Status, Challenges, and Possibilities of Aalborg's Renewable Energy Transition

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Master Thesis

Cities and Sustainability

Urban, Energy and Environmental Planning

Aalborg University

2024

AALBORG UNIVERSITY

STUDENT REPORT

Department of Planning

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http://www.plan.aau.dk/

Title:

Status, Challenges, and Possibilities of Aalborg's Renewable Energy Transition

Semester:

4th semester, master thesis

Project period:

01.02.2024.-18.06.2024.

ECTS:

30

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Characters: 187 400

Pages: 93

Annexes: A, B, C

Abstract: The global push for renewable energy necessitates transforming energy systems, demanding infrastructure, technology, and governance changes. This thesis examines Aalborg, Denmark, as a case study to explore the challenges and opportunities for a transformation towards renewable energy. We propose a method for Aalborg to integrate Ectogrid, a novel district heating technology, as part of its upcoming energy system update. Through a multi-level governance analysis, we investigate the governmental and institutional framework shaping ongoing and future developments and the challenges that the city has been experiencing in its transition. This case study identifies a focus area within Aalborg that is suitable for an experimental pilot project aimed at accelerating the city's renewable energy transition and electrification. A key challenge lies in Denmark's existing fossil fuel-dependent infrastructure, institutions, and limited renewable energy legislation. These factors, combined with a high degree of privatization, restrict the municipality's role in energy planning. Addressing these challenges is crucial for enabling Ectogrid's integration and fostering a sustainable energy future for Aalborg.

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SUMMARY

In recent years, the energy sector has undergone significant transformation due to climate change and the energy crisis, leading to a shift from heavily fossil-dependent systems to renewable energy sources. This transition necessitates a radical change in physical infrastructure, technology, as well as the planning and governance of energy across various levels of government.

This thesis aims to examine the challenges and opportunities in Danish energy planning, with a specific focus on Aalborg municipality and city as a case study. The goal is to propose a method for Aalborg to integrate Ectogrid as an additional layer in the city's district heating system, aligning with the forthcoming update. The methodology involves document analysis, semi-structured interviews with pertinent stakeholders in the energy sector in Aalborg and Ectogrid. Through a comprehensive multi-level governance mapping as well as a through, multi-scale investigation into various urban characteristics, a case study of Aalborg was created. Further investigations outlined a focus area portraying crucial features and suitable for an experimental pilot project, aiming to enhance the city's renewable energy transition as well as the electrification of the energy sector.

A major challenge lies in the entrenched nature of both the physical and legislative systems in Denmark, which have been designed around and for the use of fossil fuels, making it challenging to transition to new energy systems and technologies. Additionally, the lack of renewable energy-enforcing legislations, combined with Denmark's high degree of privatization, has limited the municipality's role in energy planning to that of a facilitator. Addressing these challenges is essential for enabling the integration of Ectogrid and advancing sustainable energy planning in Aalborg.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIXES

ABBREVIATIONS

3GDH	3rd Generation District Heating
4GDH	4th Generation District Heating
5GDH	5th Generation District Heating
AME	Agreements about the Municipalities Economics
CCS	Carbon Capture and Storage
DH	District Heating
EC	Energy Crisis
EU	European Union
GHG	Greenhouse Gas
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
kWh	Kilowatt-hours
MLG	Multi-Level Governance
OECD	Organisation for Economic Co-operation and Development
PJ	Petajoules
PV	Photovoltaic
RE	Renewable Energy
RES	Renewable Energy Source(s)
RET	Renewable Energy Transition
RQ	Research Question
SRQ	Sub-Research Question
TWh	Terawatt-hour
SUP	Strategic Urban Planning

ACKNOWLEDGMENTS

We are extremely grate for the unwavering support and guidance of our supervisor, Furqan Asif, throughout my master's program. Their expertise and patience have been invaluable, playing a pivotal role in the success of this thesis. We are also thankful for our co – supervisor, Henrik Lund, who was ready to talk, listen and give valuable feedback when we needed it.

We also want to thank the people who agreed to agree to be interviewed as their insight and expertise was instrumental for our thesis. So, we would like to say thank you to Mats Carselid, Jørgen Lindgaard Olesen, Silas Alvin Hupfeld, Cecilie Overgaard Jensen and Peter Serup

And lastly a heartfelt thank you to our friends and family who have supported us and helped us throughout the whole thesis.

1 INTRODUCTION

Responding to the climate crisis and aligning its ambitions with various international and European Union (EU) initiatives (e.g., IPCC reports, Paris Agreement), Denmark has set out to transition its energy sector to renewables to become a self-sufficient and net-zero nation by 2050. As stated in the legally binding Climate Act, adopted by the Danish Parliament in 2020, Denmark must achieve to be a climate-neutral society by 2050 at the latest, keeping in mind the Paris Agreement's goal to limit global warming (Lov om Klima, 2020). Essentially, the government's ambition is to create a carbon-neutral energy sector that relies on a combination of renewable energy (RE), coal, and biomass while incorporating CCS technologies (Regeringen, 2020). However, the reliance on non-renewable resources as primary energy sources and cities' dependence on exports for heating and cooling presents a significant challenge to energy sustainability, particularly since fossil fuels remain the principal energy producers and account for the largest share of energy sources (Ritchie & Rosado, 2020). Addressing the issue of fossil fuel dependency, Denmark aims to phase out fossil fuels by mid-century (State of Green, Energy transition, 2022).

The more significant milestones in Denmark's journey over the past decade, include the continuous actions taken to increase renewable energy supply and capacity (e.g., offshore wind power). As a result, in 2020, the solar and wind power generated was equivalent to 50% of the gross electricity consumption (Green Solutions, u.d.); (State of Green, 2021). Furthermore, according to projections, RE will cover 100% of the electricity consumption by 2028, and 58% of the overall energy consumption in 2030 (State of Green, 2021).

However, based on the latest IPCC reports, adjustments to the transition are highly expected, accompanied by drastic and immediate changes in the energy sector. The report foreshadows a higher global warming than predicted, consequently raising the risks (IPCC, 2023). According to the projections, the global energy transition is off-track, current policies are unsatisfactory to reach climate neutrality, and the energy system "will require substantial changes" over the next 30 years ((Clarke, 2023); (IPCC, 2023). While it is acknowledged, that different countries will have different approaches to the transition, some common factors can be expected: "widespread electrification", increased energy efficiency, "use of alternative energy carriers", renewable dependent energy systems and CO2 removal (Clarke, 2023).

Therefore, despite Denmark's significant progress in the adoption of renewable energy technologies, numerous barriers persist. These challenges range from policy and regulatory barriers to technological limitations and financial constraints. Overcoming these obstacles is crucial to accelerating the transition to a RE future and achieving climate goals.

The purpose of the thesis is twofold. Firstly, with the application of a multi-level governance analysis, the thesis aims to provide an overview of the governmental background, focusing on the policy and regulatory aspects and additionally highlighting the various stakeholders and interests, that helped accelerate the decarbonisation of Denmark and have the power to influence the future changes. Secondly, based on a case study of Aalborg and through an academic exploration, the thesis delves into the status of the renewable energy transition (RET), while also exploring the institutional dynamics and the physical-, and technological challenges that may hinder the city's progress, as well as the vast possibilities that may lie ahead. By understanding these dynamics and the, we can pave the way for a sustainable energy future that benefits both present and future generations.

1.1 Climate and Energy Crisis

The climate and energy crises are intertwined global concerns that demand immediate attention and coordinated action (ESABCC, 2023). The transition to RE is a pivotal element in addressing the demand, necessitating a fundamental shift in the energy system, driven by the urgent need to limit global warming and reduce greenhouse gases (GHG) emissions. Shifting to renewables has become a focal point, partnered with the need, to be self-sufficient and not dependent on imports and subsequently, to mitigate the global climate and energy crises (IPCC, 2023) (IRENA, 2023)

The climate crisis, driven primarily by human activities, is characterized by a significant imbalance in the Earth's energy balance, with the most significant contributor being the increasing carbon emissions, mainly due to the fossil fuel dependency (IPCC, 2014). According to IRENA, the RET is off-track and in order to stay on course in successfully mitigating the climate crisis, the energy sector's rapid adjustment is crucial on various scales (IRENA, 2023).

The energy crisis (EC) refers to a "significant shortage in energy supply" to a region or a country "at a specific time" and "in a specific place". The shortage is often due to factors such as resource depletion, natural disasters, market manipulation, increased demand, or political conflicts (e.g., the 1970s oil crisis; the gas crisis following Russia's attack on Ukraine) (Knowinsiders, 2022).

The latest political aggression resulted in shortened energy supplies between Russia and the EU, which worsened the EC, resulting in a significant rise in energy prices, threatening the economic sustainability of European businesses and the cost of living for citizens. The crisis has also highlighted the need for a structural approach to address the root causes (e.g., lack of self-sufficiency) rather than relying on external energy sources to reduce prices (ESABCC, 2023).

The scientific consensus is clear: the net effect of feedback processes amplifies warming (Figure 1), the transitioning is behind and if no technological or policy changes are made immediately to mitigate

emissions, further warming, and consequently, increasing threats are to be expected in the century (IPCC, 2023).

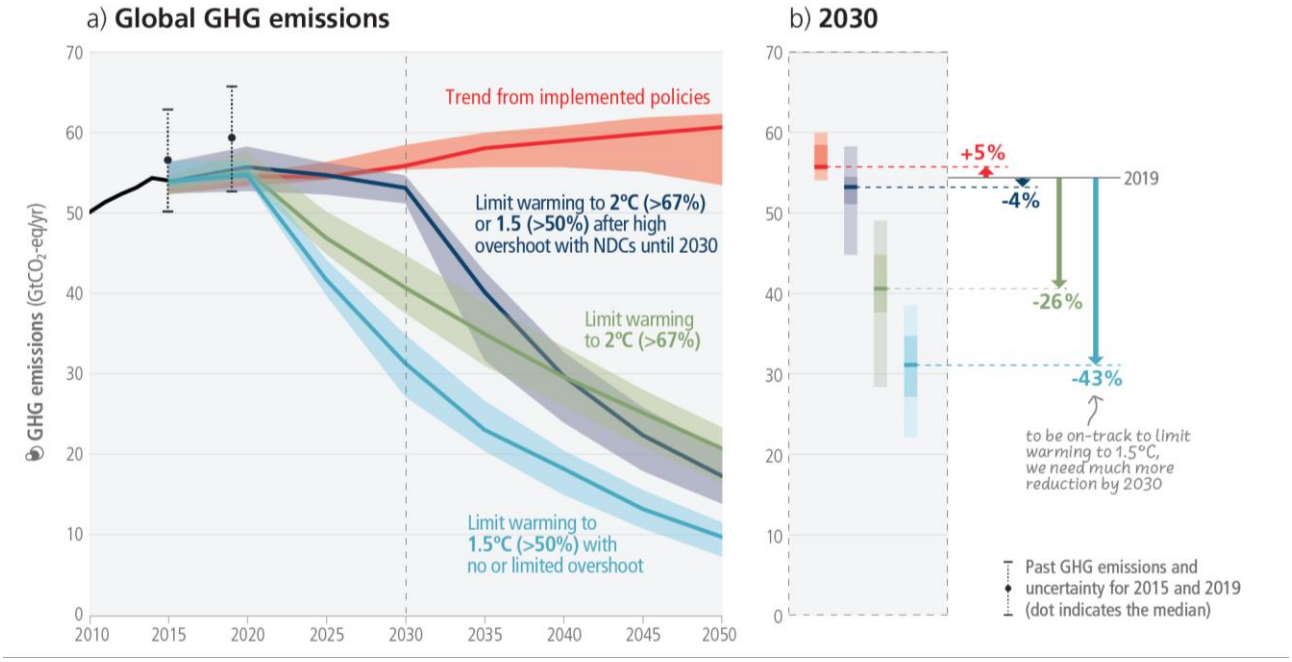


Figure 1 – The likeliness of exceeding 1.5 ˚C pathway and the threat of increasing warming after 2030. A: Global GHG emissions of modelled pathway, B: projected emission outcomes from near-term policy assessments for 2030 (IPCC, 2023).

Therefore, policymakers must focus on reducing energy demand through technical and non-technical approaches, such as energy efficiency and behavioural changes, and increasing the supply of secure, domestic, and low-carbon energy sources. This includes ensuring a stable investment framework, simplifying permitting procedures, and strengthening the energy grid, flexibility, and storage capacities (ESABCC, 2023).

Moreover, EU and national policies should foster the electrification of energy end-use sectors and align price signals with climate objectives by pricing carbon emissions from all fossil fuels. The current energy crisis can also expedite the deployment of cleaner, sustainable renewable energy sources (e.g., wind and solar), akin to how the 1970s oil crisis propelled significant advances in RE and energy efficiency (IEA, u.d.).

In summary, the climate and EC are pressing global issues that require a multifaceted approach to address their root causes. By reducing energy demand, increasing low-carbon energy supply, and aligning price signals with climate objectives, we can mitigate the impacts of both crises and transition towards a more sustainable future.

1.2 Background on How the Ambitious Goal Came to Be

Upon creating the Paris Agreement in 2015, the shared, legally binding, international commitment to pursue efforts to limit global warming rise to 1.5 ˚C by 2050 was established (UNFCCC, 2015). Subsequently, IRENA presented a pathway to achieve this ambition, which relies on electrification and energy efficiency as crucial drivers to decarbonization, enabled by renewables and green hydrogen, thus advancing the transition to green energy ((IRENA, 2021). Considering the events of recent years and other historical milestones (e.g., COVID19, Russia-Ukraine war), as well as the following consequences that deeply impacted the energy sector, the EU set the overachieving goal to become the first climate neutral continent on Earth (European Green Deal, 2021). Additionally, the EU established the legally binding target to reduce GHG emissions and to reach net-zero by 2050 (European Climate Law, 2021). Hence, the energy sector's shift towards renewable and sustainable solutions are unavoidable, thus ending the fossil fuel era.

It was found, that accelerating the deployment of renewables is crucial to meet the climate goals stated in the Paris Agreement and to achieve net zero emissions by 2050 (Renewable Energy Transition, 2024). The reason behind placing renewables into the focal point, among other things, is due to the potential in creating a sustainable and net-zero system, as well as the property to simultaneously deal with issues, such as energy security, energy affordability, the climate mitigation, and decarbonization. Through the RET, the main ambition is to reduce the overdependence on fossil fuels (Figure 2; Figure 3), to reduce imports and increase exports, to increase energy efficiency and to mitigate the environmental impacts (Renewable Energy Transition, 2024).

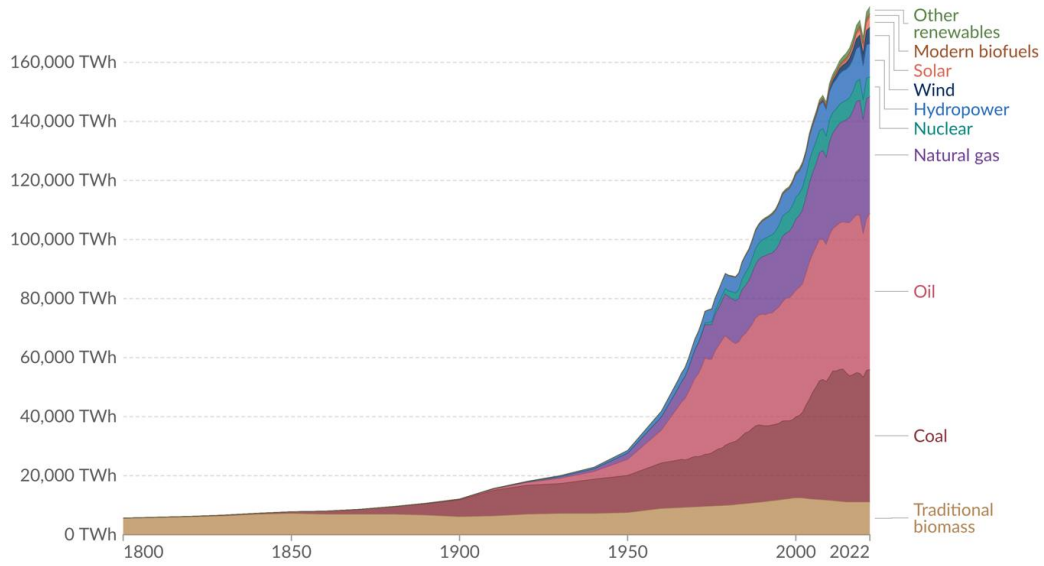


Figure 2 – Global primary energy consumption by source and measured in terawatt-hours (TWh). The figure shows the ruling dominance of fossil fuels in hand with the increasing trend of renewable energy sources (RES) (Ritchie & Rosado, 2020).

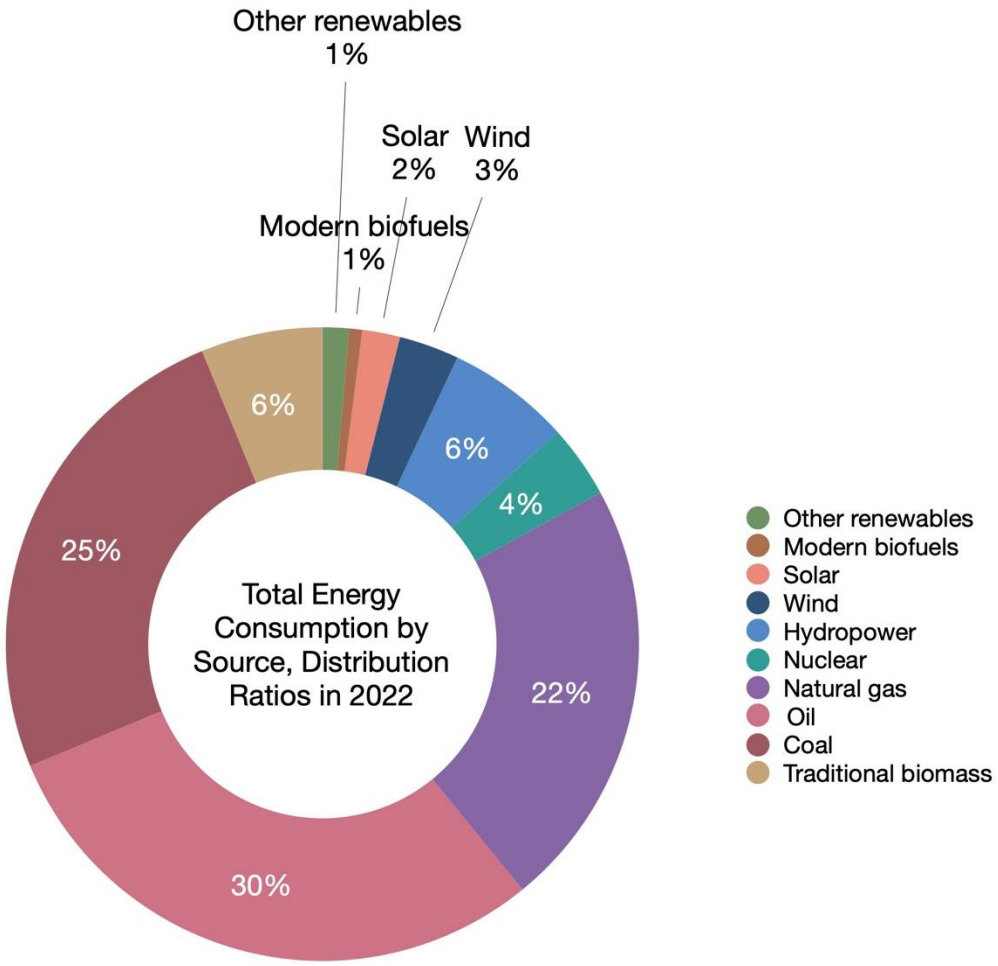


Figure 3 – Total of global primary energy consumption by source and measured in terawatt-hours (TWh). The figure shows the distribution of the various energy sources, for the year of 2022. Based on data retrieved from Ritchie & Rosado, 2020.

Despite the past decade's progress in the transition (e.g., increased renewable based electricity capacity), further changes are crucial in order to achieve a climate neutral future. In recent years, more and more reports surfaced, establishing the need for the energy sector, to take radical and immediate actions, as soon as possible, stating that failing to do so will potentially further perpetuate the existing risks and negatively influence RET and consequently, the climate crisis (IRENA, 2023).

The latest report from IPCC puts into words the importance of acting on the climate crisis as soon as possible. The report predicts a temperature increase higher and earlier than previously expected, which highlights the seriousness of the matter (IPCC, 2023)

1.3 Denmark's Energy Transition

"*The technological transformation of Denmark's energy system is fast and visible, notably in electricity with offshore wind, biomethane, district heating, and carbon capture and storage (CCS) development*" (IEA, 2023a).

In 2020, the Danish Parliament enacted the *'Lov om Klima'* (Climate Act) stating the target to reduce the GHG emissions by 70% (reference year: 1990) until 2030 and to accomplish climate neutrality by mid-century (Lov om Klima, 2020). Responding to the ambition to become a lead figure in Europe's RET, the Danish government proposed to push the climate neutrality goal to 2045 and to achieve 110% GHG emissions reduction by 2050. Given Russia's invasion of Ukraine and the ensuing consequences, Denmark has intensified its efforts to phase out fossil fuels and accelerate RE deployment (Figure 4). In accordance with a national agreement, all sectors will be operated on 100% green gas by 2035 and natural gas for heating purposes will be eliminated (e.g., household heating). Henceforward, as a mid-term goal (2030), Denmark aims to increase offshore wind generation by seven times and onshore wind by four (IEA, 2023a).

Denmark's sustained progress in reducing carbon emissions underscores the need for a significant transition from fossil fuels to renewable energy sources to achieve the target reduction by 2030 (The Danish Government's Climate Partnerships, Energy and Utilities Sector, 2020). This highlights the pressing urgency for a comprehensive shift to renewable energy in order to meet ambitious carbon reduction goals.

