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How do cities work with transformative change?

Malmö's and Copenhagen's approach to energy efficiency in buildings

Paulina Lis

Supervisor
Lena Neij

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Tel: +46 – 46 222 02 00, Fax: +46 – 46 222 02 10, e-mail: iiiee@iiiee.lu.se.

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"The self is a style of being, continually expanding in a vital process of definition, affirmation, revision, and growth, a process that is the image, we may say, of the life process of a healthy society itself."

Robert Penn Warren

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Thank you,
Paulina

Abstract

Global inefficient energy use poses a significant risk to climate change and air quality worldwide; therefore, there is an urgent need to transform today's energy system into one that is rooted in efficiency. The building sector represents an opportunity to reduce energy use and has the potential to unlock additional co-benefits. Today, many of the technologies and design solutions have been proven effective in both reducing energy use in buildings and cost; however, the efficiency gap is still prevalent and prevents the potential in energy efficiency from being realized.

This thesis explores how cities work with transformative change to achieve energy efficiency in buildings. Specifically, the paper will discuss how concepts of *visions, experiments, learning, and collaborations*, which are central in transition management literature, are applied in the city context and guide transformative work. Research relies on case studies analysis of Malmö and Copenhagen, with focus on interviews with municipal representatives, and analysis of vital, relevant documents. Due to ambitious targets and experimental approaches, both cities have gained national attraction and recognition as the leading examples of sustainable urban development.

The research confirms that indeed, cities do work with concepts of *visions, experimentation, learning, and collaborations,* and recognize these elements as viable and essential pathways for exploring future sustainable solutions. Nevertheless, the result highlights that although cities recognize the value of *visions, experiments, learning, and collaborations*, they often see them as separate 'projects' rather than integrated elements of one governance cycle. As a result of this study, it is better understood that different levels of transformative processes in cities can be influenced by formal processes and the extent to which they influence the structure, culture, and practices within cities. Results of this study show that differences in internal processes and organizational structures can influence levels of *visions, experiments, learning, and collaborations* in cities. However, operationalized learning stands out as the connective tissue that has a unique potential to elevate the impact of all four transition elements and improve energy efficiency in buildings.

With much attention in literature given to the need for a transformative change in society, this study reveals the need for more research and understanding of broader societal learning necessary to accelerate the transformation towards more energy-efficient buildings. Additionally, there is a need to develop more applied materials and tools that help practitioners understand the nature of transformative change and apply its principles in local governance structures.

Executive Summary

This research project set out to analyze *How cities work with transformative change to achieve energy efficiency in buildings?* Due to the increasing pressure on Earth's systems' boundaries, resource efficiency is a prerequisite to sustainable development goals. Energy efficiency in the building sector is particularly important because of potential co-benefits such as energy security, air pollution, clean air which exist across societies and eco-systems. All government levels recognize this potential through various policy instruments such as mandatory and voluntary energy efficiency regulations. On the one hand, many market-ready and cost-effective solutions have already been developed to achieve the technological potential of energy efficiency transition. However, the *energy efficiency gap* is still prevalent, and the overall growing energy use in the building sector is alarming. Therefore, this thesis concerns itself with the nature of the transition process and its management through the instruments of *visions, experiments, learning, and collaborations – key concepts identified in the transition management literature to use when guiding and supporting processes of transformative change* . Understanding and application of such transformative approaches are necessary to move to pass the current status quo of the incumbent energy regime and develop new ways of thinking, doing and organizing which must lead to the responsible use of Earth's resources.

As the global urban population is growing, so is the demand for new buildings and upgrades to the existing building stock. This demand necessitates energy efficiency and creates an opportunity to unlock co-benefits in areas of quality of life, social equity, and economic prosperity. However, the demand for more building stock is also posing risks of system lock-ins and inefficient energy use in buildings for decades to come. Cities will be the centers of global energy consumption, and therefore a key actor in addressing these challenges and opportunities. It is in their best interest to actively create pathways for local and national stakeholders to understand shared value opportunities and the alternative cost of inaction. If these opportunities are not realized, cities will have to face the effects of overburdened electricity grids, energy poverty, declining building stock and overall lover quality of life, while also missing out on innovations that catalyze economic prosperity.

The transition management framework was chosen to guide research into *How cities work with transformative change to achieve energy efficiency in buildings?* The transition management model is particularly applicable to the research of sustainable transitions because it emphasizes the necessity of a radical diagnosis of persistent problems and structures that co-evolved along with these problems (Grin et al., 2011, p. 2). To overcome these problems, transition management calls for participatory approaches (collaborations) to develop an ongoing cycle of processes of envisioning, experimenting and learning. These processes should mutually reinforce each other to influence structures, culture, and practices to develop new values in the system and individual level (Feindt & Weiland, 2018; Shove & Walker, 2007, p. 622; Frantzeskaki & de Haan, 2009; Grin et al., 2011, p. 109). Therefore, the four components of *visions, experiments, learning, and collaborations* are the foundation of the research analysis framework.

To better understand how cities, navigate energy efficiency transitions, this thesis project will follow four research questions developed in line with the critical elements of the transition management framework:

- RQ 1 Do the cities have visions (roadmaps, goals developed among several actors) for how to reach a transformative change in the built environment?
- RQ2 Do cities facilitate and work with experimentation (such as living labs, testbeds, demonstrations) to achieve energy-efficient buildings?

- RQ3 Do cities support learning for transformative change, i.e., do they evaluate activities, pertaining to the energy-efficient built environment, to learn and inform future actions?
- RQ4 Do cities facilitate and support internal and external collaboration to achieve energy-efficient buildings?

To answer the research questions, this project relied on a case study of Copenhagen and Malmö. These two cities represent exemplary cases due to their long-standing and ongoing commitment to progressive environmental and social sustainability. The data collection process included interviews with municipal staff in both cities and analysis of relevant official documents such as Climate Action Plans and Energy Strategies. Additionally, a literature review provided insights into best practices in transition management which were used to develop an analytical framework. This framework allowed for quantitative analysis of the qualitative data, which supported a comparable level of understanding of each case and potential further applications in future research. However, the research process also uncovered limitations to the method approach. First, the analysis of transitions through data points collected at one period of time provides a limited view of the process. Therefore, research that captures more data points over time is recommended to understand better how to analyze transformative change. Second, there is an overall need for the development of more transition assessment tools and need for more awareness and knowledge of these concepts. New tools and materials could support academics and practitioners in developing new ideas for how societies can use visions, experiments learning, and collaborations approach to evolve towards sustainable development.

The literature review found that the technological potential for achieving energy efficiency exists, this potential is well understood and often identified as cost-effective (Lucon et al., 2014, p. 714). The highest potential (both technological and financial) exists when technology solutions are bundled into packages and building systems can be optimized in an integrated way along with passive strategies and human behavior strategies (Lucon et al., 2014, p. 686; The McKinsey & Company & C40, 2017, p. 29). In order to achieve such a deep level of integration and full potential of energy-efficient buildings, actors with the building sector must apply new methods of working together and consider social, environmental and economic opportunities (Jensen et al., 2018, p. 142).

Barriers preventing the uptake of energy efficiency solutions and resulting in the *energy efficiency gap* can be broken down into five distinctive groups: (1) Institutional and political barriers; (2) Market and economical barriers; (3) Financial barriers; (4) Technical barriers, and (5) Behavioral and social barriers (Jensen et al., 2018, p. 143) (Becqué et al., 2016, p. 42). The broad scope of these five categories translates to the complexity of projects and the necessity for a multi-stakeholder alignment, to overcome the lack of prevailing direction and realization of broad incentives to energy efficiency. These barriers are a result of many dynamics within the multi-level governance system. However, many cities take it upon themselves to address these barriers and influence existing regimes to develop new ideas. Concepts of visions, experiments, learning, and collaborations can be beneficial to break the status quo and develop new ways of designing, building and living in cities.

The results of the analysis in the thesis show that Malmö and Copenhagen work closely with transformative concepts to pursue energy efficiency and capture their co-benefits in local projects. The study finds that *visions and collaborations* are most evolved in case study cities. This is due to the high level of participatory approaches that support the inclusion of local values. In Copenhagen, *roadmaps* also support visions with indicators, short term strategies, and a transparent overview of progress. Experiments are also well developed in Malmö and Copenhagen; however, more work could be done to extend experiments beyond the technological innovation domain and to include innovations in policy, social structures and organizational domains, necessary to realize transitions. This research finds that *learning* is the least developed area of transition management in case study cities and that the connective character of this element might be the key to unlocking more in-depth transformative change. Both Malmö and Copenhagen are recognizing the need to implement formalized learning as an element of mutually enforcing the transition management cycle. Through connecting and multi-phase processes cities can elevate the impact of visions, experiments, learning and collaborations from an individual project scale and to a broad and deep systemic change.

This research also finds that although a significant amount of academic and research literature exists on the topics of *visions, experiments, learning, and collaborations,* there is much less material being developed with the practitioner's audience in mind. This may result in limited access for practitioners and limited general societal knowledge as to *how cities should work with visions, experiments, learning, and collaborations in a multi-phase and systematic way?* An abundant depository of case studies in academic and research literature should be translated into materials designed for practitioners. Additionally, assessment and evaluation tools should be developed to support practitioners in understanding how concepts of visions, experiments, learning, and collaborations can support their goals and influence organizational structures. Development of such tools and would support a more accurate verification of the impact of visions, experiments, learning and collaborations on energy efficiency and whether they have the potential to move beyond project scale and unlock a broader systemic change and lead to a radical change in building energy efficiency.

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Abbreviations

ASHRAE	The American Society of Heating, Refrigerating and Air-Conditioning Engineers
BACS	Building Automation and Control Systems
BMS	Building Management System
C40	The C40 Cities Climate Leadership Group
ECEEE	The European Council for An Energy Efficient Economy
EEA	European Environment Agency
EMS	Energy Management System
EPBD	Energy Performance Building Directive
EU	European Union
EuroACE	The European Alliance of Companies for Energy Efficiency in Buildings
GHG	Greenhouse Gas
GIS	Geographic Information System
HVAC	Heating, Ventilation, and Air Conditioning
IEA	The International Energy Agency
IMT	The Institute for Market Transformation
IPCC	The Intergovernmental Panel on Climate Change
JRC	The Joint Research Centre
LEED	Leadership in Energy and Environmental Design
LTRS	Long Term Renovation Strategies
NZEB	Nearly Zero-Energy Buildings
OECD	Organization for Economic Co-Operation and Development
PHI	Passive House Institute
SDG	Sustainable Development Goals
SEA	Swedish Energy Agency
STRN	The Sustainability Transitions Research Network
UNFCC	United Nations Framework Convention on Climate Change
USGBC	The U.S. Green Building Council
WBCSD	World Business Council for Sustainable Development
WEF	The World Economic Forum
WRI	The World Resource Institute
WSBC	World Sustainable Buildings Conference

1 Introduction

Earth's planetary boundaries have been pushed beyond the safe and stable levels due to human activities (Rockström et al., 2009). Out of nine planetary boundaries, two: the climate change and land-system change are already in the zone of risk and uncertainty, and another two, the biosphere integrity and the biochemical flows are in the high-risk zones (Rockström et al., 2009). This situation results in an increased occurrence of events such as droughts, heatwaves, and flooding, much of which will pose significant risks to urban areas around the world (Revi et al., 2014, p. 538).

The energy sector is central to addressing planetary boundaries because it relies primarily on fossil fuels to power the global desire for continuous economic growth. The energy sector is responsible for over 66% of global GHGs and almost 90% of the CO_2 emissions (IEA, 2019b, p. 8; Johansson, Patwardhan, Nakićenović, Gomez-Echeverri, & International Institute for Applied Systems Analysis, 2012). However, the impact of the energy sector goes beyond the climate change, it is also a leading contributor to global air pollution, and therefore has further impacts on public health and environmental health of ecosystems around the world (IEA, 2019b, p. 8). Because of these adverse effects, a clean energy transition is essential to meet objectives set in the following UN Sustainable Development Goals (SDGs): SDG 7 Affordable and Clean Energy (access to affordable, reliable, sustainable and modern energy); SDG 3 Good Health and Well-Being (on health, specifically target 3.9 on reducing the number of deaths and illnesses from air pollution); SDG 13 Climate Action (which aims to take urgent action to combat climate change and its impacts) and SDG 11 Sustainable Cities and Communities (reduce the adverse per capita environmental impact of cities, and increase resource efficiency)(United Nations 2019). While energy efficiency is a vital strategy to addressing climate change, many countries also frame impacts of energy use in the context of other policy goals, such as ending poverty and reducing air pollution and increasing energy security (IEA, 2019b, p. 9).

The 2015 Paris Agreement set ambitious targets to prevent catastrophic impacts of climate change. However, the pace and scale of the energy transition are not in line with those targets and therefore pose global risks. Consumption of fossil fuels remains a crucial factor in its polluting impact. Global coal consumption increased in 2018 (WEF, 2019, p. 6) and energy-related CO_2 emissions rose in 2018 by 1.7% (IEA, 2019b, p. 2). Also, the share of fossil fuels in total primary energy supply has remained stable at 81% for the past three decades. (WEF, 2019, p. 6). According to the World Economic Forum (2019), some of the critical challenges to energy transition have been lack of electrification in the energy sector, which remains at only 19% of the final consumption of energy, and continuous investment in the fossil fuels which has been growing again since 2017. However, fossil fuel consumption can remain high even as the electrification continues and therefore, energy efficiency should remain a top priority regardless of the energy source.

The building sector is central to the transition to the low-carbon economy and the key to mitigation strategies (Lucon et al., 2014, p. 676). It is one of the most energy-intensive sectors worldwide because it is responsible for 32 % of total global final energy use (24 % for residential buildings and 8 % for commercial buildings) (IEA, 2013a; Lucon et al., 2014, p. 678). The total CO_2 impact of the building sector is estimated at 30% of global emissions (IEA, 2019b, p. 8). The energy use trends in buildings are a concern, particularly when analyzed along with the global population growth trends. Since the year 2000, the global building floor area increased by 65%, and with that, the demand for energy consumption grew five-times faster than improvements in the carbon intensity of power generation (IEA, 2019b, p. 2). Therefore, although the energy intensity per square meter improved, emissions from the building sector increased by 25% since 2000 (IEA, 2019b, p. 2). Energy demand for cooling in the building sector is of particular concern as it has doubled between 2000 and 2017, making it the fastest-growing end-use in buildings (IEA, 2018). Energy use for cooling purposes is closely related to the temperature outside the building, and therefore the demand for cooling will increase as the global temperatures rise. The rising demand for cooling creates risk because, without efficiency gains, its energy demand could more than double by 2040, with even higher growth in rapidly emerging economies (IEA, 2019b, p. 11). System lock-ins in the building sector are of particular concern, as the building life-spans are long and the building stock tends to turn over only every 30 to 50 years, and retrofits are relatively rare (The McKinsey & Company & C40, 2017, p. 7). The International Panel for Climate Change (IPCC) (2014) calls for the urgent adoption of the highest level of building energy performance standards in order to prevent catastrophic impacts of locking the undeveloped and new building stock into old and inefficiency energy use patterns (Lucon et al., 2014, p. 675).

Energy efficiency in the building sector represents one of the most significant opportunities to reduce our reliance on fossil fuels as it remains to be the cheapest “fuel alternative” (IEA, 2013b, p. 26). Energy efficiency in buildings is also increasingly supported by the deployment of technologies that support a broader energy transition. Smart Meters and Smart Grid solutions can assist with measurement and verification of energy performance, as well as the integration of renewable energy sources (centralized and decentralized) and the electrification of the transport sector (IEA, 2019b, p. 8).

Energy efficiency in the building sector means delivering the same level of comfort and functionality for building occupants with less energy. The IEA's Efficient World Scenario (EWS)(2019) estimates that on average, buildings in 2040 have the potential to be nearly 40% more energy-efficient than today (IEA, 2019a), with critical opportunities in areas of reducing energy loads used for space heating, cooling, and water heating. Through improvements to the building envelope (the physical barrier between indoor and outdoor, i.e. walls, windows, doors, etc.), deployment of heat pumps, higher efficiency of building systems equipment and use of building controls, there is an estimated potential for following energy savings: 43% in space heating, 43% in water heating and 25% in space cooling (IEA, 2019a). IEA (2019) points out that new and innovative technologies (e.g., integrated thermal storage, advanced insulation, low-emissivity windows, solar thermal technology, advanced district energy, solar cooling, and integrated renewable façades) might help to achieve an additional 30% increase in energy efficiency by 2050 (IEA, 2019a). However, the full potential of such solutions is not yet understood, and therefore more innovation and research are needed (IEA, 2019b, p. 15). Strategies targeting behavior changes also represent significant energy efficiency potential with up 20% reductions from energy audits and community-based initiatives, and up to 15% with strategies involving consumption feedback such as smart meters and enhanced billing (EEA, 2013, p. 5). IPCC (2014) calculations reveal that building design strategies, energy-efficient technologies, and behavioral changes combined "can achieve a two to ten-fold reduction in energy requirements of individual new buildings and a two to four-fold reduction for individual existing buildings largely cost-effectively or sometimes even at net negative costs" (Lucon et al., 2014, p. 675).

The potential and the urgency of energy efficiency and its contribution to economic, social, and environmental co-benefits, has been gaining momentum among policymakers. At the macro level, the EU has adopted the *Clean Energy for All Europeans* package which includes *Energy Performance of Buildings Directive (EPBD)* and the revised *Renewable Energy Directive* both of which will lower the environmental impact of buildings. The EPBD directive mandate all member states to implement national-level regulations to meet Nearly Zero Energy Buildings codes. Other regions worldwide such as California, Japan, and Korea (Reda & Fatima, 2019, p. 599) have also recognized these opportunities by implementing policies that set nearly net-zero energy targets for new buildings and increase energy efficiency for the already existing building stock. Although these macro-level initiatives are essential, transition in the building sector has been increasingly recognized as important areas where cities have the power to further influence energy use and climate change (C40, 2014; Lucon et al., 2014, p. 718; UNFCC, 2017).

Cities use over 70% of global primary energy use, and the EU foresees an energy demand in urban areas to grow by 54% by 2050 while the generation from fossil fuels will decline by only 19% (JRC, 2019, p. 100). With the majority of the building development taking place along the rapid urbanization trend, it will be cities where the quest for sustainable development and energy efficiency will unfold (JRC, 2019, p. 83; Revi, A et al., 2014; STRN, 2019, p. 29). European cities can further enhance the EU's role as a key player in worldwide city development discussions both through its extensive policy experience in this area and concerning science and knowledge production (JRC, 2019, p. 5).

Cities can play a critical role in energy transition because of their significant share of energy use but also because they have an opportunity to support the deployment of experiments, testbeds and living labs for new energy efficient-building concepts (Bulkeley, 2013, p. 22; JRC, 2019). Due to the concentration of actors and activities, cities are attractive to entrepreneurs and policymakers who seek to develop innovative solutions, and therefore, cities can serve as seedbeds for innovative niches that produce energy-efficient solutions. (Bulkeley, 2013, p. 22). With collaboration from national governments and international partners, innovative ideas have the potential to be scaled up from the urban meso-level and expanded to national and international scales to contribute to macro-level policy goals (Bulkeley, 2013, p. 22).

The trends in urban energy efficiency approaches rely on complex infrastructure and organizational interdependencies within the urban building sector. Current trends in the building sector include the deployment of flexible buildings (manage energy needs through smart meters, consumer engagement and support for the effective management of energy grid peaks), development of net-zero and energy-efficient buildings (reduce energy needs by designing passive buildings and improving existing thermic insulation), and making energy production and distribution more efficient (district heating and heat pumps) and sustainable (use of renewable sources) (JRC, 2019, p. 100). Further, the complexities of the energy transition in cities result from interdependencies between building systems and urban infrastructure. For example, in some cities (e.g., London, UK and Lodz, Poland) over 40% of water is lost due to leaks in water pipes, which leads to losses and inefficiencies in energy needed to pump and heat water that ends up wasted (JRC, 2019, p. 100). In addition to the high level of complexity and interdependencies within the socio-technical system, energy efficiency upgrades take place within the ridged, pre-existing urban fabric which poses additional challenges (JRC, 2019, p. 100). One challenge is that an inefficient design of older building stock can often inhibit the deployment of new technologies.

Additionally, retrofits to the existing building stock often take place during regular tenancy, which disrupts business and day-to-day life (JRC, 2019, p. 100). Lastly, social equity aspects of energy transition and energy efficiency of the building stock is a central element of a broader need for sufficient affordable housing for an increasingly diverse population and in the context of rising property prices and need for integration among diverse populations in urban areas

(JRC, 2019, p. 5). With all these elements intertwined and played out at the city level, to unlock efficiency of the building stock, the transformative change must rely on a coordinated action across economic, technological and sociopolitical systems (WEF, 2019, p. 7).

For many societal actors, the implementation of bold energy efficiency goals creates a significant disruption and a shift from the 'business as usual' scenario. In the building sector, these actors can include private companies (architects, designers, construction, technologies, etc.), governments (who develop policies and building codes), non-profits (who advocate, develop certification systems) and of course, those who occupy buildings (residents, office workers, visitors, etc.). Local governments themselves are also an important actor with their visions to address urban population growth, limited resources, climate impacts, and increasing ambitions to attract prosperity, innovation, and improved quality of life. Cities should take on a proactive role in interactions among diverse stakeholders and steer their actions through a complex and dynamic environment where new initiatives and struggles emerge, in order to achieve ambitious climate and energy goals. Through active governance modes and policy development cities can support stronger integration of efficiencies among sectors and upscaling and replication of effective strategies.

In the governance of the built environment, cities operate at a unique meso-level position. On the one hand, cities are influenced by top-down policies from EU and national policies, building code and directives, and on the other, they are home to many bottom-up, local-level initiatives driven by a local market and community actors (Rotmans, Kemp, & van Asselt, 2001, p. 19). According to the Joint Research Centre of the European Commission (2019), the meso-level impact provides opportunities for at least 65% of the global urban agenda goals (JRC, 2019, p. 6). Because of the complex nature of the building sector, a transition to the energy-efficient built environment must go beyond market-driven technology deployment and regulatory approaches at a macro level, and it must also require an evolution in current governance approaches at the municipal level.

Human activity has pushed Earth's planetary boundaries beyond its limits. Societies around the world are heading towards an unknown future where uncertainties posed by climate change will create a scale of challenges like no other before. Today, there is a broad consensus that technologies exist to improve building energy efficiency and that rapid deployment of these technologies is necessary to prevent system lock-ins, achieve energy efficiency, and subsequently, climate goals. On the other hand, opportunities that can unfold along the energy efficiency transformation are tremendous and carry many economic, environmental, and social co-benefits for societies. In Europe, policies are in place to deliver co-benefits of Near Zero Energy Buildings but is the policy approach enough to transform the marketplace and achieve energy savings? Are all actors ready to adopt new and necessary approaches to achieve these ambitious goals? Because technologies exist within the social and market context, such deployment will depend on if and how societies develop their ability to govern and work within the rapidly changing, increasingly risky, unknown and complex realities of climate change impacts. The cultural fabric of our societies is changing too, and local governments can have a chance to activate the potential of urban residents, building sector workforce, clean-tech innovators and policymakers to work together towards a common goal of transformative change.

This thesis explores the research gap in the subject of sustainable urban transitions. Firstly, as studies and research networks explicitly point out, there is currently lack of research focused on transitions in cities and built environment (Markard, Raven, and Truffer 2012, 961) and therefore a need for more transition research needed with a specific focus on urban areas (Sustainability Transitions Research Network 2019).

Secondly, the concept of nearly net-zero energy buildings and carbon-neutral cities is gaining momentum in policy and the marketplace new and transformative approaches are necessary to achieve sustainable development. Therefore, the critical question of this thesis is, how can cities support the process of such a transformative change? Moreover, what is the role municipal governance can play in harnessing this potential, convening actors, and directing transition pathways towards energy efficiency and sustainable urban development?

1.1 Aim and research question

Against the background presented in the previous section, this thesis aims to advance our understanding of how cities support a transformative change to achieve energy efficiency in buildings. While the analysis of the subject of energy-efficient buildings' potential can be complicated and can present many perspectives, this thesis will focus on aspects of technological potential and necessary organizational processes to achieve this potential. More precisely, the analysis of transformative change will use the concepts of visioning, experimentation, learning, and collaboration; transition management literature recognizes these concepts as key to transformative change. In recent years concepts of transition management have been gaining interest in academic research and in applied cases, due to its potential to break through system-lock-ins and innovate new ways of solving wicked problems through visions, experiments, learning, and collaborations. This thesis will assess how cities work with these concepts in their effort to achieve energy efficiency in buildings and the potential for transformative change. Four research questions will guide this thesis process to achieve its aims:

- RQ 1 Do the cities have local visions (roadmaps, goals developed among several actors) for how to reach a transformative change in the built environment?
- RQ2 Do cities facilitate and work with experimentation (such as living labs, testbeds, demonstrations) to achieve energy-efficient buildings?
- RQ3 Do cities support learning for transformative change, i.e., do they evaluate activities, pertaining to the energy-efficient built environment, to learn and inform future actions?
- RQ4 Do cities facilitate and support internal and external collaboration to achieve energy-efficient buildings?

Case study cities analyzed during this research project are Copenhagen (Denmark) and Malmö (Sweden), both municipalities are located in the Øresund region, a dynamic area with a strong focus on innovation, quality of life and environmental leadership (Vojnovic, 2013, p. 594). Both cities have been globally recognized for its ambitious environmental goals and therefore, were chosen as good exemplary cases to analyze how cities use transformative approaches in the process of achieving energy efficiency. Table 1presents a brief overview of each case study city. For the purpose of better readability Table 1 does not include data sources, for the full version with sources please see Appendix 1.

Table 1 Case study cities overview

	Malmö	**Copenhagen**
Population (in 2019)	334 000	548 317
Past population growth trends	43% since 1990	20% between 1993 and 2013
Estimated future population growth trends	Not available	20 % population growth by 2025
Agency over the built environment	The municipality has to follow national building codes. More stringent energy requirements than national codes can be encouraged but cannot be enforced.	The municipality has to follow national building codes. More stringent energy requirements than national codes can be encouraged but cannot be enforced.
Relevant municipal departments	City Planning Department, Real Estate and Infrastructure office, Environmental Department	Copenhagen Properties & Purchasing, Energy & Technology, Climate Program, Neighborhood Area Renewal Sydhavnen

Source: Table with sources is available in Appendix 1

In an attempt to analyze the complex system of transitions in the built environment this thesis will rely on the transition management literature, and more specifically transformative change will be analyzed using a framework based on key concepts from this literature – *visioning, experimentation, learning, and collaboration*. This theoretical framework was chosen because it represents a governance approach that emphasizes the importance of social actors in achieving sustainability (Frantzeskaki, Loorbach, & Meadowcroft, 2012, p. 25). The core idea in transition management literature is that "in order to facilitate transitions, it is necessary to evolve governance models by bringing together actors from science, policy, civil society and businesses and develop cooperative rather than competitive relationships between them" (STRN 2019, p. 15). The transition management literature is highlighting the four elements *visions, experiments, learning and collaborations* as crucial foundation blocks to achieving transitions, which are complementary to policy and market actions and aim to address the unknown and learning aspects of sustainable transitions.

1.2 Scope and limitations

This study represents research conducted through a case study method, analyzing Malmö's and Copenhagen's work with transformative change *(visions, experiments, learning, and collaborations)* to achieve energy efficiency in buildings. Due to time limitation, the scope of two cities deemed feasible to deliver an in-depth and comprehensive analysis. However, the two cases are a limited representation of cities, and therefore results of this study cannot be generalized and seen as representative of cities overall. Due to the location of both Malmö and Copenhagen in the Nordic region, representative of advanced and developed economies, these case studies represent a particular and narrow view in terms of culture and economic context.

