Universiteit Utrecht

MANAGING THE UNMANAGEABLE

Examining how cities can address the challenges that arise in their strategy-making process for decarbonizing their heating and cooling infrastructure

MASTER'S THESIS: SPATIAL PLANNING

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Preface

Researching and writing this thesis has been an amazing process. I have learned a lot about myself and this topic, the sheer immensity of which has impressed me greatly. It has been a fantastic experience to learn about all the initiatives of people who do their best to ensure a better world for tomorrow. In a world where powerlessness and bleak perspectives on the future seem to reign supreme, meeting and discussing initiatives and positive developments with people who genuinely give their all to improve the world has been enlightening. I hope this positivity has shone through in the thesis.

Many people have helped create and develop this thesis. First and foremost, I would like to thank Jochen Monstadt for his excellent supervision and his creativity and enthusiasm on this subject. His invitation to join the Decarb City Pipes 2050 project has profoundly impacted my life, and I am confident this one decision will shape my future in ways I cannot yet foretell. I would also like to thank everyone in the Decarb City Pipes 2050 project, who gave me this incredible opportunity. In particular, I want to thank Elisa Kochskämper for her continuous feedback and patience during the development of the city report on Bratislava, which helped me shape the case studies in this research.

I would like to thank the people in my life for supporting me throughout this process. First, I would like to thank Silke for her enthusiasm, cooperation, and the discussions through which we've gained new insights. We have helped each other throughout the process, and I am eternally grateful for her wisdom and support. I want to thank my girlfriend, Maaike, for her loving care and support of me throughout the process. She keeps me grounded and can bring me back to the core argument when I'm lost in all the details. I want to thank my parents, Liselet and André, for their support throughout my studies and their enthusiasm and listening ears when I come home with another long story about my experiences. André and Maaike, in particular, were the cornerstones of the finalised thesis, providing feedback, ideas and ways to improve when I did not know where to start, and I could not have done it without them. I want to thank Simone and Cassimy, who remain interested in my many stories and ideas and both support and criticise my tendency to do too much in too little time. And, finally, I would like to thank all my friends for always believing in me while I'm off doing who knows what. From the bottom of my heart, all your support made this thesis possible, for which I am so grateful.

Abstract

The mitigation of the effects of climate change is an increasingly urgent matter. To that effect, many cities aim to decarbonise their heating and cooling infrastructure, as the heating and cooling of the built environment requires a significant amount of the city's energy demand. As this is a long-term development, cities usually use strategic frameworks to guide the transition process of decarbonising these infrastructures. However, this transition faces many significant challenges in both the social and the technical domains. These challenges severely limit cities in their capabilities to implement strategic frameworks and, therefore, the ability to enable and guide the transition in urban areas. This research aims to chart these challenges and explore how cities can address them to move forward with the transition.

To explore these challenges and assess their impact on the transition, this research examines the transitory development of decarbonising heating and cooling infrastructures through a multi-case study on Bilbao and Bratislava. The socio-technical transition of the decarbonisation of heating and cooling infrastructures in both cases is analysed using the four-track approach proposed by Strategic Spatial Planning theory and literary criteria for strategic frameworks. Furthermore, the extent to which the projectification phenomenon impacts the transition is assessed. The research concludes by identifying the uncertainty resulting from socio-technical heterogeneity as the major challenge to the transition, resulting in unclarity in long-term visions and in short-term and long-term actions. A further consequence of this uncertainty is identified as the paradoxical dependency of authorities on regime actors to facilitate the socio-technical regime change necessary to enable the transition. The projectification phenomenon is identified as a challenge to the transition and a possible pragmatic solution to the implications of the uncertainty-related challenges. The wicked nature of the problem is addressed. Finally, this research provides recommendations for further research and policy recommendations for municipalities to act on the identified challenges and learn from practical examples.

Key concepts: ***Strategic Spatial Planning, Decarbonising heating and cooling infrastructure, Urban governance, Projectification, Socio-technical transitions***

Table of contents

List of tables

List of figures

1. Introduction

July 2023 was the hottest month in recorded history (NOS, 2023). Extreme weather conditions characterised the month, which has resulted in thousands of evacuations, forest fires, record temperatures in land and sea biomes, and dozens of casualties (UN News, 2023). Extreme weather significantly impacts societies, and its effects are projected to increase in the coming years as the climate crisis deepens. Petteri Taalas, the WMO Secretary-General, states (ibid.): "*We have to step up efforts to help society adapt to what is unfortunately becoming the new normal.*" It seems the effects of climate change are not a vague threat in the far future, its effects are currently felt, and its influence is devastating. Decarbonising our energy infrastructure is an increasingly urgent issue to mitigate the further impacts of climate change.

Cities worldwide urgently need to address their influence on climate change and transition towards more sustainable energy systems (Hast et al., 2018). Recognising this urgency, ambitions promising the decarbonisation of energy systems before certain deadlines are thrown about. The EU aims to be climate-neutral by 2050 (Directorate General for Climate Action & European Commission, n.d.). European cities, therefore, increasingly develop their own visions and strategic frameworks to envision and plan their transition towards this climate-neutral ambition (Lomas et al., 2020).

One of these ambitions is decarbonising the heating and cooling (H/C) infrastructure. The H/C infrastructure of European buildings can require up to half of the city's total energy demand. Decarbonising this infrastructure can be a significant step towards climate mitigation ambitions (Reda et al., 2021; Di Lucia & Ericsson, 2014). This energy demand is still primarily through fossil sources, primarily natural gas, meaning these systems must decarbonise before 2050 to remain aligned with the EU objectives. Furthermore, the dependency on this fossil source has proven a significant risk following the energy crisis (International Energy Agency, n.d.). The vulnerability and fossil fuel dependency of current H/C infrastructure means that the decarbonisation of these networks is considered by most to be a priority. While this ambition is promising, developing and eventually achieving a strategic framework faces significant challenges. The reality of decarbonising H/C infrastructure is incredibly complex. Therefore, this research is structured around the research question:

How can cities address the challenges in their strategy-making process for decarbonising their heating and cooling infrastructure?

To understand these challenges, this research first reviews socio-technical transitions theory. Here, the establishment, expansion and stagnation phases of transitory processes are highlighted, combined with the multi-level perspective framework including technological niches, socio-technical regimes and landscapes. How cities can utilise urban experimentation to further innovation in technological niches is examined. Second, this research reviews the technical domain and the social domain of the transition, exploring the socio-technical heterogeneity of decarbonising H/C infrastructure. Third, as strategic frameworks are utilised by authorities to guide transitory processes for the decarbonisation of infrastructure, the literary concept of Strategic Spatial Planning is reviewed. Finally, this research explores to what extent the projectification phenomenon in urban organisations poses a challenge to the transitory process of decarbonising H/C infrastructure.

Next, the research aims to provide an integrated answer to the research question through a practical analysis of the concepts and phenomena examined by the literature review. This practical analysis is done in a multi-case study, examining and comparing the largest city in the Basque Country, Bilbao, and the capital of the Slovak Republic, Bratislava. The cities are introduced, after which their status quo on H/C infrastructure is examined. Then, the governance of the heating transition is reviewed in each city, consisting of policies on all levels of governance, the process of H/C infrastructure planning and stakeholder involvement. The presence and impact of the projectification phenomenon for decarbonising H/C infrastructure are assessed. Finally, each case study concludes with an overview of each city's key challenges, divided into challenges within the social domain and challenges within the technical domain. The context and challenges described in the case studies are then assessed on their similarities and differences. The information gained through the practical analysis is then reviewed using the concepts and phenomena examined in the literature review. This research concludes with an assessment of the major challenge to the strategy-making process for decarbonising H/C infrastructure identified by using the case studies and reviews to what extent the projectification phenomenon impacts the transitory process. Finally, the research lists recommendations for future research and policy.

1.1 Scientific relevance

The urgency of infrastructural decarbonisation is high, but there is much uncertainty surrounding this development. It is well known that transformation to zero-carbon H/C systems is challenging. However, how challenges arise in the social and technical domain and how cities can address those challenges remains relatively uncharted territory. Furthermore, the socio-technical heterogeneity of the decarbonisation of H/C infrastructure is a relatively unexplored concept. This research aims to chart these challenges to provide a groundwork for future research in this transition.

Additionally, authorities aim to decarbonise, using a strategic framework to guide this transition. However, strategic spatial planning as a literary concept has remained relatively unexplored in the last 20 years and has not yet been related to the decarbonisation of H/C infrastructure. This research aims to review the strategic spatial planning concept as a guide to developing strategic frameworks envisioning the decarbonisation of H/C infrastructure.

Furthermore, the projectification phenomenon is a relatively recent development. Therefore, the extent to which this phenomenon positively or negatively influences socio-technical transitions is relatively unexplored. This research aims to examine the effects of projectification in municipal organisations aiming to decarbonise their H/C infrastructure, as well as its impact on the strategy-making process and implementation of strategic frameworks, and therefore contribute to the scientific understanding of the phenomenon.

Finally, through a multi-case study, this research aims to identify challenges to the decarbonisation of H/C infrastructure that can be generalised and applied to many contexts. Through the multi-case study, this research aims to provide recommendations for future research and policy recommendations that can be readily used in different contexts.

1.2 Societal relevance

Climate change mitigation is one of society's most pressing tasks. One of the ways in which a significant development in mitigation can be achieved is through the decarbonisation of H/C infrastructure. However, cities currently face numerous challenges limiting how this decarbonisation ideal can be realised. This research focuses on charting these complexities and reviewing cities' strategy-making processes and strategic frameworks for facilitating this transition. This research contributes to this knowledge by studying and comparing those processes in two cities with different climates and governance structures. The results of this research could provide context for different European cities aiming to decarbonise their heating and cooling infrastructure, as well as provide a way to work with or against the projectification phenomenon and provide insight into the criteria to which the development of strategic frameworks for the decarbonisation of heating and cooling infrastructure can be developed.

1.3 Structure

The research is structured in 6 chapters:

- **Chapter 1: Introduction.** This chapter introduced the topic, the scope and aim of the research. It has introduced the main research question, as well as provided a summary of the approach of the research. The chapter concludes by assessing the scientific and societal relevance of the research.
- **Chapter 2: The literature review.** This chapter first introduces the concepts of socio-technical transitions of infrastructure and urban experimentation. Next, the chapter assesses the complexity of the decarbonisation of heating systems in the technical domain, analysing the supply of H/C through centralised and decentralised H/C infrastructure and the reduction of H/C demand through thermal insulation. The chapter continues by addressing the organisational complexity in the social domain of the transition and the influence of technological heterogeneity on organisational aspects. Then, the concept of Strategic Spatial Planning is reviewed, examining its contextual aspects, the four-track approach to Strategic Spatial Planning and the literary criteria for strategic frameworks. The chapter concludes by exploring the projectification phenomenon as a possible challenge to the transition of decarbonising H/C infrastructure. The transition process towards decarbonised H/C infrastructure is visualised in the conceptual framework.
- **Chapter 3: Methodology.** This chapter introduces the methodology of the research, assessing the research’s sub-questions and the research typology. The case study selection process is discussed, and the research design is explained; the empirical research is done through a document analysis and semi-structured expert interviews. The chapter concludes by discussing the limitations of the findings of this research.
- **Chapter 4: Results**. This chapter assesses the results of the empirical research. First, the findings on Bilbao are discussed, after which the findings on Bratislava are discussed using the same structure. The chapter concludes by comparing both cities, assessing each city's challenges in decarbonising its H/C infrastructure in the social and technical domains.
- **Chapter 5**: **Discussion**. This chapter relays the results of the empirical research to the discussed theories and phenomena in the literature review. The results are analysed using the four-track approach, after which the chapter discusses the usefulness of the strategic criteria to H/C infrastructural development and addresses the wicked nature of the transition.
- **Chapter 6**: **Conclusion.** The final chapter of this research identifies the general challenge to the decarbonisation of H/C infrastructure. It furthermore assesses to what extent the impact of the projectification phenomenon can be identified as a potential challenge. The chapter concludes with recommendations for future research and policy recommendations.

2. Literature review

In 2019, around two-thirds of global energy consumption was consumed by cities (Reda et al., 2021). There are many aspects to the high share of city emissions, such as transport, industry, and heating and cooling. Heating and cooling infrastructure, specifically, is a significant consumer of energy. In colder countries like Scandinavian Denmark, Sweden, and Finland, the heating of homes was responsible for more than 50% of local energy demand (Reda et al., 2021). In hotter climates, the cooling energy demand can also represent 50% of local energy demand, though this could grow to 70% in extreme temperatures (Eveloy & Ayou, 2019). Additionally, space cooling is typically characterised by significant seasonal and daily variations, which significantly strain electricity grids. The effects of climate change make the cooling of homes increasingly important, which causes more significant energy usage (Guy & Karvonen, 2016). One can see this becoming a vicious cycle in which climate change causes hotter climates, to which more air conditioning is required to ensure liveability, to which more energy is being used, to which more emissions are being released, causing more significant effects of climate change, and so forth. Indeed, the heating and cooling of our living spaces are great energy consumers, and this is expected to continue to increase in the coming decennia (Hast et al., 2018).