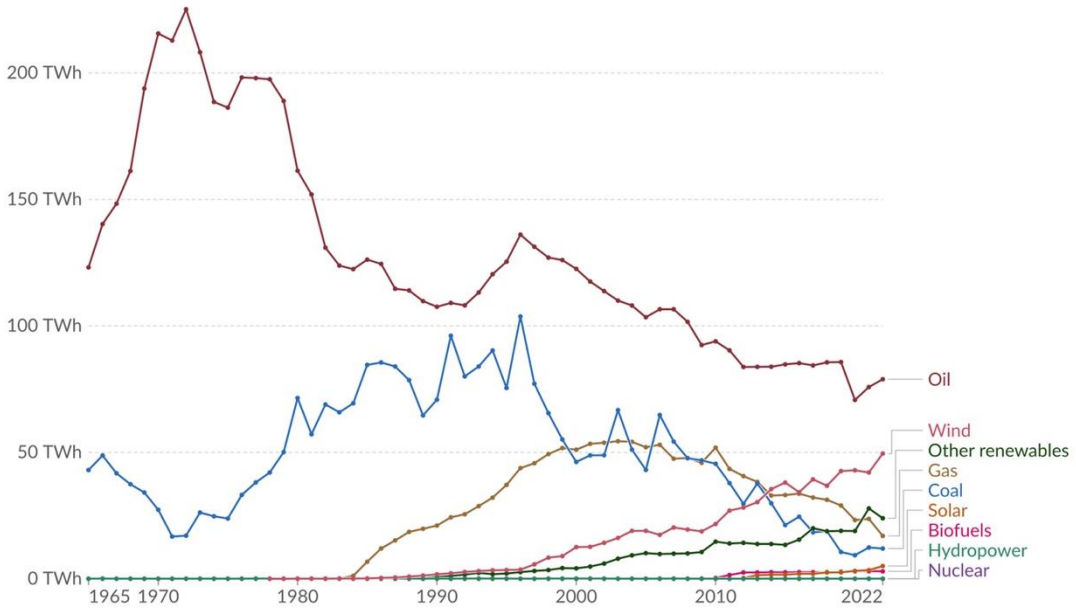


Figure 4 - Denmark's changing consumption levels by source (Ritchie & Rosado, 2020).

1.4 Denmark's Progress with Renewables

The following sections rely on the data found in the recent energy policy review of Denmark, (IEA, 2023a), as well as the '*Energy Mix*' article (Ritchie & Rosado, 2020).

Denmark is a frontrunner in utilizing various RE sources, including wind, solar, bioenergy, geothermal, and hydropower. However, the country 's energy demand remains highly dependent on fossil fuels, indicating the usage of oil, coal, and gas as primary sources. Reason behind the dependency originates mainly from the industrial, transportation and commercial sectors (e.g., heavy industry and transportation, power plants, aviation, shipments). On a positive note, the country's wind energy production has reached impressive levels due to its unique geographical features, such as terrain and coastal proximity. The growing supply of renewable energy sources (RES) indicate a significant potential for further growth. What sets Denmark apart from other countries is its ability to balance high and low consumption levels (Figure 5).

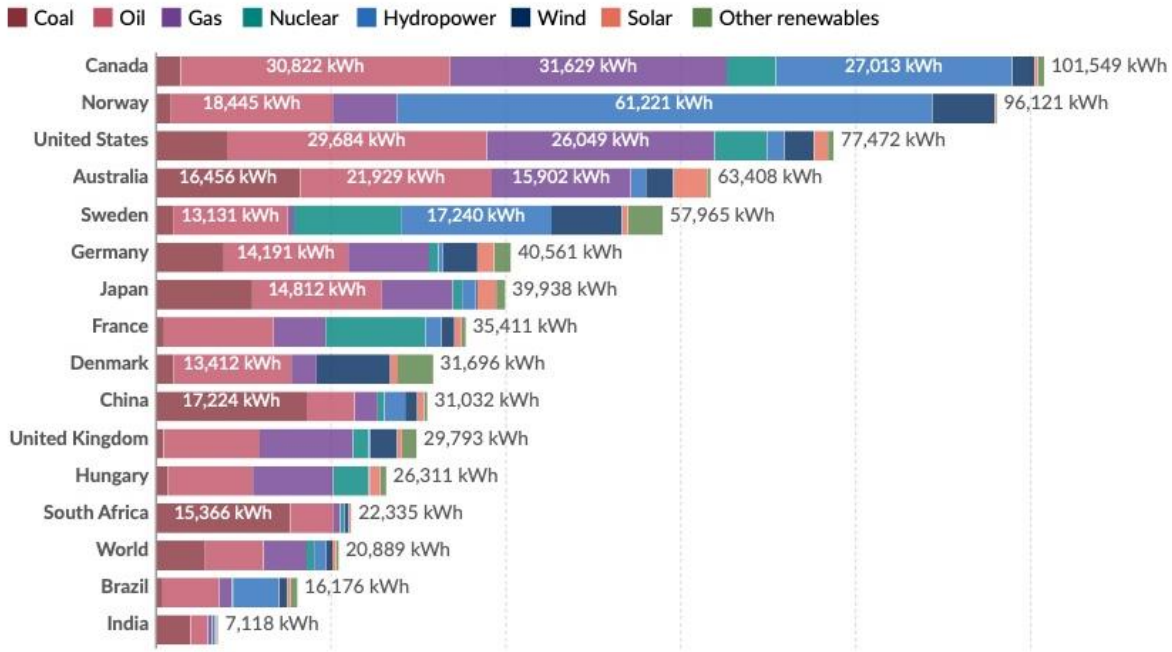


Figure 5 - Per capita primary energy consumption by source, where the energy is measured in kWh/person (Ritchie & Rosado, 2020).

Wind power is notably strong in the country, as it produces double the amount of energy compared to the runner-up of the industrialized OECD countries (Pioneers of Clean Energy, n.d.). One of the nation's ambitions is to significantly expand the on- and offshore wind and solar electricity generation, aiming to quadruple generation rates by 2030. Depending on the progress of the energy transition in Europe, this would mean a considerable step towards the country's goal of reaching 12.9 GW and 35 GW of offshore wind production by 2050 (IEA, 2023a). Regrettably, certain developments have

encountered delays in their implementation. Specifically, no onshore wind turbines were installed, and the commissioning of offshore wind developments on energy islands has been postponed until after 2030.

The Danish total energy source (TES) levels and year-by-year shifts were significantly impacted by global events and initiatives such as climate goals, the COVID-19 pandemic, and the Russian-Ukrainian war (Figure 6). The impact is reflected through the slight dynamic change in energy sources, between 2005 and 2022. While the share of fossil fuels shows a 22% decrease, the share of RES shows an increasing trend. This has resulted in a 14% growth in bioenergy and waste, as well as a 4% increase in variable renewables. However, oil remains a primary TES contributor, with a share of 36%. (IEA, 2023a).

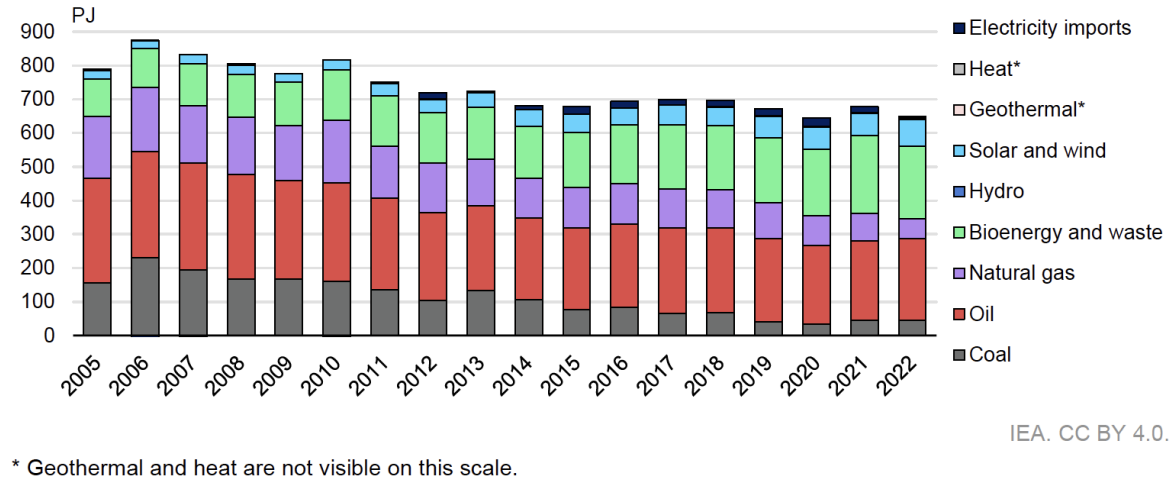
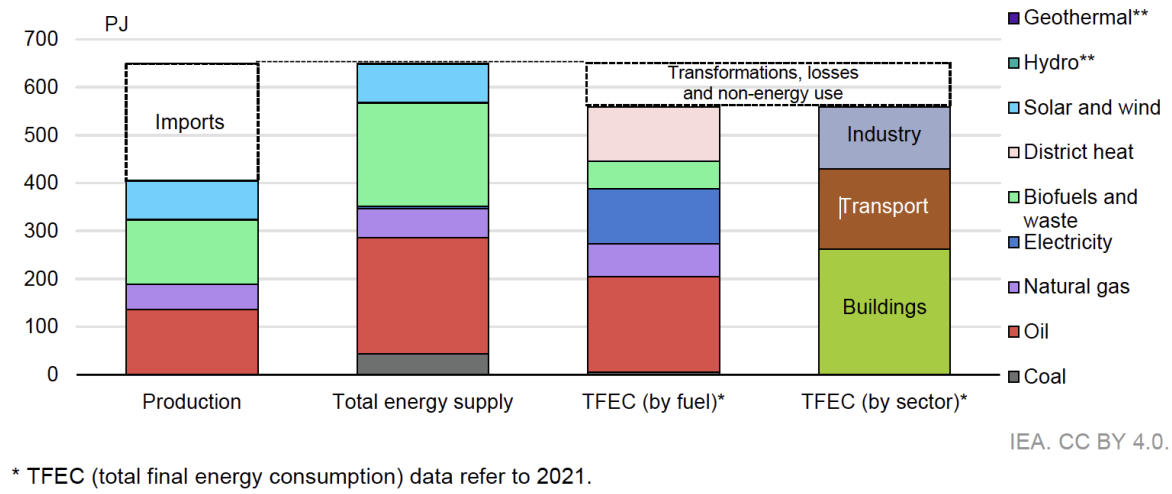


Figure 6 - Danish TES by source between 2005 and 2022 (IEA, 2023a).

Based on 2022 data, the TES largely depended on imported energy (40%) sourced from external suppliers using fossil fuels and biomass (Figure 7). In terms of domestic energy production, the primary source was derived from oil (137 PJ), closely followed by bioenergy and waste (133 PJ), solar and wind (79 PJ), and natural gas (52 PJ). Hydro and geothermal production had the lowest energy yields (0.07 PJ and 0.08 PJ, respectively). Notably, when comparing to earlier years, we can perceive significant shifts in energy production. Oil and gas production have decreased by 68% and 76%, respectively, while bioenergy and waste have seen a 33% increase, and solar and wind power have shown a remarkable 107% increase (IEA, 2023a).



* TFEC (total final energy consumption) data refer to 2021.

Figure 7 - Overview of the Danish energy production, supply, and demand (IEA, 2023a).

Given the anticipated electrification trend in Europe and Denmark's commitment to increasing renewable energy sources to achieve a climate-neutral society, it is reasonable to expect that Denmark's position in the energy market will evolve from being a net importer of electricity to becoming a net exporter over time (IEA, 2023a).

1.5 Problem Formulation

As cities confront the escalating challenges of climate change, the need to adapt to urban environments has risen to a critical priority. The alarming emissions rate from human activities, particularly heat and electricity production, is exacerbating global GHG concentrations. Denmark, in a bid to achieve carbon neutrality by 2050, has set ambitious climate laws, aiming for a 70% reduction in GHG emissions by 2030. However, it is now evident from IPCC and IRENA projections that to effectively combat the climate and energy crisis, Denmark must embrace drastic, immediate, and rapid measures and actions in its energy transition. As fossil fuel dependency diminishes, a new era of electrification, RES, and sustainable solutions is on the horizon.

Within the context of strategic energy planning, and RET, one of the biggest challenges lie in overcoming the gap between the energy planning and the integration of innovative solutions into the existing infrastructure and institutional framework. A city-scale integration would require drastic changes in the physical infrastructure, that is partnered with not only the concerns regarding financing developments, but it would also take long time to successfully achieve full integration.

Under the scope of the semester project, the thesis focuses on the RET and its relation to Aalborg. The report investigates the governmental and institutional framework shaping ongoing and future developments, the different actors and interests that influence decision making, as well as the challenges that the city has been experiencing in its transition. Furthermore, taking into account the strengths and opportunities of the city, the thesis aims to explore the potentials for future developments. A multi-level governmental analysis coupled with a short case study of Aalborg city in Northern Denmark offers insights into the 'status, challenges and potential' of adjusting existing systems and infrastructures towards a net-zero and climate-neutral society. By addressing these critical issues, the study aims to contribute to the local and national ambitions to reach climate neutrality by 2050 and consequently, it aims to provide a perspective for other cities on how to progress in the renewable energy transition.

1.6 Research Design

To investigate the problem stated before, the following research question (RQ) has been developed to better understand the status, challenges, and potentials in the Aalborg's Renewable Energy Transition (RET).

"What is Aalborg's position in the renewable energy transition and how can the city adjust to achieve the ambitious goal of becoming climate neutral by 2050?

The RQ is explored through three sub-research questions (SRQ) that aim to aid in answering the main question.

SRQ1: What is the status quo in the city's energy planning and what are the institutional dynamics leading the change?

Through a document analysis, the first SRQ aims to explore the current energy system, the existing and future plans, regarding the RET and the governmental, institutional background, including the different stakeholders and their interests.

SRQ2: What are the challenges that the city has been facing so far and what are the plans to negate?

Utilizing qualitative data collected from semi structured interviews and document analysis, the second SRQ dives into the main barriers that Aalborg has been facing in its RET and the threats that have the power to hinder future progresses.

SRQ3: What are the potentials hidden in the city and what technological possibilities could be utilized to adjust?

The third SRQ explores the potentials in the existing infrastructure as well as the possibilities offered by technological innovation.

Based on the research question, a research design has been created to support the research process and outline its foundation.

2 CONCEPTUAL FRAMEWORK

This chapter describes the conceptual framework applied in the context of the research, which accompanied by the preliminary analyses, forms the foundation of the research design and the following studies. It includes aiding points for interpreting the results and application under the project's scope.

2.1 RENEWABLE ENERGY TRANSITION

According to assessments from IPCC, the transitions away from fossil fuel sourced energy is off-track and need drastic and immediate changes (Irena, 2023). The shift away from carbon intensive technologies towards RE is complex as the is a major interdependence between sectors as well at the institutional level. Different frameworks can help guide the RE transition by identifying patterns path dependencies which hinders the transition.

This thesis has chosen to blend two frameworks together due to their similarity and to fill in possible gaps that utilising one or the other might present. These frameworks are renewable energy transition (RET), mainly featured in IRENA's report *World Energy Transition Outlook 2023* (Irena, 2023) and carbon lock-in, first coined in 1999 by Greogory C. Unruh in his doctoral thesis *Escaping Carbin Lock-in* (Unruh, 2002) which has since gained popularity in the climate change policy debate.

Both frameworks categorize the issue with carbon and GHG emission into three dimensions (Table 1)

Table 1 - Comparison of carbon lock-in types and renewable energy transition, set up in the same order as the literature presented it.

Carbon Lock-in	Renewable Energy Transition
Infrastructural and technological	Physical infrastructure
Institutional	Policy and regulatory enablers
Behavioural	Skills and capacity

The frameworks also have alike aims of identifying the entrenched barriers that stem from the systems that has so far been geared towards fossil based energy, and find ways to progress towards a low carbon / carbon neutral future (Irena, 2023), (Seto, et al., 2016).

2.1.1 Physical infrastructure and technology

This dimension is concerned with the physical infrastructure which can present as a barrier or lock-in due its very nature. The physical infrastructure e.g. the buildings, the facilities (such as coal power plants), pipes, cables, streets etc. As these structures are built to last often decades, it can make it difficult and costly to transition to another system, such as from fossil fuel based energy to renewable based energy (Seto, et al., 2016). In other words, the physical infrastructure, and often technologies, are dictates the energy production of the future.

In the RET framework, the solutions for the instructional lock-ins are, among others, to provide incentives RE infrastructure, set mandatory targets for new or renovated buildings and to provide public finance for developing RE infrastructure (Irena, 2023).

2.1.2 Institutional

This dimension deals with the institutional lock-ins that arises from decisions taken deliberately by powerful, economic, social and political actors (Seto, et al., 2016). The actors who benefit most from the status quo of the existing energy infrastructure will push for policies and regulations that further their interests, which in turn often will expand their resource, economic and political dominance which allows them to shape the institutions to their benefit. It is made clear in carbon lock-in framework that these institutional features are always intentional and not an unintended side effect (Unruh, 2002). These institutional lock-ins are often designed to create feedback loops, thus reinforcing the policies, making them resistant to change (Seto, et al., 2016).

A change or transition from the status quo of an institutional lock-in is more likely to happen if the conditions increase the institutional flexibility, creating windows of opportunity in which actors can promote and push for carbon reducing policies and regulations (Seto, et al., 2016). A Danish example of this is the oil crises in the 1970s which caused the government to seriously start investing in alternative energy sources (Farbøl, Sørensen, & Olesen, 2018).

The RET framework outlines the issue of lack of policies and regulations that support, financially or otherwise, the development of RE but also that they are still shaped around fossil fuel (Irena, 2023). For the RE transition to happen there must be changes to the institution on all the levels of government, from local to global (Irena, 2023).

2.1.3 Behavioural and Skills

The third dimension is where the two frameworks differ the most, although they are still quite similar. This dimension is concerned with people and individuals on the local level. Carbon lock-in focuses on the behavioural patterns which drive and locks-in the fossil dependent energy system (Seto, et al.,

2016). RETs focus is on spreading awareness and educating people in order for them to be part of the transition, either via skills in the workplace or in pushing for a RE transition (Irena, 2023). Carbon lock-in also recognises the need for educating the people as this is major predictors of an individual regarding the climate change as a genuine threat and thus needs action (Seto, et al., 2016).

In Denmark, where the physical planning and implementation is characterized by a high degree of voluntary action, it is important to have the locals, if not support, at least not their ire and this is best accomplished by them understanding the necessity of a transition to RE. More than that, working towards a carbon free society will need for behavioural changes with the individual.

2.1.4 Why these frameworks?

By combining the two frameworks of RET and carbon lock-in, it allows the RE focus of the RET framework with the more established vocabulary and wider focus of the carbon lock-in framework.

For the most part, the thesis' analysis revolves around the two first dimensions of the physical infrastructure, technology and institutional. Part of the thesis focus on answering the question of where RE is institutionally planned and governed in Denmark, in order to explore what challenges and potentials that are within the system. The other part of the analysis explores how RE and new technologies can be integrated into the existing infrastructure of Aalborg city. The two dimensions are suitable to explore these focuses through.

The last dimension of behavioural and skills are not a big part of this thesis analysis. However, the dimension is still vital in the RE transition in Denmark. There is a greater need for awareness, understanding and cooperation with the locals close to the physical planning of RE facilities and there is also necessity for skills and knowledge in order to carry out the transition.

2.2 Strategic and Tactical Urban Planning.

Strategic urban planning (SUP) and tactical planning is two distinct methodical approaches that both aims to improving urban areas.

Strategic urban planning focuses on the long term vision, with focus on analysing the internal & external factors that have an impact on the challenges and opportunities within the plans. The process aims to have the plans adaptable to ensure that they evolve alongside the needs and aspirations of residents and stakeholders (Baftijari, et al., 2007). The framework includes establishing the steps in which the targets and goals should be realised. Compared to other planning strategies, SUP is aims for developing long term plans and policies to steer the development of cities and other urban areas with the objective to adapt to new circumstances (Hanna, Bigelow, & Pratt, u.d.).

SUP is a step-by-step system that outlines the main goals and identifies key development in relation to urban region growth and transformation. It involves an all-inclusive process, which fuses economic, social, and environmental issues into making a sustainable inclusive urban setting (Zou, 2014).
The strategy of SUP aims to assess the current state of affair in order to determine the best course of action in accordance with the long-term plans and vision of the actors.
An outline of the process:

Tactical planning on the other hand, deals with short term goals but is often a strategy used in combination of strategic urban planning as tactical planning are able to take overarching plans and create quick and “bite-size” goals. It can help break down the long term plans objectives that can be achieved in smaller increments and also be more focused (VanZandt, 2023).

In order to reach the goal of 100% RE and zero emissions by 2050, there is a need for long term and short-term planning. The overarching vision that SUP offers helps steer the course and it helps keep an overview despite unexpected situations (Such as COVID-19). While the tactical planning helps the overall strategy by breaking it down to achievable goals (VanZandt, 2023).

This thesis final aim is to present a proposal for a chosen area in Aalborg city, based on the analysis of multi-level governance mapping and the findings from the comprehensive case study. To do this, both the long- and short term planning must be considered, and these two types of planning are used to frame the proposal. This is done by analysing the current urban challenges and potentials in Aalborg, both in the physical infrastructure of the city but also the in the institutional governance.

2.3 Multi-Governance Framework

Multi-level governance (MLG) framework offers a way of understanding how different governing bodies, actors, and stakeholders, private and public, interact to plan and implement policies from international to local levels (OECD, 2010). It depicts many of the fundamental’s insights about the institutional configurations, planning and policy making processes of modern democratic states (Behnke, Broschek, & Sonnicksen, 2019).