Within each case study, the research relied on an analysis of documents and interviews for the data collection process, and both data sources represented specific limitations. Only a limited number of interviewees was available to discuss the project during the research period taking place over the Swedish and Danish summer holiday period. Such a limited number of interviewed employees represented only specific insights into the content. Additionally, because case studies looked back at the past ten years of climate action in these cities, lack of access to additional historical data created gaps in the data collection process. In the case of interviews and analyzed documents, the language barrier was a limitation. Analysis of such documents relied on translations from its original language (Danish or Swedish), the Google Translate function was used to accomplish that. Because of the author's lack of Danish or Swedish language skills, some gaps may have occurred and not been identified in the translation process. Level of spoken English language (in both interviewer and interviewees) influenced data collected during the interviews.

As for the potential of achieving energy efficiency, this thesis discusses technology and design process potentials, but it does not discuss market readiness potentials, behavior change potential or financial aspects of specific strategies.

1.3 Ethical considerations

The author received introductions to individuals at Malmö and Copenhagen municipalities from the thesis supervisor, Lena Neij, Copenhagen Business School prof. Luise Noring and Climate Kic Urban Transformations program staff, Sandro Benz. These valuable introductions lead to a better understanding of the municipal organization in both cities and ultimately allowed for the data collection process. Throughout the thesis project process, Climate Kic's urban transformation team has also provided feedback to the analytical framework and research approaches.

Concerning data collection, all interviewees received an email, before the interview, with the information about the purpose and scope of the data collection process. Before starting each interview, interviews gave consent to record the information. The interview data was recorded on a password protected the mobile device, and additional handwritten notes were taken and summaries transcribed to digital format. Data has been stored on password-protected computer and phone. All interview data is presented as anonymous in this report.

1.4 Target audience

Target audiences for this thesis are cities, businesses, policymakers, research institutions, and non-governmental organizations (NGOs) working with research or implementation of sustainable objectives at the city level. The findings of this thesis can be valuable to actors working with energy efficiency in the built environment and to those looking into other areas of urban transformations (e.g., water, waste management, transportation) that require innovation and transformation to achieve sustainability objectives.
Additionally, this thesis might be of interest to those engaged in the development of long-term strategies and supporting short-term actions that aim to advance co-benefits of energy efficiency. Co-benefits can be achieved through broad and innovative coalitions representative of the complexity of urban governance. Although this thesis is providing analysis from a local government's perspective, often such initiatives are undertaken by non-governmental organizations (such as e.g., C40, ICLEI, Climate Kic, WWF), energy utilities or educational institutions. Private sector actors such as real estate companies' developers, architects, and urban planners and technology representatives often play a crucial role in such initiatives and might be interested in the findings of this thesis.

1.5 Thesis disposition

Following the introduction chapter (*Chapter 1*), this thesis will discuss the following content:

Chapter 2 Energy Efficiency in Buildings presents a literature review current policy context and technological potential for achieving energy-efficient buildings. The review leads to the conclusion that to transform the building sector towards energy efficiency mandated at the EU level, its actors must engage in new transformative and more collaborative ways of working together. Such transformative and collaborative approaches can provide a more in-depth understanding of barriers and opportunities to overcome them. Chapter 2 also presents a literature review on the barriers and what actions cities can take to tackle them. The literature review concludes that a new way of engaging with actors is necessary to achieve full energy efficiency potential and develop financial models that support it.

Chapter 3 Theoretical framework presents a review of the literature discussing topics of transitions and specifically transition management. The focus is on four elements of transition management: *visions, experiments, learning, and collaborations* — the review of these four elements in applied and grey literature supplements the academic literature review. The material reviewed in Chapter 2 provides a foundation for the analytical framework applied in the analysis.

Chapter 4 Method presents the approach to research design, data collection, and data analysis. The methodology used in this research is based on an inductive approach based on the transition management framework. The inductive approach leads to the development of a questionnaire that was used to analyze Malmö and Copenhagen work with *visions, experiments, learning, and collaborations* in achieving building energy efficiency.

Based on the collected data, *Chapter 5 Transitions in Øresund* describes how the Malmö and Copenhagen work with transformative change. Chapter 5 provides insights into how *visions, experiments, learning, and collaborations* are used in these two cities to achieve energy efficiency buildings. Analysis of the results and discrepancies between the two cities reveal barriers that each city is facing in the way of achieving the full potential of its transformative actions. Specifically, an essential role of reflexive strategies and operationalized approaches is revealed as necessary to take energy efficiency initiatives from project scale to systemic change level.

The *Discussion in Chapter 6* presents present comments identified barriers to transformative approaches in urban building energy efficiency efforts and suggested recommendations to overcome them. This section also commented on the chosen analysis method and discovered the limitations of the analysis framework that was used in the research project.

Chapter 7 Conclusions chapter presents the conclusions and reflection on results. Future research questions and actions that can support a better understanding and deployment of transformative concepts are also discussed in this section.

2 Energy Efficiency in Buildings

This chapter will present the literature review on essential topics related to energy efficiency in buildings. The first section will present an overview of the current European Building Performance Directive (EPBD), which sets a long term and broad goal for the role of buildings in the clean energy transition in the European Union (EU). The second section will discuss the technological potential to achieving EPBD's goals and some of the process transformations necessary to improve collaborations within the building sector. Final sections of this chapter will present examples of how cities around the world work to address barriers to energy-efficient buildings and tap into the opportunities created by this transition process.

2.1 European framework for building energy efficiency

Energy efficiency has high potential to contribute to energy savings in Europe (Güneralp et al., 2017) therefore a bold and necessary goal for Nearly Zero Energy Buildings (NZEB) has been set through the policies within the *Clean Energy For All* package, and specifically the Energy Performance and Buildings Directive (EPBD)(Directive 2010/31/EU). Recently, the Amending Directive (2018/844/EU) to EPBD came into force on July 9th, 2018 and set the new, more ambitious and broader scope of targets that align the building sector towards the EU's 2030 and 2050 climate goals. The most prominent elements of the directive are goals for nearly zero energy buildings and a stronger emphasis on retrofits of existing buildings. Both the EPBD and the Amending Directive (2018/844/EU), have the potential to transform the building sector in Europe by mandating member states to implement regulations and strategies which aim to catalyze a broad market shift towards energy-efficient buildings. The EPBD sets a target for a transition of the EU's building stock from its current state to a nearly zero energy building stock.

Article 9 of the EPBD defines a nearly zero energy building as a "building that has a very high energy performance (…), or very low amount of energy required should be covered, to a very significant extent, by energy from renewable sources, including energy from renewable sources produced on-site or nearby" (EU 2010). This definition is purposefully high-level and vague, as the EPBD mandates member states to develop more specific definitions that apply to the context of their respective markets. EPBD requires all the new public buildings to be NZEB by January 1st, 2019, and all other new buildings to be NZEB by January 1st, 2021.

As for the existing building stock, EPBD amending directive adds a new objective to accelerate the energy renovation of the existing building stock, by mandating member states to create plans that will lead to the transformation of the building stock to reach nearly zero-energy performance levels by 2050. The amendment also mandates a more collaborative process through consultations with stakeholders in the preparation and implementation of the Long Term Renovation Strategies (LTRS) (EuroACE, 2018, p. 15). Both the new and the existing building stock are also a subject to the *Smart Readiness Indicator*, a strategy to modernize the building stock to integrate innovative technologies that allow for increased control of energy efficiency, flexibility in the occupant comfort and deployment of electric mobility projects (EuroACE, 2018, p. 15). The Smart readiness Indicator strategy of the EPBD includes provisions mandating building automation and control systems (BACS) and electronic monitoring before 2025 for certain types of large buildings (EuroACE, 2018, p. 15).

The EPBD directive also requires all EU member states to implement minimum energy performance standards for buildings and technical building systems in a way that is ambitious and cost-effective. The actual energy performance should be a subject of public disclosure of energy performance, through a display of energy performance certificates. All of the EPBD strategies require significant financial investment and therefore the directive includes a strengthening of the provision on financing (Article 10), which now requires the member states to link financial measures that support energy renovation works to the improvement in the targeted or achieved energy performance of the funded buildings (EuroACE, 2018, p. 15).

The original EPBD and its recent amendments will both continue to significantly influence the market and regulations to stimulate energy transitions and catalyze co-benefits of energy-efficient buildings for citizens, businesses, governments, and ecosystems (EuroACE, 2018, p. 17). IPCC estimates that co-benefits associated with energy efficiency in buildings are at least twice the resulting operating cost savings (Johansson et al., 2012; Lucon et al., 2014) and capturing their full capacity can boost a cumulative global economic output through $18 trillion by 2035 (OECD, 2014, p. 19). Key categories of energy efficiency co-benefits include a)health effects, b)ecological effects, c)economic effects, d)service provision benefits, and e)social effects. Beneficial health effects result from improved indoor air quality improves the comfort and well-being of building occupants and has also been proven to increase productivity and learning capacities. Energy-efficient buildings may result in a 1%-9% increase in productivity attributed to reduced lost working days (lost, for example, due to asthma and respiratory allergies) and improved worker performance from changes in thermal comfort. When monetized, these productivity gains can be the highest value co-benefits to energy efficiency (Lucon et al., 2014, p. 707). Beyond increased productivity, the energy efficiency can yield even more positive economic effects, through the new market activities, the building sector will experience an increase of more local jobs and increased asset values for property owners. This activity can also result in an increased inflow of public finances (due to an increase in taxes) and reduced social security payments due to a reduction in unemployed and under-employed persons and reduced overall healthcare costs. Alleviation of energy poverty is another very important social co-benefit of energy-efficient buildings, and it can make up to 30% of the total value of benefits of energy efficiency investment, this applies particularly to an existing building stock where energy inefficiencies result in high financial costs to occupants and high levels of discomfort. (Lucon et al., 2014, p. 708). Energy security and balanced, reliable energy grids are an increasingly more critical objective of energy efficiency, because they can results in increased grid flexibility, accelerate the integration of renewable energy strategies and diversification of energy sources in domestic systems which promotes independence from unsustainable or insecure energy sources (Lucon et al., 2014, p. 707). Finally, because fossil fuels are a primary source of energy, less energy use means fewer fossil fuels used and less CO_2 which means improved outdoor air quality resulting in improved health and well-being of citizens and reduced negative impact on ecosystems.

The EPBD and its target of the NZEB, follow the 'energy efficiency first' principle in both the energy-related policies and legislation, and to the building design, (EuroACE, 2018, p. 57). However, the effort required to push energy efficiency performance to achieve NZEB and in both new and existing represents a drastic and significant shift to actors in a sector that "is particularly prone to lock-in, due to favoring incremental change, traditionally low levels of innovation, and high inertia" (Lucon et al., 2014, p. 679).

2.2 Strategies for new construction, retrofits and operations

The World Bank points out to three areas where buildings can launch energy-efficiency 1) during the design and construction of new buildings, 2) through retrofits of the existing building stock, 3) during the operations phase of the building, through effective maintenance of energy management systems and monitoring of building functions (Liu, Meyer, & Hogan, 2010, p. 1). Successful reduction of energy use in all these three phases relies, among other factors, on available technologies, many of which are proven and cost-effective (Lucon et al., 2014, p. 714). Although specific methods to achieve energy efficiency in buildings vary significantly per building type and its location, at a high level, typical steps in the design of energy-efficient buildings are similar and include:

1. Appropriate site selection and climate-specific building orientation, thermal mass, and shape (new buildings),
2. High-performance envelope specification,
3. Maximization of use of passive features (daylighting, heating, cooling, and ventilation),
4. All remaining loads should be delivered through efficient *systems-level* optimization,
5. Highest possible efficiencies and adequate sizing of individual energy-using devices,
6. Proper ongoing commissioning use and maintenance of systems and devices (Lucon et al., 2014, p. 698).

2.2.1 Design, design process and technologies

Technology and design solutions to increase energy efficiency in buildings are well demonstrated and cost-effective and have the technological potential to deliver up to 30% of energy savings of in the buildings sector worldwide by 2050, even as floor area doubles globally (IEA, 2019b, p. 4; Lucon et al., 2014, p. 675). However, the question remains of why these solutions have not been adopted more rapidly in the marketplace?

The potential of energy efficiency is visible by comparison of average energy use and established building codes with the highest performing buildings. In Sweden, average residential energy use is 158 kWh per square meter (Swedish Energy Agency, 2015) in Denmark an average residential energy use is117 kWh per square meter (Næss-Schmidt, Heebøll, & Fredslund, 2015, p. 13). Sweden has more diverse and severe climates than Denmark with the majority of the country in colder zones, Climate zone 4, which includes Malmö has an average residential energy use of 147 kWh per square meter (Swedish Energy Agency, 2015). Both countries have a long history of energy efficiency in their building codes, and currently, both have established standards in compliance with the Nearly Zero Energy Buildings requirements of the EPBD. Sweden's building code sets a maximum energy consumption at 90 kWh per square meter for non-electrically heated homes and 55 kWh per square meter for electrically heated homes (Boverket, 2018, p. 147). These values represent requirements for Climate zone 3 (which includes Stockholm and central areas of the country) and are adjusted for other areas with geographical factors representative of the three other climate zones (Boverket, 2018, p. 147). In Denmark, the current building code, the BR18, sets a maximum energy consumption for residential buildings at 30.0 kWh per square meter plus 1000 kWh per year years divided by the heated floor area (Bygningsreglementet, 2019).

Both countries' progressive approach to pushing energy efficiency standards in the past decades has brought current requirements close to these of the Passive House Institute (PHI) standards. PHI has three levels of compliance that are set based on the total maximum energy consumption, 1) Classic (75 kWh per square meter), 2)Plus (60 kWh per square meter) and 3)Premium (45 kWh per square meter) (Passive House Institute, 2015). Figure 1 represents

Sweden's and Denmark's current energy use compared to the potential of the current new construction building code requirements and the Passive House standards.

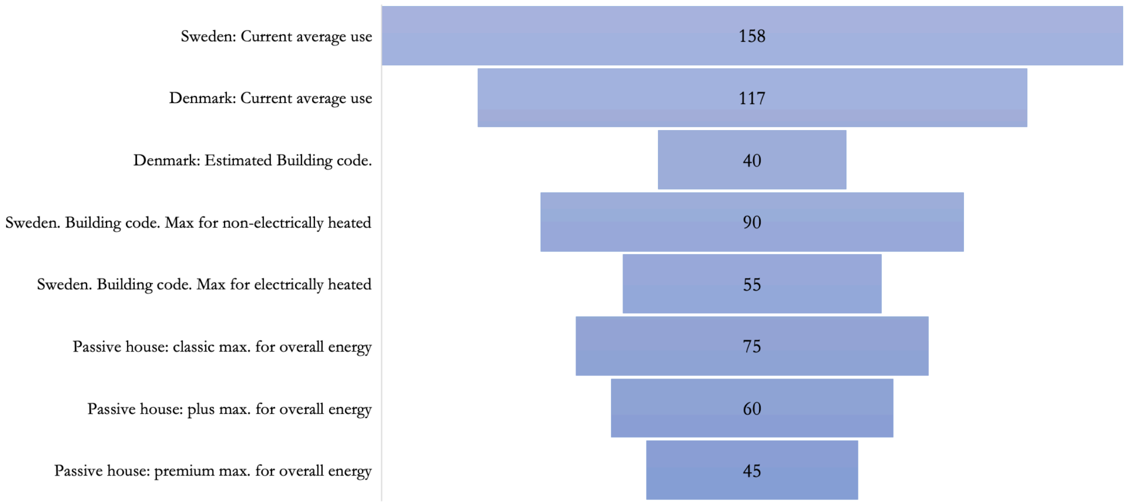


Figure 1 Sweden's and Denmark's residential energy use and Passive House Institute standards, in kWh/m²

Source: Own figure based on sources cited in text

The value proposition of the houses designed with energy performance that represents current code, or Passive House standards, is increasing as the cost of construction of such buildings is going down (The McKinsey & Company & C40, 2017, p. 31). Passive strategies are one of the critical elements of achieving energy efficiency because they significantly reduce or eliminate the need for active energy use (Liu et al., 2010, p. 8). Passive strategies begin with the building location and orientation which is responsive to the local context (e.g., sun path, wind patterns, humidity) and include super-insulated and air-tight building envelope (the barrier between indoor and outdoor environments, such as windows, doors, bridges, etc.), appropriate roof color (white for hot climates) sun shading and natural ventilation, etc. that help minimize the need for energy load (Becqué et al., 2016, p. iii; Liu et al., 2010, p. 8). These strategies will help a building manage an energy load, for example, by enabling the building to collect solar heat in winter and reject solar heat in summer and/or by integrating active solar technologies (such as solar collectors for domestic hot water and space heating or PV-panels for electricity generation) (Bogdan Atanasiu, 2011, p. iii).

Passive strategies and other energy-efficient solutions within the building should be evaluated as one integrated system rather than sperate solutions, especially if the property has other environmental goals. Jensen et al. and Pacheco-Torgal (2017) discuss sustainable strategies by analyzing co-impacts of building systems beyond energy performance. For example, increasing airtightness of the building envelope has tremendous potential for minimizing heat loss but can pose challenges with managing humidity and subsequent mold in the building and building walls, another example can be related to using of building envelope color to gain or reflex heat in a passive way, which can have negative glare effect on nearby neighbors (Pacheco-Torgal et al., 2017). Although some of such trade-offs exist between building systems, it is through a holistic understanding of building systems and their deeper integration that net-zero energy performance can be achieved. It is the synchronization of multiple efficiencies, and conservation measures can yield benefits beyond the sum of efficiencies of each system alone (Ma, Cooper, Daly, & Ledo, 2012, p. 892). Benefits of integration and effective bundling of technologies translate to financial aspects as the investment-cost savings are several times higher when a more integrated approach to energy efficiency measures is implemented (Lucon et al., 2014, p. 686; The McKinsey & Company & C40, 2017, p. 29)

Beyond the building system-level integration, a deeper systemic integration should be considered between the supply side, storage, and demand-side management of energy. Such integration relies on the building operations phase and the human factor, which can influence energy consumption patterns. Figure 2 represents those categories and their role in the building systems.

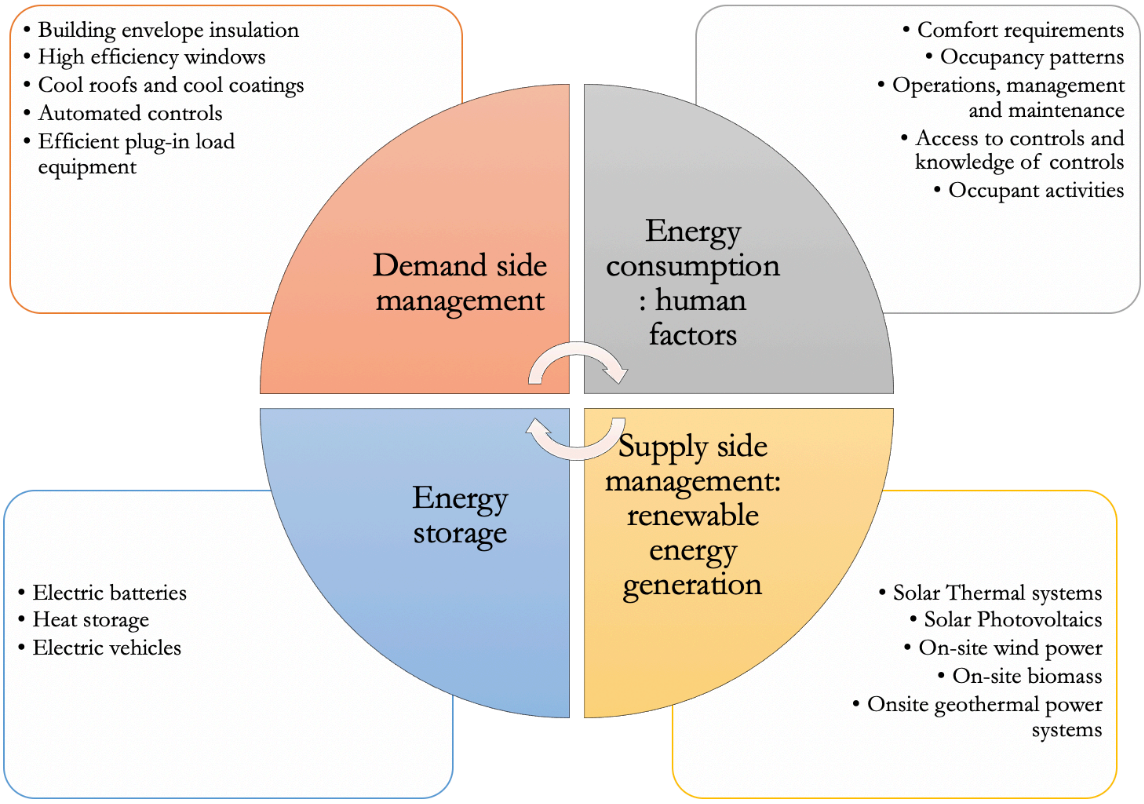


Figure 2 Main categories of building retrofit technologies

Source Ma et.al 2012 and own elaboration

Potential for energy efficiency for existing residential buildings in Sweden

In Sweden, buildings account for 36% of the country's overall delivered energy (21% for residential buildings and 15% for non-residential buildings, respectively), which is slightly below the average of 40% in the EU (Mata & Johnsson, 2017, p. 344). A study conducted by Mata and Johnsson (2017) presents a technological potential for up to 60% of savings in Swedish buildings (Mata & Johnsson, 2017).

Table 2 Energy Conservation Measures potential in Sweden presents the potential of specific technologies from the Mata and Johnsson (2017) study.

Table 2 Energy Conservation Measures potential in Sweden

Energy Conservation Measure	Residential building	Non-residential building
Upgrade of the ventilation system with heat recovery	23.5%	49.4%
Insulation of the façade	7.8%	4.9%
Installation of solar panels to provide 50% of the hot-water demand	4.3%	2.3%

Source: Adapted from Mata and Johnsson 2017

However, deployment of energy measures in packages, rather than separate applications can achieve significantly more substantial energy savings. Studies estimate the highest potential for combined a) improvements to the building envelope, b) improvements to the ventilation system and installation of heat recovery system and sealing of the building envelope through window replacement, c) upgrades to the lighting system, together can produce savings of 38% in residential and 56% in non-residential properties (Mata & Johnsson, 2017, p. 351). Potential for these saving varies widely depending on the time of construction of the property, and there is a significant difference in energy consumption between the buildings constructed before and after 1980 (SEA, 2011d). Swedish building code introduced energy efficiency considerations in the mid-'40s through considered insulation materials requirements; however, it is not until the 60's that the coeds included more specific energy requirements (Kiss, Manchón, & Neij, 2013, p. 189). After that, the stringency of the Swedish government's focus on energy efficiency was impacted by the rise (60's and 70's) and fall (80's) of global oil prices (Kiss et al., 2013, p. 189). Following this, Sweden has begun the implementation of other building codes that have addressed the maximum energy consumption of new buildings and retrofits (Mata & Johnsson, 2017, p. 347). Buildings constructed before these energy codes, especially the Million Homes Programme developments form the 60's and 70's, represent the highest energy efficiency potential (Formas & WSBC, 2011, p. 4). The cost-effectiveness of these measures is largely dependent on the cost of both measures themselves and the cost of energy. Although the technological potential exists for these strategies to deliver on energy efficiency, other market factors such as financial potential and market mechanisms (not discussed in this thesis) still need to be developed (Mata & Johnsson, 2017, p. 359).

Building efficiency potential for existing residential buildings in Denmark

The average heat demand per square meter in existing Danish buildings is approximately 135 kWh (Danish Government, 2014, p. 9). Similar to Sweden, the highest technological energy efficiency potential exists in the residential sector, specifically single-family homes (detached) require which over 70% of Danish heating energy (Danish Government, 2014, p. 9). Denmark as Sweden, also begun implementation of its building energy regulations in the early '80s, however, more than 70 % of the current total building stock in Denmark and more than 80 % of the stock of detached houses were built before that time and their average heating demand is around 165 kWh per square meter (Danish Government, 2014, p. 9). The Danish strategy for building energy efficiency retrofits estimates that upgrades to heating and hot water systems can deliver up to a 35% reduction in energy use in the building stock by 2050 compared to 2011.

Additionally, mechanical ventilation with heat recovery and improving the airtightness of the building envelope could bring the net heat energy demand in buildings down to more than 45 % by 2050 (Danish Government, 2014, p. 13). A study conducted by Aalborg University (evaluating upgrades of the entire building envelope, ventilation with heat recovery and solar heating systems for hot water production) reports an even higher potential for reduction of the energy consumption for space heating and domestic hot water by as much as 73 %, if upgraded buildings were to be close to low-energy building level as stated in the Danish Building Regulations (2010) (Kim B. Wittchen, Jesper Kragh, & Ole Michael Jensen, 2011, p. 1363). The same study calls for a need for €103 billion investment needed to achieve these savings. However, this number could be cut down to €57 billion if energy efficiency improvements were conducted together with other upgrades (Kim B. Wittchen et al., 2011, p. 1363).

Role of integrated approaches and collaborations

One way to summarize the essence of transition towards energy efficiency, from the perspective of the built environment professionals, is to see it as a switch from siloed optimization to an integrated process where buildings' passive features, buildings' systems, and human factors are systematically integrated to achieve the highest possible level of building performance. Increasingly energy efficiency is considered along with energy storage, energy generation, and occupant behavior. In the building sector, these elements translate to a broad range of sub-markets with a large number of diverse expertise, dispersed projects and a broad range of decision-makers (Lucon et al., 2014, p. 722). Besides, more integrated efficiency packages make a better financial case (The McKinsey & Company & C40, 2017, p. 29)

In a traditional, 'linear', design process, technical experts (designers, engineers, architects, contractors, landscape architects, etc.), owners, occupants go separately through the phases of pre-design (conceptual design), design and construction (schematic design, design development, construction documents and bidding and construction). In such a process, different system components are specified, built, and installed without an integrated optimization approach and therefore missing out on the more profound opportunities of the whole system optimization (Lucon et al., 2014, p. 684). An *integrative design* approach aims to eliminate such silos through a process of a repeating pattern of research and analysis and team workshops (charrettes). Through this pattern, project teams come together to reiterate ideas to maximize performance optimization between building systems and design components (William Reed et al., 2009, p. 130)

The integrative design approach recommends that the representative expert groups of stakeholders begin working together from the earliest possible phases of the design process (pre-design), as early as the choice of site. This is because understanding building location and site, and therefore a choice of building orientation and design envelope (e.g., windows, entrances, façade) will have a fundamental impact on the design of all building systems (heating, cooling, ventilation) and therefore energy use (Jensen, Maslesa, Berg, & Thuesen, 2018, p. 143). Although the integrated approach has been initially discussed as a concept applied to new construction, it can also be relevant in the retrofit phase. Over the last decades, the requirements to reduce the energy consumption of buildings have gradually become much stricter in building regulations in most countries, which means that the older the building, the less energy efficient it will typically be (Jensen et al., 2018, p. 143). Furthermore, the amount and sophistication of technical building installations or services have increased drastically. A reflection of this has been comprehensive literature on intelligent buildings. Thus, building renovations provide the possibility to change building design/layout, functions, architectural expression, etc. to match users' current and/or future needs" (Jensen et al., 2018, p. 143).

Another benefit of an integrated approach can be a better understanding of the financial case related to energy efficiency retrofits. Often, the financial case for retrofits is challenging due to many market barriers (discussed further in the next section). However, energy renovations, while combined with other building upgrades, can have a better payback time and make a more general financial sense (Jensen et al., 2018, p. 143).

Further, Jensen et al (2018), also advocates for a holistic sustainability approach that includes social, economic and environmental aspects to fully realize opportunities related to energy retrofits (Jensen et al., 2018, p. 142) and its supplementary activities such as energy auditing, building performance assessment, quantification of energy benefits, economic analysis, risk assessment, and measurement and verification (M&V) of energy savings are all essential to make the case for retrofits (Ma et al., 2012). These findings are consistent with reasons for energy retrofits in Sweden (maintenance, cost, energy savings) and Denmark (deterioration of the building stock, payback time, energy savings, ability to produce energy locally, indoor climate, branding, and CSR) (adapted from Jensen et al. 2018).

To be successful, an integrative design approach should be operationalized by the project teams. Such operationalization can be accomplished through a long-term and short-term operational tools such as alignment of goals and values, transparency in budget allocation and expenses, holistic risk assessment and allocation, regular workshops, and education of staff in handling partnerships (Jensen et al., 2018, p. 143). In such context, it is essential to recognize that the integrated process differs from the concept of best practices in terms of energy efficiency project management and project phases such as one identified by Ma et al. (Figure 3) but rather is an additional layer to the regular best practices and steps.