To mitigate the effects of climate change, a decarbonised answer to the energy demand of heating and cooling is essential. This infrastructural change requires a socio-technical approach (Reda et al., 2021). As Ottens et al. (2006, p.134) state: "*Infrastructures contain many hardware elements, and these are (still) the main reason why infrastructures are engineering systems, but they 'contain' or 'involve' people as well – people in different roles and involvement in many different ways, going far beyond the way people are 'involved' with satellites and computer processor chips."* The so-called heating transition is dependent on the engineering systems (technological development) as well as the "involvement" of many different stakeholders. Therefore, approaches to decarbonising H/C infrastructure will require analysis in both the technical and the social domains.

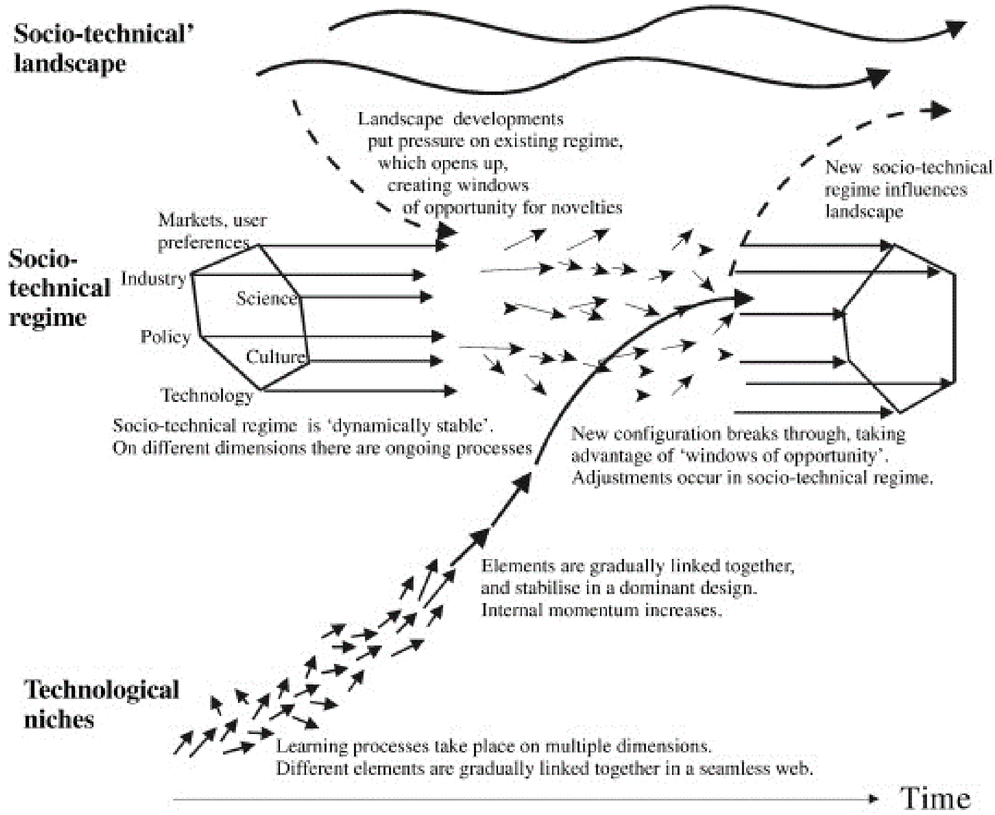
This literature review will discuss how this socio-technical transition can occur, and the challenges literature identifies that currently influence its execution. First, the theory of socio-technical transitions is discussed. Second, the technical and social domain of decarbonising H/C infrastructure is examined. Third, adding to the challenges within the transition's organisational complexity, the projectification phenomenon is explored. Finally, the literature on Strategic Spatial Planning is discussed as per the use of its concepts as guidance to the transition.

2.1 Socio-technical transitions

H/C systems are infrastructures or "infrastructure networks". These typically consist of a generator of a flux or current, channels through which this flux is distributed, and multiple receivers (Neuman, 2010). This is fluid, however, as infrastructures can also consist of many generators and one receiver. For heating and cooling, this network generally consists of a heating/cooling generator (e.g. gas boilers), heating up or cooling down a liquid (water or a refrigerant) that can be distributed through the channels. The liquid then releases its stored temperature to heat or cool a designated area, typically a room in a building (Carroll et al., 2020). Heating and cooling can be delivered in a centralised way through, for example, the use of District Heating and Cooling Networks (DHCs) or in a decentralised way through, for example, the use of gas boilers or heat pumps (Guy & Karvonen, 2016; Carroll et al., 2020).

The infrastructural nature of heating and cooling systems means decarbonising these systems adheres to the theory on socio-technical transitions. This theory states that socio-technical transitory processes consist of three sequential phases: i) the *establishment* phase, in which uncertainty is high and massive investment in the new system is necessary; ii) the *expansion* phase, in which the new system gains momentum following its establishment on an initial market through various economic forces; iii) the *stagnation* phase, in which the new system is established as the new status quo, leaving little room for agency and innovation through extensive long-term investments and strong vested interests of stakeholders (Tongur, 2017). It can be argued that the transition to decarbonised H/C systems is still in the *establishment* phase, as will be expanded upon when examining current technologies in *paragraph 2.2.*

Figure 1: The multi-level framework of socio-technical transitions



Source: Kern, 2012

The multi-level perspective framework on socio-technical transition has complemented these phases, suggesting these are enabled through an interplay of developments at three different levels: technological *niches*, socio-technical *regimes* and socio-technical *landscapes* (Smith et al., 2010; Tongur, 2017). New systems and innovations are experimented with and tested at the niche level, trying to gain momentum to leverage change in the regime. Changes at the landscape level can exert pressure on the regime level through slow developments (e.g. shifts in ideology or climate change) or disruptive events (e.g. earthquakes or nuclear disasters) (Tongur, 2017; Raven et al., 2012). Once these pressures are significant, the regime can become destabilised, creating a *window of opportunity* for the systems at the *niche* level to rise to their expansion phase and become the new socio-technical regime (Tongur, 2017; Rutherford & Coutard, 2013). This is transitory process is visualised in *Figure 1.* As decarbonised H/C systems primarily remain as technological niches compared to the socio-technical regime of gas-powered H/C networks, experimentation and innovation with these systems on the niche level and changes in H/C policy on the landscape level will be required as leverages for regime change. In cities, both are experimented with through the use of *urban experimentation.*

2.1.1 Urban experimentation

An urban experiment is defined by Suitner et al. (2022, p. 178) as "*a (daring) trial – a process whose outcome is uncertain due to a multitude of parameters*". Urban experiments are try-outs, small, planned initiatives embodying new configurations that practice in real-life urban settings. Urban experiments usually consist of networks of different actors, knowledge, and resources. It is a learning-by-doing, or trial-and-error, process (ibid.). Urban experimentation is fluid, open-ended, contingent, and political (Raven et al., 2019). It transports a complex phenomenon (e.g. decarbonising H/C systems in urban areas) to a controlled environment, scaled down to a manageable level (Evans, 2016). Experimentation at this level means these phenomena can be observed and manipulated while being open to surprises within the experimental process. These experiments are conducted to lead to new insights into urban problems or phenomena and are initiated with the explicit ambition to leverage regime change. An important note is that external processes heavily influence all experimentation, as experimentation is inseparable from the surrounding context (Raven et al., 2019).

Urban experimentation can provide more context regarding the heating transition to zero-carbon H/C concepts. Centralised and decentralised approaches to decarbonised H/C are continuously innovating and being experimented with. This could give context to the viability of different H/C systems and provide a way to develop future H/C infrastructure within the city. Successful urban experiments might change city policy on H/C systems, possibly allowing landscape changes to exert pressure into creating a window of opportunity. Examples of landscape changes might be nationally subsidising the installation of heat pumps or instigating large-scale energy retrofitting efforts in housing. As urban experiments in heating increasingly become a cooperation between cities, this information might be shared to benefit the transition in other cities. Contemporarily, as previously mentioned, these systems remain in the establishment phase. Uncertainty surrounding these systems is high, and massive investments remain required to experiment and innovate with these systems before regime change can occur. To examine the current situation on decarbonised heating and cooling systems, these systems are explored through the technical and social domains in the following paragraphs.

2.2 Complexity in the technical domain

The technical domain of the transition concerns itself with the technological development in decarbonised heating and cooling systems, influencing supply and demand. The development in supply can be roughly divided into two categories: centralised decarbonised H/C systems and decentralised decarbonised H/C systems. The technological development in demand is categorised as thermal insulation. All categories enable *energy retrofitting*, referring to the adaptation of new technological developments to obsolete systems, increasing energy efficiency by reducing both the energy consumption of technologies and the energy demand of buildings (Pacheco-Torgal et al., 2017).

2.2.1 H/C supply - Centralised decarbonised H/C systems

A centralised approach to decarbonising H/C can be realised through District Heating Networks (DHs) and District Heating and Cooling Networks (DHCs). DHCs supply heating and cooling on a large scale, involving the distribution of heated or chilled water from one (or several) heat production plants through a network of pipes to consumers in a city or town (Guy & Karvonen, 2016). The heat can be produced through a combination of renewable resources. DHC networks have great potential due to their flexibility to integrate various energy sources, like unrefined biomass, deep geothermal heat, industrial waste heat, combined heat and power plants (CHPs) and heat recovered from waste incineration (Hast et al., 2018). The cooling can be produced through natural and excess cold sources, mechanical chillers and cold storages (Werner, 2017). The exact way H/C is produced and distributed depends on the generation of the DH infrastructure (Mbiydzenyuy et al., 2021). All generations of DH infrastructure and technology depend on a centralised H/C production system, distributing H/C across urban areas on a large scale.

There are four generations of DH/DHC technology. The first generation of DH was established and installed between 1890 and 1930 (Mbiydzenyuy et al., 2021). This system relies on high-temperature steam production, distributing its heat through pipes with operating temperatures between 120°C and 200°C (Barco-Burgos et al., 2022). The second generation, installed between 1930 and 1980, used high-temperature water as a heat carrier instead, which meant smaller diameter pipes could be used to increase the system's efficiency and lowering operating temperatures to between 120°C and 160°C (Barco-Burgos et al., 2022; Mbiydzenyuy et al., 2021). The third generation has been in use since 1980, propelled by the oil crises of the 1970s (Mbiydzenyuy et al., 2021). The third generation improves the efficiency of the network, lowering the necessary temperature below 100°C and improving other productivity gains by using pre-fabricated and pre-insulated pipes together with pre-fabricated substations (Averfalk & Werner, 2017). This generation can also be used as a DHC system (Barco-Burgos et al., 2022). Though there are some instances of the first two generations still in use, this generation is currently in widespread use and has been installed to expand European DHC systems until 2020 at least (ibid.). The fourth generation of DHC technology has been developed relatively recently, and its implementation is still being experimented with (Averfalk & Werner, 2017). The fourth generation again increases the energy efficiency of the DHCs. It can be classified as low-temperature DHC, heating water between 30°C and 70°C, which can be implemented and used efficiently with renewable H/C sources. This generation has great potential for reducing the energy necessary for H/C while improving renewable resource use. A possible 5th generation is also being investigated (Mbiydzenyuy et al., 2021). This consists of ambient loops with neutral distribution temperatures (15°C-60°C) combined with decentralised heat pumps to control inside building temperature. This shows that new technologies and ideas on DHC are still being experimented with. However, concepts beyond the 4th generation are still too infantile to be useful for heating and cooling policies.

There are many benefits to using DHC networks. The distribution of H/C through DHC networks (i) requires less energy than individual systems; (ii) is flexible and efficient in its capacity; (iii) has energy-saving potential in peak periods; (iv) lowers unit costs due to lower energy-, maintenance- and construction costs; (v) has a reduced environmental impact due to both a reduction in and easier handling of emissions in a remote, centralised plant, (vi) offer more reliable service and (vii) saves space at the end-user site since the heating and cooling systems are remotely located (Eveloy & Ayou, 2019; Werner, 2017). All these benefits mean that transitioning to DHC systems can be a great way to reduce the emissions currently produced by heating and cooling homes. District heating has been implemented to a great extent in the Scandinavian countries, Sweden, Finland, and Denmark, often used as examples of a well-done transition towards a sustainable DHC system (Averfalk & Werner, 2017; Guy & Karvonen, 2016). Sweden transitioned from DHC systems entirely dependent on oil in 1960 to completely running on biomass and other renewable energy sources in 2011 (Di Lucia & Ericsson, 2014). While discussed as a rare successful transition, it should be noted that the technology in these DHC systems is also rapidly becoming outdated.