Planning has become more decentralized and complex in an ever more globalized world. Through its *multilevel* the MLG recognizes the that the earlier dominant vertical division of authority has migrated not just below the governmental level of state but moved horizontally (Behnke, Broschek, & Sonnicksen, 2019). However, this migration comes with challenges to the more conventional policy and practices of legitimacy under the growing complexity of (Behnke, Broschek, & Sonnicksen, 2019).

Individual governments or governments departments seldom have the competence, resources or tools required to effectively respond to public challenges in their area of responsibility (Daniell & Kay, 2017). This is also true for Denmark, especially in climate planning such as RE.

2.3.1 Vertical and horizontal planning

MLG is often conceptualized in the two dimensions of vertical and horizontal. As mentioned above, vertical planning operates on a top-down approach, with a clear hierarchy of decision-making, where higher levels (supranational or state) make overall decisions that lower levels (local) must adhere to. For example, the Danish planning act operates as the main legislation for physical planning in Denmark (OECD, 2010).

In contrast, horizontal planning employs a bottom-up approach, fostering collaboration and inclusion of different actors in decision-making. Authority is dispersed across sectors and spheres of influence, including private, non-governmental organizations, and community societies (Daniell & Kay, 2017). This approach promotes a greater sense of ownership among actors and allows for more flexibility and adaptability (OECD, 2010).

The conceptual framework of MLG for this thesis aims to break down the constellations of institutional or governing actors, policies and legislations in order to understand what the constraints and situational inducements in order for them to reach their goal (Behnke, Broschek, & Sonnicksen, 2019).

2.3.2 MLG in Denmark

The Danish planning system necessitates collaboration across governance levels, involving public and private sectors. To achieve positive policy outcomes in a multi-level government, it is crucial to understand and manage the challenges of governing across sectors (Daniell & Kay, 2017).

The planning of RE in Denmark involves various levels of government and actors. By using MLG and mapping, this thesis aims to unravel the complex web of legislations, policies, and directives related to RE, creating a comprehensive outline of where RE is planned and governed to identify challenges and potential for developing RE in Aalborg municipality.

3 METHODS

In this chapter, the methods employed to conduct the research will be presented. The report incorporates a mixed methods approach in relation to [...]. The mix combines quick scan, literature reviews, data analysation through various strategy documents, and case study conducted in Aalborg, Denmark. Furthermore [...]

3.1 Quick Scan and Literature Review

Throughout the development of the thesis, extensive research was conducted to comprehend and master the utilization of various frameworks. The research involved a structured literature review combined with a rapid scan of documents for pertinent information related to the topic at hand. Keywords such as "net-zero," "net-zero energy districts," "high-performance energy districts," "energy planning," "energy transition," "renewable energy transition," "green transition," "multi-level perspective," "strategic urban planning," "tactical urban planning," and "decarbonization" were used to locate and investigate various studies and reports.

After locating and scanning the literature, its relevance was classified into "need to know," "interesting," and "irrelevant" categories. The "need to know" category formed the foundation for further research, while the "interesting" literature was set aside for later review. Additionally, the references of the relevant literature were examined and searched to expand the research (snowballing).

3.2 Multi-Level Governance mapping

The purpose of creating a multi-level governance mapping is to answer key questions regarding the planning of RE and Aalborg municipality's climate targets, such as "Where is renewable energy planned and governed?" and "What are the challenges and potential in the levels of governance?"

The mapping first determines where RE is planned, implemented, and governed, focusing on the public sector. It visualizes relevant sectorial legislations and highlights key actors on different levels of government (international, central, regional, and local) to gain an overall understanding of the Danish planning system and highlight areas where RE planning occurs.

Secondly, the mapping aims to identify challenges and potential in various levels of governance concerning the planning and implementation of RE. Mapping can be used to shed light on possible governance gaps or bottlenecks that hinder effective implementation of RE policies.

Lastly, the mapping can be used to assess the effectiveness of current plan systems and implementation tools and mechanisms in achieving climate goals on different levels. This thesis

focuses on Aalborg municipality and their target of being self-sufficient on RE by 2040 in the North Jutland region and the overarching target zero emission by 2050 (Aalborg kommune, Klimaplan for Aalborg Kommune, 2020). The mapping will provide insights into the extent to which these tools contribute to progress towards the 100% RE and zero emissions target.

For this thesis, MLG is visually represented with two diagrams, which are shown in the thesis analyses One diagram frames the Danish planning system relevant to planning, implementing, and governing RE, and the other zooms in on the organization of Aalborg Municipality and maps out public actors with references to private actors.

By incorporating these suggestions, the text can be further refined to improve its clarity, organization, and overall effectiveness in conveying the concepts and ideas.

3.3 Document Analysation

Document analysis is a qualitative method and is characterized by systematically reviewing and evaluating relevant documents (Kutsyuruba, 2023). For the mapping and the subsequent analysis, primarily Danish legislations, policies and official planning documents has been used to construct the diagrams of

In the case of MLG and the mapping in this thesis, mainly legislations-, policies- and different planning documents were used to create the diagrams of Denmark's planning system and Aalborg municipality.

A particular set of documents were analyzed by choosing a handful of keywords relating to RE and sustainability, and using the search function in the PDF program to ascertain how many times the word was mentioned and where in the document it was placed. This was the Agreements about the Municipalities Economics (AME) documents which reflect the State's priorities. Looking at a timeline of 7 years (Documents from 2014 – 2024) can give an overview of the shifting priorities and what caused them. This data provides useful insight into RE planning and climate planning in general over the years. The data is collected and presented in a table in the analysis.

3.4 Semi-structured Interview

The semi-structured interview approach was chosen due to the flexibility of the method, which allows the interviewer a higher autonomy to explore pertinent ideas that may come up in the course of the interview than in a completely structured interview (Adeoye-Olatunde & Olenik, 2021). As experts in their area, the purpose of interviews was twofold. One, to learn and obtain knowledge about certain technical topics that is not necessarily in any public documents either due to it being internal information or due to the information being uncertain or too new to be published to the public.

Secondly was to gain an insight into their experiences of their field and how the governance system works in their area as the theoretical application written in documents and the practical application can differ vastly.

For the interviews, general interview guides were created for each individual interview as their specific insight and knowledge was sought after.

The guide was meant to provide structure and aimed at addressing the research objective, rather than be red verbatim. As characteristic of semi-structured interviews, the questions were meant to provide a natural flow of conversations and the questions were primarily open-ended with follow-up questions (Adeoye-Olatunde & Olenik, 2021). Although the questions for the interviewees differed, there was overall themes of interest.

Table 2 - Themes in interview guides used in the interviews.

Governance	Technical
RE and energy planning on the different levels of government.	
Roles of the interviewee and their institution	
Authority, roam of possibility, area of influence in regard to RE	
Institutional or legislation related challenges	The development of district heating
The structural relationship between, mainly, public actors	CO2 Storage
Russia/Ukraine war impact on RE planning and implementation.	The energy grids capacity regarding the future demand

3.4.1 THE INTERVIEWS

A total of four interviews were conducted. Table 3 shows the interviewees, their role and date of the interview. Additionally, the first interview was accompanied by a site visit in Medicon Village, where the authors were introduced to the ins and out of the Ectogrid system, as well as to the Ectogrid table, an interactive tool to understand and simulate grid operations (Figure 8).

Figure 8 – The authors' field visit in E.On Medicon

Table 3 - Overview of Interviews.

Interviewee	Actor	Date	Location
Mats Carselid	Ectogrid, Medicon Village	29–04 -2024	In person, Lund, Sweden
Jørgen Lindgaard Olesen	Climate and Environmental Department, Aalborg Municipality	03-05-2024	Online
Silas Alvin Hupfeld	Team leader – strategic energy planning in Aalborg Utility	10-05-2024	Online,
Cecilie Overgaard Jensen / Peter Serup	Civil engineer at City- and Land Department, Aalborg Municipality / City- and Land department, Aalborg Municipality	15-05-2024	Online,

3.4.2 Transcription

All four interviews, both in person and online were voice recorded with consent from the interviewees. This was done in order to capture the data most effectively for analysis and to allow the interviewers to be more in the moment and focused on the interview rather than note taking (Adeoye-Olatunde & Olenik, 2021). The duration of the interviews were around 1.5 hours, except the interview with Mats Carselid which took approximately 3 hours due to also touring Medicon Village and the Ectogrid facility.

The transcription was done via Microsoft Word's internal transcript function. In the case of the interview with Cecilie and Peter which was done in Danish, the transcription was done via Microsoft Teams internal function, then cleaned up, translated directly to English and then corrected manually.

When 'cleaning' the transcript, it was to remove unnecessary filler sounds, phrased and words that are usually only there to fill in pauses or gaps. As the nonverbal communication, such as body language and these filler words, are not relevant for this thesis' research objective, they were cleaned from the transcript to allow for an easier read for the interviewer.

Due a limited timeframe, a free, online AI tool (NoteGTP) was chosen to create summaries of each individual interview due to the large quantity of transcript (Appendix A). Each summary was subsequently manually checked and changed to reflect the interviews better. Each summary includes key highlights, the most talked about question (theme) and a mind map that shows the key themes and key takeaways. The summary was made as to have an easy overview of the interviews content.

3.5 Case Study

An in-depth exploration was undertaken to examine the urban dynamics of Aalborg, a city located in Northern Denmark. This analysis seeks to deliver a thorough overview of the essential urban elements and their pivotal role in transitioning from a fossil fuel-dependent urban environment to one centred on renewable energy, thus propelling the city toward a climate-neutral future. The analysis employed a holistic and multi-dimensional approach to investigate the factors influencing the existing system's adaptation and transformation.

The case study initially examined broader factors, such as the intricate components and features of the current physical infrastructure, before delving into more granular subject-specific areas. As part of the analysis, visual representations of maps were generated using QGIS to illustrate and analyse information about the existing infrastructure and energy system. Additionally, diagrams containing data sourced from various national and local Danish sources (e.g., Danmarks Statistik, Energinet, Aalborg Kommune, Kommuneplan, etc.) provided further insights.

3.6 GIS Mapping

A comprehensive, multi-scale approach was utilized to generate maps to analyse various urban aspects within the case study and the designated focus area. The data utilized for these maps primarily originated from geoportal websites in Denmark, including geodata, kort plandata, and energikortet, as well as the municipal and local plans of Aalborg. Additionally, specific maps from energinet were also utilized during this process.

4 MULTI GOVERNMENTAL ANALYSIS

This section provides a comprehensive analysis of where energy is planned and governed in Denmark and what role and tools the municipality of Aalborg has when trying to reach the goal of being self-sufficient with RE by 2040 and having zero emission by 2050. Through a multi-level governance analysis framework (MLG), this analysis focuses on the challenges and potentials in the Danish planning system regarding RE planning.

In the context of climate change mitigation, cities are expected to play a crucial role by implementing effective climate policies and shaping local climate governance. This framework involves a complex mix of actors, institutions, and networks, which can be challenging to navigate (Haarstad, 2016). Despite these challenges, local governments are expected to take the lead in framing, catalysing, and operationalising successful climate mitigation efforts (Neji & Heiskanen, 2021).

What is the status quo in the city's energy planning, and what institutional dynamics are leading the RE transition?

Through a multi-level governance analysis, the first SRQ aims to explore the current energy system, the existing plans and regulations regarding the RET, and the governmental and institutional background.

Municipal governance extends beyond the scope of local government, encompassing a diverse range of institutions, networks, and socio-technical arrangements. There has been a growing acknowledgement of the increasing importance of local authorities' role in addressing climate change and driving low-carbon energy transitions (Neji & Heiskanen, 2021). Municipalities now face the strategic challenge of positioning themselves in relation to energy security, carbon markets, and their public image as climate change response becomes a crucial aspect of their agendas (Haarstad, 2016).

City governments and local authorities are viewed as pivotal actors in implementing adaptation measures and in governing responses to adaptation, both within and beyond their own jurisdictions. This understanding extends to international and transnational governance institutions, where there are increasing initiatives toward municipal governments. For instance, the European Commission has launched several initiatives aimed at addressing climate change and promoting low-carbon transitions in collaboration with city authorities, such as "The 100 Climate-Neutral and Smart Cities by 2030" (Neji & Heiskanen, 2021).

Given the growing complexity and fragmentation of climate change and low-carbon transition governance, there is a need to assess and conceptualise the whereabouts of the authority and capability for addressing these challenges. A fundamental question can be posed: "Where is renewable energy planned and governed?"

This section delves into the intricacies of the Danish planning system and sectoral legislation pertinent to RE planning.

4.1 THE INSTITUTIONS OF ENERGY PLANNING

Denmark's planning system is marked by a high level of decentralisation involving a diverse array of actors. This tendency is evident in the general structure of the RE sector.

In 1992, at the same time as the Planning Act came into effect, an executive order from the Minister of Environment and Energy ordered municipalities to find suitable sites for wind turbines throughout the country. The planning directives included provisions for public hearings prior to any actual applications for the construction of the turbines, which was a significant help in getting public acceptance for their installation. Thus, energy planning started as part of the Planning Act (IRENA, 2013).

With the end of the 90s, there was a shift within energy governance as the EU's Electricity Liberalisation Directive from 1996 was implemented in Danish law with the electricity reform of 1999. Before the liberalisation, electricity companies owned all stages of the electricity value chain, from production to transmission to the final distribution of electricity to end users, the customers. The reform separated distribution companies from their power plants and divided the monopoly activities into network operations and competitive activities such as the production and trade of electricity (IRENA, 2013).

Power distribution became the responsibility of local not-for-profit cooperatives, municipalities, or companies with a concession. In 2005, the state established Energinet to ensure system responsibility, supply security, and a well-functioning electricity and gas market (IRENA, 2013). Power transmission became the responsibility of Energinet, a new, wholly state-owned company. Power generation was divided into central power plants owned by DONG Energy (now Ørsted), plants owned by Vattenfall and municipal and local consumer-owned combined heat and power plants, and wind power with 85% ownership by Independent Power Producers and the rest by the central power companies (IRENA, 2013).

4.2 MAPPING AND DESCRIPTION

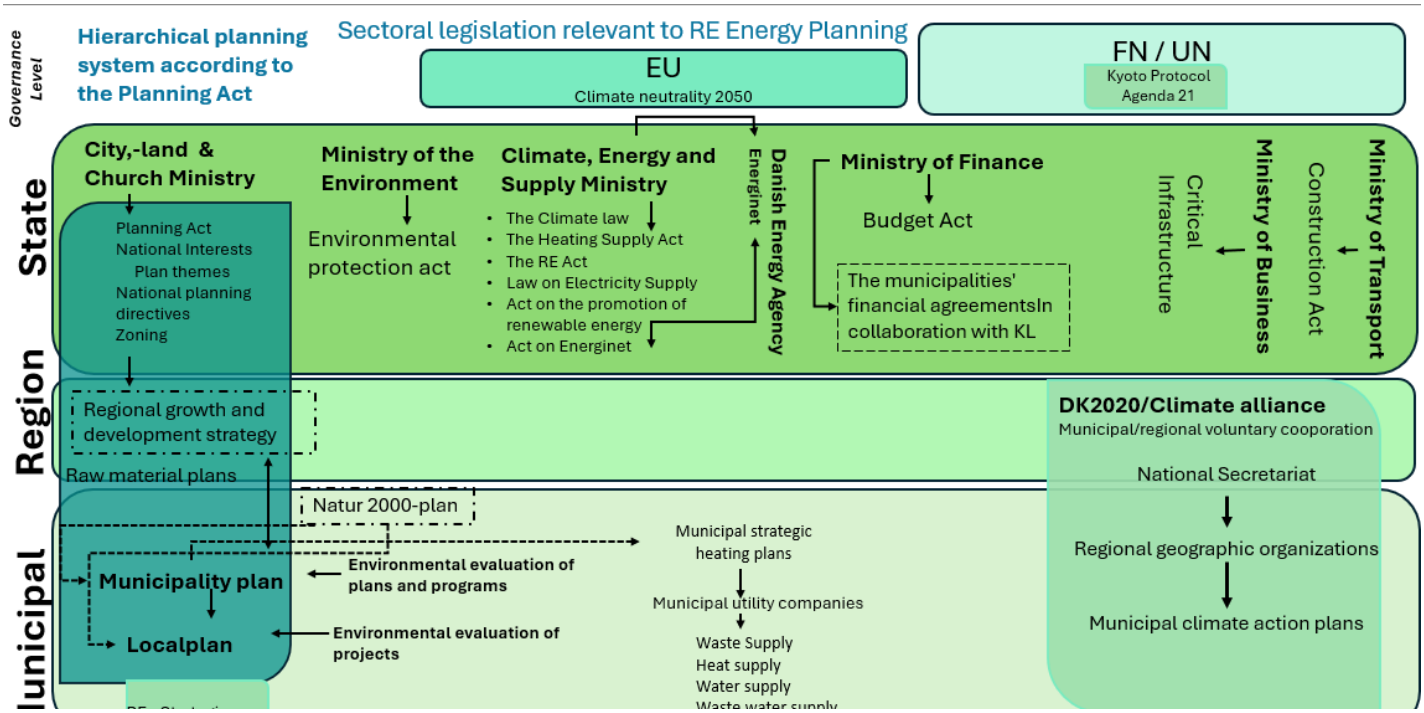


Figure 9 - Multi-level governance mapping of the Danish energy planning with sectorial legislation relevant to renewable energy planning

4.3 HIERARCHICAL PLANNING SYSTEM OF PHYSICAL PLANNING FRAMING ENERGY PLANNING

4.3.1 THE STATE LEVEL OF PLANNING

Within this next section, we will focus on the possibilities and the limits of the direct authority of the municipality and the "municipal planning monopoly", whereby legally binding physical plans must be approved by the municipalities before being ratified by the state institutions.

The fossil free energy transition is a form of socio-technical transition and as such, it involves profound changes in the institutions that govern society. Local governmental authorities in Denmark possess greater political agility compared to private actors or national governments when it comes to specific aspects of decarbonising municipalities, although their direct agency is limited. They must operate within the frameworks established by national or supra-national governmental entities. As can be seen on Figure 9, the two ministerial areas which have

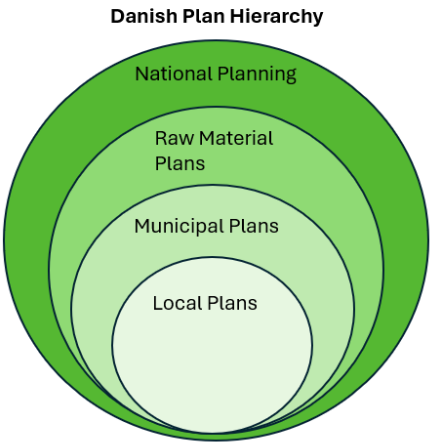


Figure 10 - Simplified visualization of the framework of Danish Plan Hierarchy

the biggest impact on the municipality's jurisdiction are the Planning act and the budget act. The primary function of the Planning Act is to provide a more holistic evaluation of future land use while balancing public and private interests (Pagh, 2021).

The hierarchical structure of the Danish planning system and the decentralisation of responsibility to the local level underscore the critical importance of aligning national interests with municipal planning. This is achieved through the five national interests outlined in the Planning Act's Purpose Determination (Planlovens formålsbestemmelse): *climate*, *environment*, *nature*, *growth*, and *development* (Elholm, 2023). The inclusion of climate in the Purpose Determination of the Planning Act is crucial for several reasons. Firstly, elevating *climate* to the same level as the other four purposes underscores its importance and ensures that it is treated as a priority. This means that if a climate-related project were to conflict with one of the other four purposes, it would be given equal consideration and would not be automatically dismissed. Additionally, including climate in the Planning Act grants the state the authority to intervene if a municipality is not taking sufficient action in this area, as it would no longer align with national interests. By incorporating *climate* into the Planning Act, municipalities are empowered to incorporate climate considerations into their physical planning, such as RE and emission reduction strategies (Elholm, 2023).

Prior to the inclusion of *climate* as a Purpose Determination, there was no legislation in the national interests that addressed GHG emissions or climate-related issues, nor was there a push for a RE transition. Climate measures have primarily focused on safeguarding land areas against flooding, heavy downpours, storms, heat waves, and drought (Pedersen & Lindhard, 2022). The legislative amendment aimed to ensure that the Planning Act incorporated climate considerations and measures to prevent GHG emissions rather than climate mitigation (Pedersen & Lindhard, 2022).

The legislation now includes the national interest in securing areas for the development of RE facilities, including wind turbines and solar cells (Landdistriktsstyrelsen, 2023). A notable change to the Planning Act as a result of the inclusion of *climate* is the revision to the Cultural Heritage and Landscape section.

In *Overview of National Interests in Municipality Planning 2023*, under the section *Conservation Worthy and Larger Coherent Landscapes*, it is stated that landscapes worthy of conservation and larger contiguous landscapes designated in the municipal plan are to be secured and preserved. This includes keeping the landscape clear of construction and technical installations (Landdistriktsstyrelsen, 2023).

This is to preserve such areas and avoid their eradication, to keep the relatively few places in Denmark unaffected by cities and technical facilities (Landdistriktsstyrelsen, 2023). However, with the legislation change and the inclusion of *climate* into the national interests, it has been made possible

to set up wind turbines and solar panels in the manor- and estate landscape unless these are of special quality (Landdistriktsstyrelsen, 2023). While municipalities are not required to plan RE facilities on such landscapes, the legislation provides an opportunity for municipalities to expand RE production, thereby contributing to Denmark's goal of quadrupling its renewable energy output.

However, as great as it is that *climate* is now included in the national interests, it is curious that it only happened last year (2023). As stated above, concerns about GHG emissions and the hugely negative impacts on the climate were discussed nationally and internationally in the 1980s when climate change was finally recognised as a threat (Maslin, 2021).