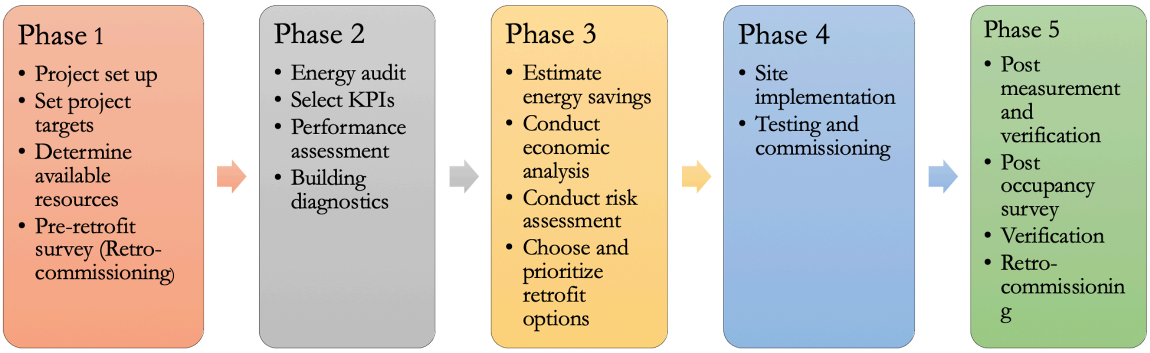


Figure 3 Key phases to building retrofit

Source: Adapted from Ma et al. 2012, p. 891

2.2.2 Commissioning, operations and verification of performance

Once the spaces are built or retrofitted, and all physical design components are in place it will be the actual and ongoing performance of building systems, combined with the human factor that will both determine the energy efficiency performance of the facility over time. The human factor influences building performance twofold, one through behavior of occupants and occupancy patterns (e.g., through incorrect use of lights, regulation of temperature, opening windows), and two, through the procedures, skills and techniques of the facilities' operations and maintenance staff (e.g. calibration of sensors, scheduled commissioning process, transfer of knowledge during employee turnover) (CIBSE, 2004; Ma et al., 2012, p. 892). Studies show that in Nordic countries between 10% and 20% of energy savings can be materialized through occupant behavior changes (Owens & Wilhite, 1988, p. 853) and that these savings can be often achieved with no- or low- capital investment (Ma et al. 2012, p. 891). Effective operations strategies such as commissioning (a process of planning, documenting, adjusting and verifying performance to deliver a properly functioning building systems) can prevent up to 20% of unplanned energy use (Lucon et al., 2014, p. 688) and, if financially feasible should be performed on an ongoing basis (US Green Building Council, 2009). Commercial buildings are being retrofitted every 20-30 years on average, and during that period it will be the facilities management and operations that influence if the building systems are performing optimally (Min, Morgenstern, & Marjanovic-Halburd, 2016, p. 198).

Best practices related to operations and maintenance of facilities can be divided into two categories of procedures and technological solutions. The procedural best practices are often an excellent first step, low-cost and easy to implement an approach to understanding energy systems and other technical systems in buildings, which can lead to better recognition of issues and upgrade opportunities over time. Development of such documentation can support achieving energy efficiency in buildings by providing facilities' staff with information necessary to ongoing maintenance, in case of emergencies and in the transition of building knowledge among different employees and contractors, supporting energy audits and systems commissioning processes.

Energy Audits are a useful tool for the realization of the energy efficiency potential in existing buildings. Energy Audit standards are developed by organizations such as The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and lead to the development of recommendations of energy strategies (US Green Building Council, 2009). The EPBD encourages this procedure through the mandate of the Building Renovation Passports "a document – in electronic or paper format – that outlines a long-term (up to 20 years) step-by-step renovation roadmap for a specific building and based on an on-site energy audit" (Fabbri, 2017, p. 1410). The Energy Passport is prepared in collaboration with the building owner, which supports the achievement of the full energy-efficiency potential by the end of the term covered by the roadmap (EuroACE, 2018, p. 32).

Another critical tool in realizing energy efficiency is the concept of measurement and verification (M&V) of the actual energy performance. M&V often aligns with the process of benchmarking, which relies on verifiable energy performance data. Building and system-level metering technologies should support understanding of the energy performance and provide for insights into how specific systems respond to upgrades on changes in human factor elements. In newer buildings, integrated building automation systems provide for measurement and control. Further building automation technologies such as adaptive thermostats, lighting sensors, and plug load monitors can lead to engagement with demand response programs (by running appliances such as dishwashers and tumble dryers at times of low demand) which connect building efficiency strategies to broader goals of grid balance and deployment of e-mobility and on-site generation (The McKinsey & Company & C40, 2017, p. 33). Measurable and verified energy performance is the foundation of the understanding impact of deployed measures on energy performance, compliance with energy regulations or targets, and an essential element of voluntary and mandatory energy disclosure programs. The European Council for an Energy-Efficient Economy (ECEEE) recommends that beyond commonly used *kWh/m²/year* metric, it is advisable to use other indicators which are indicators in line with CEN/ISO Standards because a combination of indicators can provide a more accurate picture of the energy use (EuroACE, 2018, p. 55).

Energy performance disclosure is mandatory in both Sweden and Denmark and has to be presented at the time of lease and sale. New buildings have to produce a certificate no later than two years after the building has been put in use.

2.3 Barriers to energy efficiency projects

Technologies and procedures to increase energy efficiency in buildings are well known, proven, and often financially beneficial, yet they are not fully deployed, which results in an efficiency gap. The World Resource Institute (WRI) describes the efficiency gap as "the difference between efficiency actions that are technically and economically available and actions that are implemented" (Becqué et al., 2016, p. 42). Barriers resulting in the energy efficiency gap can be broken down into five distinctive groups: (1) Institutional and political barriers; (2) Market and economical barriers; (3) Financial barriers; (4) Technical barriers, and (5) Behavioral and social barriers (Jensen et al., 2018, p. 143) (Becqué et al., 2016, p. 42). The broad scope of these five categories translates to the complexity of projects and the necessity for a multi-stakeholder alignment, to overcome the lack of prevailing direction and realization of broad incentives to energy efficiency.

The split incentive dilemma is one of the most common market challenges to overcome in achieving energy-efficient buildings, it is described as an issue of ownership of the investment being responsible for the cost of the energy upgrade but not experiencing the incentive of energy efficiency (Jensen et al., 2018, p. 143; Lucon et al., 2014, pp. 675, 709). In other words, the benefits of the investment do not accrue for those who invest (Becqué et al., 2016, p. 42). Other market barriers include imperfect information and imperfect competition (due to incentives in fossil fuel industries and other non-energy efficient strategies, as well as low energy tariffs) (Lucon et al., 2014, p. 675). Dispersed and diffused nature of the building sector market structure, where multiple locations and small end-users are involved, is also a significant challenge (Becqué et al., 2016, p. 42; Lucon et al., 2014, pp. 675, 709). Financial barriers to energy efficiency are related to perceptions of energy efficiency investments being risky, complicated, and that financial returns on projects are exaggerated.

Additionally, high up-front investment, high transaction costs and often a need for bundling of many small transitions, making it a challenging proposition for financial institutions to get behind (Becqué et al., 2016, p. 42; Lucon et al., 2014, p. 714). Although technologies for energy efficiency are well known and understood as useful (Lucon et al., 2014, p. 714), technological barriers still exist and prevent uptake of these solutions. WRI (2016) points that it is a large number of available technologies can pose difficulty to project owners, who do not know how to navigate the best solutions (Becqué et al., 2016, p. 42). Navigating complex market of energy efficiency technologies can be especially tricky in areas where local energy companies lack the necessary knowledge to aggregate various technologies and projects and develop a financial case for customers (Becqué et al., 2016, p. 42). At the city level, institutional barriers in local governments can create additional challenges for the deployment of energy efficiency projects. For many local governments, management of the demand side of energy is a relatively new subject and traditionally local governments have been more engaged in the energy supply-side policies, however limited grid capacity in many rapidly growing cities is changing municipalities' interests in engaging with energy system (Becqué et al., 2016, p. 42). This new role that local governments are taking on, also means a transition within internal municipal departments, which have to advance their knowledge and systemic approach to energy efficiency strategies and policies, while operating with limited human and financial resources (Becqué et al., 2016, p. 42). However, because market forces alone cannot achieve the energy transition without external influence, local governments should seek ways to overcome internal barriers and provide leadership on the development of long-term policy frameworks including regulations and incentive schemes, and other pathways that can influence the development of energy efficiency strategies on the local level (Lucon et al., 2014, p. 675; WBCSD, 2016, p. 4). Awareness among the building sector actors, policymakers, and consumers is an underlining cause for many of the energy efficiency barriers (Lucon et al., 2014, pp. 675, 709). The lack of knowledge about the actual energy use is one of the factors contributing to a lack of awareness of energy issues. Verified energy use data can be aggregated into benchmarking platforms and provide insights on actual benefits of energy efficiency investments (Becqué et al., 2016, p. 42). From a consumer perspective, low awareness means a lack of access to information about energy use at their specific unit (e.g., apartment) or inability to translate the energy use into an understanding of necessary building upgrades (Becqué et al., 2016, p. 42). Awareness and knowledge barriers are influenced by the lack of institutional capacity to train a new workforce which is necessary to deliver, maintain, and manage energy-efficient buildings. Such workforce shortages can result in a lack of market capacity to deliver energy efficiency projects and affordable costs (Lucon et al., 2014, p. 719). Human factors such as cultural aspects, cognitive and behavioral patterns can also be a challenging barrier to overcome (Lucon et al., 2014, pp. 675, 709).

2.3.1 City governance to overcome barriers to energy efficiency

Cities around the world have many different approaches to engaging with building energy efficiency and addressing challenges to accelerated implementation of efficiency strategies. These can vary based on local municipal power structures and local government's capacity to influence energy efficiency and built environment as well as other factors specific to the local context such as the local energy prices, local market conditions, local stakeholder dynamics and other factors.

According to the World Bank, three critical areas that cities can focus on when trying to achieve systematic change in building energy efficiency are: 1) assess the building stock, which will lead to the identification of critical opportunities for accelerated impact, 2) lead by example and implement efficiency measures in public buildings, 3) leverage and tap into the expertise of local stakeholders (Liu, 2014, p. 2). The World Resource Institute builds on that list and also adds to specific actions cities can take and highlights the need to: 4) set and facilitate efficiency improvement targets, 5) develop, adopt and enforce building efficiency codes and standards, 6) facilitate and develop incentive and finance.

Understanding of the local building stock and its primary energy loads is the first step to informed energy policies and strategies. The types of buildings in the portfolio mix, age of the building groups, densities, and population types in specific city areas will all play a role in how a municipality should approach energy efficiency strategy. This information can be translated into baseline building performance that later serves as a foundation for benchmarking and progress measurement. An understanding of specific energy loads in the building portfolio is the next step in developing targeted strategies that reduce energy use and emissions. In some countries, the national government provides tools to develop such datasets (e.g., The Energy Star Portfolio Manager in the US). However, in areas where that is not the case, municipalities can take the lead in developing databases based on the information available in building departments (e.g. the City of Copenhagen has a database of energy use the municipal building stock). For example, New York City captures water and energy information of more than 26,000 buildings across New York's five boroughs and shares it in a visualized, publicly available format (see Figure 4). This information supports NYC's Local Law 84 of 2009, a local benchmarking ordinance which requires private buildings over 50,000 square feet and public sector buildings over 10,000 square feet to report their energy and water consumption each year for public disclosure (New York City & New York University's Center for Urban Science and Progress, 2015).

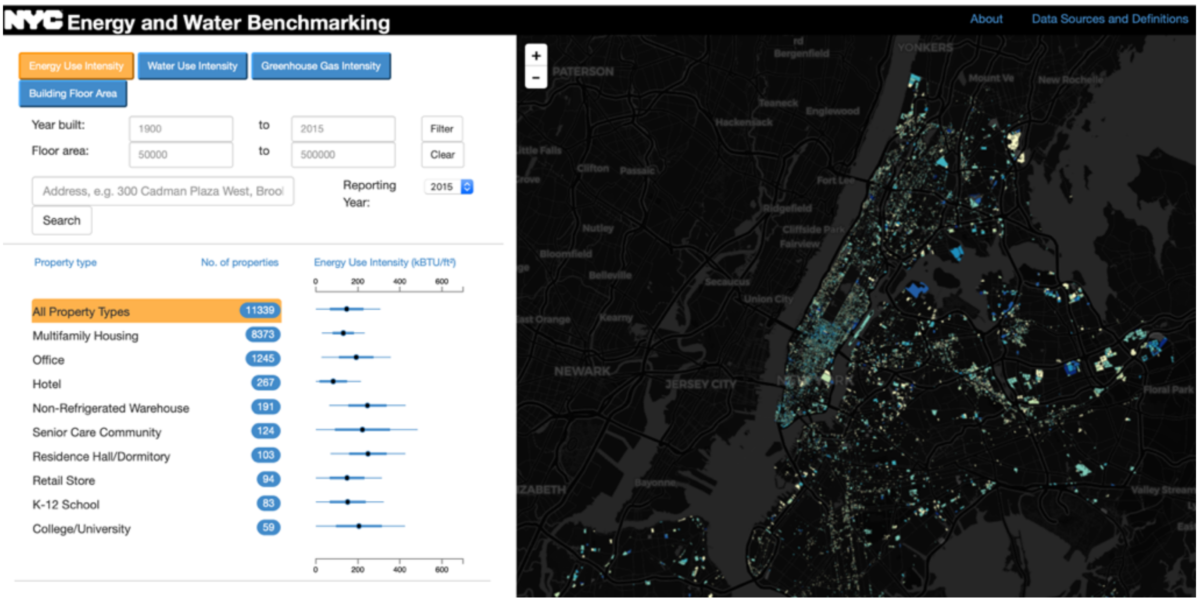


Figure 4 Visualization of the New York City Energy and Water Benchmarking data

Source: Adapted from https://serv.cusp.nyu.edu/projects/evt/ by the New York City & New York University's Center for Urban Science and Progress, 2015

However, the Institute for Market Transformation (IMT) points out that using the baseline data for benchmarking alone is not a sufficient use of information and cities must do more to achieve energy efficiency and climate goals (Beddingfield, Hart, & Hughes, 2017), additional uses of data for stakeholder engagement, education and awareness are also important. These uses can include building performance information and mandatory disclosure regulations or voluntary certification and information programs. Such programs can take on a form of challenges and friendly competitions among building owners. Voluntary challenge programs have proven successful in Chicago, USA (savings of 90 million kilowatt-hours of electricity and 70,000 metric tons of avoided GHG emissions) and London UK (energy savings translated to 268 tons of CO_2), where the focus is on near-term actions, specific targets and engagement of public and private stakeholders (Trencher, Downy, Takagai, & Nishida, 2017, pp. 67 and 85). Challenges and competition programs also provide an opportunity to inform stakeholders about available programs and incentives as well as boost the marketing and visibility of projects through PR strategies and involvement of local leaders. Thanks to *smart city* technologies such as sensors, cities can collect and analyze multiple data points, getting a new understanding of dynamics related to the built environment. This data can be provided to the clean-tech sector through open Geographic Information Systems (GIS) and other data portals and stimulate new ideas for shared value development and be the foundation for leveraging the creativity and intelligence of society as a whole (DNV GL, 2018, p. 29). Today the value of technologies that provide building energy use data is closely connected to the ability to influence users and their energy use behavior which can help stabilize the electricity grid and support uptake of renewable technologies. Municipalities, especially those with rapidly growing populations and building stock need to collaborate with communities, the utility, and energy providers to ensure grid capacity and harmonization (DNV GL, 2018, p. 29). Such collaboration can lead to additional complementary initiatives and potential co-funding opportunities (DNV GL, 2018, p. 29). One such example is the *City of Things* project in Antwerp, Belgium, which focus how open data access and can provide information about the building stock and at the same time a platform for a living lab experiment between the local council, researchers, technology companies and residents (IMEC, 2019).

A program such as the Chicago or Better Buildings Challenge or London's Business Energy Challenge is one example of how cities can set and facilitate energy efficiency targets. Besides such voluntary programs, some cities engage in legally binding targets which can be related to broader climate action. The city of Copenhagen is one example where the achievement of the carbon neutrality target relies on the increased energy efficiency of Copenhagen's building stock (Copenhagen's specific energy efficiency targets are discussed further in Chapter 5). Specific targets are increasingly set in indicators directly related to energy efficiency such as benchmarking or CO_2 emissions. The setting of specific and measurable targets supports cities' ability to publicly *lead by example* by setting more stringent timelines or deliverables than those in the public sector. For example, in addition to aforementioned New York City, the City of Los Angeles building ordinance requires that all municipal buildings that are larger than 7500 square feet must be able to publicly benchmark and disclose water and energy use information by December 1st, 2017 while the private building sector has a more lenient area and timeline requirements. More ambitious targets for the public buildings can accelerate energy efficiency work in municipal building stock and therefore provide municipal staff with much-needed insight into strategies, barriers, and opportunities to energy efficiency transition.

Additionally, because municipalities have a higher degree of control over their building stock than over the private facilities they can move forward quickly demonstrating leadership and saving public money in the process while engaging external stakeholders and developing more local awareness and buy-in (The McKinsey & Company & C40, 2017, p. 34). The City of New York leverages its leadership position to facilitate innovation and stakeholder engagement through a program called the Municipal Entrepreneurial Testing Systems (METS), which is a pathway for clean-tech companies to beta test their products using municipal buildings as a test laboratory for services and products. The METS program evaluates the potential of technologies in areas of lighting, HVAC, building management systems, analytical software, and more, against competitive criteria of product's capacity to generate savings, product viability, scalability, and potential for job creation (New York City, 2019). Engaging stakeholders who work along the building supply chain (e.g., building owners, energy utilities, national and regional governments) is a crucial strategy for achieving building energy efficiency in cities (IMEC, 2019; Liu et al., 2010, p. 2). For the municipal actions to capture opportunities of building energy efficiency in a systemic way, it should consider those opportunities and stakeholder's shared value along the whole life cycle of the building because it highlights the multitude of actors and collaborations needed to achieve multiple inputs (Becqué et al., 2016, p. 40). Having such a broad understanding can allow cities to develop policies that can help align the interests of all actors around implementing cost-effective energy efficiency options at each stage of a building's lifecycle (Becqué et al., 2016, p. 40).

Depending on a specific local power that the municipality has to influence urban fabric, it can also engage a range of regulatory tools that influence building energy performance at different scales. One example of how cities can influence energy efficiency is through municipal master plans because they determine the uses, sizes, and efficiency of buildings that can legally be built in specific neighborhoods or areas (Becqué et al., 2016, p. 40). Zoning requirements can also promote higher-density development, which over time can decrease building energy demand by as much or more than efficiency improvements alone (Güneralp et al., 2017).

Another area that municipalities can influence energy efficiency though regulations are by setting specific requirements for design and systems in local building codes and deployed during the design and construction process, for example, building orientation, number of floors, materials, heating/cooling systems, and insulation level selected for buildings. These factors help determine and may lock in the energy efficiency levels of the building, for example, through energy-inefficient façades (Becqué et al., 2016, p. 41). Cities are increasingly recognizing that careful verification of building codes is key to making sure construction has been completed according to regulation. Ensuring that new construction adheres to energy-efficient design principles is one of the simplest ways to reduce emissions over the long term. Each new building constructed to high standards is one that will not need to undergo a potentially expensive and disruptive retrofit later to meet emissions reduction requirements (The McKinsey & Company & C40, 2017, p. 41).

Cities can also work to influence energy efficiency during the retrofit phase, for example, San Francisco, USA, and Toronto, Canada, have created specific programs to enable lower-income communities to retrofit homes, such as in affordable housing and older apartment buildings to improve safety and reducing health hazards such as indoor condensation and mold in the process, which align with simultaneous energy efficiency projects to develop a stronger business case and maximize social benefits of projects (The McKinsey & Company & C40, 2017, p. 31).

Another way cities can accelerate energy efficiency retrofits is to implement programs that bypass natural renovation cycles by connecting energy upgrade requirements to more frequent triggers, such as changes in ownership (The McKinsey & Company & C40, 2017, p. 34). One example of accomplishing this is implementing energy efficiency standard when the building is put up for sale or lease because they allow various stakeholder (the developer, realtor, appraiser, owner, and lender) to assess the future operating costs accurately, and include them in the valuation of the property, and in the bank's evaluation of the owner's future ability to repay the loan. Building out new tenant space inside an existing building creates an opportunity to invest in high-performance, energy-efficient options, including appliances, lighting, and energy control systems (Becqué et al., 2016, p. 41). Closer cooperation with financial sector stakeholders and other actors can engage municipalities in the development of incentives and finance mechanisms that can further support energy efficiency projects. For example, the City of Mexico has developed *Mexico City's Sustainable Buildings Certification Programme (SBCP)* offers several financial benefits to property owners who reduce energy and water use. Participating owners and tenants receive incentives such as tax reductions, reduced energy, and water bills, access to project financing, expedited permitting procedures (Trencher et al., 2017, p. 104).

3 Theoretical framework

This thesis aims to advance knowledge of how cities support transformative change and energy efficiency in buildings. The role of cities in energy efficiency and climate transitions is changing and becoming more prominent; therefore, there is an urgent need to understand how cities work in these new conditions.

This thesis research is rooted in the transition theory and more specifically, the transition management framework. Because transition management has a normative approach to sustainable development as its long-term goal, it provides valuable insights to transformative change (Loorbach & Rotmans, 2006a, p. 133). To realize this transformative potential transition management literature emphasizes elements of visioning, experimentation, learning and collaboration (Bulkeley, 2013, p. 38; Grin, Rotmans, Schot, Geels, & Loorbach, 2011; Grin et al., 2011; Marvin, Bulkeley, Mai, McCormick, & Palgan, 2018, p. 40; Sandin, Neij, & Mickwitz, 2019, p. 12; von Wirth, Fuenfschilling, Frantzeskaki, & Coenen, 2019, p. 230). This chapter will discuss sustainable transition literature with a focus on the transition management framework and its key components of visions, experiments, learning, and collaborations.

To broaden the perspective on transitions, a review of academic literature includes insights from grey literature; however, due to its supplementary character only, this material is presented in text boxes.

3.1 Sustainable Transitions

According to (Grin et al., 2011, pp. 321–322), a sustainable transitions approach to sustainable development is rooted in ideas that:

1. Sustainable development requires a drastic re-orientation of societal development
2. Profound, interlinked transformations are necessary for the state, the market, society and technology, and their mutual relations,
3. Sustainable transitions take place in the context of a more extensive set of changes (Grin et al., 2011, pp. 321–322).

The transitions approach aims to turn these ideas into research and action that must go beyond the target setting practice, which has not to produce much progress in the area of climate change (Grin et al., 2011, p. 322). This new approach evolved in the 1990s when it became clear that even the most ambitious environmental targets are not beneficial if they are not realized (Grin et al., 2011, p. 322). Sustainable transitions literature points to the following issues being partially responsible for the lack of progress in the area of environmental goals:

- Problems and solutions were defined primarily based on expert knowledge, and interventions were designed based on administrative scales and environmental areas (e.g., water, soil, air). This approach can be challenging in some areas of knowledge that are institutionally (politically) privileged and can produce siloed approaches and competing priorities (Grin et al., 2011, p. 321).
- The democratic pragmatism - *leave it to the people* approach - that works through modes of anticipatory problem solving or conflict resolution within established institutions. The challenges with this approach are social concerns take priority over environmental issues (Grin et al., 2011, p. 321).
- Economic rationalism - *leave it to the market* approach - which has produced minimal results primarily because of a lack of institutionalized focus on environmental concerns with the existing market and economic structures (Grin et al., 2011, p. 321).

In response to these challenges the transition management proposes a "quest for a new value system," a new approach to governance that is rooted in the following principles (Grin et al., 2011, p. 2):

- Radical diagnosis of persistent problems is necessary and must include the analysis of structures that have co-evolved along with these problems.
- Sustainable transitions will be a result of experiments and structural change as well as their mutual reinforcement over time.
- Sustainable transitions are to be explored through participatory approaches and must take into account complex relations between social, economic, and environmental realms.
- Societies must face more considerable changes and make difficult choices that go beyond ideas of win-win, new business opportunities, competitive advantage, or people /planet /profit.

The transition literature emphasizes that in order to achieve these principles, there is a need for the fundamental change in values and modifications of the social order (system level), including the routines of everyday life (individual actor level) (Feindt & Weiland, 2018; Shove & Walker, 2007, p. 622). To realize the potential for transformations, a fundamental change in structure, culture and practices must occur (Frantzeskaki & de Haan, 2009; Grin et al., 2011, p. 109) and imply a long-term radical but incremental change at both system and actor level (Grin et al., 2011, p. 109). Table 3 describes in more detail the system's elements that must evolve during transformative processes.

Table 3 System elements evolving during transitions

Structure	Physical infrastructure (physical stock and flow), economic infrastructure (market, consumption, production), institutions (rules, regulations, collective actors such as organizations, individual actors)
Culture	The collective set of values, norms, perspectives (coherent, shared orientation), paradigm (way of defining problems and solutions)
Practices	An ensemble of production routines, behavior, ways of handling and implementation at the individual level, including self-reflection and reflexive dialogue.

Source: Adapted from (adapted from Grin et al. p109)

3.2 Transition management

The Transition Management (TM) approach focuses on influencing societal systems to move into a more sustainable direction, it combines a "prescriptive approach toward governance as a basis for operational policy models, and it is explicitly a normative model by taking sustainable development as long-term goal" (Loorbach & Rotmans, 2006a, p. 163). The Transition Management approach is rooted in concepts of bringing together frontrunners from policy, science, and business to collectively develop strategies and visions on how to address complex societal challenges and experiment in an effort to understand and resolve those challenges while contributing to a sustainable transition (Loorbach, Wittmayer, & Shiroyama, 2016, p. 14) . TM builds on four key governance levels that have the potential to influence transitions, and these are strategic level: visions, operational level: experiments, reflexive level: learning and tactical level: collaborations. Other transition frameworks such as Multi-Level Perspective, Technology Innovation Systems, and Strategic Niche Management also recognize the elements of visions, experiments, learning, and collaborations (Grin, Rotmans, Schot, Geels, & Loorbach, 2011). However, unlike the other frameworks, the TM approach adds a time dimension and views these elements as interconnected phases of a cyclical process. As such it is building on the approaches presented in the reflexive governance and aims to promote an on-going, collaborative learning and can be described as "*a quest* not a recipe for robust solutions" (Grin et al., 2011, p. 108). Figure 5 represents the components of the Transition Management Cycle

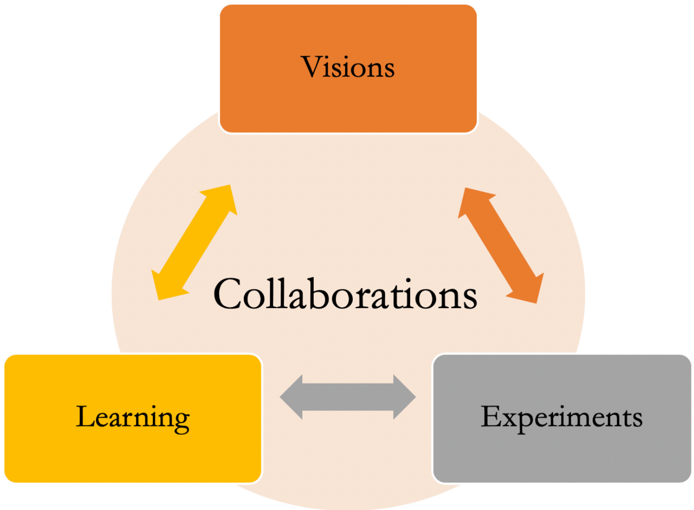


Figure 5 The Transition Management Components
Source: Adapted from Loorbach and Rotmans 2006 p.173

The transition management framework originated as a response to a need for new governance models. Loorbach and Rotmas (2006) expressly point out that top-down steering by government ("the extent to which social change can be affected by the government policies") and liberal free-market approach ("the extent to which social change can be brought about by market forces") should no longer be viewed as valid options to generate sustainable solutions, if operating in the way they have thus far (Loorbach & Rotmans, 2006a, p. 162). At the same time, both government and free-market are essential to realizing the objectives of sustainable development and as such must be more effective in directing their efforts towards a long-term societal change by opening up to new, often informal, networks and processes which can generate new and innovative agendas, and to structure and coordinate those informal networks of actors that, collectively and over time, can influence regular policy (Loorbach & Rotmans, 2006a, p. 162). This approach is also present in the IPCC (2014) reports stating that in order to achieve transformation towards a low carbon built environment, market and policy must work in tandem to address market failures (Lucon et al., 2014, p. 714). To achieve that, the TM builds on pillars of visions, experiments, learning and collaborations but adds a process component to it, thereby offering an approach that "combines advantages of incremental politics with those of planning to address six problems of steering: 1) ambivalence about goals, 2) uncertainty about cause-effect relations, 3) distributed power of control, 4) political myopia, 5) determination of short-term steps for long-term change and 6) the danger of lock-in to new systems" (Feindt & Weiland, 2018, p. 666; Kemp, Rotmans, & Loorbach, 2007). To overcome these barriers TM framework relies on an "inclusive definition of innovation encompassing all societal, technological, institutional, and behavioral practices that introduce or operationalize new structures, culture, practices, or actors" (Loorbach & Rotmans, 2006a, p. 170).