Though there are many benefits to DHC, many issues limit cities from achieving their potential. Technologically speaking, the fourth generation of DHC networks is still juvenile and has only been fit for relatively small-scale development compared to its third-generation counterpart. It has not yet seen widespread implementation as its testing phase is arguably incomplete (Mbiydzenyuy et al., 2021). Therefore, investment in these technologies is not always secure, as some locations for DHC networks have a less-than-guaranteed return on investment. This is combined with the high initial investment required, creating a significant barrier for private organisations to invest in these DHC networks (Hast et al., 2018). Finally, the economic viability of implementing DHC networks depends on high urban density and scalability. High urban density means heat can be supplied to many buildings relatively cheaply as the scale of the infrastructure per person is reduced (Werner, 2017). Furthermore, adjacent buildings and homes within the same multi-apartment complex can benefit from each other's heat supply (Siggelsten, 2017). Urban sprawl is causing a significant constraint on older DH networks (Mbiydzenyuy et al., 2021). Most major DH systems in Europe were built in 1950-1980 and designed for a 20-30 year lifetime (ibid.). These standards do not apply to the standards of current urban life. For DHC networks to remain effective, they must adapt to such expansions while meeting new requirements, like higher expected service standards and decarbonisation. This means a transition will have high upfront costs, heavily limiting the possibilities of DHC.

2.2.2 H/C supply – Decentralised decarbonised technical solutions

Decentralised approaches to decarbonising H/C supply have appeared to adhere to the specificities of each building's H/C demand. Consumers have increasingly opted for decentralised zero-carbon H/C supply systems that work well in smaller-scale settings (Carroll et al., 2020). These systems are referred to as heat pumps, primarily providing H/C for a small network of buildings or a single building. The general categories of these heat pumps are listed below.

Air-sourced heat pumps (ASHPs)*:* Widely used in the global north are singular ASHPs. These devices provide heat to a building using a refrigeration cycle to transfer thermal energy from outside to heat to the system's refrigerant inside (Carroll et al., 2020; Energy Saving Trust, 2023). AHSPs can also operate in the opposite direction: heat can be removed from the building to cool it down. Singular air-sourced heat pumps are furthermore quite energy efficient, which means they can play a crucial role in climate change mitigation (Hartley et al., 2016). ASHPs are identified as very flexible by Cheng et al. (2022), being able to make use of a variety of different heating sources, as well as being able to connect to a DHC network. Due to the decentralised nature of the ASHP, the system is less vulnerable to peak demand stress (Carroll et al., 2020).

Western countries increasingly subsidise the implementation of ASHP to make it more attractive for individuals to install such a pump, as many barriers currently prevent it (Hartley et al., 2016). The energy efficiency of ASHPs depends on the quality of the individual ASHP variant, the climate in which the ASHP operates, and how the electricity that powers the ASHP is generated (Carroll et al., 2020). The ASHP's potential is, therefore, highly dependent on situational factors. Additionally, upfront costs for installing these systems are generally high for individual households, proving to be a barrier for personal instalments. Furthermore, ASHPs are often large and unflattering heating systems installed outside the building. They often produce a continuous noise, making their general installation seem unappealing to both the individual and their environment (Reichl, 2021). To make installing ASHPs more appealing, subsidies have proven effective tools. The Netherlands, for example, subsidises €500 to €2500 of the costs of installing a heating pump in your home (Rijksoverheid, 2023). This increase in the guarantee of investment return from the government means installing ASHPs is more attractive for individuals and public-private partnerships (Cheng et al., 2022).

Geothermal heat pumps (GHPs): A more stable variant of the heat pump is the GHP. Compared to the rapidly changing air temperature that ASHPs need to adapt to, GHPs use the relatively stable temperature of ground temperature as the exchange medium (Self, Reddy & Rosen, 2013). This is advantageous, as ground temperature is warmer than winter air and cooler than summer air, providing less energy-intensive H/C. (Lund et al., 2004). Relative to ASHPs, GHPs are quieter, more durable, and more dependable (Department of Energy, 2023). There are four types of GHP, with varying effectivity depending on external factors such as climate, soil conditions, available land, and local installation costs. A hybrid option with ASHPs is also possible. GHPs are, however, often more costly, being multiple times the cost of ASHPs (Department of Energy, 2023). This means GHPs are relatively inaccessible for individual consumers compared to other types of heat pumps.

Solar-assisted heat pumps (SAHPs): The final variant of heat pumps is the SAHP, a heat pump combined with a solar collector (Energy Saving Trust, 2023). This solar collector is a series of solar panels converting sunlight into heat. A SAHP can also convert heat from the air, allowing the system to produce hot water even when the sun is not shining. This happens using passive convection, which depends on the wind instead of powered fans (Energy Saving Trust, 2023). SAHPs also heat the water directly, which makes pumps, plate heat exchangers or motorised valves unnecessary. This means the solar-assisted heating pump is more energy efficient and less noisy than the other heat pump counterparts (Arctic Heat Pumps, 2023). The solar panel provides electricity for this convection. Furthermore, they are easy to maintain, durable and cheaper than GHPs, though more expensive than ASHPs (SolarReviews, 2022; Energy Saving Trust, 2023). However, though their solar-dependent disadvantage is somewhat mitigated, SAHPs remain less reliable as heat providers. If sunshine is limitedly available, electricity from the electrical grid is necessary as a backup (TheSolarHub, 2023).

2.2.3 H/C demand – Thermal insulation

To enable effective energy retrofitting, the energy demand of buildings should also be reduced. This is realised through the *thermal insulation* of the building envelope: the physical barrier between the exterior and interior environments enclosing a structure (Hagentoft, 2001; Pohoryles et al., 2022; Zhou et al., 2016). Concretely, this generally refers to the insulation of the building's roof, walls, windows, doors and foundation. Buildings, particularly buildings with a high building age, lose their interior temperature as hot or cool air escapes to the exterior environment (Mauro et al., 2015). The thermal insulation of the building envelope reduces this escape, meaning the energy needed to reach and maintain a comfortable temperature is significantly diminished, improving energy efficiency significantly. In the most literal sense, this improves energy efficiency by reducing the necessary energy for H/C to maintain a comfortable temperature (Pohoryles et al., 2022; Zhou et al., 2016). This is generally realised through renovation or refurbishment of buildings.

How thermal insulation is effective is dependent on the quality of its installation. This can vary greatly and have a significant impact on the energy efficiency of a structure. This quality is identified by Sulakatko et al. (2017) as influenced by design, material selection and on-site construction. Sulakatko et al. mainly identify problems within the latter, as shortcomings within the on-site construction process can create on-site degradation factors. They state that 66% of arising defects and reduced thermal properties of structures can be related to on-site activities. Examples of the most common recorded degradation factors by Sulakatko et al. (2017) include, among others, the application of insulation layers during unsuitable climate conditions that harm the quality of the material and an increased gap between insulation plates that increase the risk of crack formation in the insulation plates. The quality of thermal insulation installation can have a long-term effect on a structure's energy efficiency.

Reducing energy demand through thermal insulation significantly impacts the supply side of the heating transition. Effectively reducing energy demand can complicate transitions to decarbonised H/C modes (Zhou et al., 2016). Because effectively insulated buildings maintain a liveable temperature at most times, widespread investment in thermal insulation might influence potential investments in DHC networks. Reducing energy demand in this way can increase payback times for DHC networks, as reduced energy supply means the infrastructure is less used and, therefore, less profitable. This adds to the barrier of high-upfront investment (Barco-Burgos et al., 2021). It should be noted that most European buildings are not insulated properly up to this standard (Pohoryles et al., 2022). Furthermore, this may not apply to 4th generation of DHC networks as these operate at a lower temperature, though this should be researched further (Lämmle et al., 2022). On the other hand, thermal insulation can be considered a necessity for the effective use of heat pumps, as these systems benefit significantly from thermal insulation. Electricity usage can be reduced by 40%-42% when heat pumps are integrated with the installation of thermal insulation (ibid.).

Effectively installing thermal insulation in buildings will require a balance between all these factors and, consequently, long-term planning on a large scale combined with high investments in time and financial resources from public and private actors. Furthermore, as energy retrofitting will take a long-term approach, spatial variegation in energy demand will likely occur between already retrofitted areas and awaiting retrofitting (Bouzarovski et al., 2018). This might further influence the development of heating systems, as the need for decentralised decarbonised heating systems can be expected to increase in areas where retrofitting is planned to occur later. Between different contextual aspects, upfront costs and timeframes for the transition, a combination of all listed options will likely be required to further H/C ambitions, increasing the complexity of the transition.

2.2.4 Heterogeneity in technological aspects

The transition to decarbonised H/C infrastructure will have to account for its heterogeneous nature, as can be observed by the long list of differing, sometimes conflicting, H/C technologies. Creating pressure from policy changes within the landscape level is a complicated process. Each option has its benefits and drawbacks, and installing one option in one place influences the possibilities of other options elsewhere. The heterogeneity of these options has a consequence that solutions might provide a barrier to each other's effectiveness. For example, as DHC works best when implemented on a large scale in a dense urban area, individually installing many heat pumps could hamper DHC 's efficiency, as not all heat pumps offer an option of connection to DHC. Implementing a DHC system becomes less viable with every building that does not require the infrastructure for its zero-carbon H/C (Guy & Karvonen, 2016). On the other hand, the many iterations of different heat pumps increasingly diversify and complicate the heating market. The thermal insulation of buildings is an influential factor in choices for decarbonised heating technologies. Building type, age and climate influence each building differently (Wiryadanata, 2016). Therefore, through technological heterogeneity, there is not necessarily a "right" answer to decarbonisation. There is no true or false. There is a better solution and a worse solution. The transition is a complex process in which different options can reduce the effective installation of the other, and taking all options into account can risk the long-term economic redundancy of some systems. This can be identified as a challenge to the strategy-making process, as this significantly influences the social aspects of the transition.

2.3 Organisational complexity in the social domain

When examining the technological heterogeneity, the organisational complexity of the transition becomes apparent. As previously mentioned, large-scale infrastructural energy networks can be identified as social systems as much as technological ones (Guy & Karvonen, 2016). Socio-technical infrastructural regimes interact with many actors, organisations, and networks (Di Lucia & Ericsson, 2014; Reda et al., 2021). As described by Itten et al. (2021), the transition will be *disruptive, contested* and *non-linear* to change the regime. It is a long-term, complex, ever-changing, societal and organisational process where well-intended choices can have significant unintended consequences. Efforts to establish pressures from the landscape level can backfire and unintentionally harm the transition in the long term. Therefore, the decarbonisation of H/C infrastructure can be defined as a *wicked problem*: an ill-defined, ambiguous problem associated with strong moral, political and professional issues *(*Ritchey, 2005). The transition is highly stakeholder- and contextually-dependent, and there is no "right" way to answer its problems. Consequently, the technological heterogeneity and the organisational and social complexity and implications of the heating transition are of significant influence in the private and public sectors as well as on residents.

The vast majority of established actors in the H/C sector are private companies, meaning municipal actors advocating for a shift in the socio-technical regime are primarily, if not wholly, dependent on public-private partnerships to achieve that change (Werner, 2017; Di Lucia & Ericsson, 2014). There are organisational limitations to the implementation of zero-carbon H/C networks. In both sectors, the more proactive actors see organisational structure, path dependency, and a conservative mindset as barriers (Di Lucia & Ericsson, 2014). Established actors move slower than new entrants due to sunk costs in, for example, fossil fuel generation or combined heat and power (CHP) plants (Guy & Karvonen, 2016). Incumbent energy companies are not a homogeneous group sharing common values and attitudes to innovation (Mbiydzenyuy et al., 2021). Many solutions are viewed as niches competing with regime technology rather than elements of an emerging regime configuration. This also means that established actors are naturally inclined to resist new entrants (Guy & Karvonen, 2016). These partnerships face difficulties due to a lack of knowledge about H/C technology at the public organisational level and unfamiliarity with policies and decision-making at the market level (Guy & Karvonen, 2016). Adding to that, the priorities of the private and public sectors differ fundamentally. Where public organisations (should) primarily prioritise the quality of life and the management of their designated population, the profitability of their business is the priority of private organisations (Ward & Mitchell, 2004). There is a lack of information and understanding on both sides (Mbiydzenyuy et al., 2021). In some instances, industries and energy lobbies have influenced policymakers, viewing niche innovations as a possible threat to energy companies. This makes for a paradoxical situation (Reda et al., 2021). On the one hand, cities are committed to climate mitigation goals and aim for their targets through boosting experimentation and new technologies, while on the other hand, their own energy companies are contributing to reinforcing the regime structures that undermine their targets. As the transition is dependent on public-private partnerships, these two sectors must be joined in their efforts, which adds a challenge that must be overcome (Guy & Karvonen, 2016).