The UN's Agenda 21 (1992) is not legally binding (or enforceable) and falls into the same category as other agreements, such as the Kyoto Protocol adopted in 2005 or the UN's Paris Agreement 2016; they are instead a declaration of intent. Nonetheless, in 2000, Denmark incorporated Agenda 21 into its Planning Act, meaning that Danish municipalities were obligated to develop their own plans for sustainable development (Olumeko, 2024). This was one of the few sustainable measures written into the Planning Act, as most other laws involved heat and electricity supply.

The inclusion of Agenda 21 in this governance analysis, despite its limited focus on RE, is to highlight Denmark's lack of concrete and legally binding climate legislation in the Planning Act prior to 2023.

This makes the government's decision to repeal one of the few existing climate-related acts even more peculiar.

Denmark's international commitments, such as the Paris Agreement and the European Green Deal, raise the question: Why has Denmark only recently begun developing and incorporating legislation to promote climate mitigation solutions, such as RE, into its planning system? The answer may lie in the concept of institutional lock-in and the dynamics of power and interest groups. Although Denmark has made significant strides in RE, particularly with wind energy, these advancements often come in response to broader motivations such as energy security.

Similarly, recent institutional shifts towards promoting RE and climate mitigation appear to be influenced by external pressures and internal strategic interests rather than purely environmental considerations.

One of these external pressures could be the increasing number of voluntary non-governmental agreements, actors, and solutions at a national level, the most influential of which in Denmark is DK2020.

DK2020 (now The Climate Alliance) partnered with actors such as Realdania, Concito and C40 Cities in 2019 to facilitate sustainable development in the Danish municipalities through the DK2020 Climate Action Plans. This partnership came as a continuation or link to the Paris Agreement.

DK2020's main goal was to assist municipalities in reaching net-zero emissions as a geographical area by 2050 at the latest (DK2020, 2020). The municipalities needed to create their own local climate action plans, approved by DK2020 and C40, to reach this goal; as of last year (2023), all 98 municipalities had created a climate action plan and joined the partnership (KL, 2023).

However, the Climate Alliance and its climate action plans operate on a voluntary basis, lacking any legal enforcement. This mirrors the general approach to sustainable development and planning that has been had in Denmark since 1999, where voluntary commitments frequently dominate (IRENA, 2013).

Danish planning at the municipality level involves a lot of development planning, such as overall-, vision-, master planning, local development planning, etc., for different sectors. These development plans can be a valuable tool, e.g. communicating and supporting local site-specific development. They can offer open and new forums for discussion that can include citizens and local knowledge and thus establish ownership in the local community. The downside is that they have little to no basis in the Planning Act, so the role of development- and sustainable plans can be unclear. This can result in confusion among political decision-makers and cause frustration among other stakeholders who work with the plans (Hansen, u.d.).

The new addition of *climate* to the Planning Act's national goals might render the DK2020 climate plans easier to incorporate into the municipality plan and, therefore, into the physical planning.

Since its inception in 1992, the Planning Act has undergone numerous amendments, leading to the addition of various special provisions related to topics such as allotments, coastal protection, retail space limitations, and local sustainability action plans such as Agenda 21 (Post, 2018).

Agenda 21 is a comprehensive plan of action regarding sustainable development that was developed back in 1992 at the global Earth Summit conference hosted in Rio de Janeiro, Brazil (Nations, 1992).

One of the main objectives of Agenda 21 is for each local authority to develop its own local Agenda 21 plan. Agenda 21 has a broad focus with four sections and addresses issues such as combating poverty, protecting the atmosphere, and conserving biological diversity (Nations, 1992). The document is 351 pages long and mentions energy 157 times, but RE only 26 times. The other mentions of energy focus on efficiency, conservation, and better energy consumption. As stated earlier, Agenda 21 was in 2000 written into the Planning Act but was removed as of last year (2023) with no explanation from the government as to why they removed one of the few legislations regarding climate change action Denmark had (Olumeko, 2024).

As mentioned earlier, back in the 1970s, the Danish government began implementing rules and regulations to rush the development of wind turbines through grants, subsidies and tariffs. However,

the support as well as regulations that pushed for wind turbines were removed in 1999 as Denmark's electricity market was liberalised (IRENA, 2013).

This, together with Agenda 21, is an example of the forward- and retrogressive tendency there has been in the Danish Planning Act concerning policies and regulations that aims to reduce GHG and push for a RE transition.

It would require a further study to look into the different actors and investigate who might be interested in the liberalisation and decentralisation of the energy system. All this thesis can state is that the tendency is there. This tendency can also be seen as an example of where institutional lock-in fails. The regulations for RE transition aren't given the chance to take root, so to speak, and thus unable to create feedback loops that would reinforce the transition in the future, as fossil fuel energy has had decades to do.

One of the reasons that the governmental map (Figure 9) includes the Ministry for the Environment, is because its legislations are institutionally locked-in in energy planning. Environmental- and climate protection has been introduced and is implemented on all institutional levels of the government. Any physical structure projects need evaluation if they need environmental assessments.

This is not the case for the climate- or energy acts in Denmark which has only recently been included into the Planning Act. The majority of legislation regarding climate and energy assessment processes or responsibility distribution is still within the Ministry of Environment’s jurisdiction.

The environmental assessment process necessitates the preparation of an environmental impact report detailing the project's anticipated significant environmental effects. This report must be prepared and made available for public consultation before the developer can obtain permission to commence the project.

The municipal council serves as the environmental assessment authority, and screening applications must always be submitted to the municipality where the project is located. However, if the project requires an environmental assessment and the Danish Environmental Protection Agency (Energistyrelsen) is the designated authority, the application must be forwarded to the agency instead of the local municipality. This is the case when:

- Projects where the state or Energinet is the developer / project owner.
- Projects that in their extent affect more than two municipalities.
- Projects with the direct purpose of fracturing solely in connection with the exploration or extraction of shale gas.
- List companies, cf. Chapter 5 of the Environmental Protection Act (§ 40)

- Listed companies are enterprises included on a special list in the Environmental Protection Act, which require prior approval before establishment, expansion, or modification. These companies are subject to specific environmental requirements (Miljøministeriet, Miljøvurdering af konkrete projekter, u.d.).

It is the project owner's responsibility to apply in writing for a construction project as stated in accordance with the Environmental Protection Act, to the relevant municipality. The project owner is only permitted to commence construction of their facility once the environmental assessment authority has provided written notification confirming one of two scenarios: either the facility is exempt from requiring an environmental assessment, or the authority has concluded the full environmental assessment process and granted the developer approval to proceed with the proposed project. However, as stated above, there are a number of facilities which are always subject to an environmental assessment, including energy production plants (Miljøministeriet, Miljøvurdering af konkrete projekter, u.d.).

A problem with the responsibility of applying for an environmental assessment being the project developer's responsibility, is that it means that the municipality, through the local plan, can allow an area for a purpose despite it not being suitable for that purpose.

According to Cecilie and Peter, a lot of work and agreements have happened with different actors before the proposal is even brought to the municipality (Appendix A). This can include finding investors for the project, looking into the electricity grids capacity in the area, entering into contracts with landowners etc. There is a lot of work going into choosing a site for the project developer, only then for the assessment to deny the project.

4.3.2 Environmental Protection Act and Appeal Bodies

The Environmental Protection Act can first intervene and stop a project once it has started, if it is found to be in violation of the law. There are various appeal bodies, including the Planning Appeals Board and the Environmental and Food Appeals Board, which can handle complaints regarding the Environmental Protection Act (Miljøministeriet, Bekendtgørelse af lov om miljøbeskyttelse, 2024). The municipality is also responsible for conducting environmental assessments, including EIA assessments, to ensure that projects meet environmental requirements and standards. The draft EIA report, provided by the developer, is quality-assured and approved by the administration. Prior to its preparation, the administration also prepares a scoping note identifying the topics to be assessed, such as landscape, watercourses, and noise. This note is sent for consultation with relevant authorities to ensure that all relevant and necessary topics are included in the environmental

assessment. As described above and from the process described Figure 9the Planning Act has many and comprehensive legislations to handle the environmental aspects of physical infrastructure but there is hardly any for preventing GHG emissions in the Danish legislation. It is only recently, within the last couple of years, any such legislation is being developed and implemented. Even Agenda 21 force of law extended to the municipalities creating their own Agenda 21 local plans. It is first around 2020 that there is a change in the legislative basis and framework that the municipality and all other actors in the energy sector are working within. However, the energy planning system is undergoing a general revision. Among other changes, the possibility of appeals and how long various appeals can take. It is clear that the government is trying to expedite the process in order to establish RE facilities faster. In other words, there is a pressure to change the status quo from the state level, creating the possibility in the institutional lock-in to change from fossil fuel to RE.

4.3.3 Agreements about the municipalities Economics

Examining the budget law can help us gain a deeper understanding of the financial, regulatory, and collaborative frameworks within which municipalities operate and how these create a lock-in. As seen on Figure 10 (the Hierarchy), although not part of the hierarchical planning system, the budget law forms the economic frame for the municipalities' expenditures.

The budget act was adopted by a broad majority in the Folketinget (Danish Parliament) in May 2012 and practically took effect from the financial year 2014. With the budget act, the requirements of the fiscal pact for balance in public finances were implemented in Danish legislation. According to the budget act, the annual structural public deficit must not exceed ½ percent of GDP. Additionally, a new expenditure policy control system has been introduced with four-year expenditure ceilings for the state, municipalities, and regions (Formandskab, 2019).

The municipality must establish a budget for four years at a time, the budget year itself and then three forecast years, and it is the municipal council that decides what the municipality's money will be used for in the new year. The budget consists of the expenses and income that are in the municipality. The expenses cover the areas that are the municipalities responsibility, such as daycare centres, schools, nursing homes, roads and much more. The municipality has income, and it comes primarily from tax income and user fees, but income is also obtained from the state in the form of grants. However, the budget is only binding for the budget year itself, so what politicians can negotiate on is always only next year's budget. This means that the municipality finds it difficult to say yes to projects where there is a budget expenditure that is binding for many years to come. This is especially a problem for RE as practically all energy infrastructures are expensive and long ventures, meaning that the physical aspects of the RE transition are forced to happen in the private sector as it can take many years for a project to pay off.

So, in the budget acts framework, there is not just an institutional lock-in of the budget act itself but there is also a physical infrastructure lock-in due to the length and cost of such facilities, which together make it virtually impossible for the municipalities to act as anything more than a facilitator in the RE transition.¨

There are different ways to evade these institutional lock-of, even seen in the regulation as we have today. The Construction Act, which falls under the Ministry of Transport (See Figure XX), is one of the only laws in Danish legislation that can transcend other legislation, such as the Property Act and override many regulations and policies related to the environment and nature (Environmental Protection Act, Nature Conservation Act). As stated in the beginning, the Construction Act mainly approves larger public infrastructure projects regarding mobility, as it is seen as critical infrastructure. According to the Ministry of Business (Erhvervsstyrelsen), it should be understood as follows: "*Infrastructure, including facilities, systems, processes, networks, technologies, assets, and services that are necessary to maintain or restore societal functions*" (Translated by authors), (Erhvervsstyrelsen, 2024).

However, mobility is not the only sector deemed as critical infrastructure. On the Ministry of Business's website, under the description of Critical Infrastructure, the energy sector is listed as one of the "Societally important Sectors" (Erhvervsstyrelsen, 2024).

In their interview, Peter and Cecilie explained how Energinet, as a state-owned company, has a history of expropriation. The most common case is the right to establish gas pipelines and gas plants according to the Gas Supply Act, but this must be approved by the Climate, Energy, and Supply Minister (Gasforsyningsloven, 2000, §55).

However, Russia's invasion of Ukraine and the subsequent energy crisis have changed the government's prioritization of RE. As described in the voting agreement Klimaaftale om grøn strøm og varme 2022 (Climate agreement about green electricity and heat 2022), the war has highlighted that climate policies and security policies are closely linked as the green transition is crucial in making Denmark independent of Russia energy (Klima- Energi- og Forsyningsministeriet, 2022). RE is, therefore, no longer just part of the oftentimes voluntary climate planning but is now considered integral to Denmark's energy security.

4.3.4 Document analysis on the Agreements about the municipalities economics

As the financial aspect of energy planning is vital in implementation and to understand the municipalities roam of possibility when it comes to energy planning, a document analysis was made on the Agreements about the municipalities Economics (*Aftale om kommunernes økonomi*) in the timeframe between 2014-2024 as the budget act was made effective in 2014. As described in methods, this was done by selecting words that are used when referring to sustainable development

and/or RE. The results are presented in table to provide a quick overview of the number of times the words were mentioned in each document and their location in the document. The Agreements about the municipalities Economics (AME) reflects the state's present priorities of what the municipalities should focus on.

Table 4 - Overview of number of mentions and locations of words in the Agreement of the municipalities Economics (Shortened to AME), 2014-2024.

Year	Klima (Climate)	Grøn (Green)	Energi (Energy)	Miljø (Environment)
2024	**Mentioned: 0**	**Mentioned: 1** Intro:	**Mentioned: 3** Other: The National Energy Crisis Staff (NEKST)	**Mentioned: 0**
2023	**Mentioned: 2** Under Renewable Energy (focus on independence) Green Public Procurement Also mentions the 17 (world goals)	**Mentioned: 17** 1. Introduction 2: The municipality's financial framework 7: Green Transition 12: Digitization	**Mentioned: 12** 7: Green Transition	**Mentioned: 3** 7. Green Transition
2022	**Mentioned: 14** 1. Introduction 7. Green transition 7x: Climate adaptation (flooding) (17 World Goals)	**Mentioned 29** 1. Introduction 2: The municipality's financial framework for 2022 4: Development of Welfare 7. Green transition 9. Digitization	**Mentioned: 17** 7. Green Transition	**Mentioned 6** 7. Green Transition
2021	**Mentioned: 13**	**Mentioned: 11**	**Mentioned: 2**	**Mentioned 1:** 11: Climate

	4: Development of welfare 11: Climate	2: The municipality's financial framework 11: Climate 12: Other areas	4. Development of welfare 11. Climate	
2020	**Mentioned: 4** 8: Climate (9. Other Areas Global Goals)	**Mentioned: 5** 8: Climate	**Mentioned: 1** 8: Climate	**Mentioned: 2** 8: Climate 9. Other Areas
2019	**Mentioned: 0**	**Mentioned: 0**	**Mentioned: 0**	**Mentioned: (1)** Appendix 1 - Box 3 Sustainability: 1 10. Other areas
2018	**Mentioned: 5** 7.Growth, coastal protection and climate adaptation	**Mentioned: 0**	**Mentioned: 0**	**Mentioned: 0**
2017	**Mentioned: 0**	**Mentioned: 0**	**Mentioned: 0**	**Mentioned: 0**
2016	**Mentioned:2** Basic data	**Mentioned: 1** Act No. 439 of 6 May 2014 amending (Energy saving package)	**Mentioned: 2** Act No. 439 of 6 May 2014 amending the Act on Rent, Act on Temporary Regulation of Housing Conditions, Act on Urban Renewal and Development of Cities and various other Acts.	**Mentioned: 1** Simplification of rules and de-bureaucratisation
2015	**Mentioned: 3** 6. Other themes	**Mentioned: 0**	**Mentioned: 0**	**Mentioned: 3** 3. Growth, employment and balance
2014	**Mentioned: 0**	**Mentioned: 0**	**Mentioned: 0**	**Mentioned: 0**

Table 5 - Additional words – number of times

Year	Paris	Verdensmål (World Goal)	Bæredygtighed (Sustainability)
2024	0	0	3
2023	0	6	1
2022	1	8	2
2021	0	3	3
2020	0	6	4
2019	0	2	1
2018	0	4	0
2017	0	0	0
2016	0	0	0
2015	0	0	0
2014	0	0	0

The tables show that it wasn't until around 2020 that there was a significant increase in the inclusion of sustainable or RE related words. This is despite the fact that international sustainable agreements, such as the Sustainable Development Goals and UN's Paris Agreement back in 2015, which aimed to mitigate global warming. A conclusion that can be drawn is that the adoption of the European Green Deal in 2020, which made climate neutrality by 2050 a legally binding goal for EU member states, significantly increased the emphasis on addressing climate, energy, and RE transition issues at the municipal level.

Considering that the AME documents are always written the year prior, the few mentions of *climate*, *green*, *energy*, and *environment* in the 2016 AME document cannot be attributed to the Paris Agreement, which was adopted in December 2015 and was only mentioned once in the AME document 2022. The AME documents for 2017 and 2019 only mention *environment* once, and that

is in the appendix. It is not until the 2020 AME document that we see a significant increase in the frequency of these terms. Early mentions of *climate* are related to safeguarding cities against flooding.

Climate, *green*, *energy*, and *environment* all experience a doubling in mentions from 2020 to 2021. From 2021 to 2022, the number of times *energy* is mentioned increases from 11 to 29, and *green* from 2 to 17, while *climate* only increases from 13 to 14. Notably, an increase in *climate* from 4 to 13 times is already observed from 2020 to 2021.

So, what are the key differences between the Paris Agreement (2015) and the European Green Deal (2020)? This thesis argues that two particular aspects stand out.

First and foremost, the Paris Agreement (2015) and the European Green Deal (2020) differ in their scope and legal bindingness. While the Paris Agreement is written as legally binding it lacks any effective enforcement mechanisms. The UNs international court of justice (ICJ) primarily deals with human rights and thus has no legal mechanisms to impose penalties on countries who do not live up to the Paris Agreement (United Nation, 2024) . Whereas the court of justice of the European Union (CJEU) has mechanisms in place to enforce laws and take up cases against national governments that fail to comply with EU Law (European Union, u.d.). The Paris Agreement's binding nature is limited to the procedural requirements, rather than the specific goals and targets set forth (MacLellan, 2021). Denmark did, however, adopt the goal of climate neutrality by 2050 into the Planning act via the climate act which was enacted in 2020. By integrating the goal of 2050 into the planning, this has highlighted the need for climate action and sustainable development and thus enabled municipalities to prioritise it in their municipality- and local plans. This prioritising from a state level is critical for the municipalities roam-of-possibility regarding RE and sustainable development in general, as explained earlier.

However, it is not until 2022 that there is a notable change in the Planning Act, as a reaction to the energy crisis caused by the Russia/Ukraine war which shifted RE from merely concerning climate change, to being a matter of national security. It can’t be ignored the enormous impact that the war and Russia have had on the furtherment of RE in Denmark, and other countries. Without much warning, there was a sudden need to find alternative sources for energy fast and RE became one of the state’s highest priorities. The war has thus caused an exogenous shock that spurred actors' attention and created a window of political opportunity in the otherwise locked-in system, which has allowed a propulsion of RE development (Seto, et al., 2016).

The propulsion in RE can be witnessed from the increase in mentions in the AME document, but it is also directly stated in the 2023 and 2024 AME documents:

*"Denmark must be independent of Russian gas and be a net exporter of green energy in 2030, Expansion with solar parks and onshore wind turbines can deliver cheap green power already in the relatively short term, so that Denmark can be powered by green power" (*Translated from Danish to English by authors*)* (Regeringen & KL, Aftale om kommunernes økonomi for 2023, 2022, s. 11).

This likely explains the surge in mentions, particularly in *energy*, which increased from 2 to 17 between 2021 and 2022. However, in the 2024 AME document, the mentions have significantly decreased, although energy security remains a prominent topic, while the word *green* has dropped from 17 in 2023 to 1 in 2024. This decline may indicate a slowdown in the momentum, a closing of the window, for RE. As mentioned in the earlier, Silas told in the interview how the war caused an exponential increase in residents connecting to district heating in Aalborg. He also noted that as the energy prices stabilised, the demand gradually returned to a level similar to the previous status quo, showcasing the impact of the crisis on energy consumption patterns and infrastructure development as well as the behavioural lock-in, as people return to their habits.

4.3.5 PARTIAL CONCLUSION

The two most, directly influential pieces of legislation on the municipality's ability to carry out RE transition are the Planning Act and the budget act as they set the framework for what the municipality can spend its finances on and what must be in the municipal plan. As the analysis described, after 1999, not much has been directly mentioned about energy or the prevention of GHG emissions in the Planning Act. Which has meant that if municipalities had a desire or ambition to carry out RE or carbon neutral development, they have needed to either seek financial support from the EU or from private partnerships. Otherwise, all they can do is to prepare strategies and master plans that could attract project developers, with a hope for a specific development.

The institutional lock-in for the municipalities happens as they lack any political or legislative tools to realise their strategies or plans themselves, which in turn has reduced the municipalities to a primary facilitator role - before the legislation changed in 2022 and 2023 respectively. However, in regard to RE and general GHG reducing policies have tended to be retrogressive in the Planning Act. Due to this tendency and how new the legislation is, it is too early to say whether these changes are enough to break the lock-ins.

4.3.6 MUNICIPAL LEVEL

Decentralisation enables municipalities to undertake and decide on land-use planning in both urban and rural areas by transferring spatial planning tasks and responsibilities to them, granting them autonomy (Galland, 2020). However, at the national level, planning authorities retain the power to

review and potentially block municipal planning and projects of national and regional significance (Galland, 2020).

One of the central challenges for municipalities in their energy planning work, is that they have very different opportunities to influence decisions within different sectors. Although they still have the primary authority of local planning, their primary role has become that of a facilitator: Through the role of authority, the municipalities have the opportunity, within the framework of current legislation, to draw up plans for the sector and subsequently administer on this basis. For new collective heat supply facilities and biogas plants, for example, project proposals must be approved by the municipal council, which may require adjustments to existing plans and the creation of new local plans (Klima-Energi- og Forsyningsministeriet, 2019). Wind turbines and large solar power plants need a valid planning basis and usually requires a local plan unless a rural zone permit suffices. Within the municipal system, many authority roles are frequently located in the different administrations or municipal companies that have transitioned from being directly managed by municipal administrations to becoming independent legal entities, such as stock companies, limited liability companies, or partnerships. This results in effort within the various sectors needing to be coordinated.