3.2.1 Visions

The strategic phase of TM relates to long term planning and concerns itself with high-level development of visions (Loorbach & Rotmans, 2006a, p. 169), which strive "for a fundamental, irreversible reframing of our current paradigms (Brugge, Rotmans, & Loorbach, 2006; Sondeijker, Geurts, Rotmans, & Tukker, 2006, p. 15). The concept of the *transition arena* is central here as it provides a platform for different actors to come together, challenge each other, and work to develop a common understanding of problems and solutions. Loorbach (2006) describes the transition arena as a "small network of frontrunners with different backgrounds, within which various perceptions of a specific persistent problem and possible directions for solutions can be deliberately confronted with each other and subsequently integrated"(Loorbach & Rotmans, 2006a, p. 169).

Envisioning is a critical phase in the transition process that can play a role as a temporary transition arena. It provides an informal but structured setting for a diverse group of stakeholders to engage in a series of meetings where they can express a spectrum of interests, perspectives, and assumptions which are then negotiated and debated, and results are captured in drafts of a long-term vision and developed into transition pathways to realize this vision (Frantzeskaki et al., 2012, p. 11; Loorbach et al., 2016, p. 49). Increasingly, the role of science is gaining importance in such envisioning events, as it "can act as a common starting point in arenas with diverse participants, who can use it to connect their context and practice to the arena issue at hand" (Loorbach et al., 2016, p. 171). Visions created through a participatory process allow for a direct dialogue between local stakeholders and policymakers and therefore can contribute to a joint perception of the problem, the accountability of the process outcomes and support successful implementation of the developed plans (Loorbach & Rotmans, 2006b; Loorbach et al., 2016, p. 54). This approach can be particularly helpful where a diverse group of stakeholders cannot achieve consensus, and connecting different problem orientations is more achievable and practical (Loorbach et al., 2016, p. 171).

Envisioning process should include the development of guiding transition principles, creating a vision and operationalization of the vision into strategic objectives (Loorbach et al., 2016, p. 55). The guiding principles of the visioning process should be built on core values of participants and formulated into principles that guide all future developments. This process should take into account, any pre-existing visioning work or initiatives, and participants should have a choice to build from scratch or build on pre-existing initiatives (Loorbach et al., 2016, p. 69). During the envisioning process, it is crucial to capture storylines and images of the future systems as seen by process participants, and a broader audience made up of a variety of actors, including those with opposing views and different knowledge. Those storylines and images will formulate a comprehensive vision that synthesizes varied representations of the future (Loorbach et al., 2016, p. 69). Finally, visions should be operationalized into a suite of strategic objectives that focus on the values represented in the guiding principles. These objectives and accompanying indicators should be used to assess the actions and progress of transformative change (Loorbach et al., 2016, p. 69). *Appendix 2* provides supplementary material to this section *Appendix 2* presents best practices for visions, developed based on own elaborations and Bosch-Ohlenschlager (2010).

Box 1 presents insights from grey literature and applied cases related to the use of visions in cities working with climate and building energy efficiency challenges.

Box 1 Visions in applied literature
International organizations and private companies recognize the crucial importance of the development of visions in the process of increasing building energy efficiency and broader climate action (DNV GL, 2018; Rocky Mountain Institute, 2017). One such example is the EcoDistricts Protocol framework – a tool developed in Portland, Oregon, the USA to support sustainable communities. This framework calls for the creation of comprehensive roadmaps which include elements aligned with the transition's literature such as the specific context of a local area, a list of objectives, indicators, and goals. However, it also adds elements of baseline performance assessment, implementation responsibilities, funding and schedule, and formal commitments as the components of a vision document (EcoDistricts 2018). The EcoDistricts protocol also promotes a participatory development of roadmaps and commitments. However, it also urges stakeholders to a mandatory commitment to three imperatives of Climate Change, Resilience, and Equity. Another framework recognizing the importance of visions is the C40 Climate Action Planning Programme. C40 approach includes the following additional elements: a review of existing policies with specific importance given to an understanding of co-benefits; definitions of actions and strategies and development of criteria for action prioritization (C40, 2018).

Further, C40 emphasizes the need to consider the inclusivity of process, policy, and impact on the development of sustainable scenarios at the urban scale. As for the specific strategies related to the build environment The Carbon Neutral Cities Alliance's Framework for Long-Term Deep Carbon Reduction Planning identifies, based on their member cities, that visions for redesigned building energy efficiency systems typically include following elements: high-efficiency existing buildings, building energy performance information for the market, performance-driven management of building energy, growing "Green Buildings" economic sector, Net-Zero/Zero-Energy and Energy Positive Buildings and Living Buildings (CNCA, 2014) . C40 framework expands on the CNCA and also recommends inclusion of climate risks and hazards related to building environment and projected trajectories of for emissions (C40, 2018).

3.2.2 Experimentation

In the transition management governance cycle, experiments are an instrument to operationalize visions and to broaden, deepen and scale up existing and planned initiatives (Raven, Bosch, & Weterings, 2010; Rotmans & Loorbach, 2009). Unlike regular projects, transition experiments' starting point is one of the societal challenges (such as the problem of climate change) and an opportunity to foster learning, and new collaborations that contribute to addressing these challenges and a broader transition (Fuenfschilling, Frantzeskaki, & Coenen, 2019, p. 221; Raven et al., 2010, p. 58; Roorda, C. et al., 2014, p. 46). Because sustainable transitions are open-ended processes of searching and learning, experiments are both a goal in itself and an instrument necessary to continuously innovate and redefine existing culture, structures and practices in an evolutionary manner (Frantzeskaki et al., 2012, p. 25; Loorbach et al., 2016, p. 28; Roorda, C. et al., 2014, p. 46). Expanding on that approach, the research conducted through the GUST project (Governance of Urban sustainable Transitions) concludes that in order to evaluate the effectiveness of experiments, an integrated approach that analyses both the process (the extent to which experiments lead to institutional change) and goal-oriented perspectives (achieving actual sustainability gains) (Madsen & Hansen, 2019, p. 284). Experiments should be innovative, ambitious, and involve a high level of risk and but also a potential to make a significant contribution to the transition process in order to contribute to a transformative change (Loorbach & Rotmans, 2006a). Experiments contribute to the formation of new networks between diverse stakeholders, and their collective articulation of joint expectations and visions which consequently leads to changes in cognitive frames and assumptions about the problems and solutions (Geels & Schot, 2007; Madsen & Hansen, 2019, p. 284).

To define what is an urban experiment, literature points out to the importance of following criteria: a) geographical contextualization, b) developed with purpose of experimenting and testing, c) have an explicit goal of learning, d) are characterized by a co-design by several actors of different societal domains, e) operate in long term schemes, minimum 2 years (von Wirth et al., 2019, p. 236). Further, in the practical guide to transition management Rooda, C. et al. (2014) recommends evaluation of experiments based on following characteristics: a) radicality (how different is the experiment from current dominant practices), b) content (does the experiment address challenges identified in the envisioning process), c) feasibility (is the project feasible in the short term, does it engage diverse actors), d) strategic value (will this experiment support achievement of the long-term changes), e) communication and mobilization value (is the project relatable and exciting, and does it have a 'wow' factor) (Roorda, C. et al., 2014, p. 31). Bosch – Ohlenschlager (2010) identifies specific details of how transition experiments are explicitly different from typical innovation experiments; Table 4 presents a summary of these Table 4 (Bosch-Ohlenschlager, 2010, p. 63).

Table 4 Characteristics of transition experiments

	Innovation experiment	**Transition experiment**
Starting point	Possible solution	Societal challenge
Nature of the problem	Pre-defined and structured	Uncertain, complex, defined through a participatory process
Objective	Find an innovative solution	Contribution to transition understood as a fundamental change in structure, culture, and practices
Perspective	Short and medium-term	Medium and long-term
Method	Testing and demonstration	Exploring, searching and learning
Learning	1st order, single domain, and individual	2nd order (reflexive), multiple domains (broad), and collective (societal learning)
Actors	Specialized staff (e.g., researchers, engineers)	Multi-actor alliance (across society)
Experiment context	Partly controlled context	Real-life, societal context
Management context	Project management focused on project goals	Transition management focused on societal transition goals

Source: Adapted from (Bosch-Ohlenschlager, 2010, p. 63)

Cities and urban areas have been increasingly emerging as place-based centers for climate and sustainability experiments. The majority of urban experiments started after the ratification of the Kyoto Protocol in 2005 and an increased understanding that cities are essential sites for responding to climate change (Bulkeley, 2013, p. 97; Madsen & Hansen, 2019, p. 282). Experiments in the built environment account for almost 25% of total urban experiments, with almost 75% of those focused on energy consumption and production in the built environment. Types of urban energy experiments include the use of energy-efficient materials, energy-efficient design, building-integrated alternative energy supply, building-integrated alternative water supply, new-built energy, and water-efficient technologies, retrofitting energy and water-efficient technologies and energy and water-efficient appliances (Castán Broto & Bulkeley, 2013, p. 95). Local governments are a leading actor for most of the urban experiments (66%), however civil society, private companies and other levels of governments are increasingly playing a pivotal role too (Castán Broto & Bulkeley, 2013, p. 99). However, the apparent role of leadership in local experiments is giving way to the importance of new partnerships that support capacity building and consensus and "increasing importance of non-governmental actors in areas traditionally considered as governed by governmental actors" (Castán Broto & Bulkeley, 2013, p. 99). Kronsell and Mukhtar-Landgren (2018) identify three ideal roles that municipalities can take on in the development of urban experiments: *promoter, partner, and enabler* (Kronsell & Mukhtar-Landgren, 2018). Although the urban context is a popular and an essential ground for governance experimentation, in order for place-specific experiments to create impact beyond a specific location, their outcomes should be diffused through processes of *embedding* in local structures (deepening), horizontal *diffusion (broadening)* through translating and vertical diffusion through *up-scaling* (Bosch-Ohlenschlager, 2010; von Wirth et al., 2019, p. 232). The next section on Learning further discusses these concepts.

Box 2 presents how applied resources discuss experiments in cities.

> ***Box 2 Experiments in applied literature***
> Applied literature also agrees on the importance of urban experiments for achieving energy efficiency in buildings and the critical role of local governments in the process. Literature highlights explicitly the role of the municipality as a *promoter*, where it can lead the market change by using municipal facilities as essential incubators for piloting new sustainable energy technologies. Increasing use of technology in the energy-efficient buildings can lead to the development of Smart City projects focused on predictive analytics for building energy use and monitoring and result in new experimentation formats such as an Energy Clusters, Smart Economic Zones, Emerging Technology programs, Cleantech incubators, Living Laboratories, Smart City Studios, PowerMatching Initiatives, Energy Transition Centers, and Launch Cafés (DNVGL 2018). The World Business Council for Sustainable Development has conducted a series of experiments called *Energy Efficient Building Laboratories* in 10 cities and developed a list of best practices to develop experiments that support the market transition towards energy-efficient buildings*; Appendix 2* presents those best practices. The WBCSD noted that 40% of participants of the Energy Efficiency Labs reported new opportunities as a result of process participation (e.g., in the form of news contacts, improved knowledge of the market resulting in product innovation).

3.2.3 Learning

"Learning can be understood as an active or interactive process of obtaining and developing new knowledge, competences, or norms and values. The aim of learning (…) is to contribute to a transition: a fundamental change in structure, culture, and practices. The learning process in transition experiments is, therefore characterized by a process in which multiple actors across society develop new ways of thinking (culture), doing (practices), and organizing (structure)." (Bosch-Ohlenschlager, 2010, p. 62)

The reflexive (learning) phase should be a constant aspect of transitions and should include a) monitoring of actions, goals, projects, and instruments that have been agreed upon, b) monitoring of actors within the arena, their behavior, networking activities, alliance forming, and responsibilities, and also their activities, projects, and instruments, c) experiments need to be monitored concerning specific new knowledge and insight and how these are transferred internally and externally, but also with regard to the aspects of social and institutional learning, d) the transition process itself must be monitored with regard to the rate of progress, the barriers, and points to be improved, and so forth (Loorbach & Rotmans, 2006a). It is essential that learning is implemented at all transition levels and integrated as a part of governance processes to prevent system lock-in and to enable exploration of new ideas and trajectories. Learning should not be only implemented after the project, neither it should be detached from the actual governance itself (Loorbach & Rotmans, 2006a). Monitoring of the process should provide insights that align actors around a common language and stimulate the process of social learning that is a result of cooperation between them and collective reflection on lessons learned and future next steps (Loorbach & Rotmans, 2006a).

Typical activities in the learning process include *monitoring, assessment, and evaluation*, which can take place through government evaluations, academic research, societal or media debates

(Frantzeskaki, Hölscher, Bach, & Avelino, 2018, p. 86). These activities should be conducted in a collective manner, where all actors learn about the present state and dynamics of the system (point a), possible future states of the system (point b) and how ways that influence how systems transform towards future states (from point a to point b)(Loorbach et al., 2016, p. 19). These activities should support societal learning process through experience and cognitive engagement and lead to both first-order learning (optimizing within an existing frame of reference) and secondary learning (a process which changes existing assumptions and frames of reference) (Bosch-Ohlenschlager, 2010, p. 62; Loorbach et al., 2016, p. 20). In addition to facilitating social learning and reflexive approaches, learning activities should be broad and cover many dimensions of a challenge such as institutional technological, environmental, economic and socio-cultural and relationships between these aspects (Bosch-Ohlenschlager, 2010, p. 62).

The literature identifies three mechanisms through which learning can occur, and experiments can influence sustainable transitions beyond a specific context, and these are deepening, broadening and scaling-up (Bosch-Ohlenschlager, 2010, p. 64; Rotmans & Loorbach, 2009). *Deepening* or embedding refers to the adoption and integration of experiments or their outcomes into existing local structures and communities of practice. Analysis of experiments specific to urban development and governance points to the deployment of outcomes of experiments as related to adopting and integrating new technologies, adapting processes within existing regulations and infrastructures (Frantzeskaki et al., 2018). Deepening emphasizes the value if system learning, where participants explore relationships between structure, culture, and practices of a system they operate in (Bosch-Ohlenschlager, 2010, p. 65). *Broadening,* also referred to as translation or horizontal diffusion, refers to the replication of learning and experiments in new contexts (e.g., new cities, new actors). Replication often relies on learning networks of actors who see value and opportunity in adapting particular learning and experiments in their specific context (Frantzeskaki et al., 2018). Supra urban networks and network governance structures are of importance in knowledge sharing and institutionalization of lessons learned and experiments (Fuenfschilling et al., 2019, p. 225). *Scaling* refers to seeking ways to expand the experiments and thus learning process content and scope. It is a process of transforming knowledge produced at a specific scale and making it relevant and applicable to another scale. Scaling can occur through a) spatial scaling (geographical growth), b) content scaling (extending across domains and practices), c) actor scaling (extending towards different partnerships and actors involved), and d) resource scaling. *Appendix 2* presents best practices for experiments and learning, developed based on Bosch-Ohlenschlager (2010).

Box 3 Presents how applied sources discuss learning in cities.

Box 3 Learning in applied literature
Applied literature acknowledges the importance of learning with a focus on monitoring of progress towards transition agenda and goals; however, no applied literature was found addressing learning in other areas (actors, experiments, transition process itself). Urban transition organizations put more importance on monitoring, measurement, and verification of environmental aspects such as energy use and CO_2 emissions, which plays a crucial role in the achievement of efficiency and reduction goals. Today most of the measurement and verification is completed through digital technologies, able to collect, process, and translate information data into verified performance results, necessary for transparency and communication. DNV GL points to the growing importance of *open data* policies, processes, and standards as a lever necessary to catalyze societal creativity for environmental change (DNV GL, 2018). C40 also calls for an ongoing and transparent monitoring and broad communication of progress made on the transition goals; however, it does not provide more specific details on this should be accomplished (C40, 2018). By nature of their operations, organizations such as C40, Rocky Mountain Institute, Covenant of Mayors, World Council for Sustainable Development or EcoDistricts, among others, play a role in learning within and among cities. Through the development of educational events, materials and providing direct technical support these organizations often play an essential role translating learning through their networks (The McKinsey & Company & C40, 2017, p. 61).

3.2.4 Collaborations

As presented in previous sections, the transition management approach aims to facilitate an ongoing evolution of the perception of climate problems and solutions to them. Because the participatory approach is at the foundation of the Transition Management framework, collaborations are embedded in all elements of envisioning, experimentation, and learning. By creating new interactions among diverse stakeholder groups, the transition process creates space for new ideas, interactions, and social relations (Loorbach et al., 2016, p. 103). Further, by combining ethical (inclusion of the dimensions of participatory governance, equity, and transparency) and management perspectives to stakeholder engagement, these collaborations can facilitate reflexive activities and mutual learning (Mathur, Price, & Austin, 2008). Through this process, the empowerment of the actors in the arena contributes to transitions in their immediate environments and to creating a long-term climate for the transition. Short-term empowerment relates directly to the actors in the arena being able to step in and take an active role in the process, while long term empowerment refers to influence 'beyond the arena' and having the potential to create a broader and long-lasting environment for change (Loorbach & Rotmans, 2006a, p. 284; Loorbach et al., 2016, p. 103).

The transition team is recognized as both a key actor and a space for interaction in the transition process itself. Typical 'management' tasks of the transition team, such as administration, coordination, monitoring, and overall facilitation of the process, has to do with the team's role as an actor. However, team members also contribute their specific background knowledge, networks, and overall input, and in this case, becomes a space of collaboration (Loorbach et al., 2016, p. 103). This two-fold character of the transition team has particular importance within municipal organizations, where teams are often made of representatives of multiple municipal departments. Therefore municipal teams have an opportunity for intra-organizational learning and identifying barriers, opportunities and general attitude towards transition within the municipal government (Becqué et al., 2016, p. 126; Loorbach et al., 2016, p. 103). Loorbach et al. (2016) describe a case of the City of Montreuil where internal collaboration was set to be non-hierarchical (collaborative decision-making process) and open (no predefined outcomes) and therefore allowed for a more integrated understanding of city's challenges (Loorbach et al., 2016).

Both the transition team and the transition management process rely on the collaboration of well-chosen actors who can influence the current regime and challenge the status quo. Actors participating in the transition process should represent frontrunners who possess the ability for system-level analysis, be motivated to address local sustainability challenges, be resourceful with robust access to knowledge and networks, have collaborative attitudes (Frantzeskaki et al., 2018, p. 233) and should be able to commit to long-term work and have authority to deploy the tactical elements in their respective organizations (Loorbach & Rotmans, 2006a). Through the transition processes current networks of actors undergo change and a) new relations are formed, b) quality of relations changes, c) existing roles change, d) new actors and new roles emerge (Loorbach et al., 2016, p. 103). These changes in networks can lead to a *network hybridization*, understood as a "multidimensional form of diversity in networks, and each of the constituting dimensions (sectoral, administrative, niche/regime, grassroots/incumbents) represents opportunities for using differences for the benefit of transition" (Loorbach, Wittmayer, and Shiroyama 2016, p. 176). When actors in the arena represent diverse levels of administration, businesses, education, science, NGO's and geospatial aspects, network hybridization can lead to valuable new combinations of perspectives such as bottom-up (grassroots, niche) and top-down (regime), and leading towards a transformative change (Loorbach et al., 2016, p. 93).

Box 4 presents how applied sources discuss collaborations in cities working with transformative change.

Box 4 Collaborations in applied literature

Both academic literature case studies and applied literature provide direction on what specific type of collaboration activities can be deployed at a city level and in an effort to support energy efficiency targets, importantly these activities have to be customized to a specific context.

The World Business Council for Sustainable Development emphasizes the importance of involving actors representative of the whole value chain in the building energy efficiency process and the importance of recognizing different groups that have an interest in, or could play a role in, energy efficiency strategies, these can include architects, developers, owners, tenants, banks, city planners, utility firms, policymakers, etc. (WBCSD, 2016). The Eco Districts Protocol focuses on the management of the collaboration among stakeholders and an ongoing alignment through tools such as a) letters of support from collaborative parties, b) a common agenda and c) shared indicators, all aiming to reinforce activities among different groups, promote continual communication and form a backbone of organization support. The EcoDistrict approach to management shares similar activities to those identified in the transition management process; however, it does not explicitly call for *experiments* that can play the role of 'mutually reinforcing activities. The Rocky Mountain Institute (RMI) addresses collaborations and role of stakeholder specifically as it relates to financing mechanisms, RMI points to the importance of stakeholder evaluation (specifically with a focus on ownership, installation, risk mitigation, and operations and maintenance of buildings) through a mapping process that includes an analysis of the flow of capital, information and services (Rocky Mountain Institute, 2017). RMI also points to the importance of critical enablers to deploy successful innovative financing schemes, and these can include financing institutions, energy agencies, and local governments. Both vertical and horizontal integration of stakeholders is recognized by RMI, C40, DNV GL, and ICLEI who point to the importance of alignment within multi-level governance and peer learning networks. In the case of energy efficiency, the importance of hybrid networks and private-public partnerships has been documented by these groups in the resources mentioned above (Loorbach, Wittmayer, and Shiroyama 2016, p. 176).

4 Method

Building against the background of the theoretical framework literature review, this chapter discusses the research design and methods used to answer project research questions. Section 4.1 will present the choice of the *case study* approach and methods for data collection, and section 4.2 will present the analysis framework developed through an inductive approach and based on the Transition Management elements.

4.1 Research design

A case study research approach was chosen for this project because it allows for analysis of specific cases while also providing an opportunity for a holistic, real-world perspective on the subject (Yin, 2014, p. 4). A case study is also a preferred approach to research of contemporary events, such as *how cities work with energy efficiency and sustainable transitions*. The literature also recommends a case study when the collected data is observational rather than experimental, and the researcher is not able to manipulate behaviors or occurrences within the research context (Gerring, 2017, p. 29; Yin, 2014, p. 9). Through a holistic case study approach, this thesis will analyze how the City of Copenhagen and the City of Malmö work with transformative change in achieving building energy efficiency. The analysis looks at each city as one unit, and there is no additional evaluation of sub-units (e.g., municipal departments). This choice was made because of the nature of building energy efficiency work within local governments, which often entail work across multiple departments (Yin, 2014, p. 55). Such a research approach supports the inquiry into the nature of the intra-organizational dynamics within selected cases. However, it is essential to acknowledge that such a holistic case study poses limitations with only an abstract and high level, to a certain extent, understanding of the issues.

Multiple case study was chosen to support the exploratory research and allow for an in-depth analysis of two specific cases. The two cases, Copenhagen and Malmö, were selected with anticipated similar results (a literal replication) (Yin, 2014, p. 55) and to understand the specific nature of transformative municipal approaches to building energy efficiency in the Øresund region. Yin (2014) recommends that replication logic for case studies is rooted in the theoretical framework, therefore another reason for choosing Malmö and Copenhagen was due to both cities already working with concepts of *visions, experiments, learning, and collaborations*, which allows for alignment with the theoretical framework of transition management (Yin, 2014, p. 58). Yin (2014) also suggests that a limited choice of case studies (2-3) in a multiple case study approach is justifiable if the theory is "straightforward and the issue at hand does not demand a high degree of certainty" (Yin, 2014, p. 61). Because the transition management literature is extensive and straightforward, and the nature of research is exploratory, the author deemed feasible a choice of only two cases. Analysis of transformative change in cities is a new and evolving research field with no defined indicators and data points that should guide the case study research of transition management in cities; therefore, research for this project will have exploratory character.

Another reason for the choice of Malmö and Copenhagen was the fact that they represent an example of exemplary case studies. Preliminary research confirmed that a) both cities established their carbon neutrality vision in 2009, b) both cities have the presence of experimentation spaces (urban living labs), and c) both cites' carbon neutrality plans include building energy efficiency as one of the key strategies to achieve carbon neutrality. Due to these ambitious targets and experimental approaches, both cities gained national recognition as the leading examples. As such, Malmö and Copenhagen have been identified as exemplary case studies, and studying them can lead to a better understand of how visions, experiments, learning, and collaborations are used within cities to achieve building energy efficiency (Walliman, 2006, p. 46). The geographical and organizational boundaries of each municipality (Københavns Kommune, Malmö stad) represent the boundaries of the unit of analysis. However, in terms of ownership of buildings, both municipality-owned and private buildings were researched. For each case study, document analysis and interviews were conducted to corroborate findings and define lines of convergence for data triangulation purposes (Yin, 2014, p. 121). Due to a small sample of cases and general nature of case study research the results of the project do not represent a larger sample of cities, however, it can contribute to conceptual generalization and understanding at a higher level (Yin, 2014, p. 41). Because of the limited amount of case studies, research allowed for an in-depth analysis of each case to understand dynamics and patterns within each organization and will allow for comparison of organizational approaches within a similar set of cases.

4.2 Analytical method

The transition management literature was used to develop an analytical framework for this thesis, see Chapter 3. The transition management themes of *visions, experiments, learning, and collaborations* were used to structure the analysis and explored through a review of the literature. The outcome is a list of 56 questions, which relate to practices that influence the use of visions, experiments, learning, and collaborations. Appendix 3 includes a complete analysis framework questionnaire*Appendix 3*. This questionnaire matrix was applied when reviewing the collected data, to analyze Malmö's and Copenhagen's approach to working with the transition towards more energy-energy efficient buildings. By providing a "point" for each score, the analysis can translate the results into a radar graph which provides a visual representation of each city's work on *visions, experiments, learning, and collaborations*. Each city could score a maximum of 100 (1 point for each 'yes' answer), divided in following way 20 points maximum for visions, 30 points maximum for experiments, 16 points maximum for learning and 34 points maximum for collaborations. A maximum amount of points is related to the number of transition management elements that a specific best practice is addressing. Collaborations have the highest number of points available because they are an integrated element in visions, experiments, and learning. The analysis provided a separate score for each city, and results were translated into percentage format and visually presented as a radar chart. This analysis approach sheds light on each city separately and allows for a comparison between Malmö and Copenhagen. Chapter 5 includes the radar graph with results for both cities is presented.

4.3 Methods for data collection

Data collection during this research project relied on semi-structured interviews and a literature review, including a review of relevant documents. The staff of both Malmö and Copenhagen municipalities was interviewed during the project. The initial set of interviewees was identified based on preliminary discussions with the thesis project supervisor, Lena Neij, IIIEE doctoral researcher and Malmö stad employee Roland Zinkernagel, CBS professor Luise Noring and Climate Kic Urban Transformations team members Sandro Benz and Erik Van Wijk. Initial introductions by these individuals allowed for establishing contact within both Malmö and Copenhagen organizations and effectively led to new introductions and interviewees. The focus of the research was to interview individuals in municipal departments related to the building sector, energy, and climate initiatives. A list of departments represented in interviews is available in *Appendix 4*. Three interviews were conducted at the Copenhagen municipality, and five interviews were conducted at the Malmö municipality. As for the interview procedures, all interviewees were first contacted via email and provided with a brief introduction to the research project and the researcher's background. Once agreed to the interview, interviewees received a copy of interview questions (a list of interview questions is available in *Appendix 5*), a description of key concepts discussed during the interview, and a disclaimer language about the purpose of research and use of data. All interviews were conducted in person, except one which was completed via a skype call. During the meeting, the researcher took hand-written notes. Additionally, interviews were recorded on a password protected device. Upon completion of each interview, the notes were translated into electronic text with the support of recordings when necessary.