2.3.1 The influence of H/C heterogeneity on organisational aspects

Furthermore, authorities trying to make this transition occur increasingly need to consider the technological and contextual heterogeneity of zero-carbon H/C (Meles et al., 2022). Through different contexts that apply to energy demand for H/C on a local scale, H/C supply can be variegated significantly between neighbourhoods. Each neighbourhood, district, or building can have its own "right" solution to decarbonising H/C infrastructure. To account for this, development plans for decarbonising H/C become increasingly diversified. Decarbonising heating and cooling and energy retrofitting in cities' heating visions are often adjusted to a district or neighbourhood scale to suit small-scale needs better (Franceschinis, 2016). For example, Amsterdam's heating transition roadmap consists of many divided heating districts, each with a solution tailored to its needs (Monstadt et al., 2023). These adjustments often complicate the organisation of large-scale infrastructural development necessary for decarbonising H/C infrastructure.

In addition, this heterogeneity complicates the heating market significantly. Installing widespread decentralised decarbonised solutions is harder to control or monitor than centralised ones (International Energy Agency, 2021). Managing control mechanisms for decentralisation depends on the capabilities of local authorities, who often lack financial resources and capacity (Decarb City Pipes, 2023). H/C strategies and policies proclaim a transition strategy on a city-wide level, which implies a degree of control over the transition. However, due to the dependency on public-private partnerships and the heterogeneity of the heating transition, the control authorities have on this transition is limited (Franceschinis, 2016). The dependence of decentralised decarbonisation technologies and thermal insulation installation on situational factors means individuals are expected to take the initiative to inform themselves and install the “right” installation for their household. This might cause spatial variegation through differences in the quality of installation, the appropriateness of these installations for each building, and on-site degradation factors. This can increase the inequality of H/C, as lower-income households cannot install high-quality heat pumps or afford the combination with high-quality thermal insulation plates, even with subsidies (Wiryadinata et al., 2016). A transition organised through small-scale, decentralised and individualised installations risks being chaotic, adding to the mentioned risks regarding energy inequality, and is likely to be challenging to upscale to the necessary large-scale infrastructural development.

On the other hand, the installation of centralised decarbonised solutions poses challenges as well. Large-scale DHC development poses large-scale upfront costs, which clashes with the risk-averse nature of private companies. Private companies often require guarantees of return on investment if asked to participate in the decarbonisation efforts of municipalities (Demirel et al., 2022). This makes them disinclined to agree to invest in large-scale DHC efforts. This is particularly relevant considering the impact thermal insulation and decentralised solutions can have on the payback length of these investments, increasing uncertainty for return on investment and, therefore, increasing the risk associated with these investments (ibid.). This limits the possibilities for locally organised DHC significantly. An example of this can be found in the DHC in many European cities. These networks are approaching the end of their lifespan and require an update (Werner, 2017). To remain competitive and ensure climate mitigation, these networks must progress to fourth-generation DHC. Though their transformative leverage is great, the costs of this progression form a barrier. The costs are to be paid upfront but discounted over several decades. They must account for continued urbanisation and a decrease in density, while they also must remain cost-effective when subjected to increasingly strict requirements concerning decarbonisation. Decentralised alternatives seem to be the economically safer approach to the sustainable heating transition. This vision is pushed by many authorities (International Energy Agency, 2021).

Ultimately, the socio-technical heterogeneity of the decarbonisation of H/C will mean a thorough analysis will be required on a case-by-case basis. Some locations will provide possibilities for large-scale 4^{th} generation DHC networks, some will depend on decentralised installations of heat pumps, and most will require swift and effective thermal insulation. It can be argued that the transition towards decarbonised H/C infrastructures in most locations will require a combination of these options. Furthermore, the transition paradoxically depends on regime stakeholders' organisational capabilities and initiative to install the technologies and change the technical regime. Understanding the effects of the socio-technical heterogeneity of the transition in each location will require urban experimentation and innovation with the different H/C options mentioned.

The nature of the transition as a *wicked problem* must be considered when discussing zero-carbon heating and cooling options in each location, as there is no “right” solution. Ritchey (2013) identifies wicked problems as subjective problems created by stakeholders competing and cooperating and are, therefore, subject to constant change. Therefore, he states that their course of development cannot be predicted. Uncertainty remains a significant factor in wicked problems and long-term infrastructural transitions. To guide this uncertainty in the heating transition, this research poses the use of the Strategic Spatial Planning concept.

2.4 Strategic Spatial Planning

Changing H/C infrastructure to decarbonised systems is inherently a long-term process. The developmental process and construction of decarbonised H/C systems will take time and, as demonstrated by the previous paragraphs, is subject to various uncertain factors. Strategic Spatial

Planning could be applied to guide the transition throughout this process. A spatial strategy can provide a way to keep sight of the larger perspective, guide short-term actions towards a vision, and provide ways to contact stakeholders and citizens (Albrechts, 2004). Strategic Spatial Planning could offer a viable way to support the transition towards decarbonised H/C infrastructure as a long-term development.

2.4.1 The Concept of Strategic Spatial Planning

The concept of Strategic Spatial Planning (SSP) has its roots in the 1960s and ’70s. It was initially drafted as a comprehensive planning system at different administrative levels (Albrechts, 2004). The definition of SSP has seen many variants throughout the decades in which the concept has found meaning. Generally, SSP can be conceived as a framework to guide long-term spatial development (Newman, 2007). Newman’s definition of SSP implies preparation and a plan for spatial development. This definition complements Friedmann (2004), who states that SSP is an integration of ‘everything’ in policy terms: a comprehensive, integrated approach. A strategic framework encompassing spatial development inevitably addresses other policy domains simultaneously. Albrechts et al. (2003) address the potential of this widespread integration: the involvement of valuable stakeholders in the spatial development process. SSP is, therefore, best defined as: “*a guiding policy framework for long-term spatial development”.*

SSP as a concept is in itself ambiguous. How, where, and when SSP should be applied depends on the context to which it is to be applied. Three different contextual aspects can be identified within SSP literature as influential on the application of SSP: 1) the *scale* of the plan, 2) the *sociopolitical* context, and 3) the definition of the *timeframe*. First, the contextual aspect of scale is influential in the detail of the framework. A small-scale strategy or framework can incorporate topics and developments (Albrechts et al., 2003; Albrechts, 2004). A strategy for a neighbourhood, for example, can incorporate details on the type, pros, and cons of heat pumps fit for installation in each type of building present. An urban strategy on a city scale might find incorporating these details tedious or even redundant (Newman, 2008; Friedmann, 2004). City-scale strategies might find it more insightful to create a strategic framework within which different viable types of heat pumps of the city are listed and in what neighbourhoods these are to be applied. Regionally, the strategic spatial policy becomes vaguer, more akin to governance guidelines (Albrechts et al., 2003; Albrechts, 2004). Details like how a specific heat pump should be developed are not included; regional strategic policy could offer a guideline for urban development incorporating heat pumps or DHC networks. The national scale typically removes all details regarding specific urban development but offers a general spatial development framework that municipalities can use to formulate their city-scale strategies (Olesen, 2014; Albrechts, 2004). Suppose national strategic frameworks aim to guide towards a regime where heat pumps are the primary H/C system. In that case, it is the responsibility of the lower levels to formulate strategic frameworks for this development on their authority level. One can liken this to the tensions between the different levels of governance in multi-level governance frameworks, to which Faludi (2012) closely identifies SSP. The scale to which the strategic framework is constructed influences its conceptualisation, and the different strategic scales depend on each other. National strategic frameworks influence regional or local frameworks, and local developments and strategies influence regional and national strategies.

The second contextual aspect is the sociopolitical context in which the strategy is developed. In the Western world, this is primarily a neoliberal context. Neoliberal political ideology has gradually been implemented in the governance model of New Public Management (Connell et al., 2009). This primarily entails making the public sector more efficient through privatisation and outsourcing former public tasks and services to various quasi-public organisations (Olesen, 2014). In H/C infrastructure, this can be seen through the management of DHC systems, which is usually done through these organisations.

The ideology promotes market and business rationality, which should be made to operate as effectively in the public interest as it does in securing private interest (Connell et al., 2009). A significant part of new public management is decentralising spatial responsibilities to lower administrative levels. Local policy, not national policy, is considered best for spatial solutions. Considering strategic frameworks, the aim of new public management is their depoliticisation and collaboration with stakeholders and citizens for spatial development (Olesen, 2014). Consequently, local authorities are increasingly responsible for spatial strategies for urban development (Gilbert et al., 2013). This means spatial strategies are increasingly diversified between local authorities. As stated in the paragraph before, the scale of strategy is essential in its conceptualisation. This diversification widens the gap between theoretical strategic spatial planning and its practice. It has led to critics of the SSP concept stating its theorisations are either too theoretical, too naïve, or too far from the current reality of the SSP context in New Public Management (Newman, 2008). This means the theoretical usefulness of SSP in this sociopolitical context is subject to debate.

This debate is continued in the final contextual aspect, the context of the frameworks' timeframe. Many different deadlines can be proposed and justified within a strategic framework. It is no longer unusual to find urban strategic frameworks aiming for their development to the 2030, 2040, or even 2050 deadline. This longer term is fraught with difficulties, of which the most pressing is the previously mentioned uncertainty. The course of the development of strategic goals, such as the development of decarbonised H/C systems, cannot be fully predicted. Hyslop (2004, p.58-59) states: "… t*here is a need to work towards a vision and to minimise pre-emptive actions by sectional interests (…) [Cities] use excessively long time frames for their strategic plans (…). In most aspects, there is little point in doing this.*" Strategic planning is a slow process compared to the rapid pace of socio-technical urban development (Newman, 2008; Friedmann, 2004). This means planning for long-term developments is an increasingly difficult process the more time the strategy takes into account. Therefore, critics use this argument to debate the usefulness of SSP as a concept. This is illustrated by Hyslop (2004), who directly questions the point of long-term planning. If SSP is an integration of 'everything', and if that 'everything' changes rapidly, a comprehensive strategy that remains useful throughout its timeframe is an impossibility. This argument is further accentuated by the difficulty sustaining collective action and the possibly limited ambitions of key actors (Newman, 2008; Sartorio, 2005). Furthermore, in this uncertainty, one must avoid making unnecessary decisions that would close off options for future developments (Friedmann, 2004). If the situation in 2050 is entirely different, a decision made in 2023 could be detrimental if still in effect. When applied to the H/C infrastructure development, a comparison can be made to the influence of thermal insulation on the return of investment on both heat pumps and DHC infrastructure. The *wicked* nature of the transition again becomes apparent.

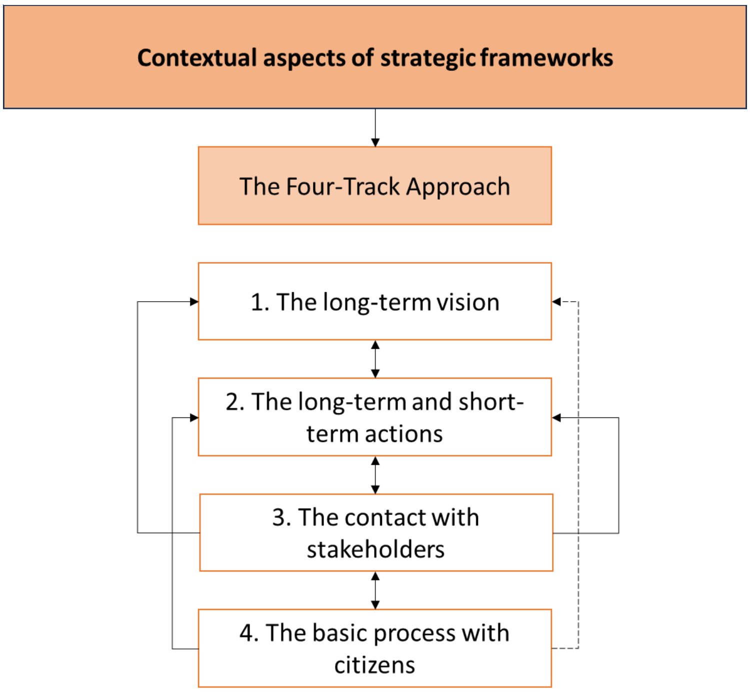
This research contributes to this debate by arguing that ruling out the usefulness of SSP entirely is not the solution to these issues. The socio-technical heterogeneity of the heating transition and the urgent necessity of urban development towards decarbonised H/C infrastructure require strategic guidelines to ensure a long-term transition towards decarbonisation. The ambiguity of SSP as a concept for H/C development is both a hindrance and its saving grace. The framework can be as concrete as the timeline, sociopolitical context, and scale demand. This means the three contextual aspects are inherently linked and influence each other in the developmental process of strategy-making.