4.3.7 MUNICIPALITY PLAN

The Planning Act requires each municipality to have a comprehensive municipal plan covering its entire geographical area. This plan serves as the foundation for all physical planning within the municipality. It translates the city council's policies into specific objectives, guidelines, and frameworks that the municipality must administer accordingly (Post, 2018). As mentioned in the framework of Danish plan hierarchy, certain plans cannot conflict with others. In the case of the municipal plan, it must not go against the national planning or sector planning, such as the natura 2000-plans or the raw materials plans on the regional level (Figure 9).

The municipal plan is the basis for all spatial planning and is the plan that summarises and concretizes the overall political goals for the physical development that the city council will work towards in the coming 12 years (Post, 2018). The municipal plan lays down the guidelines for land use as well as the overall physical development of the cities and the open land, which the municipality must administer according to (Post, 2018).

That is, how should the cities develop, where there are special agricultural, natural, and cultural values that must be safeguarded, and where there can be renewable energy plants? This is where citizens, businesses and other stakeholders can see how the politicians want to manage the areas in the municipality. If a municipal plan is changed, a municipal plan supplement must be drawn up. Planning for and development of renewable energy plants must consider the many interested parties at stake

and at the same time contribute to achieving both the national and municipal goals set in the energy field. At the same time, it must be made visible to potential project developers, energy communities and the public in general, where renewable energy plants do not want to be located, and where, after a closer assessment, it may be possible to place renewable energy plants.

4.3.8 LOCAL PLANS

Municipals' plan (not the Municipal Plan) has provisions on the future use, design of buildings, and a number of other matters, and these plans have a direct legal effect on owners, tenants, and users of the properties covered by the plan. A local plan consists of provisions with associated map annexes and must be accompanied by an explanation of the plan's relationship to the municipal plan and other planning for the area (Post, 2018). The municipal council always has the right to draw up a local plan, for example, if it wants to leave its mark on a private building project. In some cases, it may be necessary to first impose a temporary ban on an unwanted project, which would otherwise be able to be built according to current regulations. The municipal board may, under section 47, subsection 1, in the Planning Act, expropriate real estate that belongs to private individuals or private rights over the real estate when expropriation is of significant importance for the implementation of a local plan or town planning statute and for safeguarding general public interests (REF). It can, for example, be whether In the Environmental Protection Act § 58, which stipulates that a municipality can plan on expropriation in favour of a wastewater plant (Miljøministeriet, Bekendtgørelse af lov om miljøbeskyttelse, 2024).

The amendment to the Planning Act in 2012 stipulated that the planning justification of a local plan can be climate adaptation, not climate prevention (By- Land- og kirkeministeriet, 2018). The municipalities have, therefore, been given the opportunity to adapt the local plan area to the consequences of climate change. In this connection, there is also access to the local plan catalogue to determine provisions in a local plan that can be included as part of a climate adaptation project. This applies, for example, to which provisions can be laid down on preventive measures to protect against flooding. Such a local plan provision can then form the basis for expropriation.

While both the climate act and the amendment to the Planning Act for climate preventions to be added as a national interest has been enacted since 2012, it is still not within the regulations to allow for expropriations for climate preventive measures, including RE-plants.

Authorization for expropriation is mainly found in a large number of laws regarding constructions of roads, railways, ports, military installations and cable installations of various kinds. An example could be Limfjordsforbindelsen via Egholm, which was proposed and adopted by the Danish Parliament in 2024 (Transportministeriet, 2024). The planning act legislation allows expropriation when it will be

of significant importance for ensuring the execution of an urban development in accordance with the municipal plan or for the implementation of a local plan (Jensen, 2024). Any expropriation has to be approved by the Expropriation Commission, which is an independent authority that only answers to the Danish Parliament. It is also them that determines the full compensation that the owners of the expropriated land (Ibsen, u.d.).

When proposing an expropriation, these are usually called construction acts and, according to the EIA Directive, is expressed as a special national law that approves a project in detail.

"Instead of the competent authority issuing a permit, it is the Danish Parliament that issues the permit through the adoption of the law." (Translated from Danish by authors) (Miljøministeriet, Vejledning til lov om miljøvurdering af planer og programmer og af konkrete projekter (VVM), 2022).

4.4 AALBORG MUNICIPALITY AS A FACILITATOR

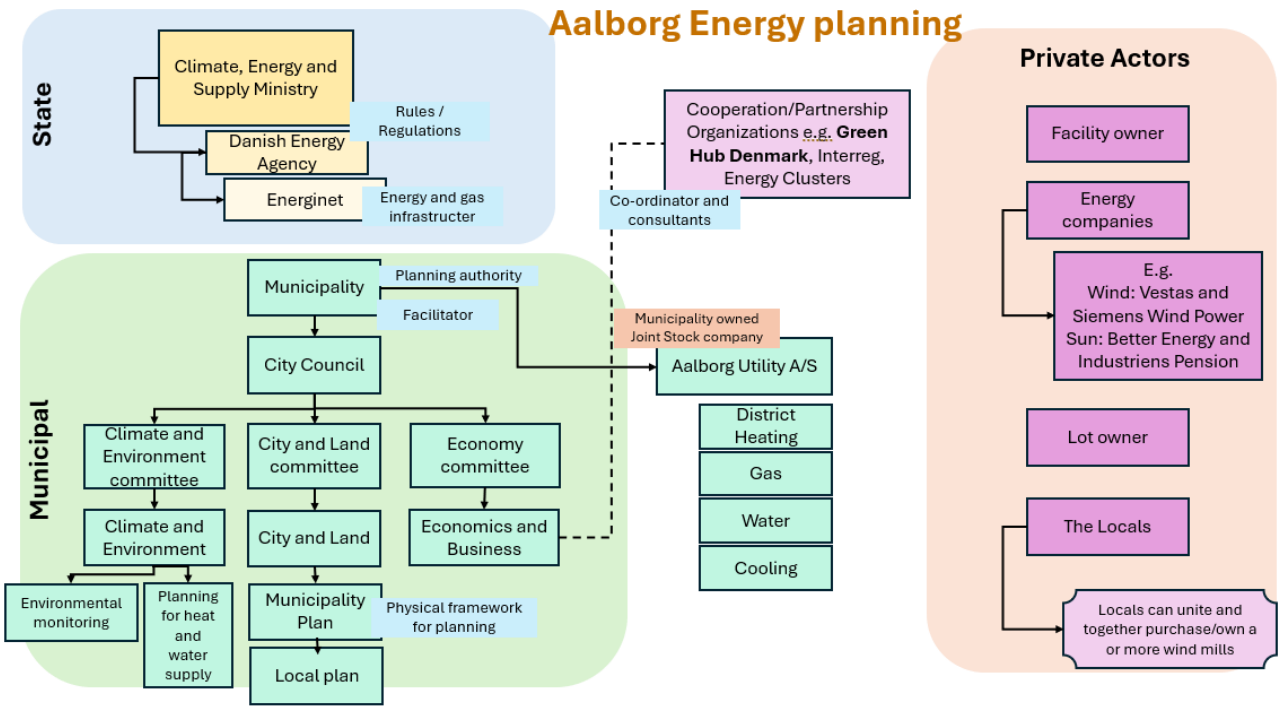


Figure 11 - Overview the actors in the energy planning in Aalborg municipality

Figure 11 show the general overview of the energy planning in Aalborg municipality, separated into state-, municipality and private actors. Aalborg Utility is somewhat separated as despite it being completely owned by Aalborg municipality; they are a stock company. As mentioned earlier in limitations, this thesis doesn't do a comprehensive analysis on the different private actors in the Danish energy planning. However, as described, despite the municipality having authority through

the local plan in regard to physical planning, they themselves and do little in realising bigger projects by themselves.

In Aalborg municipality the main actors regarding energy planning are City and Land administration, Climate and Environment administration and to a lesser extent, the Economic and Business administration. Economic and Business administration is included as the municipality's economy is handled by them and they coordinate between the six other administrations (Aalborg kommune, Organisation, u.d.). A part of Climate and Environment administration's responsibility is environmental supervision, which is relevant for any physical structure – such as a RE facility. They are also the ones that plan for the supply of heat and water (Aalborg kommune, Organisation, u.d.). City and Land is the administration with arguably the most authority and likely the biggest roam of possibility to facilitate RE (Aalborg kommune, Organisation, u.d.). It still, however, only facilitate. As described in further up, the local plan enables the municipality to designate land areas for specific purposes. In Aalborg's case, they have designated areas as energy landscapes, so no other physical structures can be built.

4.4.1 Aalborg Climate Plan

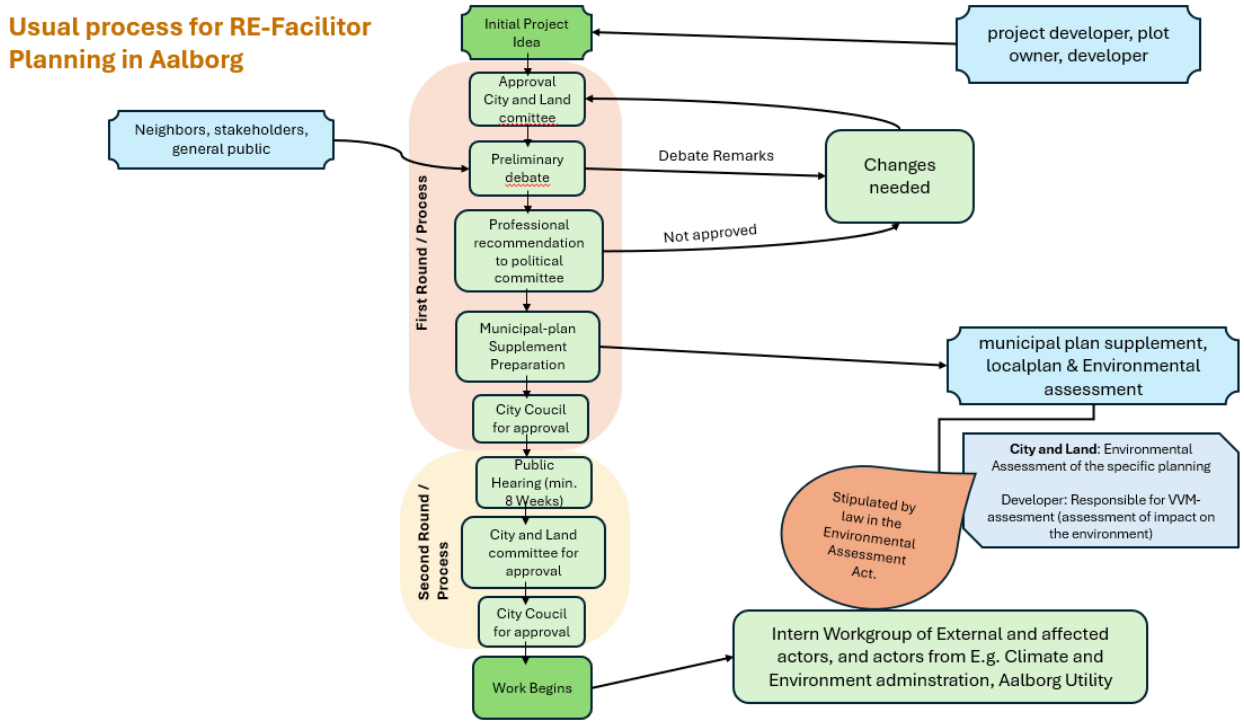
Aalborg joined DK2020 with their own climate action plan in 2020. Beside the stating their aligning with the Danish aim of being climate neutral by 2050, as directed by the EU, and the 70% reduction of GHG emission by 2030, Aalborg's DK2020 climate plans have some specific targets of their own (Aalborg kommune, Klimaplan for Aalborg Kommune, 2020). The region of North Jutland aims to be self-sufficient with RE in 2040 (Aalborg kommune, Klimaplan for Aalborg Kommune, 2020). Regarding energy planning, Aalborg's climate action plan focuses on energy saving as well as energy efficiency improvements and also increases utilisation of excess heat and local production of renewable energy. It also states the need for more wind turbines and solar panels due to the conversion of many sectors such as heating and transportation to run on green energy. One of the few concretes and in-the-work actions is the closure of the Nordjyllandsværket and the phasing out of coal by 2028 at the latest (Aalborg kommune, Klimaplan for Aalborg Kommune, 2020). Other than that, the climate plan language consists of such phrases as: *Facilitate early dialogue*, *work to realise*, *explore options*, *work actively*, *promote use*, *attract investors* etc (Translated by authors) (Aalborg kommune, Klimaplan for Aalborg Kommune, 2020). This rhetoric in the climate plan exemplifies that the municipality role as a facilitator in the RE planning and generally in any GHG prevention action.

The climate plan in itself emphasises this restricted role in the section *The municipality as a company* where the first paragraph reads:

"*Aalborg Municipality can directly influence greenhouse gas emissions from its own buildings, vehicles and public lighting*." (Translated by authors) (Aalborg kommune, Klimaplan for Aalborg Kommune, 2020, s. 31).

Noting the phrasing of the municipality being able to *directly* influence GHG emissions. This gives the effect that the opposite is then true in all other instances – that the municipality can only *indirectly* influence the GHG emissions through their role as facilitator and coordinator in all other sectors. In the beginning of this chapter, it was stated how cities are often expected to contribute significantly to fight against climate change and reduction of GHG emissions, through shaping local governance. However, at least in a Danish context, where earlier there was little legislative backing from the state and the municipality have little to no force of law when it comes to energy planning – put simply, it is doubtful that the Danish municipalities can live up to this expectation. Not without changes in the vertical planning system.

4.4.2 MUNICIPALITY'S ROAM OF POSSIBILITY



With the high level of privatisation of land area in Denmark, the physical building of e.g. RE facilities are the responsibility of private actors. As explained in the interview with Jørgen, the municipality often plays the role of facilitator through, among other things, their municipal- and local planning (Appendix A). Peter and Cecilie highlighted their ability, as a municipality, to create opportunities by

establishing the framework, yet they explained that the realisation of these opportunities is not guaranteed, as it depends on the actions of private actors. Municipalities may prioritise different projects based on their own interests and national priorities. Peter and Cecilie noted that in Aalborg's local plans, a holistic approach was adopted, e.g. selecting bigger areas reserved for energy landscapes (Appendix A). This was done in hopes of aiding an interconnection between projects (Appendix A). This approach carries the potential of rejecting projects from developers and investors that do not align with the municipality's overarching priorities, despite potential benefits in other aspects.

In theory, a municipality can opt to develop and build projects like RE independently, for instance, by creating a climate budget. However, as explained earlier, municipalities must operate within the constraints of the budget act to avoid facing financial penalties. This means that municipalities have a relatively narrow ceiling for how much they can spend. When planning larger projects, which are often expensive, such as RE, the municipality can rarely be the sole investor, as they would then have to draw from other sectors' budgets, such as elderly care or education, etc. Even if the municipality has funds available, they cannot necessarily use them, as the budget act requires the municipality to either be in balance or in profit (Formandskab, 2019).

There is the block subsidy (Bloktilskud) that a municipality can apply for. However, the block subsidy reflects agreements between municipalities and regions regarding economic priorities (as detailed in the AME Documents discussed in section 4.3.4) (Formandskab, 2019). These agreements determine which areas require focus and prioritisation in relation to budgets. If areas such as climate, green transition, and RE are not prioritised, it becomes extremely challenging for municipalities to secure block grant funding for projects in these sectors.

This emphasises the importance of the RE transition not only being mentioned in the AME documents but also being explicitly prioritised in the document.

During the interview with Cecilie and Peter, the significance of the government explicitly expressing the importance of the RE transition was also brought up. When municipal decisions are made, it is easier to "take the heat" when the topic has already been prioritised by the government (Appendix A). In today's Denmark, the RE transition is particularly prominent, especially in the wake of the energy crisis triggered by the Russia/Ukraine war. Through strategic initiatives and statements, the government has emphasised the critical need for Denmark to transition to RE. This explicit prioritisation makes it easier for municipalities not only to attract private investors interested in RE projects but also to convince locals of the benefits (bonuses and compensation) of living near RE facilities and underlines the necessity of this transition.

As politicians, the decision-makers in a municipality, have an interest in remaining in their position and that hinges on the voters. This can and has created a conflict of interest, as politicians might hesitate furthering any RE development if this would cause them potential voters. Exactly this was mentioned by Jørgen in the interview, as a barrier when trying to develop RE. This is an example of the behavioural lock-in (Seto, et al., 2016), with locals being resistant to a change that is deemed as necessary and for the common good, not just by the municipality but also the state and EU.

The "Not in My Backyard" (NIMBY) effect is a phenomenon that has been discussed, particularly in relation to the increasing number of planned onshore wind farm projects. In short, as the name suggests, the phenomenon is where residents in an area can see the necessity of a new facility or institution but object to its placement specifically in their immediate vicinity (Orbensen, 2016). This protest can be based on various factors, depending on the project. In Denmark, it is especially onshore wind turbines that are protested, but also large solar cell parks. With wind turbines, the main concerns are noise pollution and obstructed views or that it can impact the property's market value (Nielsen, 2021). Whereas the main complaint about solar cell parks is the considerable space they require and also the changed view. Both RE parks also face criticism regarding environmental and biodiversity concerns. However, Cecilie and Peter described that after the energy crisis in 2022, there has been a greater willingness to compromise from the local residents (Appendix A). This is likely due to the local residents, and the general public, realising in the wake of the energy crisis, the benefit for them in the long run. In this way, the war has also opened a window of opportunity within the behavioural lock-in, by shocking people out of their equilibrium - making them more open to alternatives to the status quo.

Another approach for municipalities to develop RE is through the green pool scheme, introduced in 2020 (Klima- Energi- og Forsyningsministeriet, Bekendtgørelse om grøn pulje, 2020). The renewable energy promotion act (VE-Loven) stipulates that renewable energy facility developers must pay a certain amount per installed MW to the municipality where the facility is located. The municipality manages these funds, which can be utilised for a broad range of municipal projects. The primary objective is to allocate these funds to support projects submitted by nearby residents of the RE facility, as well as green initiatives within the municipality (Klima- Energi- og Forsyningsministeriet, Bekendtgørelse om grøn pulje, 2020).

The green pool is not part of municipal budgets, providing greater flexibility for municipalities and potentially leading to greater acceptance of renewable energy facilities from the locals. The green pool was brought up in the interview with Cecilie and Peter who voiced that the green pool was so relatively much money that it is enough to turn into some good projects, although still not in the scale of RE facilities. (Appendix A)

4.4.3 AALBORG UTILITY A/S

In the energy area, the municipalities are primarily the authority for collective heat supply. Although this is one area where we see this public decentralisation, as Aalborg Utility is an independent company, it is 100% owned by Aalborg Municipality. This means the municipalities must process and approve project proposals for collective supply facilities. Being fully municipality owned, also means that Aalborg municipality has a greater possibility to integrate it into the fossil fuel free and zero emission goals. Although, Aalborg Utility still need to adhere to the revenue regulation and company, although municipality owned, the municipality has no direct control, rather they have seats on the committee.

The municipalities are also the authority for spatial planning, which includes planning for the location of technical facilities. With energy planning the goal is that energy planning must be done as a comprehensive plan across sectors. Consequently, this means that the municipalities must create planning that extends beyond the sectors for which the municipalities themselves are the authority. Simultaneously, the regulatory framework and planning possibilities have undergone vast changes in this area, and as we will delve into further, they still are.

The Danish Energy Agency oversees the collective heating supply, while municipalities hold administrative authority (Figure 9) (Energinet, Om os, u.d.). Municipalities are responsible for creating heat plans that outline areas expected to be supplied with district heating, including timelines and future plans for individual renewable energy sources (Post, 2018). In supply production, areas like the pipeline network are considered natural monopolies, characterised by a single provider to avoid excessive market power and arbitrary pricing. This applies to electricity grids, district heating pipes, and water pipes, where competing infrastructures side by side are impractical. Distribution of water, heat, and electricity is generally seen as a natural monopoly, while production is not.

In Denmark, the supply sector is predominantly driven and owned by municipalities, consumers, or the state. Approximately 2,000 waterworks exist, with around 50% consumer-owned and the other half municipally owned. Danish electricity companies, owning and managing the distribution network, are mostly cooperatives owned by over two million consumers, with significant state and private investment through DONG Energy (now Ørsted). The 1999 electricity reform liberalised the sector, allowing consumers to choose their electricity provider, splitting the monopoly grid from competitive production and trade (IRENA, Denmark Market overview, 2013). District heating in Denmark is produced by about 400 companies, with roughly 50 being municipally owned, covering about half of the supply, and 350 smaller consumer-owned cooperatives covering the other half. Currently, around 10 smaller private district heating companies exist (Monsalves, Jesús, Bergaentzlé, & Backer, 2022). Danish district heating companies operate under a "self-sufficiency" principle, prohibiting profit or

loss without public approval. In 2017, it was decided that district heating companies would eventually be revenue-regulated with a cap on consumer charges (Monsalves, Jesús, Bergaentzlé, & Backer, 2022).

District heating in Denmark is a voluntary system where at least 60% of residents in a neighbourhood must sign up before the area can receive district heating. When talking with Silas from Aalborg Utility about this, he explained that the minimum of 60-61% are essentially the cut-off point to if the project is economical feasible (Appendix A) Any less and the project simply won't be done. The residents who signed up are, of course, contractually obligated to connect to the district heating but it is of their own choice and the remaining 40% are not.

Silas expressed this as a barrier. According to him, Aalborg Utility do a lot of work in order to provide residents with alternative solution but neither the utility nor the municipality has any authority to impose district heating onto the residents. The municipality and utility can provide the opportunity and framework, what Silas called soft power, but they can do little else (Appendix A). Silas mentioned that legislation did exist that mandated new builds to be connected to district heating but that it was abolished.