Data collection process also included a document analysis. Documents that were analyzed were collected through an online search engine search using terms such as 'climate action plan' and 'energy strategy' for each of the case study cities. Later found documents were cross-checked with materials provided by interviewees. Analyzed documents include a review of local climate and energy strategies and websites and supporting documents related to energy labs in Copenhagen. *Appendix 6* includes a full list of these documents *Appendix 6*. Digital documents were coded in the Nvivo software using the *visions, experiments, learning, and collaborations* as overarching themes (nodes) to understand how Malmö and Copenhagen work with these topics.

5 Sustainable transitions in the Øresund region

This chapter will present the analysis of data collected during the research project. The text presents how municipalities of Copenhagen and Malmö engage with the concepts of visions, experiments, learning, and collaborations when it comes to energy efficiency in buildings. This section discusses concepts of experiments and learning are discussed together, rather than as separate sections. This decision was made after the collected data revealed that the two elements are deeply integrated into applied scenarios. Lastly, this chapter will present an overview of the analysis results and insights to Copenhagen and Malmö's work as viewed through the developed analysis framework.

5.1 Copenhagen

The following sections will present results from interviews with Copenhagen's municipal staff and review of documents concerning how the city is working with visions, experiments, learning, and collaborations to meet its ambitious goals and support a broader sustainability transition.

5.1.1 Copenhagen - visions

Copenhagen has committed to achieving carbon neutrality by 2025. *CPH 2025. Climate Action Plan. A green, smart, and carbon-neutral city (CPH 2025)* states that a reduction in energy consumption represents 7% of the CO_2 reductions that the city is planning to achieve. Although this is a relatively small portion of total emissions, it is seen as a very important element of the overall strategy, because energy efficiency is the cheapest way to cut CO_2 and will save approximately DDK500 million (667 million Euro) on just heating bills, while creating additional co-benefits (City of Copenhagen, 2016). Copenhagen plans to achieve these goals through a 20% reduction in heat over 2010 levels, 20% of reduction in power consumption in commercial sectors, 10% reduction in household and the installation of solar installations corresponding to 1% of electricity consumption (remaining renewable needs are addressed at the national level and though energy utilities). (The City of Copenhagen, 2012). In addition to CO_2 reductions, achieving energy savings is seen as an important factor in reducing overall costs if the implementation of the climate action plan as it leads to less need for investment in new power sources (The City of Copenhagen, 2012).

Leveraging visions to harness the power of the private sector investment and community support for energy-efficient buildings.

Copenhagen's climate action, including energy efficiency initiatives, are guided by an umbrella document: *CPH 2025. Climate Action Plan. A green, smart, and carbon-neutral city (CPH 2025)* (The City of Copenhagen, 2012). The development of this document begun in 2009 and from the onset Copenhagen municipality decided that the development and subsequent implementation of the plan should involve representatives of the local professionals (private sector) and citizens (community). The initial process involved almost 150 people who were invited by the municipality to work collaboratively on the development of a long-term vision for addressing climate change in Copenhagen. People participating in this process were specially selected to represent leading expertise or role in one (or more) of the 22 operational areas of the vision document. The motivation for such a broad stakeholder input was twofold. First, engaging a diverse range of representatives of community, industry, academia helped with building strong political support and by the time the document was presented to politicians it already had buy-in from many essential community members. Second, all the relevant stakeholders had a chance to connected in the very beginning of the process, which created a foundation for a long-term collaboration throughout the development and implementation process. The collaborative approach during the envisioning process resulted in a more integrated understanding of strategies within the climate action plan and resulted in more co-benefits. Understanding of these interdependencies in a long-term context (2010 – 2025 and beyond) leads to more opportunities and stronger networks within the city. Overall a common understanding of the plan and a broad base for political support were fundamental to the success of the subsequent implementation of the plan.

Four pillars of Energy Consumption, Energy Production, Mobility and City Administration Initiatives are at the core of Copenhagen's climate plan. It covers the built environment, transport and mobility, energy efficiency (in the municipal and private sector) and energy supply. This plan does not aim for each of these sections to be carbon neutral but rather work together, and most of the goals will be achieved through the net positive portion of renewable energy which can be sold and offset some of the non-carbon neutral elements of the city.

Upon the City Council approval, the municipal staff has translated CPH 2025 into *roadmaps*; each roadmap covers four years (City of Copenhagen, 2016). These roadmaps are available as public documents which serve as an update on the progress to date, and they also break down future strategies. The roadmap document provides visibility as to what is their current implementation stage of each energy efficiency strategy. Three stages discussed in the roadmaps are 1) analysis and strategy, 2)tests and demonstrations, 3) implementation. Breakdown of these three stages shows a strong emphasis that the City of Copenhagen is putting on *analysis and strategizing phases* during its innovative energy efficiency projects. As of summer, 2019, Copenhagen is at the end of its 2017 – 2020 roadmap, and in the process of developing the next and a final one. *Appendix 7* presents strategies influencing energy efficiency in the current phase of implementation.

The process called *Integrated Area Based Developments (IABD)*, which has been present in Danish redevelopment strategy since 1997 is an instrument to achieve CPH 2025 goals at the neighborhood level. These particular areas are chosen based on the need for renewal and upgrades to the building stock and based on opportunity for social and environmental impact. Projects designated under the IABD scheme begin with a six-month *Asset Based Community Development (ABCD),* a format of participatory discussions with residents. These discussions serve as a foundation for the visions created by all stakeholders within the project boundary. Afterward, the project follows a five-year vision implementation phase and a six-month closeout phase. From visioning to implementation and through the follow-up, these projects are designed as an *Interrelated Ecosystems* approach to maximize impact and leverage co-benefits and resources in local communities. *Interrelated Ecosystem* approach means that projects address 1)social inclusion, 2)circular economy, and 3) serve as an energy forum, all to support Copenhagen's climate and sustainability goals. A visual representation of the *Interrelated Ecosystem* approach is available in *Appendix 9*. Energy is an integral pillar of these projects, which promotes the integration of energy strategies deep into community fabric and into local market innovations (Aalborg University and the City of Copenhagen, 2018). All projects and strategies set in IABD visions are very localized and are an expression of local community *dreams and values*.

5.1.2 Copenhagen - experiments and learning

Leading by example as a critical strategy to achieving energy efficiency visions in Copenhagen

Copenhagen municipal government (Københavns Kommune) sees its organizational leadership in achieving building energy efficiency as a fundamental part of a broader energy transition in Copenhagen and Denmark. As an owner of 3500 properties in Copenhagen, the municipality has multiple opportunities to develop its understanding of energy efficiency in residential (e.g., social housing), public (e.g., schools) and commercial (e.g., offices) spaces.

Because the Copenhagen municipality has power over its building stock, it views it as a perfect testing ground to set high energy efficiency standards and an opportunity to learn how to implement them. Additional financial incentive exists because all municipal departments have a target of reducing budget expenses by 3%. Such a cost reduction target means that energy efficiency is a high priority for all departments that have oversight of the building stock (e.g., schools, libraries). This national-level mandate for a 3% expense reduction created context and gave room for a new momentum behind energy-saving projects. The internal energy efficiency group (within the Copenhagen Properties & Purchasing, Energy & Technology department) is engaged with the goal of municipal buildings' energy efficiency and supports other departments in energy efficiency and cost-reducing strategies. The city is using their buildings for testing of new technologies and practices (i.e. internal policies), and if successful, the municipality shares recommendations for further deployment.

In order to maximize learning and impact assessment opportunities in achieving energy savings, the municipality gives much focus on the collection of accurate and relevant energy use data. Because Copenhagen has an 80% stake in the local energy company, access to the building data is available and of mutual interest to both partners. In order to make the energy use data valuable to internal stakeholders, the municipality has developed an advanced *Energy Management System (EMS)* for municipal buildings. The system allows for an aggregated data analysis of energy use but can also provide building level and sub-metered systems data because it connects to the *Building Management System (BMS)* at the property level. The ability to view data and control properties at this granular level from one central operation spot provides for an invaluable understanding of the impact of deployed projects and the ability to respond quickly in case of emergencies. Such a level of insight and control is fundamental when planning for *flexible buildings* and demand response programs. The system is currently in its second development cycle to add capacity to track indoor comfort levels (e.g., noise, temperature, humidity, CO_2 levels) and match them with energy use, in order to understand how energy use patterns, overlay with indoor comfort of occupants. The system can track how changes in energy use are influencing the indoor environmental quality; therefore, it is visible if changes in specific building systems are negatively impacting occupant comfort. In that sense, like many other initiatives around energy efficiency, the focus is on additional co-benefits and understanding the impact of energy strategies in a systemic and integrated way. Although Københavns Kommune has developed the EMS and BMS for use in its building stock, the municipality is lending this tool to property developers on a trial basis, to promote the value of measurement and verification of the energy use.

Another strategy Københavns Kommune has to measure and verify energy use during the operations and maintenance phase is the use of *TimeSafe* software. This software tracks details of all building systems' maintenance procedures (e.g., sensor calibrations, cleaning, filter changes) and collects data from all energy and maintenance service contractors. Access to this information gives municipal staff more data points to help make sure that all building systems are maintained as recommended. Copenhagen municipality implements both the Time Safe and EMS/BMS systems with an operational goal to develop standardized protocols and language around these technologies. Such standard operating procedures help maximize the efficiency of working with different service contractors, technical manufacturers, and internal municipal departments. The development of standard protocols captures lessons learned during the testing phases. Such protocols and procedures operationalize best practices into the daily workflow of building and energy departments and support knowledge exchange among employees, during staff turnover and peer-to-peer learning with other cities. In its pursuit of innovative approaches to energy efficiency, Københavns Kommune is currently testing blockchain technologies to increase energy efficiency and integrate flexible building management system with the smart grid strategies and set the municipality for options to participate in demand control and prosumer programs.

Københavns Kommune is also working to operationalize energy performance and project delivery verification during new construction projects. Municipal staff has observed that some construction projects often do not deliver on the promised energy savings because design final project execution does not match the initial design guidelines. The municipality saw an opportunity in developing its construction verification process to achieve energy savings by adding an additional, intermediate verification step between design and commissioning This step is complementary to the national Danish building code and aims to prevent a well-known and well-documented gap between projected building energy performance (through modeling or calculations) and the actual performance of the building. Completing additional verification during the construction phase allows stakeholders to get insights into physical building elements that will end up sealed (e.g., behind walls or in the ceiling) and therefore difficult to reach once the process is completed. Best practices for implementation of the additional verification step have been captured in a public document *Sustainability in Construction and Civil Works* and are also being embedded in the formal municipal procurement process. By formalizing the verification step, the municipality will also be able to establish penalties for contractor companies that have not met the performance and specification standard when working with municipal buildings.

By using the local government's building stock as a testbed for energy strategies, Copenhagen municipality gains an insight to value proposition and business models that work and do not work in each specific case. Only projects with specific Return on Investment (ROI) (a measure of investment efficiency) move forward, so there is always interest in finding strategies that will be financially beneficial. ROI and cost savings are a reliable driver for innovation of energy efficiency, so far projects deployed in Københavns Kommune's building stock saved over 14% on energy costs which translated to the employment of 25 new staff. Other drivers for internal experiments and learning in the municipality of Copenhagen include a) need to develop new technical knowledge, b) desire to be a local and a global showcase for its efforts and work of local business community, c) opportunity to test ideas for leadership in partnership with private sector and utility, d) create publicly available documentation, e) testing creates an opportunity to save money and meet climate goals. The Copenhagen municipality also engages at the national level to influence the understanding of these lessons learned and how they can influence national-level policies.

Leveraging the power of community input

In addition to internal experiments, the municipality of Copenhagen facilitates urban living labs in its communities. The South Harbor (Sydhavnen) neighborhood in Copenhagen is currently one of the focus areas for the IABD and a Living Lab project driven by the municipality. Energy Lab in South Harbor is seeking to facilitate energy efficiency culture that is locally embedded, long term, and sustainable by activating relationships between urban areas, buildings, and individual residents. The neighborhood is made up of existing multifamily housing units and small businesses. Buildings in the area are mostly and operate with high heating losses and outdated energy systems. Copenhagen has designated this area as *a living lab* to apply a systemic and community-driven approach to addressing sustainability issues. The living lab concept came about organically, as the new areas for IABD were designated. The South Harbor project builds on the long-term strategic goals of the Climate Action Plan; however, the neighborhood level stakeholders influence more specific objectives and agendas. Copenhagen has been working to standardize such participatory and experimental approaches to solving climate and energy efficiency challenges. Copenhagen municipal staff views community-based experimentation as key to addressing local risks and developing an understanding of the value of energy efficiency among local stakeholders.

One of the objectives for the South Harbor living lab project, highlighted by Copenhagen's municipal staff, is to capture and transform lessons learned from previous experiments 'from projects to practice' (Aalborg University and the City of Copenhagen, 2018, p. 4) by intentionally exercising a meta governance approach. Meta governance concept is "a reflexive and responsive process through which a range of legitimate and resourceful actors aim to combine, facilitate, shape and particular direct forms of governance in accordance with specific rules, procedures and standards" (Sørensen & Torfing, 2009). In the case of South Harbor, meta governance approach aims to activate the local community from *passive* energy consumers to *active and empowered* advocates for the 'energy community model' which Copenhagen is currently developing in line with EU goals.

The Energy Forum component of the South Harbor living lab focuses on relationships between urban areas, buildings, and individual residents. As part of the program, the municipality offers a 30% financing for energy efficiency retrofit projects. Projects are selected and monitored by the municipal staff and, similar to internal municipality experiments, much of the experiments' focus in South Harbor is on measurement and verification of energy performance. Verified information about energy performance at a relevant scale (e.g., apartment, building) can be used to empower residents and property owners to engage in energy management. Such engagement of community members is fundamental to the future changes to the energy model in Denmark and in Europe, which include demand-driven energy efficiency and aggregation of local consumers and prosumers in the energy marketplace. By empowering residents to participate in decentralized energy markets through the *energy community model*, the living lab is seeking to reduce energy use and CO_2, while strengthening the community and create new social networks (Aalborg University and the City of Copenhagen, 2018, p. 32). In addition to the local community, the South Harbor project has been anchored by cooperation with many local and global institutions to provide scientific and market insights; *Appendix 8* presents a full actor diagram for the South Harbor project.

At the moment, there is no formal learning process related to the energy efficiency strategies in South Harbor Living Lab because IABD experiments do not produce statistically significant, yet broad enough data. This is due to the fact that IABD applied solutions are hyper-localized. However, the collaboration process and approach behind IABD living lab process have been captured during a stakeholder conference (held in Copenhagen in November 2018) and translated into printed and digital materials (available at https://www.pocacito.org/wp-content/uploads/2019/03/LivingLabs_KonferenceHæfte_WEBlow_v01.pdf).

Beyond the IABD, the role of the Copenhagen municipality in experiments is to align them with the climate action plan and energy efficiency goals. The municipality does not necessarily take, or want to take, a leading role in the experiments. However, the municipality's view is that the goal of a successful experiment would be to influence local and national policy.

Learning and collaborations for energy efficiency
When it comes to Copenhagen's take on learning, one of the interviewees pointed out that currently "the whole building industry is in a learning phase," and therefore the emphasis on collaborative approaches and experiments is Copenhagen's primary strategy to overcome barriers of this learning processes. In this view, experiments, learning, and collaboration is, in essence, about moving forward on the vision for energy efficiency. Københavns Kommune's role as a leading entity in this process is to send strong signals to the market about the need for energy efficiency and the municipality's desire to, learn from implementation experiments and implement improvements. There is a strong emphasis to take lessons learned to private sector companies who are interested in pursuing energy efficiency leadership. The building sector in Copenhagen is very much interested in participating in these initiatives and being on the frontlines of energy efficiency know-how. There is a potential that the stronger position these companies hold on the Copenhagen's market, the stronger it translates on both Danish and global markets. The municipality realized the advantages to the market but is also aware that 80-90% of investment to achieve Copenhagen's local climate and energy efficiency goals will have to come from the private sector; therefore municipality has a vested interest in catalyzing collaborations to channel that investment towards City's goals. The stronger green tech sector also contributes to Copenhagen's green economy goals.

Copenhagen explicitly recognizes the importance of an educated and empowered facilities management workforce (e.g., service technicians, facilities managers) in achieving on-going energy efficiency in building operations. Along with increasingly complex and sophisticated applications of building EMS and BMS current and future facility, staff must be able to use these new systems and effectively become energy efficiency advocates *on the ground*. To facilitate the learning of the facility managers, the Københavns Kommune' partners with local labor unions to translate lessons learned in municipal experiments and share currently applied practices with future building operations workforce.

Municipality also facilitates internal learning in areas of operations and maintenance and puts a strong focus on the operationalization of lessons learned through testing of new processes and tools. The City translates every new solution that works and makes a good business case into a guide, protocol, or a procurement standard that embeds this solution into a standard operating procedure. Diligent implementation of this approach supports knowledge development and learning, both internally and externally. Københavns Kommune's is actively engaged in peer to peer learning through international networks such as C40 or Carbon Neutral Cities Alliance. The City also works to formalize internal learning processes within the context of updating the Climate Action Plans roadmap. To achieve this, heads of relevant municipal departments gather twice a year to share lessons learned during each roadmap cycle and to embed those in the next reiterations of the document. The municipality also seeks to empower employees to take their lessons learned and turn them into a *solution pitch*, ideas that they can bring up directly to political leaders during a bi-annual forum.

The municipality also produces informational materials such as handbooks and guides, designed to elevate energy efficiency awareness among residents and local business owners.
Printed and digital documents, developed in both English and Danish language, are available on the topics of energy-efficient programs, technologies, and strategies. Copenhagen's municipality also uses physical exhibit spaces available at the South Harbor Energy Lab as an outreach instrument to engage residents. Here, residents, business owners, and delegations

from other cities can learn about Copenhagen's energy efficiency efforts and what are the best strategies applicable in their respective contexts. The project will have a community presence at Boxland (https://www.boxland.dk), a public space dedicated to educating members about energy efficiency initiatives.

However, learning in Copenhagen municipality is a 'two-way' process, and in addition to sharing much of the lessons learned with internal and external audiences, the Copenhagen municipality also invites frontrunners from the business community to present latest ideas and solutions directly to the municipal staff. External presentations from various businesses, think thanks and leading climate organizations that serve a purpose to inspire and educate Copenhagen's employees on the latest science, topics, and solutions that can aid the achievement of sustainable transitions in the city.

Reliable building energy performance data provides for a common reference point and is central to Copenhagen's learning process because it provides a common reference point for all stakeholders engaged in energy projects. Thanks to smart meter data, the municipality can develop baselines and benchmark for energy use. Verified energy data is a foundation of new operational protocols and innovative accounting methods that capture co-benefits of energy efficiency within the organization and allow for prioritization of energy efficiency projects. Data insights also come with the obligation of transparency, into progress, successes, and failures of the energy efficiency projects and broader climate neutrality. Copenhagen acknowledges that in the theme of collective learning, the municipality should share both success stories and failures, and most important lessons learned in order to catalyze a broader energy transformation. These lessons learned are used to develop stories and reporting that are key in communicating with the City Council.

5.1.3 Copenhagen - collaborations

Formal municipal processes

Thanks to recent changes in the EU regulations, municipal governments have the flexibility to collaborate with the private sector during the public procurement process (European Union, 2019) and the municipality of Copenhagen is using this to strengthen its energy efficiency project. Municipalities are now allowed to work with 3-4 selected company partners to develop a tender and pay these companies for participation in the process. This approach has proven effective in providing access to innovation and ideas that these companies bring.

Beyond public procurement, the Copenhagen municipality regularly engages with the private sector through formalized partnerships, which bring together frontrunners from diverse knowledge areas. One example of such collaboration that has started three years ago is with facility managers and property owners (the first partnership focused on the commercial sector, but a similar partnership model is on the way for the residential sector). The partnership consists of 36 partners, intending to have 40-50 (keep it relatively small and focused by design) and ones that represent about 15% of a total commercial square meter in Copenhagen. This group committed to 3% energy use reduction, and in return, the municipality provides free benchmarking, workshops and PR and branding opportunities. The focus of these partnerships is to include owners and leadership of companies and facility management staff. An official agreement between partnering companies and the Mayor helps to formalize these collaborations and create accountability between parties. Additionally, various events engaging politicians and municipal staff are an opportunity for branding and media exposure. Market dialogues are another accessible format of engaging with the private sector, often through aggregated channels such as BLOX (a local organization that connects architecture, design, construction, and tech with global decision-makers, scientists and citizens to explore and develop new sustainable urban solutions (BLOX, n.d.)). City approaches industry groups with an identified problem or knowledge gap and partners with groups like BLOX to Together organize workshops and forums to discuss potential solutions. The next steps often include, 1) piloting and testing, 2) gathering of knowledge from pilots projects, 3) political negotiations, 4) implementation into the procurement process, 5) development of protocols which describe how a specific solution should work (outcome-based rather than prescriptive approach is preferred). If the new solution is deemed feasible for broader deployment, the municipality gathers a working group to operationalize all necessary protocols and standards to assure the same energy performance. These working groups convene representatives from municipal departments (buildings and economic), technical experts, communication experts, lawyers, tenant representative (to adjust for a specific operation or building type).

International Collaborations
Copenhagen is pursuing broader opportunities for green transitions on a national and international level through collaborations and knowledge exchange in areas of policies and technologies. Currently, Copenhagen engages with the Ministry of Foreign Affairs, which is looking to export some of the city's energy efficiency ideas to Mexico and Argentina. Copenhagen municipality has recently also established a new partnership (first of its kind) with the city of Beijing. Copenhagen's Economic Growth department is actively engaged in promoting export of the local green building knows how globally. International collaborations also extend through horizontal networks such as C40, Eurocities and Carbon Neutral Cities Alliance (part of the Urban Sustainability Directors Network) which facilitate knowledge sharing occurs among peer cities. C40 has recognized Copenhagen with a 2017 Award for "Excellence in building energy efficiency and clean energy" and worked on translating some of the energy efficiency learning materials to English in an effort to support other municipalities learning the process. Beyond organizational engagements, Copenhagen's staff recognized the importance of personal learning and personal networks in understanding the energy efficiency and building marketplace, the latest cleantech solutions, and overall trends.

5.2 Malmö

The following sections will present results from interviews with Malmö 's municipal staff and review of documents concerning how the city is working with visions, experiments, learning, and collaborations to meet its ambitious goals and support a broader sustainability transition.

5.2.1 Malmö - visions

Malmö has several visions that relate to its sustainable development and to build an environment. This section will briefly introduce the *Comprehensive Malmö Development Plan, Malmö Environmental Program* and the *Malmö Energy Strategy*[1] Moreover, their content as it pertains to energy efficiency. Malmö has additional visions such as the *LFM3* (see http://lfm30.se) vision for *carbon-neutral* buildings which focuses on the use of materials in buildings, and the *Long term implementation of the 2030 Agenda in the City of Malmo* which discusses operational aspects of working with SDGs, however, neither of these documents addresses energy efficiency specifications and therefore is not further discussed in this section.

To- down and ground up

Malmö Stad has included the city's energy performance, in many local visions, created at various levels of governance. The *Comprehensive Malmö Development Plan* is the crucial, overarching document that shows how the city will be developing in the future (Malmö stad, 2018b). With regard to energy use in Malmö, the Comprehensive Malmö Plan states that the city will be reducing its GHG emissions mainly by running on renewable and locally sourced energy (Malmö Stad, 2014, p. 4) and that the city will focus on compact development as it promotes more efficient use of resources (Malmö Stad, 2014, p. 6). Malmö's Energy Strategy document (developed in 2008) provides more detailed information about the city's energy efficiency strategy. The Energy Strategy states that Malmö's goal is to achieve 100% renewable energy supply by 2030 and in order to achieve this goal, the municipality will 1) by 2020 reduce per capita energy use by 20% and achieve 50% renewables in the energy -mix, 2) commercial and public sector must achieve 30% energy use decrease and renewable energy must be 100% of the mix (Malmö Stad, 2008, p. 2). The energy strategy states that the energy savings potential for Malmö is between 16-38% for the public sector, 18-50% for existing housing and 22-56% for commercial building stock (Malmö Stad, 2008, p. 8). The energy strategy plan lays out following specific implementation guidelines to achieve these target; however, it does not point to specific targets or operationalized indicators (Malmö Stad, 2008, p. 8):

- The municipality should provide advice in connection with building permits and information about energy efficiency measures, best practices and good examples.
- The municipality should dialogue directly with larger private companies about specific opportunities and measures for energy efficiency
- The municipality should focus on measurement and verification that will allow for measurement at a granular level and support the development of energy uses base data.
- The municipality should establish programs for the implementation of energy-saving measures by educating relevant stakeholders.

The Energy Strategy points to the necessity of working with the business sector, energy utilities and residents, and it also describes following responsibilities and roles the municipality should take on in the process: 1) municipality is the deciding authority when it comes to community planning and building development in the city, 2) municipality has authority over all the energy-

[1] The Energy Strategy plan which was developed in 2008 is coming to an end of its lifecycle, and the new plan is currently in the development process. However, at the time of writing this thesis municipality has not yet been ready to share new plans and have referred to the 2008 version; therefore all analysis is based on the 2008 version of the document.

related permitting, 3) municipality should provide energy and climate advisory services, 4) as a significant energy user municipality has an obligation to lead and being a good example, 5) municipality is acting as energy producer through co-ownership of Sysav (waste-to-energy utility).

2008 Energy Strategy did not set specific building energy efficiency targets and deferred to national building code standard for energy targets in new construction. Since 2017, Sweden's building code follows the EPBD Near Zero Energy Buildings standard, and Malmö has also seen a significant uptake in energy efficiency strategies in the new commercial and residential construction building sectors. According to the interviews, these uptakes have been welcomed by the private sector developers who understand the value of energy efficiency projects. As for the existing building sector, Malmö reported challenges similar to those observed in other cities (see Chapter 2), such as a *split incentive dilemma and a still evolving value proposition.*

The energy strategy also discusses a need for systemic approaches to energy-efficient building development, one that goes beyond a project scale and is standardized and integrated throughout the governance cycle, it also calls for a need to set goals, pursue implementation and review and adjust, on an annual basis, based on progress. However, the plan does not include a specific roadmap or direction on how this will be implemented and results accomplished (Malmö Stad, 2008, p. 8).

The real estate development processes in Malmö have a significant influence on how the city engages in, the implementation of energy targets in the new construction sector. In this context, it is essential first to acknowledge that, the Swedish national building code sets the law for energy performance in new construction buildings and the municipality does not have the power to enforce targets higher than the national cod. Therefore, the municipality can only work to encourage and incentivize voluntary targets. These particular multi-level dynamics between national and municipal levels hare present in Sweden since 2015, and before Malmö (and other Swedish cities) had the possibility to set local energy standards. Reportedly, this change has created a shift in municipal motivations and approaches to promote more advanced energy performances. Since that change, the Environmental Building Strategy for Malmö serves primarily as an *online information exchange platform.*

5.2.2 Malmö - experiments and learning

In achieving its energy efficiency and green building goals, in the new construction area, Malmö's work is strongly tied to the process of real estate development. This local context is vital to describing how, why and when the municipality works with partners and collects input from stakeholders during new construction projects. Malmö stad is the owner of 50% of the development land within the city boundaries and has the sole authority on releasing permits for development within the city limits. The *Comprehensive Malmö Development Plan* sets a general direction on what should be developed on each parcel; however, more detailed plans are also developed for each site. The Urban Planning Department is responsible for the Development of these detailed plans; however, the process also involves other city departments such as Environmental, Real Estate, Traffic, Public School. The development of these plans takes place through formal meetings and is also informed by informal discussions. Depending on the scope of the development, the municipality may invite universities and consultants to provide additional expertise. An essential element of these detailed plans is a definition of *critical concerns,* which Malmö stad wants to address at each particular site. These concerns are presented as *questions* that developers must answer in the process of bidding for the development site. An example of such question provided by interviewees: *how will the developer increase energy performance at this site?* For the competitive, high value and high visibility sites, this gives the municipality an opportunity to collect solution ideas from various developers and pick the one they deem most ambitious yet feasible (based on the understanding on developer's capacity to deliver the project). As a result of this process, exemplary performance showcases (lighthouse projects) occur in areas that have high visibility and value in the marketplace, because developers have to be more competitive to win a bid there.