2.4.2 The process of strategy-making

The strategy-making process defined by theoretical SSP emphasises collective action, bringing together different stakeholders' organisational resources. Strategic spatial planning is ideally guided by these imaginative actors who can overcome collective action problems (Newman, 2008). Cities seek to fulfil this role at a time when the power of the state under New Public Management is weakening in relation to other actors (Olesen, 2014). It is, therefore, difficult to sustain collective action, hindered by the limited ambitions of stakeholders that are integral to the strategic frameworks' success. The guiding actor must manage constraints and work with political opportunity (Newman, 2008). This means a strategic framework functions best as a cooperative umbrella document to which the actions of all actors can be measured and guided: an ultimate vision or strategic goal integrated deeply into the organisational actions.

The process of strategy-making is identified by Albrechts (2004) as consisting of a four-track approach: (i) the ***long-term vision,*** (ii) ***the long-term and short-term actions,*** (iii) ***the contact with stakeholders,*** and (iv) ***the basic process with citizens.*** These tracks are not linear but constantly interact with each other to create and alter the strategic framework. The first track, the vision, envisions the ideal the strategic framework strives towards, also referred to as strategic goals. In the case of H/C, this is naturally a fully decarbonised H/C infrastructure. The vision is primarily influenced by the three contextual aspects of strategic frameworks. The second track, the long-term and short-term actions, identifies the long-term and short-term actions. Albrechts (2004) emphasises the importance of creating trust in the strategic goals by solving problems in the short term so that long-term actions can be supported. The third track, the contact with stakeholders, involves relevant stakeholders whose contribution, role, support and/or competencies are necessary to provide legitimacy towards the strategic goals. For H/C infrastructures, this includes, among others, installation companies, DHC management organisations, and energy companies. The relationship between those actors, through power relations, implications in financial instruments or organisational capacity, should be considered. The fourth track, the basic process with citizens, emphasises an inclusive process involving citizens in major decisions. Albrechts idealises a process in which citizens understand different points of view and build up social and intellectual capital, influencing track 2 significantly through the creation of trust and, by extension, the long-term vision of track 1. These four tracks should be the foundation of every strategic framework; the concept is visualised in *Figure 2*.

Figure 2: The Four-Track approach to strategy-making



Of course, there is more to the quality of a strategic framework than the strategy-making process. Combined, Albrechts (2004), Sartorio (2005), and Newman (2007) identify 15 criteria that an urban strategy must uphold. These criteria should be kept in mind during the strategy-making process and should be present to some degree. As there is no "right" way to conceptualise strategy, there is no "right" way to meet these criteria. If all are present and adjusted to the context in which the strategy is being made, one can judge a strategy's validity. The absence of one or more of these criteria could, on the other hand, indicate that the strategy is not yet valid. These strategic criteria are listed below:

1. Clarity
2. Motivational impact

3. Internal consistency
4. Compatibility with the environment
5. Appropriateness in light of the resources available
6. Degree of risk
7. The extent to which the values of the strategic framework are matched with the often contradictory personal values of key figures
8. The extent to which key stakeholders (preferably key decision-makers) are involved in the strategy-making process
9. Active involvement of senior-level managers.
10. Time horizon
11. Flexibility
12. Workability/practicality
13. Focus on key concepts
14. Trusted and committed leadership.
15. Politically realistic

With this in mind, SSP could guide the long-term development of H/C infrastructure through Strategic Spatial Heat Planning (SSHP). Strategic frameworks are guiding, open processes shaped by continuous decisions and act as a frame of reference to which the development of H/C infrastructure can be measured and guided. If the core values of the four-track approach to a strategic framework are well developed, combined with the presence of the 15 criteria, the impact of the uncertainty of future developments can be limited. Strategic planning anticipates new tendencies, discontinuities, and surprises (Albrechts, 2004). The process of achieving the strategic goals the strategic framework poses will not flow smoothly from one phase to the next. It is a dynamic and creative process under constant change. To allow this process to happen in this manner, it is important to note that Albrechts (2004) reiterates the significance of a high degree of trust between the different parties, implying collaboration on equal terms throughout the process. When applied to the socio-technical transitory processes, this can ensure regime actors and systems become more willing to change under landscape pressures and, therefore, windows of opportunity can arise more frequently and be taken advantage of.

However, a significant challenge to this long-term oriented process arises through a recent phenomenon witnessed in public organisations. As this can significantly impact the execution of the socio-technical H/C transition, this phenomenon of projectification is discussed.

2.5 Organisational challenge to the transition - the projectification phenomenon

The projectification phenomenon is a developing phenomenon in urban organisations. Though the phenomenon is often described as an increasing number of projects, it is primarily an increasing *reliance* of organisations on those projects (Rosenschöld, 2017). Therefore, the phenomenon is often discussed with a negative connotation. Projectification means that, for various reasons, activities formerly organised in other ways are transformed into projects (Murawska et al., 2019). Organisational contexts are adapted to the implementation and execution of varying types of projects (Godenhjelm et al., 2014). There is a growing trend in organisational structures, both private and public, relying on these projects to enhance the action and strategic effort of the organisation within their growing complexity (Rosenschöld, 2017). Projectification as a phenomenon can therefore be defined as *the increasing reliance of organisations on temporary projects.*

The development of the projectification phenomenon is primarily identified as a pragmatic answer of organisations to organisational issues. There are two primary reasons urban organisations have become increasingly “projectified”. First and foremost, this is a matter of organisational complexity

(Rosenschöld, 2017). As organisations and municipal responsibilities become increasingly complex, sense-making is needed for understanding to remain. A project is controllable and understandable, a way in which processes can be task-specific and time-limited to achieve a set goal (Fred, 2015). As an answer to organisational complexity, the phenomenon can be analysed in *narrow* or *broad term*s (Packendorff & Lindgren, 2014). The narrow view of projectification is based on analysing the projects as an organisational solution to a specific type of task. Projects are temporary systems to solve problems, allowing experimentation and work outside regular bureaucracy (Fred, 2015). The drawback of the narrow view is that the analysis of projectification is done by seeing the phenomenon as a rational and straightforward process, which is not necessarily true. The phenomenon is influenced by the context in which it occurs and, therefore, is characterised by aspects such as bounded rationality, power, politics, and cultural norms and constructs (Packendorff & Lindgren, 2014). The *broad* view involves these cultural and discursive societal processes whereby projects are institutionalised in individual lives (ibid.). The broad view sees formal structural units as social constructions based on the increasingly episodic orientation of contemporary society and the tendency to perceive processes as temporary or transitory by nature (ibid.). The drawback of this broad view is its ambiguity; analysing the phenomenon from a societal perspective cannot provide the complete picture. Both the narrow and broad views of projectification are complementary and necessary to understand the causes of the phenomenon.

Second, the phenomenon of projectification can be identified as a safe way of intervention for local authorities. Intervention in social issues through projects and experiments signals innovation, entrepreneurship, action, and determination (Raven et al., 2017). It demonstrates the city government's proactive role in innovation with relatively little risk. Projects are made to be politically attractive and organizationally fashionable solutions, fostering the expectations of the project's outcome (Godenhjelm et al., 2014). This is reiterated as projects and experiments are often externally funded, meaning resistance to these projects is usually very low (Godenhjelm et al., 2014; Raven et al., 2017). There is little reason to be against furthering urban development through a low-risk, innovative, and experimental project. Though this encourages experimentation and innovation, identified as necessary for the heating transition, this also means the responsibility of what the project aims to achieve is transferred to the project group (Godenhjelm et al., 2014). Using projects, city governments refrain from engaging in issues with redistribution of resources where one party loses power or economic resources, and another party wins. If something goes awry, the project is accountable, not policymakers. Consequently, the phenomenon goes hand in hand with the increasing development towards just-in-time planning and interventions, with policymakers only decisively acting when necessary (Broto & Bulkeley, 2013; Godenhjelm et al., 2014). This is an evident reaction to the episodic nature of project processes.

Projectification often is associated with a negative connotation. There are more issues with the phenomenon regarding the scalability of projects and the organisational complexity it aims to reduce. Projects' small-scale and temporary nature has a consequence in project management, focusing on single projects instead of an entire transformative change (Cook & Steger, 2021). So, while a single project might succeed, scaling up its successes to a city level is often unaccounted for or exceedingly difficult. This severely limits how windows of opportunity can be utilised and how landscape policies and socio-technical regimes can be changed. Projects to initiate change are often significantly restricted by bureaucratic rules and traditions of administrative control (Fuenfschilling et al., 2018). The regime remains if the organisation is not open to the changes the projects are testing or advocating. The complexity of the organisations makes it furthermore difficult to diffuse information about the experiment through the organisation, both horizontally and vertically (Rosenschöld, 2017).

This means projectification creates tension between the project and the non-project part of the organisation, contrasting the unifying aim these projects often have.

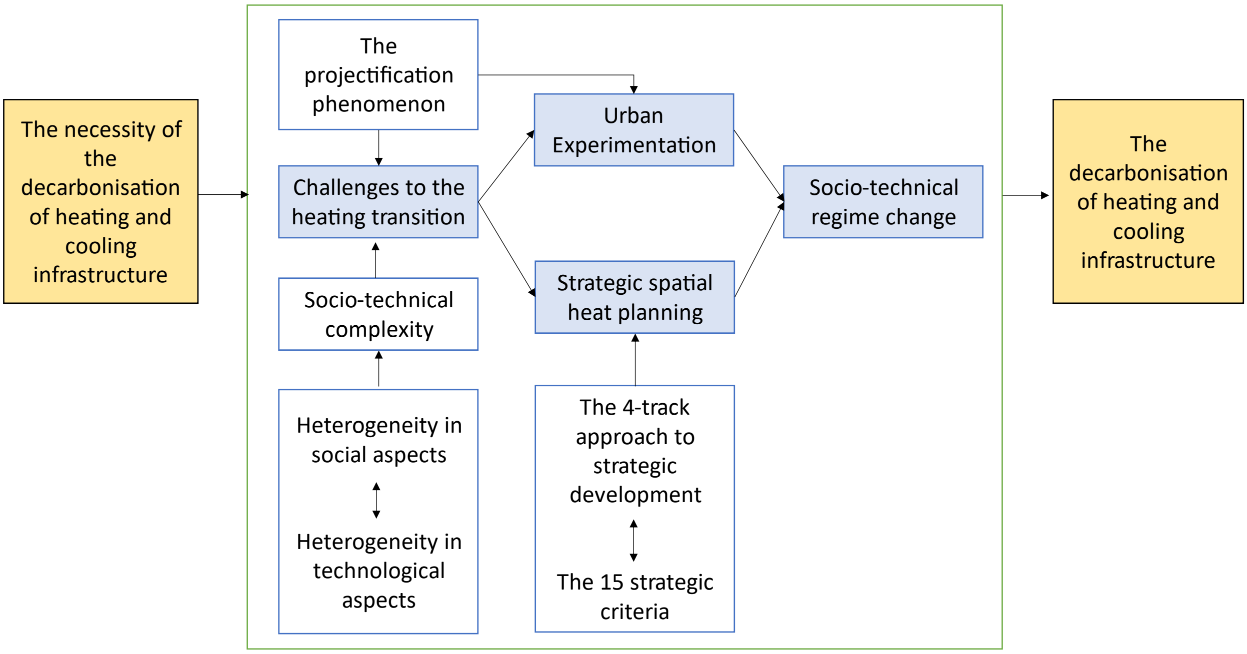
Finally, the phenomenon significantly influences the heating transition because of the episodic nature of projects. The tension between short-term action and long-term planning is relevant when discussing the phenomenon in urban organisations. Project-reliant organisations tend to become short-term-oriented and episodic (Godenhjelm et al., 2014). While this is a positive development regarding sense-making and the practicality of the process, reducing organisational complexity, it also reduces how organisations can strive for long-term strategic goals and strategic frameworks utilised (Rosenschöld, 2017). To ensure the transition towards decarbonised H/C occurs, perspectives on developments towards the long-term future are necessary (Schug et al., 2022). The actions of current policymakers will have a long-term influence (ibid.). However, as seen in the four-track approach, short-term actions are integral to strategic development. Therefore, tension exists between the influence of the projectification phenomenon and the utilisation of strategic spatial planning for long-term H/C development.