The legislation Silas spoke of was the connection obligations which gave the municipalities the authority to mandate district heating connections. Connection obligations and/or retention obligations were meant to ensure the operation of the local district heating plant by distributing the plant's expenses among enough customers (Konkurrence- og forbrugsstyrelsen, u.d.). If a municipality imposed a connection obligation and/or retention obligation on a property, it meant that fixed expenses for the district heating plant must be paid until the municipality decided otherwise. The obligation also entailed that the utility company had the right to establish the technical facilities necessary to supply the property (Konkurrence- og forbrugsstyrelsen, u.d.). However, from January 1st, 2019, a rule came into effect prohibiting municipalities from deciding that new areas must be connected to a district heating plant (Klima- Energi og forsyningsministeriet, 2021). The rules do not apply to existing connections, only to future ones. This means that as a newcomer to an "old" residential area, you still have an obligation to pay the district heating plant if the properties were subject to 25 connection/retention obligations before January 1st, 2019, (Klima- Energi og forsyningsministeriet, 2021).

By removing one of the few legislations that allowed municipalities to force district heating through, the municipalities are left with few tools and essentially only soft power to persuade residents. In the interview Silas expressed that, for the most part, residents main concern is not the type of heating or where it comes from but the pricing (Appendix A). This attitude is shown quite clearly at the hight of the energy crisis in 2022 when energy prices skyrocket due to the Russia/Ukraine war. Silas explained

how there was an exponential increase in residents wanting to be connected to district heating. According to him, they (Aalborg Utility) were able to accomplish in two-three months what usually would take a year (Appendix A). However, Silas also noted that this increase in demand as dwindled in parallel with the energy prices returning to a similar rate as before the energy crisis.

When interviewing Mats from E.ON about Ectogrid, one of the questioned asked was the challenges or problems there could be in implementing Ectogrid, he mentioned how there at times were a unwillingness from utility companies to implement new technology. As he did not specify a specific country and it was not asked, it is uncertain if this was the same case with Denmark. However, when speaking with Silas from Aalborg Utility, this perceived unwillingness was mentioned and according to him it was more a case of it can be difficult to implement new technologies due to price regulations. The utility has an obligation to ensure that the prices are as cheap as possible within the regulations.

4.5 Key points of Multi-level governance analysis

This part of the analysis delved into the energy planning in Denmark, attempting to answer the questions of *where is energy planned and governed in Denmark?* and to understand where the institutional lock-ins occur. In short, this section was to understand the different level of governments and actors roam of possibility in the RE transition. The key take-away, as this thesis is focused on Aalborg Municipality as its case study, is that despite the decentralization and disbursement of responsibility both in vertical and horizontal planning, the Danish municipalities have little authority or direct influence in the RE transition. Due to the high privatization of Denmark's land area, construction of physical infrastructure, such as RE facilities, lies with the private actors, leaving the municipalities as facilitators in RE. Furthermore, there is little or only very new legislation which enables the municipalities to prioritize RE or GHG prevention in general. However, there has been a change in legislation on the state level in the last couple of years, such as including climate in the national interests and declaring RE a matter of national energy security, which could indicate that the municipality might have more influence in the future in the transition to RE. It is a cautious optimism, however, as there have been a tendency in Danish planning of retrogressive removing GHG emission preventative legislation (such as Agenda 21) as well as the already noticeable lack of focus on climate in the newest agreements about the municipality's economics.

5 CASE STUDY OF AALBORG

As described previously [chapter 4], the various directives and initiatives articulate the need to phase out fossil fuels and transition the energy sector towards a more resilient future. Since the establishment of the European Climate Law and, subsequently, the Danish Climate Act, it has become one of the leading goals to shift the Danish energy system towards RES, thereby facilitating a climate-neutral society by 2050, at the latest (Lov om Klima, 2020; ESABCC, 2023). As a result of the global energy crisis precipitated by the COVID-19 pandemic and the Russian-Ukrainian War, the need for a self-sufficient, competent, and net-zero energy system has become a shared European goal (IRENA, 2023; EUSEW, 2024). Aside from examining the governmental background and institutional dynamics, it is also crucial to analyse the city's physical and urban aspects to understand and implement technological integration. Furthermore, it is also necessary to thoroughly understand the current energy system, its limitations, and potential solutions.

Figure 12 - Aalborg's location in Denmark (created by the authors).

In the forthcoming chapter, a comprehensive case study analysis of the Danish city, Aalborg will be presented to offer an overview of the critical urban aspects and their significance in transitioning from a fossil fuel-dependent urban environment to one that hinges on RE and, thus, towards a climate-neutral future (Figure 12). The analysis is based on a multi-scale and holistic approach, intending to investigate the various factors that influence the adjustment and reformation of the existing system.

First, the case study discusses more general factors, such as elements and assets of the existing physical infrastructure, before moving on to more subject-specific areas. As part of the analysis, maps created using QGIS will illustrate information regarding the existing infrastructure and energy system, as will diagrams containing information derived from different national and local Danish sources (e.g., Danmarks Statistik, Energinet, Aalborg Kommune, Kommuneplan etc.).

As part of the study's development, careful consideration was given to future plans and development targets, ensuring the study's adaptability to future changes. The investigation aims to bring light to the challenges and potentials that Aalborg is grappling with in the RET. Furthermore, the assessment strives to pinpoint a focus area, ripe for future integration due to its significant design characteristics and aspects. The selected focus area will undergo further analysis and design to generate solutions that address the challenges of RET. Moreover, the case study is intended to serve as an example for

other cities facing the same challenge of switching from fossil fuel dependency to renewables. A summary of the results will be further discussed in the subsequent chapters, culminating in a proposal that encapsulates all the findings and learnings from the thesis.

5.1 Introducing Aalborg

Aalborg is located in the Northern region of Denmark (Figure 13), along the Limfjord coastline, and is administered by the Municipality of Aalborg (ID 851). There are several sub-areas within the municipality (such as Nibe, Hals, etc.) covering an area of 1 137.3 km^2. The case study, however, focuses on the city of Aalborg, the most populous (2361 people/km^2 of population density), dense, and diverse sub-area regarding economic and industrial development (Statistikbanken, n.d.).

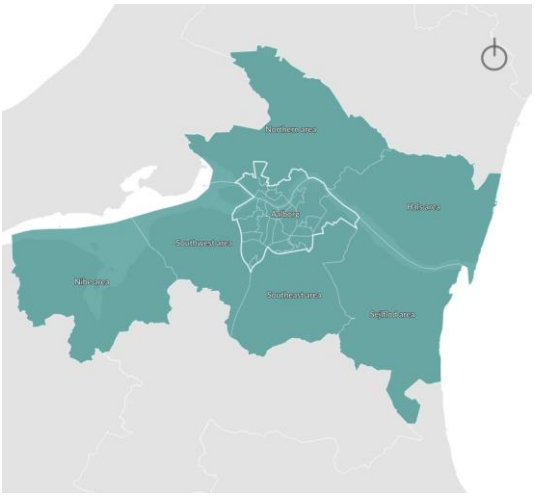


Figure 13 – The Municipality of Aalborg and its sub-areas (created by the authors).

With its continuously growing population and ongoing urbanization, the city has become the fourth-largest urban settlement in the country. This trend is projected to continue as the municipality is set on its mission to establish Aalborg as Northern Denmark's educational and commercial powerhouse (Aalborg Kommuneplan, n.d.). The rapid urban and population growth and the subsequent effects of urbanization ought to transform certain areas of the city, leading to a denser urban fabric as well as a surge in energy consumption and demand in the future.

Additionally, the city is known as a significant hub for manufacturing electronics and machinery, as well as its extensive educational and research sector, in which universities and research institutions play an integral role in creating a knowledge-based economy (Aalborg Kommune, n.d.). The presence of industries and the ongoing scientific research contribute significantly to attracting investors and developing creative solutions in the region, particularly in the field of RE integration.

Regarding the thesis topic, it is imperative to note that Aalborg intends to implement significant changes to its energy sector and urban planning and management to ensure its transition toward a renewable-based city and society. Thus, and in an effort to shift to clean energy sources, the city has been implementing several RE projects (e.g., increasing wind and solar power supplies) and is investigating initiatives for developing smart grids and energy-efficient buildings (Lund et al., 2020). In addition, the city is exploring technologies such as energy storage systems and electric vehicle infrastructure to optimize energy consumption and reduce GHG emissions (Aalborg Kommune, n.d.).

Aalborg's commitment to sustainability, desire for clean energy solutions, and intention to establish a strategic energy planning practice make it an ideal case study for analysing and identifying potential opportunities for renewable energy transition and integration.

5.2 Urban Aspects

5.2.1 Hydrology

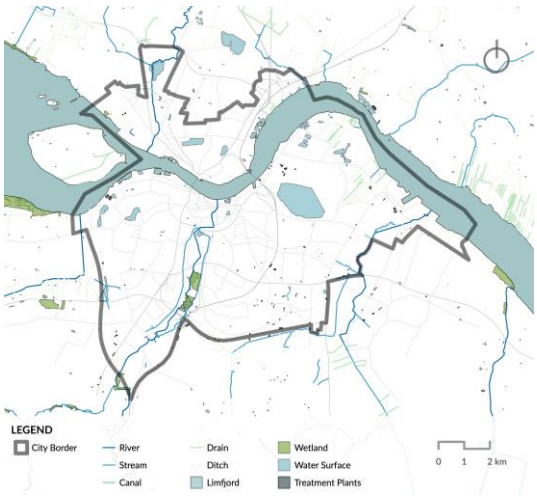


Figure 14 – Hydrology map of Aalborg city (created by the authors).

The hydrological and natural elements of the city, in general, can be summarized as follows: although the city contains green areas to some extent (e.g., Karolinelund, Mølleparken, Skanseparken, etc.), the typical landscape is a reflection of a car-dominated urban area, which is resulting in an increased demand for recreational opportunities that are currently achieved mainly through water resources (Figure 14).

One of the city's most valuable hydrological elements, the Limfjord, is a significant link between the North Sea and the Kattegat. It not only divides the city into two parts (Aalborg and Norresundby) but also offers a wealth of recreational opportunities along its coast (e.g., Vestre Fjordpark, Lindholm Strandparken). These areas provide essential access to diverse sea life and wilderness. Moreover, the Limfjord's role in attracting cruise ships to dock in Aalborg's central harbour during the tourist season has not only significantly contributed to the city's growing tourism industry but also underscored the economic importance of the fjord.

Besides the few lakes scattered throughout the city (e.g., Kridtgraven, Lergraven, Fuglesø, etc.), there is also a mining lake on the east side of Aalborg (Rørdal kridtgrav), close to the central harbour and west of the east harbour, which is surrounded by the facilities of Aalborg Portland as well as various other industrial and agricultural areas.

Another vital component of the city's hydrological system is the Østerå River, situated in the northern valley and stretching between Viborg and Aalborg, providing a recreational connection to the Limfjord. In recent years, as part of the municipality's effort to protect natural elements and increase biodiversity, parts of the river that were moved underground during the industrial era have been reopened. Based on the design of the SLA design studio, the development aims to reconnect Aalborg

with the surrounding environment and enhance the city centre's climate adaptability through nature-based elements (SLA, 2024).

Looking ahead, the municipality and the city outlined clear plans for the future. The primary focus is on maintaining and enhancing the connection between the fjord, the city, and the citizens. This includes ensuring constant access to green connections, like Østerådalen, and a diverse range of recreational opportunities. However, Aalborg is also committed to preserving the city's significant historical and cultural values. As per the plans, these values will be leveraged to enhance business opportunities, particularly in the city centre (Aalborg Kommuneplan—Bykvalitet, 2013).

5.2.2 Accessibility and Road System

Aalborg, strategically positioned at the intersection of northern Denmark's educational, commercial, industrial, and cultural sectors, serves as a vital link connecting the country's northern, mid, and southern regions. The connection is facilitated by a motorway and a bridge spanning the Limfjord, which the City Council aims to expand towards western areas as well, to improve the regional links and accessibility.

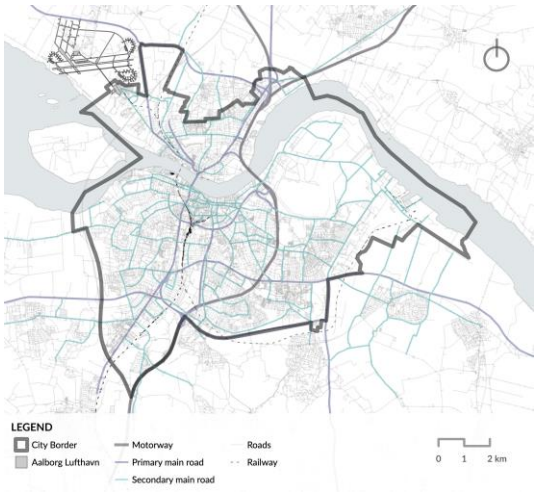


Figure 15 – Aalborg's Road system (created by the authors).

The city's road system, including primary and secondary main roads, further enhances connectivity to regional urban settlements like Hals, Nibe, and Egense (Figure 15). This prime location makes Aalborg an ideal transportation centre, ensuring easy accessibility to and within the city.

Several ports are situated along the coast of the Limfjord and serve the city's commercial and tourist interests. The east harbour is particularly important as it provides the surrounding industrial and logistical areas with the necessary shipments. The western and central ports are also home to a variety of leisure boats, from small yachts to commercial vessels, not to mention the main harbour's cruise ship traffic, bringing thousands of tourists to the city each year.

Another pivotal transportation point for the region is Aalborg's airport, situated north of the Limfjord and west of the Lindholm district. The airport is a gateway to many destinations serviced by various airlines, including KLM, SAS, Norwegian Air Shuttle, and Ryanair. This robust connectivity links Aalborg with Europe and various overseas destinations, offering travellers many possibilities.

As part of the city's public transportation system, there are several bus lines, as well as a railway that runs through the city (Figure 16). Currently, the railway operates three routes: two lines in the

direction of Hirtshals and Skagen, as well as one route that links the airport with Skørping. The bus network is divided into different categories depending on the distance and the time of operation. One of these categories is the city bus routes, which provide quick connections between the various districts in the city. With express, local, and regional buses operating on longer distances, transportation reaches outer areas and other parts of the region, including Frederiskhavn, Thisted, and Dokkedal. The night buses, on the other hand, offer the chance for public transportation after midnight. However, the amount of buses, routes and schedules are limited and require further expansion.

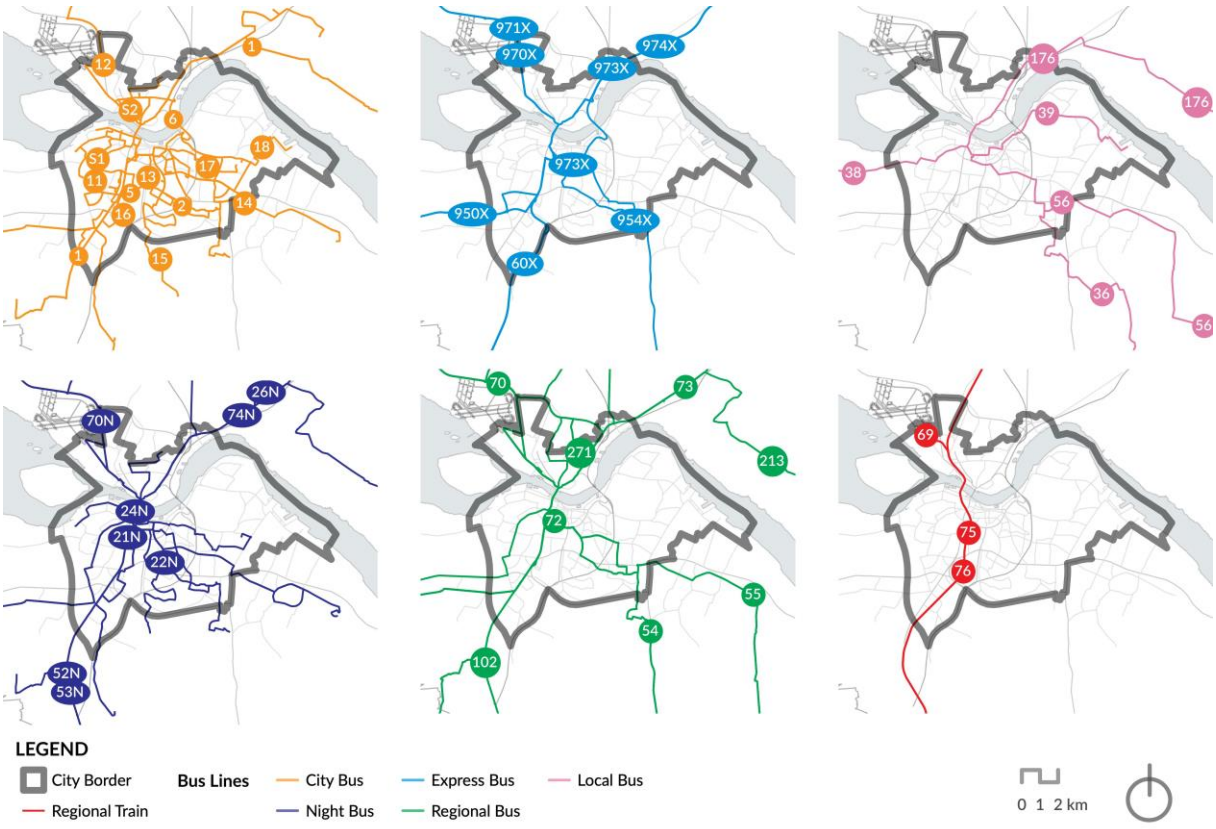


Figure 16 – Various public transportation opportunities of Aalborg (created by the authors).

It is noted that cycling connections throughout the city are well established and encourage frequent use of micro-mobility. However, some conflicts occur, whether pedestrians or vehicles invading the designated space for micro-mobility or motorcycles speeding down the bike lane.

As the city and other surrounding areas grow, further connections and improvements are required to enhance connectivity, especially since the city aims to establish a car-free city centre. Hence, investing in and developing public transportation and establishing new routes is essential, as is exploring alternative modes of transportation, including shareable micro-mobility and car sharing opportunities.

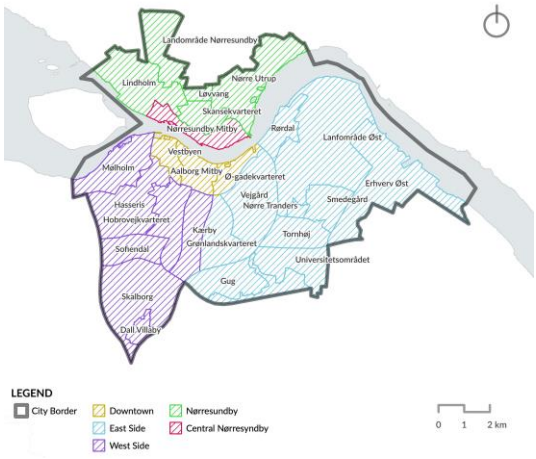


Figure 17 –Districts of Aalborg, based on the city's sub-parts (created by the authors).

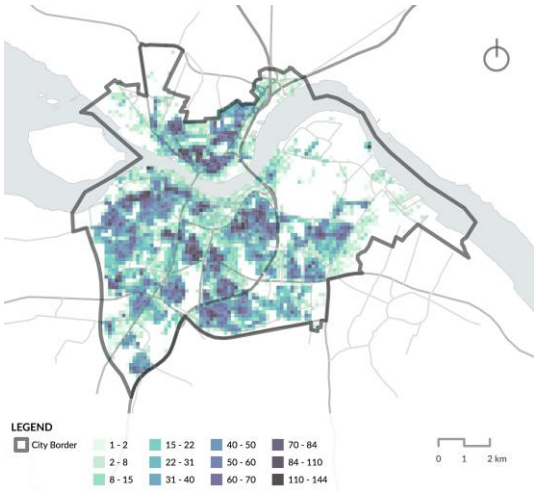


Figure 18 – The number of buildings assessed in a 250x250 m grid (created by the authors).

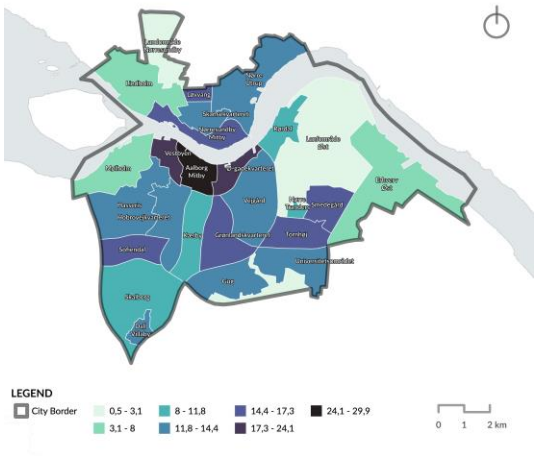


Figure 19 – Density of built areas per neighbourhoods (created by the authors).

5.2.3 Building Count and Density per Districts

The Limfjord's basin separates Aalborg into two main parts, Aalborg and Nørresundby, which are further divided into sub-parts. The sub-parts are as follows: West-, East-, and Downtown Aalborg, Nørresundby, and Nørresundby Mitby.

Several small districts within these areas contribute to the urban structure and indicate the origins of the historical town from which the development of these areas resulted (Figure 17). As previously presented, the districts are interconnected by an extensive network of roads and railways, ensuring easy access for its residents, which is further enhanced by the city's active public transportation system (chapter 5.2.2).

Assessing the city's density is also essential to improve our understanding of how the urban fabric is organized. In the case of Aalborg, two types of calculation were carried out. To begin with, a grid net of 250x250 meters was utilized. This method was chosen as a systematic and comprehensive approach to calculating the number of buildings per grid cell, giving us a clear picture of the city's building distribution (Figure 18). Furthermore, the density of the built areas per district was also assessed, wherein the area of built infrastructure was compared to the area of the districts (Figure 19). Additionally, a detailed analysis of the following data was conducted in order to assess the urban structure and to identify potential areas for further development, which will be presented in later chapters.