The board made of representatives from within the Real estate and street office department (Fastighets- och gatukontoret) oversees the final choice developers. Factors that influence the choice of winning developer include the architectural and innovative value of the project, bidding price and capacity of the developer to deliver the project. Malmö is currently developing a new and updated policy that sets a common selection standard across city parcels. Management of lease and sales of these parcels provides revenue for the municipal government. The lighthouse project plays a significant role in Malmö's approach to the energy transition. The ones that have gained much recognition are Housing Exhibition Bo01– West Harbor, Flaghusen, Fulerigalen, Hyllie, Sege Park and the latest one which is currently in progress, the Nord Harbor. These developments serve as testbeds for technologies and experiments bringing together local utilities, developers and municipality. Although this approach has a chance to push the boundaries of the energy performance of highly visible projects, projects that are not in competitive or high-profile areas might receive fewer bids from a developer. In such less competitive cases, the city has less leverage to influence energy and environmental performance. Without a standardized approach, this creates a risk of potential inequalities in the building performance throughout the city.

Once the municipality chooses the developers, the two parties begin the process of *developer dialogues,* to further specify what level of energy performance can be achieved at each development site. In addition to developers, local energy utilities – E.On and water/wastewater/energy utility - VaSyd, are present during the dialogue process. From this point onwards, each development site can have a different strategy for achieving environmental goals. Interviewees listed the following strategies used in Malmö to collaborate with the project stakeholders: *developer dialogues, evolving energy calculation models, developer tours and climate contracts. Developer dialogues* are discussion forums for the municipality and developers to bring up subjects related to specific environmental areas. Developer dialogues take place during the development phase. They can include other business representatives, who are invited by the developers to present or discuss specific technologies that can be tested or applied in the new buildings. *Energy modeling, calculation and performance verification:* during Malmö's first energy testbed project, the Bo01, very high and ambitious energy targets were a driving factor for municipal involvement. However, due to lack of experience among actors back then, ambitious targets were not met, as can often be the case with innovative experiments. In these initial phases of experiments, it was discovered that space area calculations were incorrect and therefore future energy performance did not match. It is unclear how the learning process looked in these experiments, as the interview feedback on lessons learned has been inconsistent, with some interviewees reporting lack of formalized learning, while others reporting that lessons learned have improved the development process. *Developer tours* another way for Malmö stad to collaborate with the building industry (architects and developers). The municipality organizes and leads trips with a group of developers to other cities (e.g,. Hamburg) to get common reference points and learn from other projects. Over time these tours lead to stronger partnerships among developers who began to work more collaboratively.

Climate contracts are another format of formalizing collaborations and visions in Malmö's effort to increase environmental performance. In Hyllie, climate contract has a strong technical performance and focus on partnership with local utility companies and efforts to deploy smart grid solutions that involved electric vehicles and home controls technologies. For energy efficiency, the program did set performance for 10% above the (the- current) Swedish building code (Malmö stad, E-On, & VaSyd, 2011, p. 8). Climate contracts were the 'next' evolution of site-specific energy performance visions and represented a high-level municipal commitment and political support. There are no specific energy efficiency targets set in climate contract for Hyllie document, however energy efficiency is mentioned as a pathway to achieving a 100% renewable energy mix. There is a follow up every two years on the deliverables set in climate contracts, for Hyllie, the deliverables concerning energy performance are tracked based on the actual data use which is provided by E.On. Energy performance and project progress are captured in the formal report; however, it is unclear how these reports translate into further knowledge sharing.

Operationalizing energy targets in Malmö

The current real estate development process in Malmö is influenced by the individual negotiations in the case of each development parcel, which can be problematic due to the varying level of developer ambition and municipal leverage in each case. To address this challenge, Malmö is currently finalizing the development of the 'Markanvisningspolicy' (Land allocation policy). This policy will establish the same, parcel distribution and baseline level of development standards in Malmö across all sites and parcels

Another way in which Malmö operationalizes energy efficiency and other building requirements is through *construction surveys*. When it comes to development in Malmö, there used to be three levels of verification of energy efficiency through these *construction surveys* 1) the design 2) development 3) performance (after 2 years of building use) however now only the first two levels of verification exist because the third, performance verification, is verified at the national level. These surveys are a part of the voluntary building strategy platform and are available in a format of checklists that verify environmental goals and provide insight into what type of energy efficiency strategies takes place. However, the data from the surveys are collected via the MS Word document format, which can be challenging to translate into dashboards or qualitative analysis. Therefore, the use of MS Work can create barriers to a more in-depth insight into the energy use of the Malmö's building stock.

5.2.3 Malmö - collaborations

Beyond the internal collaborations between municipal departments and collaborations with developers and energy utilities (discussed in the prior section as Developer Dialogues and Climate Contracts,) Malmö works with national-level partners. One partnership is working with the Energy Advisors program, driven by the national Swedish Energy Agency. This program allocates 2-3 individuals, in various municipal locations to help educate and address specific energy-related challenges. The focus of these groups is to raise awareness about energy-related opportunities, programs, and technologies that are in line with national Swedish energy goals through educational events and materials (paper fliers) — deliverables the Energy Advisors are driven by the national directive, and these directives change every two years. According to the interview with one of the Energy Advisors, the involvement of this unit in the municipal process is limited, and the currents primary focus is on supporting the residential property owners and tenants with educational services.

Malmö also engages in peer learning with other Swedish municipalities, such as Lund. In the past (2009 – 2015), all these two municipalities worked together to establish the same energy efficiency standard through the platform of the Miljöbyggprogram Syd program. This program aimed to make it easier for developers and builders to comply with the same energy efficiency standards everywhere. However, nationwide developers did not want cities to drive the standards and addressed it by lobbying for the national regulations. Developers wanted a national regulation, and in 2015, the Swedish Government decided not to allow such local requirements. The program has been gradually phased out since 2016 (Malmö stad, Lunds Kommun, & Lund University, 2018).

5.3 Visions, experiments, learning and collaborations in case cities

Fours research questions guided this thesis research into the nature of cities' work with concepts of visions, experiments, learning, and collaborations in the context of transformative change necessary to achieve energy-efficient buildings in cities.

The first research question asked *do cities have visions (roadmaps, goals) for how to reach a transformative change in the built environment?* the research confirms that indeed cities do have *visions* that describe the desired future pathway of the urban energy system and the role of the built environment in that process. However, visions vary significantly in how they have been developed the (process of envisioning) and in cities' strategies for implementations. The research highlighted three significant aspects that influence how visions can assist in reaching transformative change - 1) the level to which participatory approaches are deployed in an effort to formulate problems, solutions and commitment to vision implementation, 2) the level to which subsequent agendas with specific relevant indicators are developed, 3) the presence of an ongoing review and adjustments during the implementation process.

The second question asked *do cities facilitate and work with experimentation e.g., (living labs, testbeds, demonstration.) to achieve energy-efficient buildings?* Project findings confirm that cities do work with experimentation and recognize it as a viable pathway for exploring future solutions. However, the research found significant differences between how cities approach experiments involving public buildings (where the municipality is the owner) and those involving private sector buildings (where the municipality is the facilitator or a partner). These differences have a particularly significant impact on how municipality captures lessons learned from the experiments and how experiments influence a broader capacity building, learning and transformative change.

The third question asked *do cities support learning for transformative change, i.e. do they perform an evaluation of activities of the energy-efficient built environment, to learn and inform future actions?* Research results show that learning is the least developed element of the transformative processes in cities. Interviewees reported that insufficient resources are allocated towards capturing and dissemination of lessons learned from experiments, which might undermine achievement of the full potential of experiments and the transition process overall.

Finally, the fourth research question asked *do cities facilitate and support internal and external collaboration to achieve energy-efficient buildings?* Research results indicate that indeed, municipalities do engage in collaboration; however, there are significant differences between the two case study cities as to how they view the role of stakeholders in the process of transitions. Further, the view on collaborations influences to what extend participatory and meta-governance approaches to transformative change are present during all four elements of the transition management governance cycle.

Applying analysis questionnaire (*Appendix 3*) provided a more in-depth analysis of the results and their relevance to the research question *Appendix 3)*. The result of this analysis, visualized in Figure 6, indicates that overall the Copenhagen municipality's work with the transition concepts of visions, experiments, learning and collaborations has been more defined and structured than in Malmö, which led to Copenhagen's overall higher score. Nevertheless, it is impotent to state the limited number of interviews (Copenhagen-3 and Malmö -6) can be an essential factor in these final results.

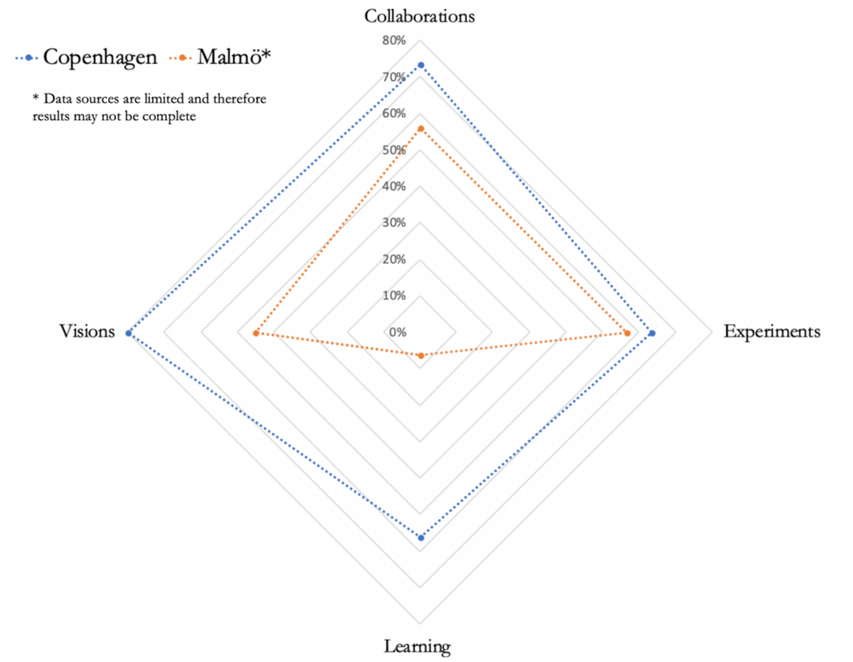


Figure 6 Copenhagen and Malmö Transition Management Maturity Graph.*
** Data sources are limited and therefore results may not be complete*
Source: Own analysis and elaboration

Regarding *visions,* Copenhagen's higher score (80%) than Malmö (45%), is a result of Copenhagen's strong focus on participatory approaches in all stages of the vision development process. Starting with the formulation of guiding principles and problem definition, through the creation of the vision to its operationalization and further implementation, Copenhagen tries to engage relevant stakeholders. Assessment of the Copenhagen's Climate Action Plan and community scale visions related to Integrated Area Based Development lead to this result. Both plans extensively and intentionally gather community input with the strategy to translate stakeholder energy into ongoing political support and community buy-in. A participatory approach is rooted in the collective definition of the problem and followed by a collective and transparent review of progress, which results in community and resident capacity building and empowerment to support energy efficiency. In Malmö, stakeholders are also involved in the development of climate plans and vision; however, to a lesser extent. Interviews uncovered that Malmö's critical partners outside of the municipality are primarily local utility companies and educational institutions. Malmö's engagement with a private sector is primarily with developer companies engaged in specific new development projects. Engagement with large companies and institutions can result in the disconnectedness of smaller businesses and residents from the transition process. This somewhat limited stakeholder representation is resulting in Malmö's lower score in this section. Principles of transformative change put a strong emphasis on the alignment of stakeholder value, with vision development and vision implementation in this context a broader and more diverse stakeholder portfolio can result in a better representation of local values. Such an approach can lead the development of a common transformation language among stakeholders which in turn makes for more effective implementation. Because the achievement of energy efficiency relies on alignments among man actors in the building sector, a broader representation of these stakeholders during the envisioning process creates a stronger basis for the successful implementation of projects.

Another reason for Copenhagen's high score in this section is a diligent and transparent approach to roadmap documents. These roadmaps represent more short-term, tactical solutions necessary to achieve long term energy efficiency ambitions. *Appendix 7* presents a snapshot of the energy efficiency elements in Copenhagen's 2017 – 2020 roadmap. Specific characteristics differentiating roadmaps from visions, in case of Copenhagen, are 1) a list of specific initiatives undertaken during the 2017-202 period, 2) the current status of these initiatives, 3) a connection to a larger, overarching initiative. These roadmaps are publicly available and serve as reporting and a communication tool for both internal departments, politicians and community at large. The development of each new roadmap (every four years) is accompanied by a review and adjustment steps, which further contribute to Copenhagen's stronger score in this section. On the contrary, lack of roadmaps and more tactical documents has been identified by Malmö's municipal staff as one of the barriers achievements of the city's visions.

In the *experiments* category, both cities score relatively high, Copenhagen (63%) and Malmö (57%). It is essential to acknowledge that while data collected in Copenhagen represented primarily experiments involving publicly owned existing buildings (e.g., municipal offices, schools, public housing), the data collected for Malmö discussed only experiments conducted in new construction private developments. These differences might be a result of the available interviewees rather than an indicator of only a specific type of experiments occurring in each city. Both municipalities use experiments to support the achievement of energy efficiency visions and both of them apply best practices to the process of engaging stakeholders during the experiment timeline. Both cities view experiments as an opportunity to test new technologies and develop new relationships necessary to achieve transition goals. Both cases reported the shared stakeholder value of storytelling and marketing opportunities around experiments. The main differences between Malmö and Copenhagen's work with experiments are in the areas of *learning and collaborations*, which is visible in the scores for these two sections.

The *learning* category score represents the lowest scores for both cities, Copenhagen (65%) and Malmö (6%). Additionally, Malmö's score stands out as significantly lower than in other sections. This discrepancy might be a result of the choice of a few interviewees in each case. In Copenhagen, an interview was conducted with a municipal staff representative who was able to provide an in-depth overview of experiments in public buildings. The results for Malmö reflect only the level of learning related to experiments in private buildings. Based on these interviews the learning processes in Malmö seems to be less developed than in Copenhagen, this might be a result of a number of factors such as the different amount of resources available at each municipality, varying rates of growth experienced in each city and potentially different sustainable development focus areas.

Copenhagen's work with learning around energy efficiency in municipal buildings is very well developed and includes ongoing review, operationalized processes and continuous focus on overcoming barriers to energy efficiency. The municipality has developed an on-going evaluation process, which captures lessons learned and best practices and translates them into guiding protocols and formal procedures (e.g., procurement). Copenhagen's newly developed knowledge is also used in peer to peer learning within global networks. Copenhagen also scores higher with learning in the private sector due to participatory approaches an ad strong focus on the 'secondary learning' of residents and stakeholders. Copenhagen's engagement with local labor unions and focus on capacity development of future facilities' technicians is particularly noteworthy. Malmö's approach to learning concerning the private sector experiments is unclear and many if the interviewees pointed out a need for improvement in this area. Some of the challenges that were highlighted in Malmö include a lack of operationalized procedures, a shortage of information depositaries with lessons learned and limited attention to crucially review phases as challenges. The choice and availability of interviewees is potentially a factor to this feedback and different results could have been found if interviews were conducted with staff directly involved with experiments. However, a current result can also be an indicator that at least some of the relevant municipal staff might not be engaged in the knowledge sharing, review process and translation of lessons learned into future policies and practices. It is also important to acknowledge that in 2018 Malmö stad City Council adopted a *Long-term implementation of the 2030 Agenda in the City of Malmö* document where it addresses operationalized learning gaps and commits the municipality to more integrated internal approaches to accelerate the transformation towards Sustainable Development Goals (Malmö stad, 2018a). A public, organization-wide and politically supported commitment presented in this document indicates that although some of the learning might not have been captured in this research, Malmö reflexive processes are present and are influencing ongoing municipal processes.

Regarding *collaborations,* both cities engage with internal and external collaborations and scoring relatively high in this section: Copenhagen (74%) and Malmö (56%). Both municipalities engage with the key stakeholder groups such as property owners, developers, and utilities. These three groups are fundamental in understanding building energy performance and the ability to influence its energy use at the building site and in the bigger context of electricity grids in urban areas. Copenhagen however, takes the collaborative approaches in an effort to achieve energy efficiency to a higher level specifically in understanding a) how municipal efforts can elevate green tech and green building companies, b) how local green tech companies can contribute to Copenhagen's green ‘brand' and economic benefits c) how partnerships with community residents can help build support base that wins political support and creates a long term momentum. During the interviews, Copenhagen municipal staff has clearly stated the value of private sector investment and community support that are necessary to achieve Copenhagen's climate goals and building energy efficiency. It is Copenhagen's intentionality to tap into these resources that permeates all *visions, experiments and learning* elements and results in a higher score overall and the *collaboration* section. Malmö is currently evolving its approach to collaborations through the development of two new models: *The M21 Partnership* (Malmö in the 21st century) and *Agreement Malmöandan.* These two programs aim to broaden the spectrum of municipal partnerships to include local NGOs, civic society, academia and private sector to be an integral part of Malmö ’s continuing role as a national testbed for urban innovations and systems (Malmö stad, 2018a).

6 Discussion

To achieve energy efficiency cities must develop new, participatory approaches and collaborations that will guide visions, experiments, and learning. Such effort is necessary to overcome business as usual patterns and prevent further system lock-ins in the building sector and cities (Bulkeley, 2013, p. 38; Marvin et al., 2018, p. 40). A socio-technical and multi-level nature of energy efficiency transitions requires involved actors to understand the implication of the integrated character of both social and technological elements, and the necessity to move beyond traditional institutional structures and governance models to achieve change (Bulkeley, 2013, p. 38). This research confirms that in such context, experimentation, considered within the multi-phase (time dimension), visions, experiments, learning and collaborations can provide an open-ended pathway to catalyzing a reflexive procedure which can influence thinking (culture), doing (practices) and organizing (structure) towards achieving transformative change (Bosch-Ohlenschlager, 2010, p. 62; Bulkeley, 2013, p. 38; Marvin et al., 2018, p. 40).

The analysis presented in Chapter 5 shows that Copenhagen and Malmö are working with the transition towards energy efficiency in buildings, and using the concepts of visions, experiments, learning, and collaborations. Both cities show especially strong effort in areas of collaborations and experimentation and Copenhagen also in visions. In all, the results show that Copenhagen and Malmö have a genuinely transformative approach to energy efficiency in buildings, but that there is a need to overcome existing barriers to make further progress. Both cases demonstrate potential that more can be done in terms of learning and indicate that there is a strong commitment already in place to exploring that potential. Transformative change is by its nature an ongoing and open-ended process; therefore, it is the commitment to an ongoing change, rather than a score at any particular point in time that will determine its success.

This research highlights the importance of **formalized processes** as a necessary component to take the impact of visions, experiments, learning, and collaborations from the project scale to a system-level change. A multi-phase view of how visions, experiments, learning, and collaborations can enforce each other over time is vital to achieving an impact that is greater than a sum of these four elements separately. To date, more focus in transitions literature and case studies have been on experiments' capacity to advance innovative projects and provide a platform for collaboration, than on the aspect of ongoing learning. Lack of resources is a general barrier to formalized processes and operational changes; however, more research to sources of funding of experiments could provide additional insights to this challenge.

Further, this research finds that the **technological potential for energy efficiency exists** in both Sweden and Denmark, and Malmö and Copenhagen are engaging in processes to achieve co-benefits of it. Copenhagen focuses its transformative efforts by actively engaging in the energy performance of existing buildings by developing processes, tools, and collaborations necessary to measure and capture social, environmental, and economic co-benefits of energy-efficient retrofits. Malmö's focus has been on the new construction sector and innovative approaches that align the building sector with the overall transition to a carbon-neutral society. This research uncovers that local governments' choice of the transformative energy efficiency activities varies significantly and is rooted in a local context, the maturity of local energy efficiency knowledge and other dynamics within the multi-level governance. Additional research to perceived and captured value of transformative change and energy efficiency could provide additional insights into why local governments choose to engage in energy efficiency and what influences their approach in doing so.

Research also finds that results for Copenhagen and Malmö can be influenced by specifics of how each city's departmental and operational structure around building energy efficiency and visions, experiments, learning, and collaborations. As a result, in Malmö, we observe experimentation and learning that is centered around specific projects (representing urban parcels and developments). Knowledge developed during specific projects remains within the city team and business representatives that have been directly involved. In Copenhagen, experiments cross boundaries of a specific building (or parcel) level, and therefore learning outcomes influence broader teams and are translated into institutional processes. Finally, different ownership of actual building developments, where the experiments took place, (Malmö – privately owned, Copenhagen – municipally-owned) had an impact on the experiments and learning process and the results of this study

Research also points out a potential new area of closer collaboration between Malmö and Copenhagen around the topic of building energy efficiency and transformative change. The two cities have a long history of collaborating across the Øresund.

6.1 Barriers to transformative approaches in cities

Because Malmö and Copenhagen represent different maturity levels of working with transformative change, different barriers occur in each case. Although both cities pointed to a general need for more resources, there is no other significant overlap in the identified barriers between the two cities. Therefore, barriers are discussed separately for each case.

Barriers to Copenhagen's path to transformative change towards building energy efficiency.

The overarching barrier in addressing transformative change in Copenhagen is *fighting the 'old way' of doing things* and *establishing new perceptions and pathways.* However, one could observe that this is not a barrier to transformative change but rather precisely an essence of the transformative change. One of the aspects of the *old ways* is the siloed and disconnected character of work among the stakeholders engaged in the building sector. The new and strict energy efficiency standards require that the industry arranges its processes in new and more collaborative ways in order to overcome points of conflicts and missed energy efficiency opportunities.

Besides the need to increase collaboration skills, the municipality sees a two-fold challenge in the area of workforce capacity to support energy efficiency transition. First, the building sector workforce (correctly, facility mangers were pointed out) faces challenges in advancing knowledge and skills at the same speed at which energy efficiency technology evolves in the building sector. Second, the municipality observes a challenge with attracting cutting edge, competitive workforce to work at the local government departments. One of the potential reasons for this is due to public sector wages being traditionally lower than the private sector, and therefore positions cannot compete with the private sector salaries.

Another barrier to energy efficiency is the fact that it *comes secondary to the social goals* of projects or building performance because the comfort and health and well-being of occupants always come first. This challenge forces the municipality to seek *new ways to capture co-benefits* (mainly indoor environmental quality) of energy efficiency in measurable ways which can be operationalized and used to understand impacts energy efficiency projects better. An effort to capture the co-benefits is both a barrier and an opportunity. However, although challenging the ability to operationalize co-benefits is particularly a case when working with politicians, who are still learning to recognize the importance of energy efficiency projects. Therefore, the municipality sees the priority of social goals as a challenge that can push project teams to a more advanced understanding of energy efficiency co-benefits.

Two last barriers identified during the interviews have to do with the *external environment* outside of the municipal organization. First, due to Copenhagen's influential purchasing power within the country, there are concerns over its progressive and ambitious decisions having an impact on the national markets. Copenhagen's significant influence on the national markets has in the past stalled progressive projects from being operationalized due to concerns over other regions' ability to deliver similar results. Two, the municipality sees a barrier in the speed of horizontal learning among cities in Denmark and globally

Barriers to Malmö's transformative change towards building energy efficiency.
Lack of operational and business procedures that connect four elements of *visions, experiments, learning, and collaborations* is an essential barrier to more effective transformative change in Malmö. Although each of the four elements is present in Malmö's approach to achieving energy efficiency, the results of this thesis cannot provide evidence that the full potential is realized. This thesis finds that the lack of connective tissue of formalized learning and communication processes can be a barrier. Development of such cross-department and cyclical processes is the new and desired way of working; however, it also represents a departure from *old, siloed ways* of working and towards a more new and *integrated operational approach.* Malmö's commitment to addressing this barrier has been established in the *Long term implementation of the 2030 Agenda in the City of Malmö* strategy passed by the City Council in 2018 and will align with City's new budgets for 2020 and onwards (Malmö stad, 2018a).

Lack of specific targets for building energy efficiency might be one reason why there are no publicly available roadmaps or agendas for how Malmö will achieve its energy efficiency statement. This lack of roadmaps and subsequent lack of review of progress or effectiveness of implemented strategies creates a perception of communication challenges and a lack of knowledge among employees. Tactical and short-term documents such as roadmaps, serve as conveying points for exchange of ideas, reporting of issues, and subsequent improvements to how the municipality is achieving its goals. Without such a common convening platform, Malmö misses an opportunity for a more aligned work among its internal departments. Further, a lack of action plans that operationalize high-level visions creates silos among departments and the lack of incentive to break these siloes and engage in cross-departmental approaches.

Malmö has been demonstrating its innovative spirit and ambition for local energy efficiency experiments. This thesis finds that the learning element of the experiments and energy efficiency transitions overall can be improved through more focus on operationalizing reflexive processes. Experiments have been a platform to address some of the inter-departmental siloes and barriers to systemic change. Additional emphasis on capturing and distribution of lessons learned from experiments can contribute to a more accelerated transition. Further such lessons should be translated into learning materials that can support internal knowledge development and peer-to-peer learning with other cities.

Thesis research finds a shortage of formal processes to capture lessons learned in Malmö. Limited operationalization of reflexive processes can mean that only employees directly engaged in specific experiments can benefit from understanding the internal processes and lessons learned during these experiments. Further, this can mean a limited impact of experiments and can pose particular challenges during staff turnover periods. New employees have minimal access to lessons learned during experiments and surrounding processes, and there is a risk that knowledge can 'leave' the organization with departing employees. Although Malmö works to mitigate these challenges by pairing older and new employees together, the process is still limited and benefits specific individuals rather than contributes to an overall capacity building across the organization.

Research points to the lack of incentives for municipality to engage in energy efficiency in low-visibility areas. Malmö relies on sales of land to generate income, and this means that in areas that experience less competition from developers (mainly urban sites with low public visibility or previously polluted industrial sites) are areas where the City has less leverage to push energy efficiency. Such an approach can create inequality issues and a risk that only areas with high visibility and competition from developers, will be pushed to achieve better energy performance.

This thesis also finds an opportunity for stronger alignment between municipal and national level strategies to achieving transformative change in the area of energy. Although both levels of governance are moving towards increased energy efficiency, their roles 'on the ground' and when working with stakeholders, do not seem to leverage each other's strengths. Moreover, uncertain incentives for retrofitting in existing buildings at the national level, create uncertainty at the city level. Some of the interviewees pointed out the changes in Swedish law, which prevent cities from enforcing stricter energy standards than a national level, as a barrier for municipal leadership in this area.

6.2 Discussion of methodical choices and limitations

The method chosen for this thesis has provided the author with information useful to answer stated research questions. The literature review has allowed for a more detailed understanding of the complexities of the building sector and its dynamics that can influence the achievement of energy-efficient buildings. Reviewed material has confirmed that the technological potential to achieve efficiency is available; however, challenges related to governance, financial case, and stakeholder dynamics are a barrier to achieving this potential. Literature review of the transition theory has provided additional details as to what are the best practices that cities should consider when engaging with visions, experiments, learning, and collaborations. This element of the literature review was significant and supported the development of the analytical framework.

