeholders, although costing more money. In fact, no single technique exists that can fully realize the objectives of all the participants. Selecting a combination of techniques based on specific projects is instead recommended. If urban facility managers are added at the technical level, they can not only choose a more appropriate technology combination model based on the comprehensive knowledge level, but also solve the problem creatively. Because of the interdisciplinary knowledge reserve and stronger ability to coordinate participation. They may provide participants door-to-door talking, which build a more understanding participation system and trust. What is more, they can also choose the more appropriate participants. Of course, under ideal conditions, they can implement professional knowledge, smarter technology and a broader network of relationships to achieve effective participation in multiple sectors and achieve sustainable urban ecosystem. However, this may also cause partial bribery, because decision makers have become the urban facility managers. Therefore, the visualization of the decision system is quite important.

Third, the factors effect participation. Some drivers are proposed for enhancing the participation. These variables like trust, efficacy, competence, responsiveness and legitimacy need to be maximized in order to achieve a well-functioning collaborative participation. However, whether the six variables are the most important factors that effected the success of participation is not known. It still needed to explore the other factors in the specific projects. What is more, the relationship between these factors are not been seek, it maybe also important for the further research. In the process of finding impact factors, the concept of facility management can be added to find impact factors from economic perspectives, urban planning perspectives, and sustainable development perspectives to guide future participation. This will make the selection of impact factors more systematic and logical. More impact factors also mean more complex evaluation systems, which puts high demands on technology, capital and manpower.

When we enlarge area of responsibility of Facility Manager to the Urban Areas, the level of complexity of duties increases and multi-disciplinarily approach is required. Therefore, current knowledge areas of FM (EN-15221-4) on strategic, tactical and operational level need to be enlarged with: urban planning, data modelling, value capture, financial and multi-criterion optimization models, social infrastructure in dynamic development, forecasting methods, financial models, demographic models, communication methods, spatial statistical methods, and visualisation methods, which should be studied further.

To approach the process of engaging citizens and municipal representatives in parallel, a development of new tools are seen to be useful, what is also the next step of the research: Tool for assessment the effectiveness of urban regeneration strategy by comparing the human behaviour on buildings and open area use, and their opinions before and after the interactive exhibitions/ and information uptake; Tool for analysing intergovernmental relations, urban social sustainability, sustainability management, and municipal sustainability performance measurement.

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