2.6 Empirical analysis

As can be concluded through the literature review, the socio-technical transition towards decarbonised H/C infrastructure will be a complex, challenging and lengthy process. To ensure the socio-technical regime changes, The process described in the literature is visualised in the conceptual framework in *Figure 3.* This process will be the subject of the empirical analysis in a multi-case study on the strategy-making process and the challenges for the heating transition in Bilbao and Bratislava.

2.7 Conceptual framework

Figure 3: Conceptual framework



3. Methodology

Research question

How can cities address the challenges in their strategy-making process for decarbonising their heating and cooling infrastructure?

Sub-questions:

1. What challenges do cities face in facilitating the decarbonisation of heating and cooling infrastructure?
2. To what extent is the phenomenon of projectification influential as a challenge to the development of decarbonised heating and cooling infrastructure?
3. How can cities improve their strategy-making processes for transitioning to decarbonised heating and cooling infrastructure?

3.1 Research typology

To answer the research question, a multi-case study will be done on Bilbao and Bratislava. The use of case studies is vital in governance-related research. Case studies are established to help research practical experience, inquiring about a particular phenomenon in detail, and finally relating the empirical data to theory (Stewart, 2012). A multi-case study is better equipped to generalise results back to theory than one case study, which gives more power to the research results. In a multi-case study, it is possible to look at similarities and differences between contexts (*ibid*.). In this way, a multi-case study can better contribute to a general understanding of the challenges that arise in strategy-making for decarbonised H/C infrastructure development.

There are three criteria set by Yin (2017) for justifying the use of a case study (or multiple) in research design. The three criteria are:

1. The main research question is a “how” or a “why” question
2. As a researcher, you have little or no control over behavioural events
3. The focus of the research/study is a contemporary phenomenon.

This research meets all three criteria.

3.1.1 Multi-Case Study - Case study selection

The multi-case study consists of two cases: Bilbao, the largest city in the Basque Country in Spain, and Bratislava, the capital of Slovakia. These two cases are selected per their relative autonomy in urban planning, creating possibilities for directly implementing local strategic H/C frameworks and witnessing the effect of their experienced challenges on those frameworks. The two cities experience self-government of urban planning in different ways. By associating this research with the Decarb City Pipes 2050 (DCP-2050) project, it is possible to analyse these two cities thoroughly. Bilbao and Bratislava vary significantly in their socio-technical H/C regime and their approaches to the transition. The multi-case study will establish these differences and analyse their potential similarities in the heating transition. To start, the exact case selection process will be clarified. This explanation will provide a more thorough look at the research methodology.

Bilbao

Bilbao is one of the key ports of Spain, giving the city a strong urban economy (Bilbao – DCP-2050, n.d.; The editors of Encyclopaedia Britannica, 2022). This, however, had a heavy industrialisation of the city in the 20th century as a consequence. The liveability of Bilbao was poor, and tourism was practically non-existent. Through having autonomy in its urban planning, Bilbao has undergone a massive transformation away from this image during the turn of the century. The steel and shipbuilding industries declined in importance steadily after the second world war, decreasing the necessity of the present, heavy industry. The service sector, particularly tourism, increased in importance (The editors of Encyclopaedia Britannica, 2022). The city developed new services, which included the cleansing of the river, the development of a subway system, the construction of a concert hall and a museum, and the transformation of industrial areas into cultural and business centres. Through this development, Bilbao transformed from a heavily industrialised urban area into a green, flourishing hub, winning the city several prizes for urban development (Bilbao – DCP-2050, n.d.).

Bilbao currently depends on its expansive gas network for heating and cooling. However, as the phasing out of gas is an energy planning priority in the city, Bilbao is currently assessing which parts of the city to roll out new H/C infrastructure (Bilbao – DCP-2050, n.d.). Bilbao's challenges in this development and how its strategy-making process incorporates those challenges align with the scope of this research. Furthermore, Bilbao is currently constructing a 4th generation DHC network from scratch (Bilbao – DCP-2050, n.d.). This development will provide insight into the development challenges of centralised decarbonised systems. Bilbao's near complete autonomy over urban planning could open up further policy experimentation possibilities. These factors mean Bilbao has been selected as the first case study for this research.

Bratislava

Bratislava is the capital of the Slovak Republic and its cultural and economic centre (Bratislava - DCP 2050 – n.d.-b). The city is, with over 420.000 inhabitants, the biggest in Slovakia by a wide margin, nearly doubling the size of the second biggest city Košice (Population of Cities in Slovakia 2023, n.d.). The commuting population towards the city is around 200.000, increasing Bratislava's population to an estimated 620.000 people. Since the separation of Czechoslovakia in 1992, creating the Czech Republic and the Slovak Republic, Bratislava has served as the capital of the Slovak Republic (The editors of Encyclopaedia Britannica, 2022). The municipality of Bratislava is a self-governing authority, creating policy in cooperation with the self-governing Bratislava Region and the 17 self-governing districts within Bratislava. Bratislava is also strongly committed to sustainable city development. Recent city strategies have focused primarily on smart city solutions and minimising the city's carbon footprint. Bratislava's mayor, Matus Vallo, has been pushing climate ambition since 2018 and has a target of zero greenhouse gas emissions by 2050 (Bratislava – DCP-2050 – n.d.).

Bratislava historically depends on extensive district heating grids for its heating and cooling. However, through new legislation and subsidies, the heating and cooling market of Bratislava is increasingly heterogeneous (DCP-2050, n.d). Decentralised heat pumps increasingly detach homes from the DHC networks, making DHC increasingly expensive per household and less viable as a sustainable heating alternative. Consequently, Bratislava residents are increasingly switching to decentralised heat pumps, creating a vicious circle. The extensive existing infrastructure could imply a potential for large-scale sustainable heating. Its heating concept is also due for an update in 3-4 years, meaning changes to its socio-technical regime will soon be urgently necessary (Bratislava – DCP-2050, n.d.). Through this context, Bratislava is pressured to draft a strategic framework to change its H/C infrastructure and faces challenges in that process that align with the scope of this research. The city can potentially be an essential ambassador and pioneer of the heating transition in Eastern Europe. These factors mean Bratislava has been selected as the second case study for this research.

These cases provide an interesting contrast. Where Bilbao has an opportunity within its technological niches for creation and experimentation, Bratislava has significant pressure from the socio-technical landscape to better its current infrastructure. Both cities share the goal of sustainable heating, but their context is very different. Both case studies will assess the status quo on H/C, explore the long-term H/C strategies and policies, examine the projectification phenomenon in each city, and conclude with the key policy challenges, challenges in financial instruments, and challenges in the knowledge and capacity within the city.

3.2 Research design

3.2.1 Document analysis

The empirical part of this research will be conducted using a qualitative research method to answer the posed research questions. Answering the questions requires a thorough understanding of the different perspectives of associated stakeholders in both case studies; a qualitative research method is most appropriate. Qualitative methods, like systematic interviews, can provide this data best to thoroughly understand the context (Butler et al., 2016). Qualitative methods can furthermore be effective in providing a more nuanced understanding of the influence of challenges to the transition in urban areas. A qualitative method might provide insight through experience into how zero-carbon H/C strategies are created and implemented in both case studies. Two qualitative research methods will be used: a document analysis and semi-structured expert interviews. The document analysis will provide the necessary context for the expert interviews. The interviews will provide expert experience and add to the information from the documentation. Through this, a concrete answer can be given to the research question, and recommendations for future research and long-term policy implementation can be made.

Document analysis is a systematic procedure for reviewing or evaluating documentation (Bowen, 2009). This does not include literary documentation or previous analytical studies but only raw data from the case study itself, as the interpretation of the previous research might incur secondary bias. There are three primary types of documents. *Public records* are official, ongoing records of the activities of an organisation, including transcripts, statements, reports, policies, and plans, for example. This is the primary form of documentation analysed in this research. This type of documentation will be the primary type in this research, as policies and strategies are part of this category. *Personal documents* are first-person accounts of an individual's actions, experiences, and beliefs, such as e-mails, blogs, or Twitter posts. *Physical evidence* accounts for physical objects in the study setting, such as flyers, agendas, and handbooks. The yielded data from the document analysis is then organised into major themes, categories, and case examples through content analysis. The research method is particularly applicable to qualitative case studies. An old quote from Merriam (1988, p.118) is relevant currently: "Documents of all types can help the researcher uncover meaning, develop understanding, and discover insights relevant to the research problem." Document analysis works best when combined with another research method, e.g. semi-structured interviews, to minimise bias and establish credibility (Bowen, 2009).

There are five specific functions of documentary material that can be identified.

1. **Contextual function**. Documents can provide data to understand further the context within which research is conducted. This includes but is not limited to witnesses to past events, background information, and historical insight. This context is then also applicable to contextualise data collected during interviews.
2. **Suggestive function**. Information contained in the documentation researched can provide some suggestions for questions that need to be asked or situations that need to be observed as part of the research. This could add to the quality of the empirical research and the data collected during interviews.

3. **Supplementary function**. Documents provide information and insights that can be valuable additions to the literary knowledge discussed in the research as a valuable supplement to other sources.
4. **Tracking function**. Change and development of phenomena or policies can be tracked using documents. This paints a clearer picture of how a project, experiment, or program has fared over time.
5. **Verifying function**. Documents can be used to verify findings from other sources. The topic should be investigated further if literary research has contradictory findings with documentation. Vice versa is research also attributed with more credibility if the documents converge with the literary findings.

A combination of these functions is present within most documentation. Documents are, however, not necessarily precise, accurate, or complete data sets. All documentation selected and analysed will be done critically, considering the document's author, target audience, and original purpose. The document's quality is of higher importance than the quantity, judging by the authenticity and usefulness of documents.

3.2.2 Expert interviews (semi-structured)

Semi-structured expert interviews are a qualitative research method that can be applied to gather rich, detailed answers. Expert interviews can add to the knowledge gained from the document analysis to answer the research question better. These interviews allow for in-depth knowledge and new perspectives not present in written data. The semi-structured interview has been selected for its structure and flexibility. In a semi-structured interview, the researcher has an interview guide with a list of questions or specific topics. However, due to the semi-structured nature, the interviewee has a great deal of leeway in how to reply. Questions from the interviewer may also not precisely follow the way outlined on the schedule. Questions not included in the interview guide might also be asked as the interviewer picks up on things said by interviewees. This also means a structure in the form of an interview guide is necessary to avoid deviation. This interview guide is provided by the literary review and conceptual framework, supported by the knowledge gained from the document analysis. Also, in multiple case study research, this structure is needed in the interviews to ensure cross-case comparability (Bryman, 2012; Kallio et al., 2016). The interview guide used for this research is found in Appendix A.

3.3 Limitations

Several factors have limited the findings of this research. First, due to the language barrier between the researcher and the two case studies, some nuances and context may have been falsely interpreted or missed. English was not the first language of any of the participants or the researcher. Therefore, assessing if both case studies have been correctly displayed is difficult. Some details in the case studies may be stated incorrectly, and some vital information may be missed. Second, there were difficulties with finding possible interviewees for the research in both cities, though primarily Bratislava. Though many were contacted, few responded. Primarily the private sector has refrained from participating in this research. Therefore, the results of this research might have been skewed to favour the public sector's perspective. To mitigate this effect, this research makes use of some previous interviews done by the DCP-2050 project. The written results of these interviews are analyses through a secondary analysis. This can have influenced the presentation of the cities in the results section and the data used to formulate a conclusion. In addition, the number of interviewees was difficult to expand due to time constraints. Third, most interviews were made possible by contacting different Decarb City Pipes project partners. This might have also influenced the results, as this network consists of people with similar perspectives, limiting the diversity of interviews and, therefore, could have resulted in an incomplete assessment of both cases. Finally, due to the enormity of the topic of the heating transition, this research has not been able to include some environmental factors, such as the influence of blue-green infrastructures. This might have provided a skewed perspective on both cities, and the influence of these environmental factors should be considered in future research.