The results of the calculations indicate that while most sub-urban areas encompassing residential and low settlements have a high building count (60-144), the density for these areas typically does not exceed 14,4% within the respective districts (e.g., Hasseris, Mølholm, Vejgård). This means that while these areas have a

significant number of buildings, they are not densely packed, which could have implications for future development and land use planning.

Retrospectively, it has also been determined that the central areas of the city, representing taller and bigger buildings, display a lower building count (8-84 generally) combined with significant densities per district (20,3%-29,9%). The calculations indicate that the densest areas of Aalborg are in the Downtown area, including Mitbyen, which ranked first in density (29,9%), followed by Ø-gadekvarteret (24.2%) and Vestbyen (20.3%). When we consider Mitbyen's historical background and its commercial and cultural aspects, it's not surprising that such a unique area results in a denser fabric. The presence of numerous office buildings, hotels, and other amenities in the Downtown area further adds to its allure. The bustling nature of the central areas, in turn, has a positive impact on the local economy, making Mitbyen one of the busiest parts of Aalborg.

Furthermore, it has also been revealed that areas with large concentrations of industry and technical facilities often appear to have low density measurements (e.g., Erhverv Øst show only 8% density, with an average building count varying between 1-8). These measurements are partly due to the attention and safe zone that must be maintained around such areas as well as the need for space resulting from industrial activities.

Lastly, it is crucial to mention that the municipal and local plans for the future indicate that due to the limited land availability, future developments will emphasize vertical spread and densification (Aalborg Kommuneplan, n.d.). The downtown areas, in particular, hold immense potential for growth and development. As per the municipal guidelines, areas have been designated for constructing tall settlements, uplifting commercial functions, and developing the city centre, potentially increasing the current ratios and measurements even further (Figure 20).

Figure 20 - Urban Development target areas, specified by the municipal plans (created by the authors).

5.2.4 LAND USE

Most of the land in Aalborg is used for residential, commercial, technical, and industrial purposes (Figure 21, Figure 22). Currently, residential usage constitutes the largest share of the land, with an estimated 27%, consisting primarily of family homes and low settlements. However, a few taller buildings have been erected since the turn of the century (e.g., housing development at Østre Havn). Another major shareholder of the land usage is accounted for technical (15%) and industrial areas (7+9%), represented by businesses and stakeholders, among which Aalborg Lufthavn, the industrial parts of Rørdal (e.g., Aalborg Portland) and the Port of Aalborg to the east of the centre, play a significant role in the urban and RET of the city. Therefore, additional technical and industrial areas have been allocated for particular uses, prioritizing the local and national green transition (Aalborg kommuneplan, n.d.).

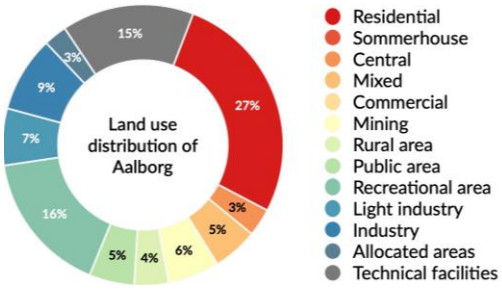


Figure 21 – Distribution of the different land use types in the city of Aalborg (created by the

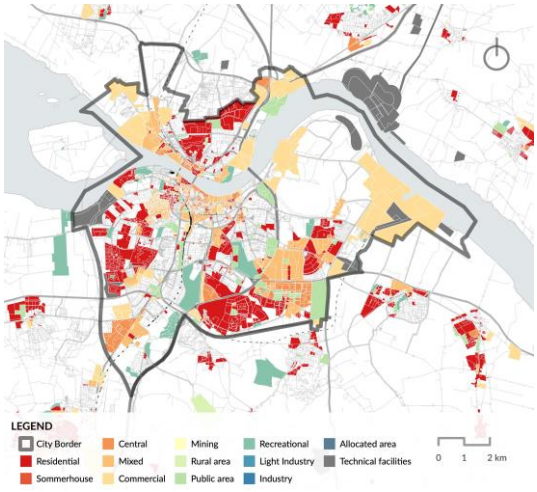


Figure 22 – Local plans, detailing the future land use of the city (created by the authors).

A notable portion of the city comprises commercial areas, with approximately 8% of the land being used for a mix of commercial and residential activities, including areas in the city centre. Nevertheless, Aalborg is planned to evolve as Northern Denmark's leading business and retail hub. Plans include developing Aalborg Midtby into an essential cultural, service, and trade centre while establishing a regional retail centre in the southern part of the city by allocating businesses to Skalborg (Aalborg Lokalplan, n.d.). According to the strategies, extensive commercial uplifting can be expected in certain parts of Hasseris, Vestbyen, and Vejgård. Moreover, the urban development plans for the city centre include a densified area that attracts tourists and businesses, while facilitating a symbiotic relationship between business interests, cultural heritage values, mobility, and city life. Hence, a rising trend in commercial and business opportunities is expected, as outlined in the municipal land use proposals (Figure 23).

Aalborg's diverse urban fabric provides an excellent opportunity for sector coupling and forming circular systems among different sectors. However, because the infrastructure is based on a fossil

fuel mindset, traditional businesses can hinder the city's collective transition. It is therefore recommended to take a collaborative approach when dealing with old and new stakeholders.

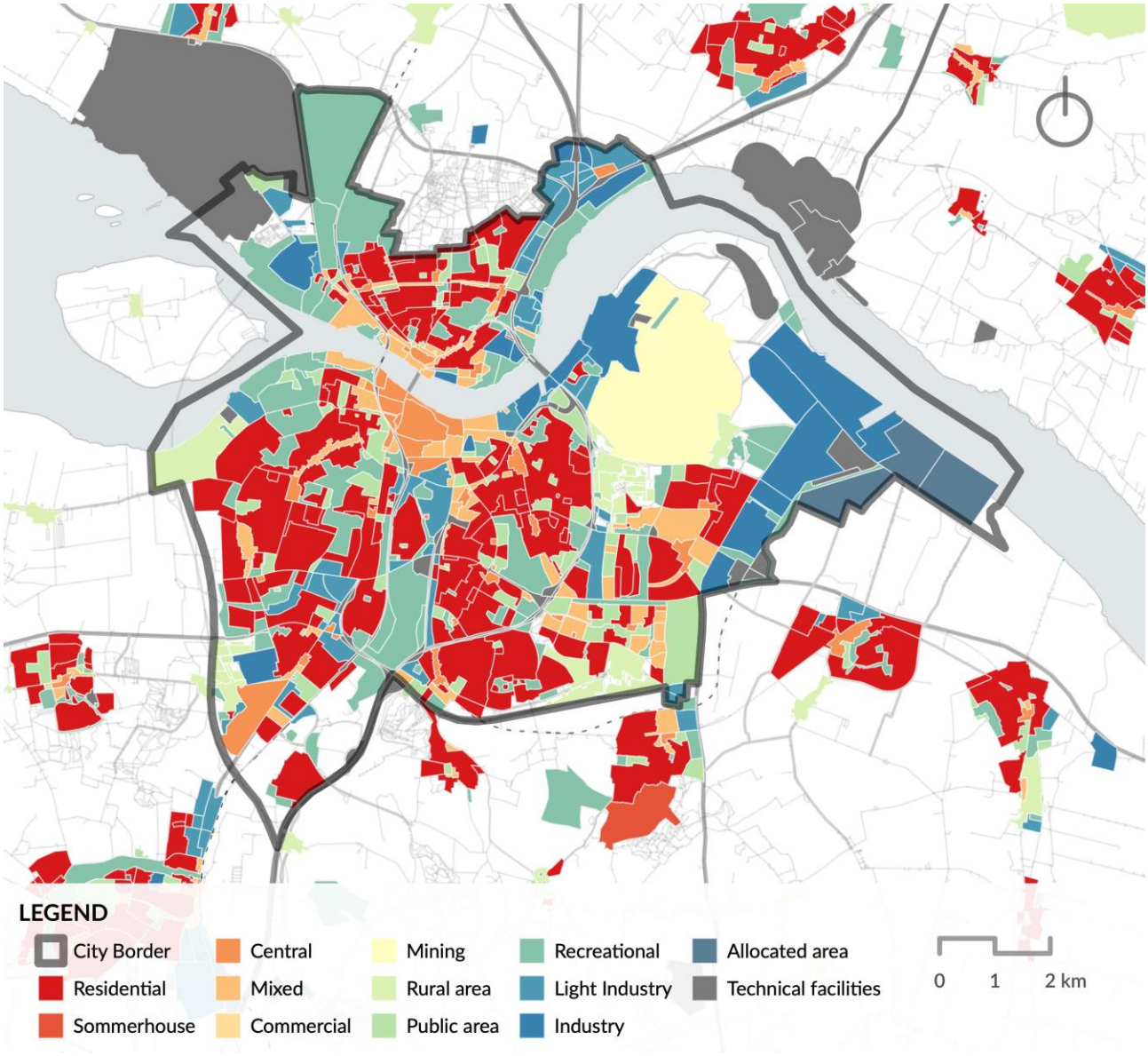


Figure 23 – The currently adopted land use of the city of Aalborg, based on the municipal plan's framework and classifications (created by the authors).

5.3 Energy Planning Perspectives

The following section will elaborate on certain aspects of the current energy system established in Aalborg, with regard to both national and local connections and data, derived mainly from Energinet and Energikortet (Energikortet, 2023; Energinet, 2024a; Energinet, 2024b), as well as the municipal and local plans concerning the energy sector.

5.3.1 Large Scale Connections of Aalborg's Energy System

Aalborg plays a vital role in the national energy system, as it not only contributes immensely to the nation's energy production and supply (e.g., Nordjylland power station, wind- and solar power contributions) but also serves as an intersection to receiving electricity imports from Sweden Figure 24). In addition, the city serves as the northern endpoint to the country's gas pipes with an established Meter and Regulator (M/R) Station that delivers natural- and biogas from the transmission line to the distribution grids. (Figure 25).

Figure 24 – Electrical transmission lines of Denmark, detailing crucial export and import data (Energinet, 2024a).

Figure 25 – Gas system network of Denmark, detailing crucial export and import data. The reference date was set to2024. June 1. (Energinet, 2024a).

5.3.2 Aalborg's Energy System

This sub-section will present Aalborg's energy system, focusing on its district heating and electricity network.

The current energy system of Aalborg, deeply rooted in the fossil fuel era, presents a pressing challenge for the RET, as the city aims to phase out fossil fuels by 2050. The urgency is underscored by the fact that the vast majority of the GHG emissions originate from the coal-based electricity and heat production at Nordjyllands power station and the fossil-fuel-heated district heating. Production rates reveal the city's heavy reliance on thermal and onshore wind power (Figure 26).

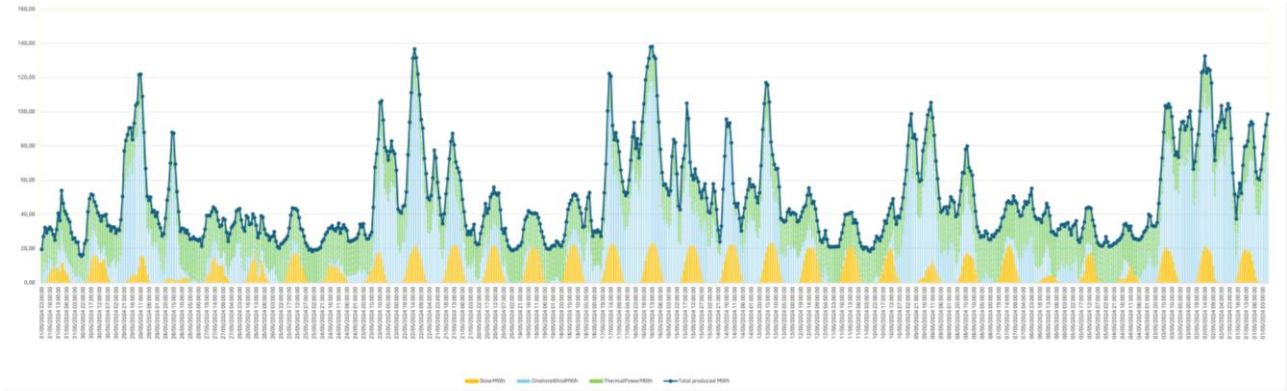


Figure 26 – Hourly energy production rates (MWh) in the municipality of Aalborg for the period of 2024.05.01-31., indicating thermal (green), onshore wind (blue) and solar (orange) power [adapted from (Energinet, 2024a)].

The district heating (DH) of Aalborg, provided by Aalborg Utility, is a centralized, 3GDH system, that operates on 55-60°C and is mainly supplied by the Nordjyllands power plant. The DH is predominantly fuelled by coal, waste, and natural gas, with only a fraction sourced from renewable energy sources (RES) and excess heat from Aalborg Portland. This highlights the current reliance on non-renewable sources and the urgent need for transition. In terms of DH coverage, substantial portions of the districts are supplied. Moreover, with the municipality's proposed plans for further expansions, the coverage is expected to increase significantly (Appendix A, interview w. Silas). The DH grid network has been mostly established; however, the majority of the physical infrastructure is nearing its life cycle and will need replacing in the near future (Appendix A, interview w Silas), presenting more pressing financial challenges.

As has been presented in the previous chapter (chapter 4), the city has joined the DK2020 climate plan, resulting in the creation of the local climate action plan, which, among other things, states targets relating to the mitigation of the climate crisis and subsequently to reducing GHG emissions (Aalborg kommune, Klimaplan for Aalborg Kommune, 2020). According to the established local targets, the city's goal is to phase out fossil-fuel district heating and shift it towards fuel-free system solutions such as excess heat and electricity-based heat pumps by 2028. Therefore, the operation of Nordjyllands power plant is scheduled to shut down by 2028. A few projects to substitute the heat production from Nordjyllandsværket are in motion (e.g., MAN-powered heat pumps and electric boilers). However, these projects are expected to substitute only a minuscule portion of the power plant's heat production (~25%), emphasizing the need for implementing additional technologies as soon as possible.

Additionally, one of the targets included upgrading the current DH system to 4th generation district heating (4GDH). However, during the case study investigation, it was revealed that the city's plan to

update the current DH system is seriously off track and might take years for the project to begin (Appendix A, Interview with Jørgen and Silas).

The electricity infrastructure in Aalborg includes overhead and underground high-voltage cables and renewable energy production facilities. Areas have been allocated for future expansion and establishment of energy parks across the municipality's area, especially concerning onshore wind turbine implementations (Figure 27).

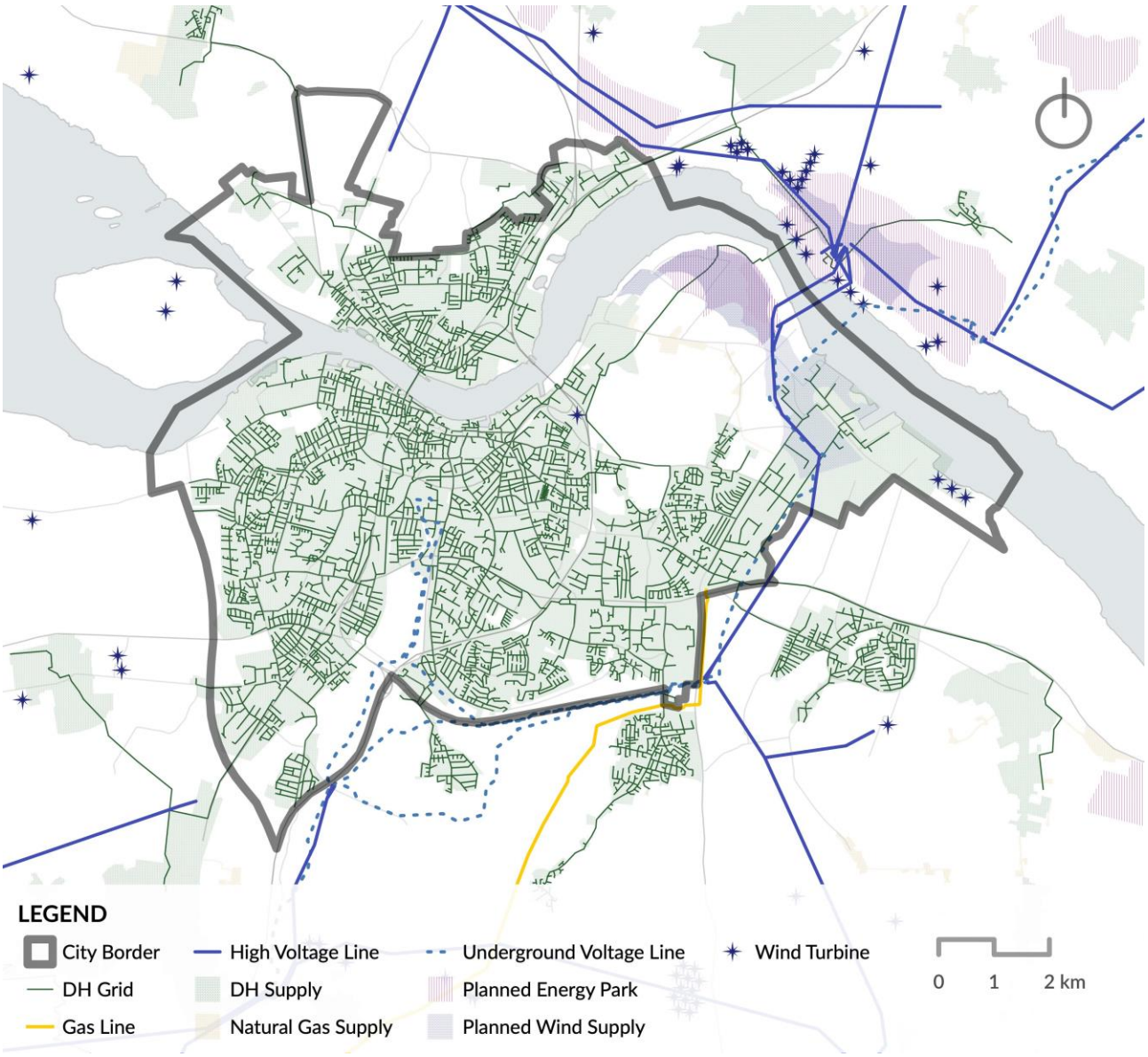


Figure 27 – The energy system of Aalborg, detailing the current infrastructure as well as the future plans of developing energy landscapes (created by the authors).

The energy and climate crisis has significantly influenced the city's approach to electricity production. It is committed to reducing emissions and transitioning to RES like solar panels and wind turbines.

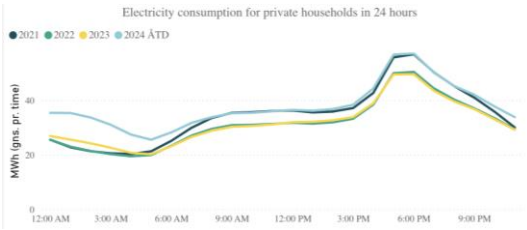


Figure 28 – Daily electricity consumption of private households, between 2021- 2024 (Energinet, 2024a).

Furthermore, the city is promoting using electric vehicles, energy-efficient buildings, and home appliances. As a result, there is a growing willingness to embrace renewable energy sources, leading to an increased supply of wind and solar power to meet the city's rising demand and consumption rates, especially in the private, residential sector (Figure 28).

6 CHALLENGES & POTENTIALS

6.1 CHALLENGES

v One of the biggest challenges against the RET is the fossil-fuel-dependent nature of the city, both in terms of the physical infrastructure and the operation and governance of Aalborg. As the city was designed and developed in the fossil fuel era, its facilities and structures are designed for a different operation than what a renewable-reliant or an electrified system requires (EUSEW, 2024). Therefore, a large-scale upgrade of the current 3GDH would be required; however, changing the whole pipe system of the city is not only a time-consuming action but also requires tremendous amounts of investments, which cities like Aalborg do not have the capacity for (Appendix A, interview w Silas). Additionally, the objectives detailing the city's urban development, such as the implementation of the 4GDH, are off-track, rendering the progress of the RET more and more unfeasible as time passes (Appendix A, interview with Jørgen). Especially since the window of opportunity, created by the energy crisis induced by the Russian-Ukrainian War, is closing.

Another significant factor complicating the RET is the high degree of privatization of Denmark's land area, coupled with the right to property stated in the Danish constitution. This leaves the municipality in a facilitator role, with limited possibility and capacity to act alone in energy planning due to the budget constraints they are under as per the budget act. This has left the development of RE in the hands of private developers, with the municipality having to make it attractive for investors.

Furthermore, the different stakeholders and business owners' private and capitalist interests do not align with RET's goals, preventing a smooth transition and resulting in conflicts in developments and constructions. The prevalent 'business-as-usual' mindset and the residents' 'not in my backyard' perspectives further complicate the situation, highlighting the complexity of the transition.

Notably, until recently (~ 2020), there was little to no legislation regarding GHG emission prevention. Everything regarding preventing GHG emissions, such as RE, was only written as goals or in non-binding plans, such as the DK2020 from Climate Alliance. This lack of prioritization from the state-level limited the municipalities' possibilities, as the climate was not part of the national interests until 2023. This situation meant that the municipality could not justify spending the budget on mitigating GHG emissions over the four other interest areas (nature, environment, growth, and development), leading to less financial support of grants from the government and a scarcity of investors.

Lastly, a recurring gap seems to be present in the municipal and local planning of RET, as well as in relevant literature, namely, that while many papers and development strategies study the theoretical aspects of the required transition, however, actual physical integration, and further changes have not been facilitated.

6.2 Potentials

As the different aspects of the thesis analyses progressed, certain potentials became visible to the authors.