As for the data collection part, both the interviews and document review were a valuable source of in-depth details that supported a specific understanding of each case and the data collected was sufficient to answer stated research questions. However, the author does recognize specific challenges related to both data collection methods and its potential impact on the final results. One, the choice of interviewees was highly limited by the summer vacation schedules of municipal staff in both Copenhagen and Malmö and not all desired interviewees were available. Although this represents a challenge and may have created gaps in results, it has also helped uncover challenges specific to learning and knowledge transfer with various departmental employees, which might not have been uncovered if only leadership staff was interviewed. As for the document review a language barrier

The transition management framework has been proven a valuable instrument to analyze the cyclical nature of visions, experiments, and learning in cities. It was uncovered that the potential laying in the cyclical nature of these governance elements is not always achieved due to a highly 'project focused' approach. The limitation of the transition management framework can be its insufficient recognition for the overlaps and an integrated multi-dimensional, multi-phase character of the visions, experiments, learning, and collaborations. This can be seen in the literature, which is usually focused on one of these four elements rather than its consequential nature necessary to achieve more in-depth and more long-term results.

The analytical framework (Appendix 3) developed for this project has allowed for an assessment of Malmö's and Copenhagen's current status of working with visions, experiments, learning, and collaboration. The analysis framework sheds light on where each municipality is currently leading and which areas still need to be developed further. However, the analysis framework is limited in that it does not provide information as to what processes have been established to improve current situations. This limitation is particularly important in the analysis of the case of Malmö, where although a low *learning* score has been observed at the current point of time, the municipality has already made firm commitments to addressing this. As such, the true reflexive nature of work in Malmö cannot be captured with the one-time use of the analytical framework. Therefore, it is recommended that this framework and analysis of transitions should rely on multiple assessments taken over multiple points in time.

Research also helped uncover that more detailed and specific understanding and definitions of collaborations might be necessary to deploy the framework in the applied cases more successfully. In this aspect, the *Systems Function* studies could supplement the transition management framework and provide more insight into specific stakeholder functions important in the participatory character of the transition process (Hekkert & Negro, 2009).

The choice of the case study method for this thesis proven a useful approach in answering the research questions; however, the results cannot be generalized. The case study method did, however, help uncover that the hyperlocalized nature of the urban development and real estate development processes has a significant influence on how cities work with visions, experiments, learning, and collaborations. Additionally, the local energy grid structure and power structure of the energy utilities can be influential factors in the process of energy transformation.

6.3 Recommendations

In order to achieve transformative impacts, cities working with visions, experiments, learning, and collaborations should strive to influence fundamental changes in structure, culture and practices (Frantzeskaki & de Haan, 2009; Grin et al., 2011, p. 109; Loorbach & Rotmans, 2006b). Local governments can support such a profound transformative change twofold, by influencing external actors and by influencing their internal operations. The following recommendations aim to support municipal effectiveness in transformative processes towards energy-efficient buildings. This section provides recommended considerations for municipal governments working with the transformative change to achieve energy efficiency in buildings.

Visions

The success of the envisioning process relies on its participatory character and ability to measure progress towards achieving it. Cities should strive to engage with diverse groups of stakeholders (relevant to a particular vison) and capture their voices to formulate guiding values and performance indicators. Envisioning process should be viewed as an arena where diverse actors can express and resolve a broad spectrum of perspectives. Relationships build during the envisioning process should be operationalized and carry through further implementation processes. Holistic consideration for social, economic and environmental aspects can drive the choice of actors and realization of the full potential of visions for energy efficiency (Grin et al., 2011, p. 2; Jensen et al., 2018, p. 143). The success of vision also relies on the ability to operationalize its objectives. Operationalization can mean that each goal is represented by indicators that will provide the ability to measure progress and to identify barriers and opportunities and serve as a foundation for transparent reporting or storytelling. These objectives should be translated into short-term agendas that break up long-term visions into more manageable components allowing for necessary check-in points, reviews, and adjustments. All of these elements should serve as the opportunity to convene and realign management and all key stakeholders.

Experiments

When engaging in experiments, municipal governments should consider applying similar principles as in the case of envisioning, such as participatory approaches and potential impact on social, economic and environmental realms (Grin et al., 2011, p. 2). The view that experiments are a goal in itself and an instrument to influence culture, structures and practices should be applied to achieve systemic benefits of experiments (Frantzeskaki et al., 2012, p. 25; Loorbach et al., 2016, p. 28; Roorda, C. et al., 2014, p. 46). It is recommended that when designing experiments, municipalities allocate necessary resources to assure appropriate alignment with existing visions, capacity for ongoing learning and active engagement of relevant stakeholders. It is through these connections that the potential of experiments scales up from the project level to a system-level change. The process of design and implementation of experiments itself should be a subject to reflexive activities and an integrated approach that analyses both the process (the extent to which experiments lead to institutional change) and goal-oriented perspectives (achieving actual sustainability gains) should be applied (Madsen and Hansen 2019, 284). Experiments should result in learning and further in structural changes that are mutually reinforced over time and move the organization on its path towards transformative change. Additionally, best practices that distinct experiments from regular, albeit, innovative projects must be applied. *Appendix 10* presents the key differences between regular innovative projects and experiments.

Learning

Current energy efficiency requirements are the most stringent ones that the building sector and governments have had to yet experience. This new situation presents many opportunities as well as pressures to adjust to the unknown requirements. The learning element of this transformation is therefore of vital importance to develop new ways of thinking (culture), doing (practices) and organizing (structure) (Bosch-Ohlenschlager, 2010, p. 62). As such, learning should be a) a constant aspect of all transition activities, b) cover a broad spectrum of knowledge such as institutional, technological, environmental, economic, socio-cultural and relationships between these aspects (Bosch-Ohlenschlager, 2010, p. 62), c) should catalyze secondary learning (a process which changes existing assumptions and frames of reference) and d) influence other elements of the existing system. Loorbach et, al. (2006) recommends that reflexive activities should include monitoring of agenda, actors, transferred knowledge, institutional learning as well as the rate of progress on the experiment's objectives (Loorbach and Rotmans 2006). Local governments should consider all these dimensions when designing and evaluating transformative activities such as experiments.

Cities should recognize and emphasize the importance of the verified building energy performance data in the development of common reference points among stakeholders. Smart meter technologies allow for more granular insight into energy use and can produce tools (e.g., benchmarking dashboards) that align necessary stakeholders (e.g., utilities, building occupants, technology providers) and provide them with information about the impact of deployed energy efficiency strategies. Additionally, energy use databases should consider alignments within the various priorities present in a multi-level governance context. Such alignments can help assure that the benefits of such systems translate between various levels of governments and the spectrum of actors.

Local governments should consider the broader context of local market conditions to identify what knowledge development is necessary to achieve energy efficiency goals. It is vital that cities understand the capacity of an available building sector's workforce (current and future projections) and use the momentum of the transition process to elevate collective local knowledge of energy efficiency and climate targets among residents, workforce, relevant companies and NGOs. The challenge and opportunity for the municipality are in aligning these actors around an ongoing evolutionary development process. Internal municipal staff may benefit from training and knowledge on the topic of transition management and adaptation to change, which will be necessary to stay ahead of some of the urban challenges in the time of climate change.

Additionally, learning should extend to the local community and residents. The transition process can be an instrument to empower these stakeholders and leverage their engagement towards broader co-benefits. Studies show that in Nordic countries between 10% and 20% of energy savings can be materialized through occupant behavior changes (Owens & Wilhite, 1988, p. 853) and that these savings can be often achieved with no- or low- capital investment (Ma et al. 2012, p. 891). Specific focus should be on the potential of behavior changes and the role of individual actors in achieving them.

Finally, because both Malmö and Copenhagen work with the concepts of transformative change, they should explore a closer collaboration within the Øresund region, specifically around the topic of transformative change and organizational challenges and opportunities of such process. These two cities have a strong foundation to develop a collective body of knowledge on this subject, and such knowledge could benefit the Øresund region as well as broader peer-to-peer city networks.

Collaborations

Participatory approaches are at the heart of transitions. It is the engagement of diverse, often opposite views, that drives the development of a shared common language, the definition of problems and visions of pathways of how the future can unfold. Municipalities can leverage the energy and resources of these actors to contribute to broader sustainable transition goals. Moreover, it is on both the individual and institutional level where the change in values among actors should occur. Through the engagement of stakeholders in all transitional processes (directly or indirectly), municipalities can catalyze buy-in, political support, and avoid *blind spots* in the development of future visions. Municipalities should also recognize the influence of national governments on the local actors and conditions, and clearly define what role they want to take in this context. Current national energy efficiency mandates and market instruments that are a result of that (e.g., energy databases, energy efficiency incentives, Energy Passports, Smart Indicators) will influence local goals energy efficiency goals. Therefore, cities should strive to understand and define their role within this multi-level context and how they can leverage their position to align macro- and micro- level resources to support energy efficiency and climate goals.

Operationalization

This thesis confirms that to fully realize the potential of visions, experiments, learning, and collaborations they need to be considered within the context of operationalized processes and procedures that are necessary to reinforce the mutual influence of these elements over time. Systems thinking is necessary to align all components and actors, but it is the added consideration for the time dimension that can take transitional efforts from the project scale to systemic change. For cities, this means considerations for the budget and resource allocations, development of standard operating procedures or protocols, and an ongoing review and updates that reflect reflexive processes and prevent system lock-ins. Municipalities should strive to emphasize best practices in the process of transition management and apply those as an additional layer to already established best practices in project management and regular operations.

7 Conclusions

This thesis highlights that although cities recognize the value of *visions, experiments, learning, and collaborations*, they often see them as separate 'projects' rather than integrated elements of one governance cycle. This fragmented approach can result in missed opportunities that come from ongoing re-alignments, reviews, and course correction adjustments. Out of four transition management elements, *learning* stands out as the one given the least formal attention, primarily when related to experiments and energy efficiency projects in private sector buildings. More research is necessary to understand the root causes of this situation. Various factors, such as organizational culture, limitations of project funding sources, or political influences, could play a role in this. It may also be that such is the nature of the learning process that arguably more exciting, innovative experiments and high-profile collaborations gain more interest than the slightly more mundane work required to evolve organizational processes and procedures. However, municipalities should explore the full potential shared value of reflexive learning processes, that can engage all stakeholders.

Cities are complex systems, continually evolving, and experiencing a multitude of changes and new realities they need to adapt to. This thesis finds that case study cities of Malmö and Copenhagen engage with the transformative change concepts of *visions, experiments, learning, and collaborations* to achieve building energy efficiency and broader sustainable development goals. In this process, both municipalities represent a high level of awareness and self-reflectance about their need to continuously evolve to meet pressures of climate change and societal transitions in urban areas. The findings of this thesis represent a snapshot assessment of how cities work with *visions, experiments, learning, and collaborations* at this point. This *snapshot view* has to be understood as only a partial insight into these processes. This limitation is a result of the analysis framework and it's single (one point in time) application during the thesis research. In its current format and with a single application, the analysis framework cannot assess the ongoing nature of the transformative processes (or commitments). In order to more accurately analyze processes of transformative change in cities, data should be analyzed over time to represent better-operationalized processes that point to a municipal commitment to transformative change. As the saying goes, *what you cannot measure, you cannot manage*. Therefore, further development of the assessment tools used to evaluate *how cities work with transformative change* would be a step towards a broader and systemic management of transitions within local governments.

Further reflection over the final thesis results, inspires a new question *do cities envision the full scope of co-benefits of energy efficiency?* Municipalities experience a dilemma of investing limited resources to catalyze energy efficiency. Therefore, a clear understanding of the value of such an investment is necessary for municipalities to allocate limited resources towards energy efficiency confidently. In the case of municipal buildings, these incentives are more understood and can result in direct cost savings and energy savings. However, the business case and value models for investing in private sector energy efficiency are less straightforward. More research is needed to understand the value of the municipal investment in energy efficiency in the private sector facilities and the new models that can identify and capture that value. Because energy efficiency is an integral component of a border energy transition, more participatory processes will be necessary to leverage the collective knowledge and to develop shared value models and incentives that empower all actors to contribute to sustainable transitions. Cities can support the development of such models by facilitating open and inclusive arenas where participatory visions are developed and capture collective visions of a sustainable future.

Cities cannot achieve energy efficiency targets on their own and must rely on collaborations to do so. This thesis concludes that more understanding is needed in how better alignments within a multi-level governance context can influence municipal transitions towards energy-efficient buildings. Specifically, more research is necessary to explore dynamics between the municipality, national governments, supranational governments, energy utilities, and building owners. Currently, the European energy transition is on its way via the means of directives and national regulations that influence all of these actors. However, the impact of these policies at the municipal level is still forming. This particular moment in time requires us to think about how to prevent negative systems lock-ins and create shared social, environmental, and economic value among all actors. Without doing so, there is a risk of siloed sectoral views and future power struggles which can result in new barriers to the energy transition. Experiments can support understanding of barriers and opportunities; however, they must involve a broad spectrum of elements such as policy, business models, social value, and other dimensions of socio-technical context.

Although a significant amount of academic literature exists on the topics of visions, experiments, learning, and collaborations, there is much less material available for practitioners who want to learn about how cities should work in a multi-phase and systematic way with these elements. Materials that describe best practices in the transition management applications and new grey literature material designed for practitioners could contribute to more uptake in transformative approaches in the local governance. Assessment tools should be developed to guide and measure transformative change and improvements when deploying visions, experiments, learning, and collaborations. Although transition management theory points to the need for measurement of transitions, the field does not provide any tools for cities to do that. Development of such tools and could support reflexive and learning activities in municipal structures by providing a more accurate verification of the impact of transition management on energy efficiency. Supporting tools could also provide insight to whether a project has the potential to move beyond project scale and unlock a broader systemic change and lead to a radical change in building energy efficiency. The analytical framework used in this thesis (Appendix 3) could provide a starting point to how cities could be verifying if their actions are designed to unlock a bigger systemic change. Such a framework combined with a toolkit of best practices (see Appendix 2) could serve as a valuable model for local governments to understand, design and deploy transformative activities in areas of building energy efficiency. Further, peer to peer learning networks, governmental agencies, and research institutions should play a role in this process and support cities in the development of knowledge and skills to embed principles of ongoing learning, participatory approaches, and evolution towards sustainable transformation in cities

8 Bibliography

Aalborg University and the City of Copenhagen. (2018, November). *Community Based Living Labs. South Harbour*. Aalborg University and the City of Copenhagen.

Becqué, R., Mackres, E., Layke, J., Aden, N., Liu, S., Managan, K., … Peter Graham. (2016). *Accelerating Building Efficiency. Eight Actions for Urban Leaders*. World Resource Institute Ross Center for Sustainable Cities.

Beddingfield, E., Hart, Z., & Hughes, J. (2017). *Putting Data to Work. How Cities are Using Building Energy Data to Drive Efficiency* (No. DE-EE0007063). The Institute for Market Transformation.

Bogdan Atanasiu. (2011). *Principles for nearly Zero-energy Buildings. Paving the way for effective implementation of policy requirements*. Buildings Performance Institute Europe (BPIE).

Bosch-Ohlenschlager, S. J. M. van den. (2010). *Transition experiments: Exploring societal changes towards sustainability*. Rotterdam: Erasmus Univ.

Boverket. (2018). *Boverket´s mandatory provisions and general recommendations, BBR. BFS 2011:6 with amendments up to BFS 2018:4*. Retrieved from https://www.boverket.se/globalassets/publikationer/dokument/2019/bbr-2011-6-tom-2018-4-english-2.pdf

Brugge, R. van der, Rotmans, J., & Loorbach, D. A. (2006). Transitiemanagement en duurzame ontwikkeling: Co-evolutionaire sturing in het licht van complexiteit. Transition management and sustainable development: Co-evolutionary governance in view of complexity. *Dutch Research Institute for Transitions (DRIFT)* /. Retrieved from hdl.handle.net/1765/7631

Bulkeley, H. (Ed.). (2013). *Cities and low carbon transitions* (1st Edition). New York: Routledge.

Bygningsreglementet. (2019). Bygningsreglementet. Energy consumption (§ 250—§ 298). Retrieved from http://bygningsreglementet.dk/Tekniske-bestemmelser/11/Krav/259

C40. (2014). *C40 Cities: The power to act*. Retrieved from C40 Cities Climate Leadership Group website: https://www.c40.org/researches/c40-cities-the-power-to-act

C40. (2018). *C40 Climate Action Planning Programme. Comprehensive support for ambitious and equitable climate action plans*. London: C40 Cities Climate Leadership Group.

CIBSE. (2004). *CIBSE, Energy Efficiency in Buildings: CIBSE Guide F*. London: Chartered Institution of Building Services Engineers.

City of Copenhagen. (2016). *CPH 2025 Climate Plan Roadmap 2017–2020*.

CNCA. (2014). *Framework for Long-Term Deep Carbon Reduction Planning*. Retrieved from Carbon Neutral Cities Alliance website: https://www.usdn.org/uploads/cms/documents/cnca-framework-12-16-15.pdf

DNV GL. (2018). *Energy Transition Framework for Cities. Best practices for sustainability, climate action and resilience*. Retrieved from https://www.dnvgl.com/publications/energy-transition-framework-for-cities-113038

EcoDistricts. (2018). *EcoDistricts Protocol. A standard for Urban Community Development*. Portland, USA.

EEA. (2013). *Achieving energy efficiency through behaviour change: What does it take?* (No. 5/2013). Luxembourg: European Environment Agency.

EuroACE. (2018). *A Guide To The Implementation Of The Amended Energy Performance Of Buildings Directive (EPBD) 2018*. Brussels, Belgium: The European Alliance of Companies for Energy Efficiency in Buildings.

Fabbri, M. (2017). *Understanding building renovation passports: Customised solutions to boost deep renovation and increase comfort in a decarbonised Europe*. Presented at the ECEEE Summer Study 2017.

Feindt, P. H., & Weiland, S. (2018). Reflexive governance: Exploring the concept and assessing its critical potential for sustainable development. Introduction to the special issue. *Journal of Environmental Policy & Planning*, *20*(6), 661–674. https://doi.org/10.1080/1523908X.2018.1532562

Formas, & WSBC. (2011). *Swedish sustainable building: Research, development, innovation, implementation*. Stockholm: World Sustainable Building Conference and Swedish Research Council Formas.

Frantzeskaki, N., & de Haan, H. (2009). Transitions: Two steps from theory to policy. *Futures*, *41*(9), 593–606. https://doi.org/10.1016/j.futures.2009.04.009

Frantzeskaki, N., Hölscher, K., Bach, M., & Avelino, F. (Eds.). (2018). *Co-creating sustainable urban futures: A primer on applying transition management in cities*. Cham: Springer.

Frantzeskaki, N., Loorbach, D., & Meadowcroft, J. (2012). Governing societal transitions to sustainability. *International Journal of Sustainable Development*, *15*(1/2), 19. https://doi.org/10.1504/IJSD.2012.044032

Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Urban experimentation & sustainability transitions. *European Planning Studies*, *27*(2), 219–228. https://doi.org/10.1080/09654313.2018.1532977

Gerring, J. (2017). *Case study research: Principles and practices* (Second edition). Cambridge, United Kingdom New York, NY: Cambridge University Press.

Grin, J., Rotmans, J., Schot, J., Geels, F. W., & Loorbach, D. (2011). *Transitions to sustainable development: New directions in the study of long term transformative change* (First issued in paperback). New York London: Routledge.

Güneralp, B., Zhou, Y., Ürge-Vorsatz, D., Gupta, M., Yu, S., Patel, P. L., … Seto, K. C. (2017). Global scenarios of urban density and its impacts on building energy use through 2050. *Proceedings of the National Academy of Sciences*, *114*(34), 8945–8950. https://doi.org/10.1073/pnas.1606035114

Hekkert, M. P., & Negro, S. O. (2009). Functions of innovation systems as a framework to understand sustainable technological change: Empirical evidence for earlier claims. *Technological Forecasting and Social Change*, *76*(4), 584–594. https://doi.org/10.1016/j.techfore.2008.04.013

IEA. (2013). *Transition to sustainable buildings: Strategies and opportunities to 2050*. Paris: International Energy Agency.

IEA. (2018). Efficiency 2018. Retrieved June 12, 2019, from Energy Efficiency 2018 Analysis and outlooks to 2040 website: https://www.iea.org/efficiency2018/

IEA. (2019a). Energy Efficiency: Buildings. Retrieved from The Efficient World Scenario identifies opportunities in several buildings sub-sectors website: https://www.iea.org/topics/energyefficiency/buildings/

IEA. (2019b). *Perspectives for the Clean Energy Transition. The Critical Role of Buildings*. France: International Energy Agency.

IMEC. (2019). City of Things. Retrieved from https://www.imeccityofthings.be

International Energy Agency. (2017). Building Performance Standards (Building Regulations). Retrieved from https://www.iea.org/policiesandmeasures/pams/sweden/name-22078-en.php

Jensen, P. A., Maslesa, E., Berg, J. B., & Thuesen, C. (2018). 10 questions concerning sustainable building renovation. *Building and Environment*, *143*, 130–137. https://doi.org/10.1016/j.buildenv.2018.06.051

Johansson, T. B., Patwardhan, A., Nakićenović, N., Gomez-Echeverri, L., & International Institute for Applied Systems Analysis (Eds.). (2012). *Global Energy Assessment (GEA)*. Cambridge : Laxenburg, Austria: Cambridge University Press ; International Institute for Applied Systems Analysis.

JRC. (2019). *The future of cities: Opportunities, challenges and the way forward.* Luxembourg: Publications Office of the European Union.

Kemp, R., Rotmans, J., & Loorbach, D. (2007). Assessing the Dutch Energy Transition Policy: How Does it Deal with Dilemmas of Managing Transitions? *Journal of Environmental Policy & Planning*, *9*(3–4), 315–331. https://doi.org/10.1080/15239080701622816

Kim B. Wittchen, Jesper Kragh, & Ole Michael Jensen. (2011). *Energy-saving potential – a case study of the Danish building stock. ECEEE 2011 Summer Study: Energy efficiency first: The foundation of a low-carbon sociey* (No. 5–507).

Kiss, B., Manchón, C. G., & Neij, L. (2013). The role of policy instruments in supporting the development of mineral wool insulation in Germany, Sweden and the United Kingdom. *Journal of Cleaner Production*, *48*, 187–199. https://doi.org/10.1016/j.jclepro.2012.12.016

Kronsell, A., & Mukhtar-Landgren, D. (2018). Experimental governance: The role of municipalities in urban living labs. *European Planning Studies*, *26*(5), 988–1007. https://doi.org/10.1080/09654313.2018.1435631

Liu, F. (2014). *Improving Energy Efficiency in Buildings. Enegry Efficient Cities. Mayoral Guidance Note #3.* The World Bank.

Liu, F., Meyer, A. S., & Hogan, J. F. (2010). *Mainstreaming Building Energy Efficiency Codes in Developing Countries: Global Experiences and Lessons from Early Adopters*. https://doi.org/10.1596/978-0-8213-8534-0

Loorbach, D., & Rotmans, J. (2006). Managing Transitions for Sustainable Development. In X. Olsthoorn & A. J. Wieczorek (Eds.), *Understanding Industrial Transformation* (Vol. 44, pp. 187–206). https://doi.org/10.1007/1-4020-4418-6_10

Loorbach, D., Wittmayer, J. M., & Shiroyama, H. (Eds.). (2016). *Governance of urban sustainability transitions: European and Asian experiences.* Tokyo Heidelberg New York: Springer.

Lucon, O., Ürge-Vorsatz, D., Ahmed, A. Z., Akbari, H., Bertoldi, P., Luisa F. Cabeza, … Maria Virginia Vilariño. (2014). *Buildings. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 671–738). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.: IPCC.

Ma, Z., Cooper, P., Daly, D., & Ledo, L. (2012). Existing building retrofits: Methodology and state-of-the-art. *Energy and Buildings*, *55*, 889–902. https://doi.org/10.1016/j.enbuild.2012.08.018

Madsen, S. H. J., & Hansen, T. (2019). Cities and climate change – examining advantages and challenges of urban climate change experiments. *European Planning Studies*, *27*(2), 282–299. https://doi.org/10.1080/09654313.2017.1421907

Malmö stad. (2018a). *Long term implementation of the 2030 Agenda in the City of Malmö.*

Malmö stad. (2018b, May). *Comprehensive Plan for Malmö. Summary in English. Adopted by Malmö City Council in May 2018.*

Markard, Jochen, Rob Raven, and Bernhard Truffer. 2012. “Sustainability Transitions: An Emerging Field of Research and Its Prospects.” *Research Policy* 41(6): 955–67. https://linkinghub.elsevier.com/retrieve/pii/S004873331200056X (June 3, 2019).

Marvin, S., Bulkeley, H., Mai, L., McCormick, K., & Palgan, Y. V. (Eds.). (2018). *Urban living labs: Experimenting with city futures.* London ; New York, NY: Routledge, an imprint of the Taylor & Francis Group.

Mata, É., & Johnsson, F. (2017). Cost-Effectiveness of Retrofitting Swedish Buildings. In *Cost-Effective Energy Efficient Building Retrofitting* (pp. 343–362). https://doi.org/10.1016/B978-0-08-101128-7.00012-5

Mathur, V. N., Price, A. D. F., & Austin, S. (2008). Conceptualizing stakeholder engagement in the context of sustainability and its assessment. *Construction Management and Economics*, *26*(6), 601–609. https://doi.org/10.1080/01446190802061233

Min, Z., Morgenstern, P., & Marjanovic-Halburd, L. (2016). Facilities management added value in closing the energy performance gap. *International Journal of Sustainable Built Environment*, *5*(2), 197–209. https://doi.org/10.1016/j.ijsbe.2016.06.004

Næss-Schmidt, S., Heebøll, C., & Fredslund, N. C. (2015). *Danish house prices and the effects of energy standards. Econometric approach*. Copenhagen: Danish Energy Agency.

New York City. (2019). Municipal Entrepreneurial Testing Systems (METS). Retrieved from https://www1.nyc.gov/html/gbee/html/initiatives/mets.shtml

New York City, & New York University's Center for Urban Science and Progress. (2015). New York City Energy & Water Performance Map. Retrieved from https://serv.cusp.nyu.edu/projects/evt/

OECD. (2014). *Capturing the multiple benefits of energy efficiency*. Retrieved from Organisation for Economic Co-operation and Development website: https://doi.org/10.1787/9789264220720-en

Owens, J., & Wilhite, H. (1988). Household energy behavior in Nordic countries—An unrealized energy saving potential. *Energy*, *13*(12), 853–859. https://doi.org/10.1016/0360-5442(88)90050-3

Pacheco-Torgal, F., Granqvist, C. G., Jelle, B. P., Vanoli, G. P., Bianco, N., & Kurnitski, J. (2017). *Cost-Effective Energy Efficient Building Retrofitting: Materials, Technologies, Optimization and Case Studies*. Woodhead Publishing.

Passive House Institute. (2015). Passive House requirements. Retrieved from https://passivehouse.com/02_informations/02_passive-house-requirements/02_passive-house-requirements.htm

Raven, R., Bosch, S. V. den, & Weterings, R. (2010). Transitions and strategic niche management: Towards a competence kit for practitioners. *International Journal of Technology Management*, *51*(1), 57. https://doi.org/10.1504/IJTM.2010.033128

Reda, F., & Fatima, Z. (2019). Northern European nearly zero energy building concepts for apartment buildings using integrated solar technologies and dynamic occupancy profile: Focus on Finland and other Northern European countries. *Applied Energy*, *237*, 598–617. https://doi.org/10.1016/j.apenergy.2019.01.029

Revi, A, D.E. Satterthwaite, F. Aragón-Durand, J. Corfee-Morlot, R.B.R. Kiunsi, M. Pelling, … W. Solecki. (n.d.). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 535–612). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press,.

Revi, A., Satterthwaite, D. E., Aragón-Durand, F., Corfee-Morlot, J., Kiunsi, R. B. R., Pelling, M., … Solecki, W. (n.d.). *Urban areas. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 535–612). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA,: IPCC.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E., … Foley, J. (2009). Planetary Boundaries. *Ecology and Society*, *14*(2). Retrieved from http://www.jstor.org/stable/26268316

Rocky Mountain Institute. (2017). *The Carbon Free City Handbook*. Basalt, Coloroado, USA.