4. Results

4.1 Case study - Bilbao

4.1.1 Introduction

Bilbao is the capital of the Biscay province, a province in the Basque region of Northern Spain. It is the largest city in the province and the region and the 10th largest city in Spain overall. The city has just short of 350.000 inhabitants in 2023 (World Population Review, 2023). The city is situated in the Bilbao Estuary, a valley by the Bay of Biscay, and is surrounded by mountains, with ocean access through the river Nervion. Bilbao is divided into eight districts: Deusto, Uribarri, Otxarkoaga, Begoña, Ibainondo, Abando, Errekalde and Basurtu-Zorrotza (Wikipedia contributors, 2023). Formerly, the city was an industrial hotspot, prioritising steel production and shipbuilding. After the oil crisis in the 1970s, steel production slowed, and Bilbao made a massive transformation from an industrial city to a green, flourishing and vigorous city, started by the development of the iconic Bilbao Guggenheim Museum. More projects are taking place to revitalise Bilbao, such as the airport terminal, the development of a public transit system, the Azkuna Zentroa, and the currently under-development Abandoibarra and Zorrotzaurre urban renewal projects. (DCP-2050, 2023a).

The Basque Country has its own Statute of Autonomy, similar to the Catalonia region, and enjoys the highest level of self-government with the corresponding bodies. This level of self-government concretely means the Basque Country has its own legislative system, can collect its own taxes, and has its own police force (Wikipedia Contributors, 2023a; The Statute of Autonomy of the Basque Country, n.d.). Taxes are redistributed to the municipalities and specific cases to the city (Interview 1). Therefore, Bilbao has a high degree of autonomy in the city's urban development and planning. Some projects that transcend the provincial border require government discussion with the national government, such as developing high-speed rail (Interview 1).

Heating in the Basque region is supplied through an extensive gas network. The Basque Country's gas supply is secure and reliable (DCP-2050, 2023a; Interview 5). Russian production accounts only for a small share of gas imports. Most of the gas consumed in the region is imported from Algeria through a series of pipelines. Furthermore, the region benefits from an LNG regasification plant located in the industrial harbour of Bilbao. The gas infrastructure was constructed relatively recently, developed in the 80s as a sustainable alternative to oil (DCP-2050, 2023a; Interview 5). Furthermore, demand for heating in the Basque Country is not as high as elsewhere in Europe. This is mainly due to the temperate, moderately warmer climate of Bilbao. Energy demand in the building sector, including residential demand, tertiary sector demand, public buildings and supermarkets, only accounts for less than 20% of the total energy demand of the Basque region (Interview 5). Energy saving is focused on the transport and industrial sector first, as those have the most significant energy demand. Therefore, the decarbonisation of H/C infrastructures is not prioritised in the Basque region. This is slowly changing with the increase in energy prices and European policy (Interview 5).

The Basque government has set up the Basque Energy Agency to manage energy development in the Basque region, initially for promoting gas, though the agency currently is involved with sustainable energy generation (Interview 5). A Bilbao Energy Agency is being set up as an energy agency for Bilbao expressly modelled to the Basque Energy Agency. When the new agency starts operation, it will consist of the city council and the Basque Energy Agency. This energy agency is expected to play a significant role in the energy transition in Bilbao. They must be in touch with all the municipal departments and have a more transversal perspective to manage Bilbao's energy transition (Interview 1; Interview 2; Interview 5).

4.1.2 Status quo on heating and cooling

Bilbao primarily relies on natural gas for heating, which reflects the larger Basque region's dependence on this energy source. According to 2018 data, 90% of the city's thermal energy supply comes from natural gas, while the remaining 10% is assumed to be from electricity. The residential sector is responsible for consuming 445 GWh/a of thermal energy, making up 55.4% of the city's total energy consumption of 807 GWh/a. Within this sector, 58.4% is used for space heating and 41.6% for domestic hot water (DCP-2050, 2023a). The dependency of Bilbao on natural gas is visible in the distribution of heating systems present in the residential sector in Bilbao. Gas powers 70% of heating systems, consisting of individual boilers (52,7%) and centralised boilers (17,3%). Heat pumps are little present in Bilbao: they consist of less than 1% of the distribution of heating systems in residential buildings. Heat pumps are more popular in the non-residential sector. There, gas boilers remain the most common systems, but heat pumps comprise 30% of the share in the distribution of heating systems. The distribution heating systems in both the residential and non-residential sectors are visualised in *Figure 4* and *Figure 5* (DCP-2050, 2023a).

Figure 4: Bilbao heating system distribution in non-residential buildings

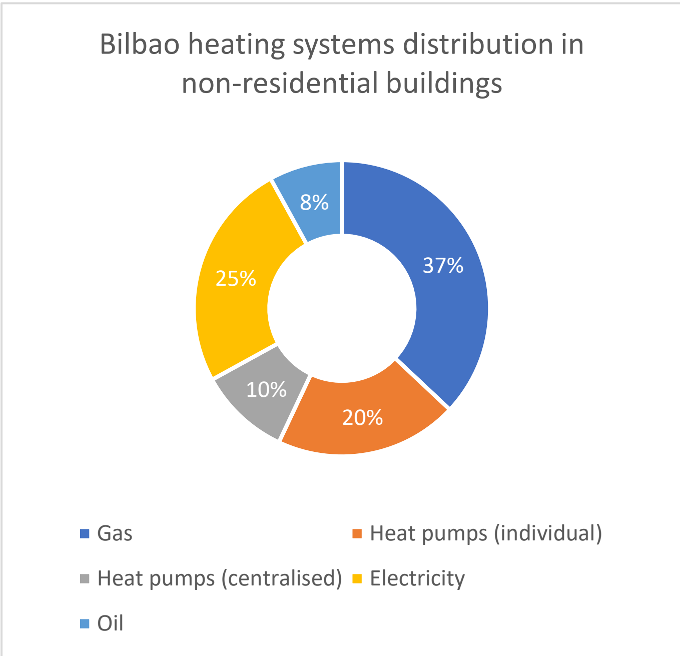
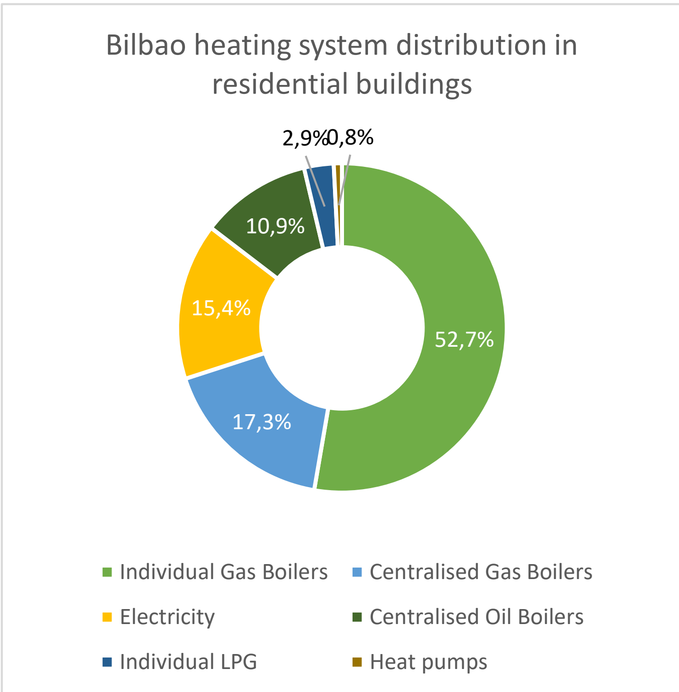


Figure 5: Bilbao heating system distribution in residential buildings



Besides the recently implemented gas infrastructure, the relatively low amount of residential heat pumps could also be a consequence of the city's relatively large amount of heritage protection. This protection is said to at least restrict building equipment and installations on roofs in the old town to conserve the city's heritage (Interview 1). Heat pumps and like installations are deemed to be visually unappealing, damaging the heritage value. This greatly limits the implementation of air-sourced and solar-assisted heat pumps in the dense city centre. The amount of protected buildings is estimated to be almost 40% of the building stock (DCP-2050, 2023a).

District heating and cooling

Currently, as can be observed by the distribution of heating systems, DHC networks do not exist in Bilbao on a significant scale. Not many cities in Spain have a DHC network, as H/C on a large scale has not been a priority for the Mediterranean country. Bilbao has one small DHC network, supplying heat to all buildings of the Basurto hospital. The network operates on biomass and natural gas and is linked to only five or six buildings (Interview 2).

To examine the potential of DHC in Bilbao, the ATELIER project is developing a 4th generation DHC system on Zorrotzaure Island (Interview 1; Zorrotzaure management commission, n.d.). This DHC network is currently being developed on the island. The network seems to have been completed in the north and south parts of the island, though it is unknown if the network is already in operation. The network in the island's central area is currently being developed, but the development faces difficulty with the high volume of private ownership. This land is being repurchased by public entities (Interview 1). Currently, public entities are estimated to own 50% of the buildings in the central area. The project aims to connect the whole island. In *paragraph 4.1.4,* this project is examined in more detail.

The development of DHC networks in Bilbao has potential at first glance, as the city's population density is high due to the surrounding mountains. Tecnalia (Interview 2), an international research and technological development centre, states: "*We have levels of above 500 MW hours per hectare, which is one of the benchmarks for the viability of DHC. Most of the city centre is above that.*" Furthermore, the presence of centralised boilers in the multi-apartment buildings of the city has potential, as these are easier to connect to a DHC network. The economic feasibility analysis done by Tecnalia seems to have a positive result for these buildings, opening up possibilities for DHC development in areas of the city where they are common. However, several factors significantly complicate the potential implementation of a DHC network. First, the city still has little experience with DHC networks, making the return on the costly upfront investments more uncertain. The Basque Energy Agency (interview 5) states that DHC network development is not attractive in the Basque Country as the heating demand is small, further negatively influencing the return on investment. "*Our low-temperature demand in the domestic circle means that kind of projects are not that attractive for investors. That is our situation.*" Second, the city seems to lack space to develop pipes due to urban density. Tecnalia (Interview 2) states: "*The problem is, at least the City Council tells us, is the space, for all the streets are quite full with infrastructure there. We'll have to look into the details of how and where is the space for the infrastructure, where it comes from, that's the work we need to do with the City Council*." The completion of the Zorrotzaure DHC network might shed more light on the potential of future DHC developments in Bilbao.

Thermal insulation

Because of the temperate climate, thermal insulation and renovation have not been priorities in Bilbao (Interview 1; Interview 2; Interview 5). As per the Decarb City Pipes project, there have been analyses of the Bilbao building stock for deep building refurbishment and thermal insulation (Interview 1). Tecnalia (Interview 2) states the potential for refurbishment in socioeconomically vulnerable areas. "*For those areas, deep refurbishment is, I think it's probably the best option. You lower the operation cost, like, a lot, and the refurbishment already has some funding structure. So you can provide funding for refurbishment at quite a high rate. For vulnerable families, for example, they can collect a lot of funding for refurbishment, like 80%*." The potential here seems primarily economical, based on a present funding and subsidy structure. This is further supported by the position of the Basque Energy Agency on the priorities for building refurbishment. Despite high energy prices, the Basque Energy Agency states that energy consumption is not one of the main levers for building refurbishment

(Interview 5). Renovating buildings only from an energy point of view is not perceived as a must by both residents and private investors. Payback periods for energy consumption remain lengthy; other levers are deemed necessary to incentivise building refurbishment. These levers consist of improving accessibility, the improvement of building security, and renovation of building facades, among others. Part of the subsidy programs from the Basque Energy Agency is the upgrade of windows for better thermal insulation and changing building boilers (Interview 5). The latter is part of the current trend in Bilbao, in which oil boilers are being changed to gas boilers (Interview 2).

Composition of the built environment

The composition of the built environment in Bilbao has an unusually high number of private owners. Interview 1: "*Here, most of the people own their flats. (…) We are not so used to renting. And that is also related to that for Bilbao, the [amount of] buildings owned by the municipality is not so high. It is around 4000 buildings.*" Most of the residents in Bilbao own their houses. The high density in Bilbao furthermore means the built environment in Bilbao consists primarily of multi-apartment buildings. There is not much room for growth but up. Flats are multi-ownership buildings. In order to execute renovations of the building envelope or changing the infrastructure facilitating the supply of H/C in the building, a consensus with the residents is necessary (Interview 1).