Although the Russian-Ukrainian War is tragic, the following events, such as the energy crisis, coupled with the climate change issues, urged the Danish Government to establish and prioritize legislations and plans, regarding the betterment of the Danish energy system, especially with regards to securing energy independency and security. Thereby creating a window of opportunity for further changes and rapid institutional reactions.

Another apparent potential lies in the city's objectives to phase out fossil fuel, thereby reducing the city's dependency and the active approach towards increasing the RE supply. The areas allocated for technical and industrial uses, including the development of Aalborg's energy landscape, provides the stage for the projected electrification of the energy sector.

Additionally, the initiative to close down the Nordjyllands power station is expected to reduce GHG emissions and fossil fuel dependency significantly. As per Aalborg's Climate Action Plan, the three MAN powered heat pumps (3x44MW), utilizing the Limfjord's hydropower and renewable electricity to generate heat, will potentially provide further enhancements for the current energy system.

Regarding the legislative barriers that could prevent physical integration of new energy system technologies, flexibility can be allowed for experimental pilot projects to discover system operation needs and legislative frameworks, such was the case in the rainwater harvesting pilot project, established in Aarhus, Nye (Aarhusvand, 2021).

Lastly, the energy crisis induced a rapidly growing line of innovative technologies and solutions, primarily focusing on electricity-based features. A relevant and ideal example is presented in the form of the Ectogrid, invented by E.On, which will be further introduced in the following section.

6.2.1 ECTOGRID

As part of the thesis research, a visit to E.ON in Lund, Sweden was made to interview Mats Carselid,

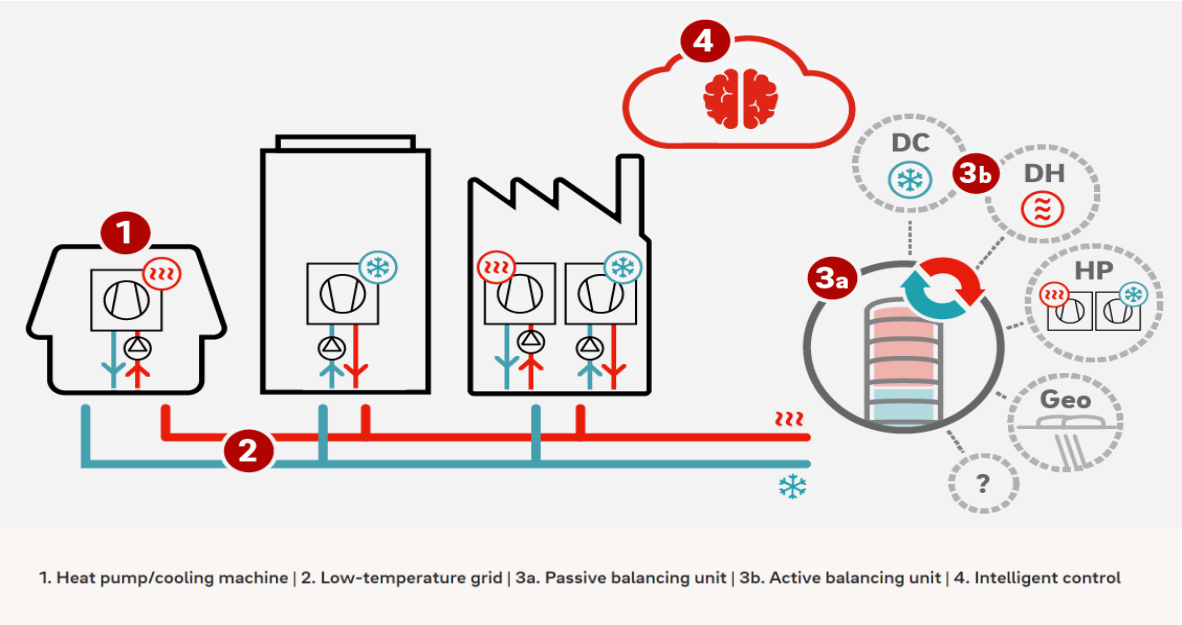


Figure 29 - E.ON Ectogrid system component explenation from E.ON website

a solution designer at Ectogrid E.ON, about their system.

Ectogrid is a closed grid system which both delivers heating and cooling from the same grid (Figure 29). Its decentralized design means that the system can operate in much lower temperature (0-40°C) than most heating systems operate in today (50-100°C) (E.ON, u.d.). This is due to Ectogrid installing either heat pumps and/ or chillers at the buildings connected to the system which raises or lowers the temperature according to the need. This reduces the energy loss which occurs in centralized distribution systems, maximising the usage of excess energy (E.ON, u.d.).

As explained by Mats, Ectogrid's name and design is inspired by cold-blooded animals which are ectotherm, meaning that they have the ability to regulate their body temperature depending on external sources which is the idea of Ectogrid (Appendix A, Interview w. Mats).

Ectogrid employs an accumulator tank to balance the temperature, by stratifying the cold and warm water levels inside the tank – called passive balancing. When there isn't sufficient balance in the tank, it being too cold or warm, the system uses active balancing by either supplying or disposing of energy (E.ON, u.d.).

At Medicon Village in Lund, their accumulator tank is equipped with sensors and coloured lights which reflects the balancing of the warm and cool levels and shows if active balance is needed (Appendix A, Interview with Mats).

Another unique feature of Ectogrid is that it utilizes only two pipes for heat and cooling, when it is traditionally two pipes for each. Ectogrid only need two pipes as the water can be pumped in either direction due to a distribution pump. This system is beneficial as it means less pipes and Ectogrid doesn't use steel pipes but rather un-insulated, plastic pipes which is more cost effective (E.ON, u.d.).

Ectogrid is supported by a cloud-based digital platform called Ecto Cloud, which utilizes machine learning and the IoT to optimize grid performance. This platform enables smart temperature adjustments, peak shaving, and predictive maintenance, ensuring the system operates at maximum efficiency (E.ON, u.d.).

The company offers various business models, including build-own-operate, where they build, own, and operate the infrastructure, and the net model, where clients own the equipment in their buildings while Ectogrid owns the grid. This flexibility allows for customization to suit different client needs and preferences.

As of now, E.ON Medicon Village in Lund is the biggest usage of Ectogrid with 17 buildings connected, as it is still a fairly new system but there are several new projects that will implement the Ectogrid system (Appendix A, Interview with Mats). Such as the as the new business district in Milan where Ectogrid is to provide heating and cooling for 32 buildings on one system (Latif, 2022) and also SilverTown in London where the five interlocking neighbourhoods will be heated by Ectogrid (lendlease, u.d.).

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Overall, Ectogrid presents a unique and innovative approach to energy management, providing a decentralized and efficient solution for heating and cooling needs for different scales as Ectogrid only needs two buildings to share energy but can also be scaled up to make energy sharing possible for a city.

Like many new technologies or systems, it is often easier to implement them in new builds as it can be integrated from the beginning and although this is also the case with Ectogrid – Ectogrid has the benefit having many of the same components as the existing systems (Appendix A, Interview w. Mats). Ectogrid can be connected to existing buildings through retrofitting, a practice that is popular as it is often more cost- and GHG emission effective as well as preserving already built structures (E.ON, u.d.).

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7 PROPOSAL

A focus area was identified based on the investigations into Aalborg's urban and governmental background, illustrating various important urban features. The criteria for outlining the site included multi-level directives to increase RE reliance and to electrify the energy sector, as well as the design standards regarding the implementation of an electricity-based, circular district heating and cooling technology, such as the E.On Ectogrid. With its diverse urban characteristics, the selected area is well-suited and makes an ideal case for an experimental pilot project. The proposed project strives to explore the possibilities of physical system integration and discover the necessary adjustments required for a successful transition toward a climate-neutral society. This chapter will provide an overview of the selected area and the respective urban features, followed by the vision of the experimental pilot project with the potential of future scaling up. The proposal is strategically aligned with Aalborg's future urban transition and development goals, explicitly aiming to facilitate immediate changes in Aalborg's RET. Additionally, it also provides a tactical solution to the city's strategic urban planning aspirations and expansion.

7.1 Focus Area Selection

Various criteria have been considered and layered together to outline and identify the focus area.

Firstly, an important aspect was to work with an older part of the city that was constructed in the industrial era, if not sooner, and contains historical values. The reason for these criteria, on the one hand, is to ensure that the energy supply to the area is established, and on the other is due to the limited life cycle of the infrastructure, specifically the district heating grid. Seeing how the pipelines will require eventual renewal, a great opportunity is provided to tactically plan and manage the renewal together with other system upgrading developments (e.g., 4GDH upgrade, installation of Ectogrid), which consequently has the potential to reduce the costs of investments. Another reason for these criteria was to ensure that the later presented proposal is adaptable in other settlements as well since the primary targets of the RET integration are existing urban environments.

Secondly, a dense and popular area was sought after, where the effects of urbanization have already left its mark on the urban fabric, resulting in diverse land use and functions, further enhancing the site's attractiveness. Concerning future development targets, any indicators facilitating increased density, population, or energy consumption were welcomed (e.g., commercial uplifting). A partial reason behind this perspective was to ensure a stable case of current and future energy demand and the possibility of sector coupling. However, it is important to note that while a high-demand area was sought after, traffic and accessibility were also assessed to make sure that during the implementation

and construction phases, connection and accessibility between other parts of the city were not hindered (e.g., traffic can be directed to other main roads, off-season phasing).

Thirdly, relations or proximity to industrial and technical facilities, as well as the presence of large business properties, were added to the examined criteria. When it comes to establishing a balanced network that circulates energy between various buildings, it is imperative to have a mix of functions that require heating and/or cooling. Furthermore, close proximity results in having to bridge shorter distances, which is another factor in reducing costs.

Lastly, conditions of ownership played a significant factor in identifying the design site, as the interests and assets that business owners and public facilities possess can be better utilized in a mutual symbiosis and collaboration than those of private residence owners. This factor is vital to consider when it comes to an experimental pilot project. By time, the residential sphere can also be convinced, but strategically speaking, physical evidence of the project's operation and success will serve as a tool to overcome initial resistance.

7.2 Focus Area Features

The designated focus area, in accordance with the previously outlined criteria, is located within the city centre and positioned along the waterfront of the Limfjord. This area acts as a nexus between Mitbyen and Ø-gadekvarteret and is delineated by major thoroughfares, including Østerågade, Algade, Østerbro, and Karolinelundsvej.

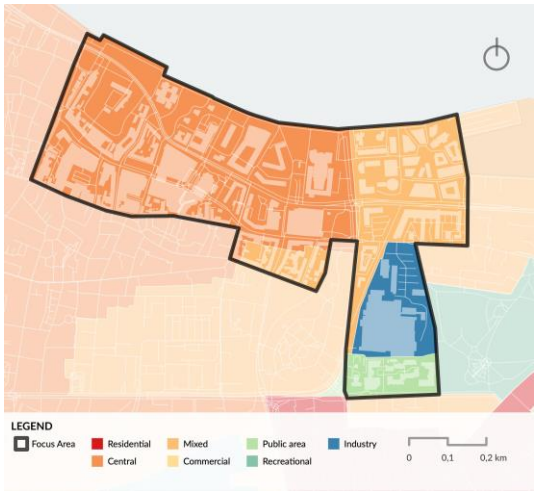

Figure 30 – Mixed land use of the focus area (created by the authors).

The site's land use encompasses a combination of central, residential, commercial, industrial, and public areas (Figure 30). A significant portion is dedicated to the city centre and its commercial activities, while residential areas are expanding due to recent housing developments targeted at younger demographics. This trend is further supported by the municipality's initiative to construct tall buildings to increase vertical density in response to limited available land and the growing population, which has led to an escalating demand for housing (Aalborg Kommuneplan, n.d.). Furthermore, the designated areas are susceptible to commercial revitalization driven by the

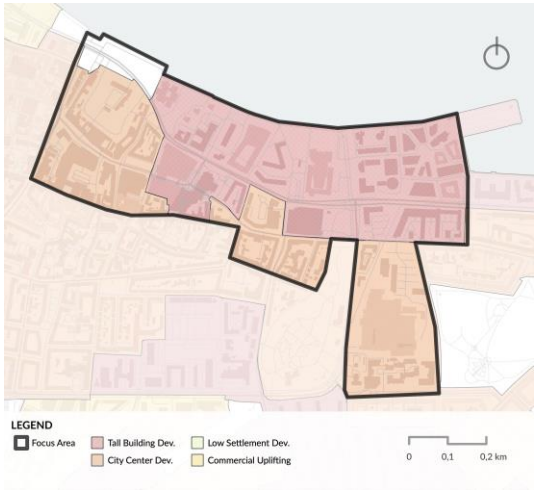

Figure 31 – Intended municipal plan for urban developments (created by the authors).

Figure 32 – Areas obliged to connect to the DH network (created by the authors).

Figure 33 – Floor count of the buildings, where G= ground floor, R= roof (created by the authors).

Figure 34 – Functions of the buildings (created by the authors).

influx of various businesses into the city centre (Figure 31). As the municipality aims to position the area as the powerhouse of northern Denmark, there is a clear emphasis on expanding the range of available services.

The focus area is primarily serviced by the city's DH system, which provides centralized heating to the connected settlements. Historically, the municipality designated areas required to connect to the DH. However, since 2019, enforcing mandatory connections to the collective heat supply has been infeasible. While the previously established connection obligations still stand (Figure 32), any new obligation can only be enforced in accordance with the regulations outlined in the local plan. The plan specifies that new constructions must be connected to the network, and existing connections cannot be terminated (Aalborg Lokalpan, n.d.). As the majority of the focus area is subject to compulsory regulations, there exists potential for the expansion of the DH grid.

With regard to the density of the designated area, a calculation of floor counts was executed to visualize the varying masses within the urban fabric (Figure 33), thus elucidating the disparate associated energy requirements of the buildings. Predominantly, the structures with the most significant floor count are situated at Østre Havn, pertaining to the recently developed residential edifices. Furthermore, relatively elevated floor counts are observed in the buildings of Musikkenhus and Nørdkraft. In sharp contrast, the industrial facility Tulip Food Company A/S exhibits a notably low floor count despite possessing a considerable floor area.

Upon assessing the buildings within the focus area, a functional analysis of each building was conducted, revealing that the main functions are predominantly

commercial and residential (Figure 34). Notably, the major commercial establishments are located along Nytorv, including the Fris and Salling shopping malls, as well as numerous smaller businesses and shops dispersed throughout the area (e.g., Føtex, Elgiganten), offering a wide variety of retail options.

Additionally, the city's commitment to creating a cultural, educational, and historical center is evident through the presence of significant buildings such as Aalborg University, Musikkenhus, Nørdkraft, and the Utzon Museum.

Considering the ownership status of the buildings (Figure 35), it is evident that the majority are privately owned, posing a challenge to the integration of new technologies. Consequently, the focus lies on buildings owned by the municipality, public entities, or large corporations such as Fris, Nørdkraft, Føtex, Salling, Musikkenhus, and Tulip Food Company. This approach aligns private and capitalist interests with the city's urban development objectives. Notably, besides the two campus buildings belonging to Aalborg University, additional dormitories are situated nearby, accommodating the university's students. As these buildings are university-owned, concerns regarding private residents' reluctance to engage in experimental projects are alleviated while addressing the heating needs of the residential buildings are preserved.

In evaluating the buildings within the specified area, careful attention was given to their energy efficiency ratings (Figure 36) and the potential annual electricity generation from photovoltaic (PV) systems (Figure 37). Additionally, the projected impacts of the ongoing global, national, and local transition to electrification were

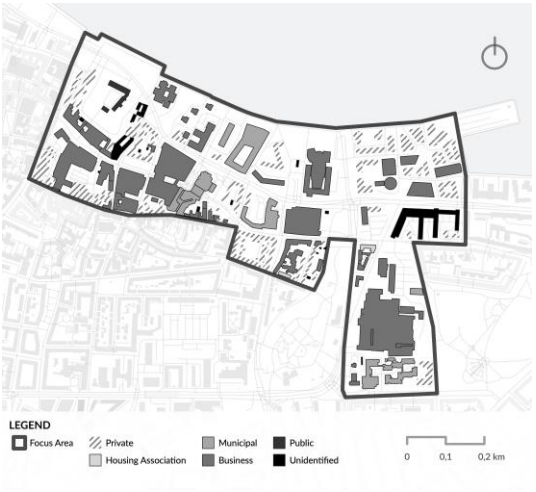

Figure 35 - Ownership conditions of the buildings (created by the authors).

Figure 36 – Energy efficiency ratings of buildings (created by the authors, based on Energistyrelsen, 2024).

Figure 37 – Potential annual electricity production from PV installation (created by the authors, based on Aalborg University, 2019).

factored into assessing the potential annual electricity output.

It was observed that newer buildings generally exhibit higher energy efficiency ratings than older structures or those necessitating retrofitting. Moreover, the larger commercial and industrial buildings demonstrate significant potential for annual electricity production.

The primary objective of the assessment in the focus area was to identify buildings with the highest potential for integration while ensuring that the selected buildings represent a diverse array of characteristics and allow for adaptability to future enhancements.

7.3 Focus Area Vision

It has been revealed that the renewable energy transition is facing tremendous challenges worldwide, and additionally, due to the fossil-fuel dependency of existing urban environments and the time restraint posed by the climate crisis, a drastic, radical, and immediate response is needed. Achieving the shared, long-term goal of phasing out fossil fuels by 2050 and reaching a climate-neutral society requires strategic urban planning. However, mid-term, tactical actions are essential to facilitate immediate integration and progress. Therefore, regarding the international goal to reach climate neutrality and to increase renewable reliance through electrification, a tactical and strategic urban planning perspective was applied to form a proposal for the previously presented focus area.

In light of the city's aim to update its centralized heat supply from 3GDH to 4GDH, and considering the tremendous investments that a full-scale system integration would require, this study proposes to facilitate an experimental pilot project on the focus area identified in chapter 7. Building on the results presented so far and on the additional assessments conducted specifically to the focus area, the study proposes beginning the DH upgrade on a small scale while simultaneously integrating the decentralized, electricity-based 5th-generation district heating and cooling system named Ectogrid (Figure 38).

To ensure the highest possible adaptability, twelve buildings were selected to partake in an experimental pilot project based on, among other things, function, density, ownership, and energy demand, ensuring that the proposed closed, circular system is balanced in its heating and cooling needs as well. The buildings include the industrial building of the Tulip Food Company, the buildings of Aalborg University, the Pier 5 hotel, the Musikkenhus, Nørdkraft, and the commercial facilities Fris, Salling, and Føtex.

Figure 38 – Proposed installation of the Ectogrid, encompassing twelve buildings (created by the authors).

8 DISCUSSION

The imperative to transition to green energy and achieve a climate-neutral future is of paramount importance. This endeavour poses particular challenges due to today's cities' historical reliance on fossil fuels and established urban infrastructures. The task of reconfiguring this foundation within a 25-year timeframe appears daunting and poses high risks. There is a clear need for flexibility in any new system, as changes must be drastic and immediate.

While there is a current emphasis on shaping new frameworks, mainly due to the global energy crisis, the pace of tangible action is slow, casting doubt on the practicality of achieving the ambitious goal of carbon neutrality. The extensive investments and sweeping changes required to battle the situation further emphasize the challenge. Additionally, the increasing use of trendy labels across sectors and users (e.g., net-zero, climate-neutral, sustainable, green energy, etc.) obscure the true meaning and practical implications of these concepts hiding behind the labels.

It is crucial to recognize the importance of cross-border energy systems and collaboration in tackling the climate crisis. The current focus on competition and individual progress, rather than a collective global effort, raises questions about the overarching goals and motivations driving climate initiatives. It is clear that we need to shift our focus from competitive advantages to a united, global endeavor to address the climate crisis.

Considering the substantial financial demands associated with such transformational efforts, the critical question of funding is inevitable. One potential solution could be the establishment of a dedicated international governing body focused solely on climate-related issues. However, the significant financial investments required for such a paradigm shift present a major challenge, particularly given the urgency for immediate action.

Furthermore, seeing how the transition is off-track and that governing bodies have basically just started to form a more specific planning framework for the transition of the energy sector raises concerns regarding the potential consequences for member states unable to meet these requirements. This prompts contemplation of the implications and viable resolutions should certain states fall short of their designated climate objectives.

9 CONCLUSION

Examining Aalborg city's institutional, technological, and physical challenges and potentials reveals a complex energy system that is still in the early stages of transitioning away from fossil fuels, which have been predominant for decades and have shaped the urban fabric. In Denmark, the Planning Act holds authority in physical planning. However, efforts to establish legislation focused on greenhouse gas emission prevention have faced challenges, leading to a lack of prioritization. However, recent events, such as the energy crisis resulting from Russia's invasion of Ukraine, have prompted the European Union and its member states to expedite changes to achieve energy independence from Russia. This has instigated modifications in the Danish energy planning system and a shift in focus for policymakers toward renewable energy to attain climate neutrality.

Through a multi-level government analysis and a strategic and tactical urban planning case study, the thesis has outlined Aalborg's status, challenges, and potential. By identifying a focus area based on various urban features and characteristics, the thesis aims to further analyse attributes and propose facilitating the physical integration of innovative technologies, such as the Ectogrid, to establish an experimental pilot project. This initiative, which is a crucial contribution to this research, is a step toward enhancing energy efficiency and developing an electrified renewable energy system in Aalborg.

The research has identified key challenges, including the entrenched nature of physical infrastructure, technologies, and institutional factors in Denmark, which have become resistant to change over time and through stakeholder investment. However, the disruption caused by the Russia/Ukraine war has opened windows of opportunities for renewable energy actors to effect changes in Danish legislation and elevate the status of renewable energy from a climate concern to a national security issue. Although these opportunities are diminishing, it is crucial to seize the momentum by implementing explorative pilot projects, such as the one proposed in this thesis.

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