Roorda, C., Wittmayer, J., Henneman, P, Steenbergen, F., van, Frantzeskaki, N., Loorbach, D, & Roorda, C., Wittmayer, J., Henneman, P, Steenbergen, F. van, Frantzeskaki, N., Loorbach, D. (2014). *Transition management in the urban context: Guidance manual*. Rotterdam: DRIFT, Erasmus University Rotterdam.

Rotmans, J., Kemp, R., & van Asselt, M. (2001). More evolution than revolution: Transition management in public policy. *Foresight*, *3*(1), 15–31. https://doi.org/10.1108/14636680110803003

Rotmans, J., & Loorbach, D. (2009). Complexity and Transition Management. *Journal of Industrial Ecology*, *13*(2), 184–196. https://doi.org/10.1111/j.1530-9290.2009.00116.x

Sandin, S., Neij, L., & Mickwitz, P. (2019). Transition governance for energy efficiency—Insights from a systematic review of Swedish policy evaluation practices. *Energy, Sustainability and Society*, *9*(1), 17. https://doi.org/10.1186/s13705-019-0203-6

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management*, *20*(5), 537–554. https://doi.org/10.1080/09537320802292651

Shove, E., & Walker, G. (2007). Caution! Transitions Ahead: Politics, Practice, and Sustainable Transition Management. *Environment and Planning A: Economy and Space*, *39*(4), 763–770. https://doi.org/10.1068/a39310

Sondeijker, S., Geurts, J., Rotmans, J., & Tukker, A. (2006). Imagining sustainability: The added value of transition scenarios in transition management. *Foresight*, *8*(5), 15–30. https://doi.org/10.1108/14636680610703063

Sørensen, E., & Torfing, J. (2009). Making Governance Networks Effective and Democratic Through Metagovernance. *Public Administration*, *87*(2), 234–258. https://doi.org/10.1111/j.1467-9299.2009.01753.x

Sustainability Transitions Research Network (2019, January). *An agenda for sustainability transitions research: State of the art and future directions*. Retrieved from https://transitionsnetwork.org

Swedish Energy Agency. (2015, March). News. Retrieved from New regional energy statistics for single- or two-dwelling buildings website: http://www.energimyndigheten.se/en/news/2011/new-regional-energy-statistics-for-single--or-two-dwelling-buildings/

The City of Copenhagen. (2012, September). *CPH 2025. Climate Action Plan. A green, smart and carbon neutral city.*

The European Parliament and The Council. (2010). Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. *Official Journal of the European Union*, (153), 13–35.

The McKinsey & Company, & C40. (2017). *Focused acceleration: A strategic approach to climate action in cities to 2030*.

Trencher, G., Downy, F., Takagai, T., & Nishida, Y. (2017). *Urban Efficiency II Seven Innovative City Programmes for Existing Building Energy Efficiency*. Tokyo Metropolitan Government Bureau of Environment C40 Cities Climate Leadership Credit: Tom Davidson / www.flickr.com Group, CSR Design Green Investment Advisory, Co., Ltd. London.

UNFCC. (2017). *Urban environment related mitigation benefits and cobenefits of policies, practices and actions for enhancing mitigation ambition and options for supporting their implementation*. (Technical Paper by the

Secretariat. No. FCCC/TP/2017/2). United Nations Framework Convention on Climate Change.

United Nations. (n.d.). UN SDG Knowledge Platform. Retrieved from Sustainable Development Goal 11 website: https://sustainabledevelopment.un.org/sdg11

U.S. Green Building Council. (2009). *LEED Reference Guide for Building Operations and Maintenance*. Washington, D.C.: U.S. Green Building Council.

Vojnovic, I. (Ed.). (2013). *Urban sustainability: A global perspective*. East Lansing: Michigan State University Press.

von Wirth, T., Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Impacts of urban living labs on sustainability transitions: Mechanisms and strategies for systemic change through experimentation. *European Planning Studies*, *27*(2), 229–257. https://doi.org/10.1080/09654313.2018.1504895

Walliman, N. (2006). *Social research methods*. Retrieved from http://www.dawsonera.com/depp/reader/protected/external/AbstractView/S9781847878182

WEF. (2019). *Fostering Effective Energy Transition 2019 edition*. Geneva, Switzerland: World Economic Forum.

Yin, R. K. (2014). *Case study research: Design and methods* (Fifth edition). Los Angeles: SAGE.

Appendix 1 Case study cities overview

Appendix 1 presents case study cities overview with data sources

	Malmö	Source	Copenhagen	Source
Population (in 2019)	334 000	https://Malmö.se/Service/Om-Malmö-stad/Demokrati-beslut-och-paverkan/Fakta-och-statistik/Facts-about-Malmö/Demographics/Population-growth.html	548 317	https://www.dst.dk/en/Statistik/emner/befolkning-og-valg/befolkning-og-befolkningsfremskrivning/folketal
Past population growth trends	43% since 1990	https://Malmö.se/Service/Om-Malmö-stad/Demokrati-beslut-och-paverkan/Fakta-och-statistik/Facts-about-Malmö/Demographics/Population-growth.html	20% between 1993 and 2013	http://eprints.lse.ac.uk/60781/1/Copenhagen-GEL_20May-Final_Full-report_1page-layout.pdf
Future population growth trends	Not available	Not applicable	20 % population growth by 2025	https://international.kk.dk/artikel/copenhagen-facts
Agency over the built environment	The municipality has to follow national building codes. More stringent energy requirements than national codes can be encouraged but cannot be enforced.	Interviews	The municipality has to follow national building codes. More stringent energy requirements than national codes can be encouraged but cannot be enforced.	Interviews
Main energy utilities	E-On, VaSyd	Interviews	Hofor	Interviews
Climate goals	100% renewable energy by 2030	Municipal Energy Strategy	Climate neutrality by 2025	Copenhagen Climate Action Plan
Relevant municipal departments	City Planning Department, Real Estate and Infrastructure office, Environmental Department	Interviews	Copenhagen Properties & Purchasing, Energy & Technology, Climate Program, Neighborhood Area Renewal Sydhavnen	Interviews

Appendix 2 Best practices for visions, experiments and learning

Appendix 2 presents best practices for visions, experiments and learning.

Visions			
	Formulating Guiding Principles	**Creating the Vision**	**Operationalization Strategic Objectives**
Process			
	Have core values of participants been negotiated and formulated into principles that guide will future developments?	Have the storylines and images of the future systems been captured, as seen by process participants and broader audience?	Have the guiding principles been collectively translated into performance indicators and embedded into a monitoring process?
Content			
	Has the list of guiding principles been embedded in the vision-building process and formalized as a base of the broader vision?	Has a comprehensive vision been developed, and does it synthesize varied representations of the future, themes and images? Does the vision transcend beyond the group that created it and is it relevant in specific context?	Has a suite of strategic objectives been formulated and is it focused on the values that are represented in the guiding principles and the vision description? Are the indicators meaningful and have constructive impact on achievement of objectives? Have definitions of actions and strategies been developed? Have the criteria for prioritization of strategies been developed?
Context			
	Have the pre-existing guiding principles and local values been considered? Have existing initiatives developed by local partners been recognized and considered? Did the participant have a choice to build new visions from scratch or start with pre-existing initiatives? Have additional external guiding principles been considered (e.g. C40, UN SDG's or TM literature)?	Has an actor analysis been developed? (e.g. stakeholder and stakeholder transition attitude mapping) Has a system analysis been developed? (e.g. baseline performance assessment) Have already existing visions and narratives been considered and used to trigger new discussions? Has a variety of actors been engaged, especially those with opposing views and different knowledge?	Have pre-existing indicators been considered and incorporated if fit? Have the existing policies been reviewed (individually and in a holistic and integrated way) to seek pre-existing objectives, strategies and indicators?

Source: Adapted from (Bosch-Ohlenschlager, 2010, p. 77)

Experiments and learning			
	Deepening	**Broadening**	**Scaling-up**
Process			
Budget and planning	Allocate resources (time, money, knowledge, etc.) to learning process	Allocate resources to interaction with partners	Allocate resources to an early involvement of strategic actors
Learning in the process	Allocate resources for reflection on and adjustment of the vision and learning goals	Allocate resources for reflection on the connection to the broader context	Allocate resources for strategic reflection on barriers and opportunities in dominant ways of thinking, doing and organizing
Learning quality	Focus on organizing a broad, reflexive and social learning process	Focus on how experiments can reinforce each other	Focus on how learning experiences can be embedded in dominant ways of thinking, doing and organizing
Accountability mechanisms	Develop incentives and accountability mechanisms that increase the quality of learning	Develop incentives and accountability mechanisms that stimulate interaction with other domains and partners	Develop incentives and accountability mechanisms that stimulate feeding back results to key actors at a strategic level
Competences of participants	Select project open minded participants who are willing to learn	Seek participants who can look outside of their discipline and are strong 'connectors'	Seek participants who are good communicators and have capacity to 'anchor' project results at a strategic level;
Strategic management	Continuously align project management and results to the societal challenge	Continuously use management to catalyze interaction with other domains and partners	Through ongoing management, strengthen connection to key actors and developments at strategic level
Content			
Vision alignment	Develop a shared long-term sustainability vision with project participants	Develop an overarching sustainability vision to provide guidance to different experiments	Develop a project or partnership sustainability vision at a strategic level
Learning goals	Formulate explicit learning goals with regard to desired (interrelated) changes in culture, practices and structure;	Define new functions and learning goals for repeating the experiment in other contexts	Develop learning goals that include barriers and opportunities in dominant culture, practices and structure
Intended results	Collectively develop generic and context specific results	Share results with other experiments and potential application domains	Stimulate structural (regime) support and resources for results
Context			
Societal challenge alignment	Connect learning project goals explicitly to societal (transition) goals	Cooperate with partners to develop new partnerships and realize shared societal goals	Work to develop collective sense of urgency with regard to societal challenge
System analysis	Evaluate alignment of participants' dominant ways of thinking, doing and organizing in the sector (from which the experiment deviates)	Identify similar experiments and potential new partners, application domains and functions;	Identify key actors with power and willingness to influence dominant culture, practices and structure;

Source: Adapted from (Bosch-Ohlenschlager, 2010, p. 77)

Appendix 3 Analytical framework

Appendix 3 presents the analytical framework used in this research project. The analysis was developed through the list of questions, developed based on the literature review.
Each question is allocated a score in dimensions of visions, experiments, learning and collaborations. 1 indicates that a point available for the area of concept of visions, experiments, learning and/or collaborations apply to the specific question. 0 indicates that no point is available in visions, experiments learning and/or collaborations for that questions. A total of 100 points is available. Final result is represented as a percentage.

Question	**Available score in each TM element**			
	Visions	**Experiments**	**Learning**	**Collaborations**
1. Has an actor analysis been developed? (e.g. stakeholder and stakeholder transition attitude mapping)	1	0	0	1
2. Has a system analysis been developed? (e.g. baseline performance assessment)	1	0	0	0
3. Has there been a participant selection process in place to encourage engagement from those who are open minded and willing to learn?	1	0	0	1
4. Have resources been allocated to an involvement of strategic actors ?	1	0	0	1
5. Have core values of participants been negotiated and formulated into principles that will guide future developments?	1	0	0	1
6. Have the storylines of the future been captured, as seen by process participants and broader audience?	1	0	0	1
7. Have the guiding principles been collectively translated into performance indicators and embedded into a monitoring process?	1	0	0	1
8. Has the list of guiding principles been embedded in the vision-building process and formalized as a base of the broader vision?	1	0	0	0
9. Has a comprehensive vision been developed, and does it synthesize varied representations of the future, themes and images?	1	0	0	1
10. Does the vision transcend beyond the group that created it and is it relevant in specific context?	1	0	0	1
11. Has a suite of strategic objectives been formulated and is it focused on the values that are represented in the guiding principles and the vision description?	1	0	0	0
12. Are the indicators meaningful and have constructive impact on achievement of objectives?	1	0	0	0
13. Have definitions of actions and strategies been developed?	1	0	0	0
14. Have the criteria for prioritization of strategies been developed?	1	0	0	0
15. Have the pre-existing guiding principles and local values been considered?	1	0	0	0
16. Have existing initiatives developed by local partners been recognized and considered?	1	0	0	1
17. Did the participants have a choice to build new visions from scratch or start with pre-existing initiatives?	1	0	0	1
18. Have additional external guiding principles been considered (e.g. C40, UN SDG's or TM literature)?	1	0	0	0
19. Have already existing visions and narratives been considered and used to trigger new discussions?	1	0	0	0
20. Has a variety of actors been engaged, especially those with opposing views and different knowledge?	0	0	0	1
21. Have pre-existing indicators been considered and incorporated if fit?	1	0	0	0
22. Have the existing policies been reviewed (individually and in a holistic and integrated way) to seek pre-existing objectives, strategies and indicators?	1	0	0	0
23. Have resources been allocated to the learning process?	0	1	1	0
24. Have resources been allocated to interaction with partners?	0	1	1	1
25. Have resources been allocated to resources to an involvement of strategic actors (especially early in the process)?	0	1	1	1

26. Have resources been allocated for reflection on and adjustment of the vision and learning goals?	0	1	1	0
27. Have resources been allocated for reflection on the connection to the broader context?	0	1	1	0
28. Have resources been allocated for strategic reflection on barriers and opportunities in current regime (dominant ways of thinking, doing and organizing)?	0	1	1	0
29. Has there been focus on organizing a broad, reflexive and social learning process that?	0	1	1	1
30. Is the distribution of learning equal to relevant stakeholder groups?	0	1	1	1
31. Has there been a focus on understanding how broaden experiments can reinforce each other and create additional alignments and co-benefits?	0	1	0	0
32. Has there been an emphasis on how learning experiences can be embedded in dominant ways of thinking, doing and organizing?	0	0	1	0
33. Have incentives and accountability mechanisms been developed to increase the quality of learning?	0	0	1	0
34. Have incentives and accountability mechanisms been developed to stimulate interaction with other domains and partners?	0	1	0	1
35. Have incentives and accountability mechanisms been developed to feedback results to key actors at a strategic level?	0	1	0	1
36. Has there been a participant selection process in place to encourage engagement from those who are open minded and willing to learn?	0	1	1	1
37. Has there been focus on participants who can look outside of their discipline and are strong 'connectors'?	0	1	0	1
38. Has there been emphasis on participants who are good communicators and have capacity to 'anchor' project results at a strategic level?	0	1	0	1
39. Are there strategies and procedures in place to continuously re-align project management and results to the societal challenge	0	1	0	1
40. Are there strategies and procedures in place to continuously use management to catalyze interaction with other domains and partners?	0	1	0	1
41. Are there strategies and procedures in place to continuously strengthen connection to key actors and developments at strategic level?	0	1	0	1
42. Develop a shared long-term sustainability vision for experiments with project participants	0	1	0	1
43. Is there an overarching sustainability vision to provide guidance to different experiments?	0	1	0	1
44. Develop a project or partnership sustainability vision at a strategic level	0	1	0	1
45. Have explicit learning goals been formulated and do they put emphasis on desired (interrelated) changes in culture, practices and structure?	0	0	1	0
46. Have new functions of experiments been defined and learning goals developed for repeating the experiment in other contexts?	0	1	0	0
47. Develop learning goals that include barriers and opportunities in dominant culture, practices and structure	0	1	1	0
48. Collectively develop generic and context specific results	0	1	1	0
49. Share results with other experiments and potential application domains	0	1	1	1
50. Stimulate structural (regime) support and resources for results	0	1	0	1
51. Have the learning project goals been explicitly connected to societal transition ?	0	1	0	1
52. Has there been cooperation to develop new partnerships and realize shared societal goals?	0	1	1	1
53. Has there been an explicit effort to catalyze collective sense of urgency with regard to societal challenge?	0	1	0	0
54. Has there been an evaluation of alignment of participants' dominant ways of thinking, doing and organizing in the sector (from which experiment deviates)?	0	1	0	1
55. Have similar experiments been identified and with that potential new partners, application domains and functions?	0	1	0	1
56. Have key actors with power and willingness to influence dominant culture, practices and structure been identified?	0	0	0	1
Total available score for each section	**21**	**30**	**16**	**33**
Total available score for all sections	**100**			

Appendix 4 Data collection. Interviews

Appendix 4 presents details of the data collection process, specifically the list of interviews conducted during the research project

Malmö

Interview date	Interview location	Role and department of the interviewee
June 26th, 2019	Espresso House, Lund C	Environmental Building Strategist, Malmöe City Planning Department
July 5th2019	August Palms plats 1, 211 54 Malmö	Fastighets- och gatukontoret - Real Estate and Infrastructure office.
July 17th2019	Skype call	Climate Strategist / Project Manager. Environmental Department.
August 9th 2019	August Palms plats 1, 211 54 Malmö	Architect Strategy Department, City Planning Office
August 9th 2019	August Palms plats 1, 211 54 Malmö	Environmental strategist at the City Building Office
July 2nd 2019	Bergsgatan 17 SE 205 80 Malmö	Energy and climate consultants in the City of Malmö

Copenhagen

Interview date	Interview location	Role and department of the interviewee
July 1st 2019	Ilandbrygge 37, Copenhagen	Neighborhood Manager, Area Renewal Sydhavnen
July 2nd, 2019	Borups Allé 177, D 1.0. 2400 København NV	Head of the Technology Section at the City of Copenhagen, Copenhagen Properties & Purchasing, Energy & Technology
July 3rd, 2019	Njalsgade 13, 5. floor 5025 DK 2300 Copenhagen S	Executive Climate Program Director

Appendix 5 Data collection. Interview questions

Appendix 5 presents the list of questions used during the semi-structured interviews.

Visions (and collaboration)

1. Does your municipality have visions created specifically for achieving energy efficiency in buildings? How ambitious are the documents?
2. How are these visions translated into roadmaps, operational plans and goals? How ambitious are these?
    a. How do you define energy efficient buildings in the visions, roadmaps, goals – what do you want to achieve more precisely?
    b. Do they (visions, roadmaps, goals) include municipal and non-municipal buildings?
    c. What scope of buildings do they cover? New buildings, existing buildings?
    d. Do they set specific time bounded goals?
    e. Can you send me these visions, roadmaps, plans? Are they available o www?

3. What stakeholder groups participate in the design and implementation of such visions, roadmaps, goals (Internal / external/ public)
4. Are such documents used in the process of achieving progress towards energy efficient or net zero energy buildings? How?

Experiments (and collaboration)

5. What types of experiments did your municipality conduct to test approaches to energy efficiency and net zero buildings? – pilot projects, demonstration projects, urban living labs, policy labs?
6. What industry groups, what municipal departments, general public, educational institutions participated in co- design and implementation of these experiments?
7. What are key focus areas for experiments and why (e.g. technology, innovation, behavior change, policy etc.). Can you provide me with a list of all your experimentation projects the last ten years?
    a. Who decides on the priorities and the implementation of those experiments? Are the decisions politically, technically or legally driven?
8. How are the experimentation projects connected to (aligned with) your visions?
9. What are key drivers and barriers to experimentation?
10. What makes these experiments useful and what makes them a failure?
11. When designing experiments, do you develop key performance indicators for them, if so, what type?

Learning (and collaboration)

12. How does your municipality learn from the experiments?
    a. What specific tools (dashboards, reports, evaluations etc.) or processes (meetings, committees) are in place to facilitate learning?
13. Are there formal processes or protocols that capture learning from experiments and inform future governance (policies, visions, etc.) based on the experiments?
14. How/if is the learning shared within the municipality and stakeholder groups?
15. Does the municipality use some specific but also some more general KPIs to evaluate success/failure as well as progress/impact of the experiments?
16. How are the evaluation processes and procedures connected to visions and experiments? Do they inform future development of such documents and if so, how?

Collaborations

1. How does the municipality reach out and engage with stakeholder input?
2. How do municipalities define collaborations?
3. What are the driving factors to collaborations?
4. What is the nature and characteristics of collaborations?
5. How does the municipality reach out and engage with stakeholder input?
6. How are collaborations connected to visions, experiments and learning? (see questions above)
7. Is stakeholder input useful what makes it so and what doesn't?

Overall governance

1. We talked about visions, collaborations, experiments and learning. Do you see any other key governance elements that are necessary for successful transitions?
2. Do you see current pace of transition towards efficient buildings as incremental or radical?
    a. And do you think it's appropriate for your municipality
3. What are three success factors that contribute to successful transition in your municipality
4. What are three key barriers?
5. What is the role of other levels of governments in these projects?

Appendix 6 Data collection. Document analysis

Appendix 6 presents a list of documents analyzed during this research project

Malmö

- Energy Strategy
- Comprehensive Plan
- Climate Action Plan
- Long-term implementation of the 2030 Agenda in the City of Malmö

Copenhagen

- Climate Action Plan
- Climate Action Roadmap 2017-2020
- Community Bases Living Labs South Harbour

Appendix 7 Energy Efficiency roadmap

Appendix 7 presents elements of roadmaps developed for the 2017 – 2020 period in the municipality of Copenhagen.

Overarching initiative	Initiative	Project phase		
		Analysis and Strategy	Test and Demo.	Deployment
Energy Consumption				
Efficient operation and installations	Efficient operation of district heating units		x	x
	Electricity savings by commercial service companies		x	x
	The Copenhagen package for residents		x	x
	Energy Leap – voluntary agreement with large building owners			x
Renovation of building envelopes	Energy savings properties involved in urban renewal project		x	x
	Energy savings in social housing		x	x
	Improvements to properties with low energy label ratings		x	x
	Dialogue when requests are submitted for building renovation			x
Flexible energy use	Data-driven flexibility in buildings			
New areas	Organic solvents	x		
	Space management	x		
City Administration Initiatives				
Municipal buildings	Energy-efficient operations			x
	Energy retrofitting with short payback times		x	x
	Total renovations			x
	New buildings will comply with building class 2020			x
Municipal procurement	Green procurement	x	x	x
	Life-cycle costings when buying products that use energy		x	
	Requirements will be placed on nonroad mobile machinery used in building and construction projects	x	x	
Teaching and outreach	Climate ambassadors			x
	Showroom for climate work	x		x

Source: Adapted from (City of Copenhagen, 2016)

Appendix 8 Experiments' stakeholders

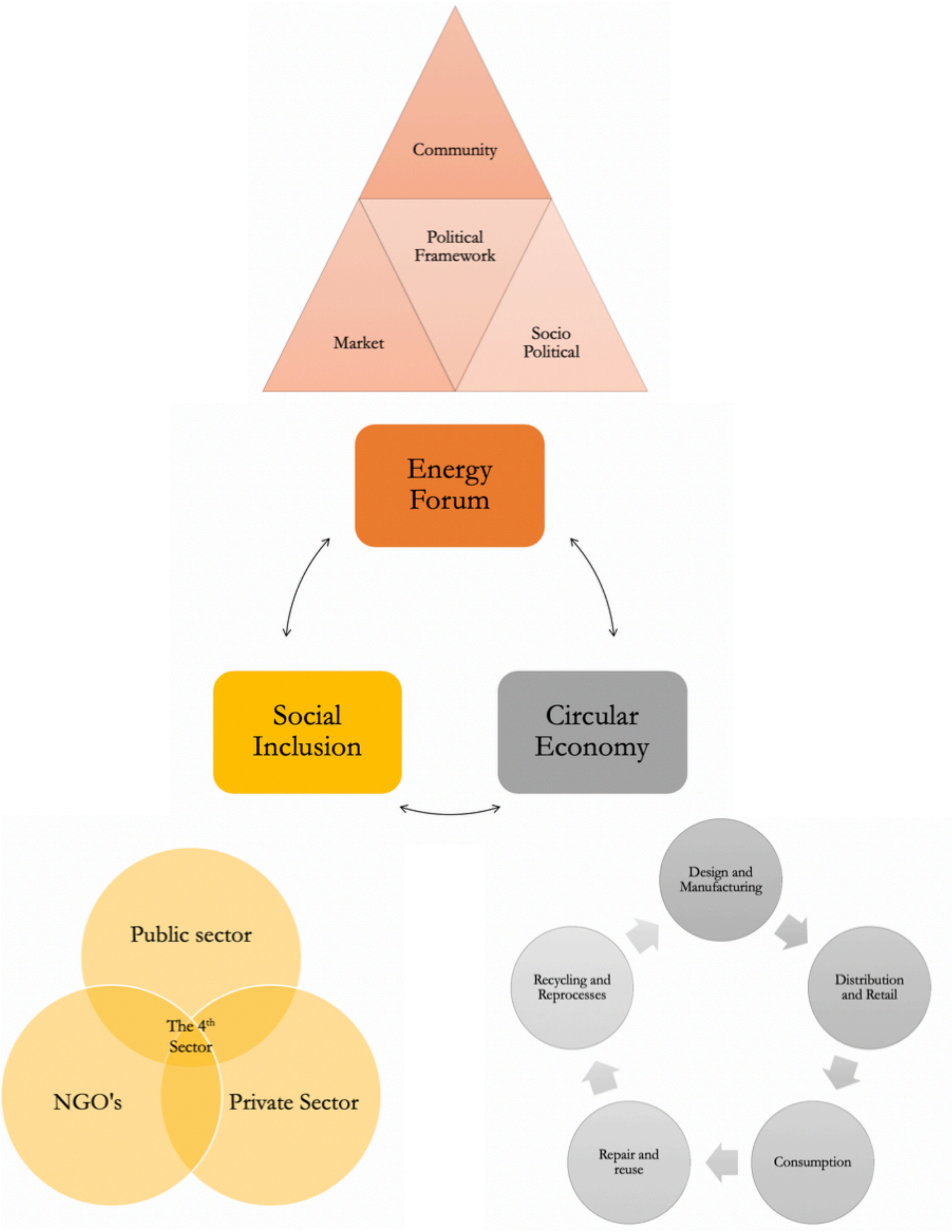
Appendix 8 presents the example of participants involved in the Copenhagen South Harbor IABD project

Element	Academia actors	Community actors	Government actors
Circular economy	Aarhus University Copenhagen Business School Aalborg University	KAB (Social housing association) Naboskab (circular economy consultants) KPH Projects (community of innovative startups and small companies) Zero 3 (an Urban Farming Company) Climate-KIC (public-private innovation partnership) Bygaard (Health food store) Net Repair Bloxhub (community of small & large companies, organizations and researchers) Preserve Copenhagen Guldminen (recclung company) Other local Sydhavns Companies KAB (Social housing association)	City of Copenhagen The Technical and Environmental Association Integrated Urban Renewal South Harbor Employment and Integration Administration Copenhagen Solutions Lab
Energy Forum	University of Copenhagen Aalborg University	KAB (Social housing association)	City of Copenhagen Climate Department Lokaludvalget Kgs. Enghave (community organization) HF Kalvebod The Danish Energy Agency HOFOR (Greater Copenhagen Utility) Radius (Energy District Company)
Social Inclusion and Business Development	Aalborg University	URBinclusion (EU Initiative to reduce urban poverty) Opzoomerne (emploment association) Kvartershuset (local community association)	City of Copenhagen The Technical and Environmental Association Integrated Urban Renewal South Harbor Employment and Integration Administration

Source: Adapted from (Aalborg University and the City of Copenhagen, 2018)

Appendix 9 Ecosystem approach to experiments

Appendix 9 presents the Interrelated Ecosystem approach to experiments in the Copenhagen South Harbor urban living labs



Source: Adapted from (Aalborg University and the City of Copenhagen, 2018)

Appendix 10 Experiments vs projects

Appendix 10 presents key differences between experiments and innovative projects.

	Innovation experiment	**Transition experiment**
Starting point	Possible solution	Societal challenge
Nature of the problem	Pre-defined and structured	Uncertain, complex, defined through participatory process
Objective	Find an innovative solution	Contribution to transition understood as a fundamental change in structure, culture and practices
Perspective	Short and medium term	Medium and long-term
Method	Testing and demonstration	Exploring, searching and learning
Learning	1st order, single domain and individual	2nd order (reflexive), multiple domains (broad), and collective (societal learning)
Actors	Specialized staff (researchers, engineers, etc.)	Multi-actor alliance (across society)
Experiment context	Partly controlled context	Real life, societal context
Manasgement context	Project managemnt focused on project goals	Transition management, focused on societal transition goals

Source: Developed based on (Bosch-Ohlenschlager, 2010, p. 63)