Public opinion and knowledge

Bilbao citizens are primarily centre to left-leaning, as seen by the most recent election results from late May 2023. Central and left-wing parties make up 25 out of the 29 seats in the City Council. The central Basque Nationalist Party (PNV) gained 36,5% of the votes, left-wing pro-Basque independence Basque Country Unite (Bildu) gained 18,9% of the votes, and the Socialist Party of the Basque Country (PSOE) gained 16,6% (20minutos, 2023). These election results are comparable to the previous results from the 2019 election, though Bildu has gained two seats, and PNV and PSOE both lost a seat. These parties primarily have a social-democratic and conservative ideology, with EH-Bildu actively pushing a Basque separatist nationalist ideology. The PSOE party states noticing a difference between the younger and older generation in Bilbao (Interview 3). The younger generation seems to feel more climate urgency and is more open to changes to further climate mitigation. The older generations are more resistant to change. The PSOE party sees the Bilbao residents as resistant when expected to oblige and stresses the importance of positive framing when convincing residents that a change is necessary (Interview 3): "*We need to send positive messages. (…) We don't say: "Now you cannot, you won't. We said just the opposite. You will live 30 times better. And it's very important how you set things. Because you* will *live better."* When constructing a strategic framework to transition to new infrastructure, positively engaging people of all ages seems beneficial.

Bilbao as a municipality is familiar with long-term transitions. Bilbao has significantly transformed in the last 20 years from an industrial harbour to a green knowledge hub. Through the interviews in Bilbao, it seems Bilbao residents are used to major developments happening in the city. Interview 2: "*That is one of the strong aspects of Bilbao that we put everywhere; we are used to this type of transition and long-term vision".* The building of trust is stated by Interview 3 and Interview 4 to be of vital importance for public support of these transitions. During the previous urban developments, people seemed to understand what was happening through the development of projects. When the major projects, such as the construction of the Guggenheim Museum, turned into reality, Bilbao residents could observe the progress of the transition and its importance. The positive engagement of Bilbao residents in the city's transformation is reiterated as important.

However, climate adaptation as an argument for urban development towards decarbonisation ambitions seems to gain relatively little leverage in Bilbao. When examining the Bilbao Environmental Strategy 2020-2050 (2020), it becomes clear that the values related to environmental sustainability are among the least established values (Bilbao Municipality, 2020). In a 2016 survey in which 1200 Bilbao residents participated, sustainability as a value ranked 16th of 19 values. According to the study's considerations, the low presence of sustainability among the priorities of Bilbao citizens leads to the conclusion that the subject is not considered a priority. However, that does not imply it is not perceived as a necessity. The City Council, seemingly reacting to this result, then proposed to develop the Bilbao 2020-2050 strategy from an environmental point of view (*ibid*.). It is unclear how this reaction has impacted public opinion on environmental sustainability.

4.1.3 The governance of the heating transition

Legal framework: policies

National policies and targets

Spain is a largely decentralised state. The country is subdivided into 17 autonomous communities. Each community exercises self-government within the limits of its statutes and the limits of the Spanish constitution. The scope of this self-government differs between each community, called asymmetrical devolution. A higher degree of competencies within an autonomous community is associated with a stronger local nationalistic tendency. The historically nationalistic autonomous community of the Basque Country, therefore, has a high degree of competencies. The parliamentary system of all autonomous communities is based on a division of powers comprising a Legislative Assembly, a Council of Government headed by a prime minister, and a High Court of Justice. Though the national government has control over finance for most autonomous communities through "fiscal equalisation", this does not apply to the Basque Country and Navarre. These two autonomous communities were granted an exception and are allowed to levy income tax and corporate tax, including flexibility on lowering or raising this tax. National policies must be developed and executed in cooperation with the autonomous communities. This is to say the national government is limitedly involved in the execution of policy on H/C infrastructure in the Basque Country. For the further policies on H/C infrastructure mentioned, the autonomy of the Basque Country should be kept in mind. Whether the Basque Country is legally obligated to follow the national energy policies is uncertain.

The Spanish national government has set up a National Energy and Climate Plan 2021-2030 (Grantham Research Institute, 2020). This is a long-term strategic document, providing a framework until 2030 with the eventual goal for Spain to become a carbon-neutral country by 2050. This goal will be achieved by mitigating at least 90% of gross GHG emissions compared to 1990. The goals for 2030 include at least a 20% reduction in emissions compared to 1990. The plan aims to reduce emissions from the non-ETS (emission trading systems) sectors by 39% compared to the levels in 2005, while the ETS sector will decrease emissions by 61% compared to 2005. The document promotes renewable energy use in three energy-intensive sectors: transport, industry, and electricity. Renewables are planned to account for 42% of the total energy end use in 2030 (ibid.). The document is backed up by a national climate change law (Interview 3).

In the heating and cooling sector, the NECP expects continuous technological improvement and new players and investment models emerging to drive decarbonisation (Grantham Research Institute, 2020). The plan focuses on renewable energy communities and proposes regulations to enable the right to generate, consume and sell renewable energy. Furthermore, the NECP proposes an increase in electricity use for heat generation. The plan primarily focuses on decentralised energy generation. Moreover, the NECP considers regulatory and financial support to enable DHC and cooling where possible, expecting DHC to use renewable fuels to play a much more significant role by 2030. The plan states that information about H/C networks will be annually collected, and mechanisms will be put in place to ensure information about energy use and efficiency is provided to the final consumers about the H/C network to which they are connected (ibid.).

Furthermore, the Long-term Strategy for Energy Retrofitting in the Building Sector in Spain (ERESEE 2020) is in effect (Spanish Ministry of Transport, Mobility and the Urban Agenda, 2020). The strategy established a roadmap for decarbonising the housing stock in 2050. The document lists 11 different measures to establish the ERESEE goals. Measure 7.5 explicitly promotes energy communities and district networks, aligning with the NECP (de Arriba Segurado, 2021). The assessment of de Arriba Segurado (2021) on the ERESEE concludes that the retrofitting rates in Spain must be increased to achieve the expected savings targets through energy efficiency.

The Technical Building Code of Spain was updated in 2019 to include new requirements for domestic and non-domestic buildings concerning the building envelope and overall energy performance. This is referred to as the DB-HE: the Basic Document on Energy Conservation (Spanish Regulations – Pladur, n.d.; DCP-2050, 2023a). Examples include limitations for the total primary energy use and minimum requirements for renewable energy use in electricity and domestic hot water. The code update aims to encourage using renewable energy systems and examines the potential switch to DHC networks with low primary energy factors (ibid.).

Regional policies and targets

The decentralisation of the Spanish governance structure has granted the Basque Country a high degree of autonomy as an autonomous community (Queens University, n.d.). The Basque country comprises the provinces of Álava, Biscay and Gipuzkoa. Bilbao is the capital of the Biscay region. Though the Basque Government is located in Álava's capital, Vitoria-Gasteiz, the Basque Country does not have a capital (ibid.).

Basque energy policy

Regarding the Basque energy policy, the country's degree of autonomy grants relative self-government. The Basque Energy Strategy 2030 is used as a guiding framework for energy development (Basque Energy Agency, 2017). This strategic document is a review of the prior 2020 strategy. The Basque Energy Strategy is primarily based on EU objectives for the energy transition, reinstating the European targets and going beyond those targets where possible. The document states that to reduce energy demand, new electricity and gas network plans are being developed within the framework of the process of reform of the Spanish energy industry. Furthermore, the strategy states that updating the regulatory monetary framework around using natural gas in the region may be necessary. Since 1982, the Basque Energy Agency has developed an integral gas distribution network, as gas was considered a clean alternative to the heavy industry fuels used before. Currently, natural gas counts for 45% of the total energy consumption in the Basque Country (Interview 5).

The Basque Energy Strategy 2030 primarily focuses on reducing energy consumption through energy efficiency and promoting renewable energy sources (Basque Energy Agency, 2017). As 70% of the Basque building stock predates 1980, renovation combined with thermal insulation is one of the measures in which the strategy aims to reduce energy consumption. The strategy makes mention of improving the energy efficiency of both private residential buildings and public buildings through similar measures. An example is on page 76, Initiative L3.1: *Promotion of Energy Improvements in Buildings and Homes*. This initiative is mainly financial, providing incentives such as subsidies for replacing windows, renovating energy-consuming equipment such as air conditioning systems, and rehabilitating buildings to consume less energy. Energy audits and diagnostics in buildings are to be promoted. The rehabilitated buildings must include a certain degree of renewable energy usage, though the exact requirements are unclear. This amount will furthermore depend on the energy production capacity of the building. The renovation of public H/C infrastructure and equipment is part of a different initiative, L4.1.1: *Improvement in energy efficiency and installation of renewable energy in buildings, facilities and vehicles owned by the Basque Government (p.83)*. This initiative lists the same measures as L3.1 for residential energy efficiency incentives. However, as this measure concerns public buildings, an action plan is stated to be drawn up to identify the actions necessary for renovation.

The Basque Energy Strategy 2030 mentions sustainable H/C infrastructures (Basque Energy Agency, 2017). DHC is mentioned sparingly in the strategic document; it is stated that facilities will be provided for DHC networks when considered viable. DHC networks are subject to some associations in the Basque Country. First, DHC within the Basque country is strongly associated with biomass as a heat source. Biomass as a sustainable energy source is regarded as having potential in the Basque Country. The overall objective of biomass is: "T*o encourage energy efficiency in the primary sector and to achieve maximum use of biomass byproducts for use as heat in industry or in heating hot-water systems in buildings and facilities in the tertiary sector.*" (Basque Energy Agency, 2017, p.86). Biomass energy production is to be fuelled using by-products of various industries situated in the Basque Country as fuel. The agricultural/primary sector is seen as another meaningful way to generate energy for biomass heating. Secondly, DHC networks are associated with CHP as a heat source. The use of CHP plants is stated as one of the seven strategic objectives of the Basque Energy Strategy. The objective describes the increase in participation of CHP and renewables in power generation from 20% in 2015 to 40% in 2030. However, the Basque Energy Strategy focuses mainly on using CHP for industrial purposes. Furthermore, reforms have limited the use of CHP, making them no longer favourable to install. The use of DHC in the Basque Country is furthermore a topic of discussion, as the Basque Energy Agency seems sceptical about its usefulness (Interview 5): "*But when it comes to DHC, as we were mentioning, it is not attractive in our area because the heating demand is not big.*" Installation of a DHC network would take many resources, and due to the low heat demand, the return on this investment would take long. The Basque Energy Agency does mention that DHC is possibly viable in dense areas when combined with buildings that fulfil a tertiary function, like sports centres. Feasibility studies seem integral in how DHC can develop in the Basque Country.

Regarding other sustainable heating alternatives, these are sparsely mentioned in the Basque Energy Strategy 2030 (Basque Energy Agency, 2017). Heat pumps are mentioned a single time, as part of measure L3.1.3, concerned with renovating energy-consuming equipment. This measure aims to influence demand for new equipment and energy-consuming systems to promote a move towards more efficient models. The measure aims to boost the change using aid programs, which will be established annually. There is no further mention of heat pumps specifically. Solar thermal energy is stated to be of less potential use than other types of renewable energy, such as the previously mentioned biomass. Solar thermoelectric-powered thermal energy is mentioned, though the technology at the time was not well-developed enough to make measures regarding installation viable. Technological development for these systems is stated to be supported. Finally, though geothermal energy is mentioned alongside biomass as having potential within the Basque Country, studies of this potential indicate that it is restricted to low-temperature varieties. Therefore, harnessing geothermal energy was deemed difficult for commercial power generation. In possible scenarios the document describes for renewable energy development, geothermal energy remains a small energy source compared to other renewable energy sources.

Among the measures introduced in the Basque Energy Strategy, it is clear that measures reducing emissions in the industry and transport sector have the most priority (Basque Energy Agency, 2017). The temperate Basque climate means that energy demand for heating and cooling is not as substantial as these other two sectors. The Basque Energy Agency (Interview 5) confirms that the decarbonisation of heating is not a priority: "*Just to give you an idea, the energy consumption in the building sector accounts for less than 20%. This includes residential and also businesses, I mean the tertiary sector. (…) And the residential sector is 11% of the demand, only. On the other hand, we have around 40% energy* *demand in the industrial sector.*" And "*As you can see, the energy consumption in the industrial sector is quite high, so the improvements in energy efficiency in the industrial sector mean a lot.*" The Basque Energy Agency stresses that this does not mean they are not making efforts in other sectors, just that these are less impactful regarding efforts for the energy transition. The decarbonisation of H/C, therefore, is less prioritised.

Apart from the strategy, the Basque Energy Agency (Interview 5) mentions a new law being developed on municipal energy strategies. If this law passes, which is expected, it will obligate municipalities greater than 5.000 residents to draft a SECAP. The action plan should be linked to the measures put forth in the Basque Energy Strategy. The Basque Energy Agency states they will provide subsidy programs and help the municipalities to carry out this task, depending on the capacity and competencies of the municipalities. As Bilbao is already developing a SECAP and is stated by the Agency to have enough capacity, it can be assumed this law will limitedly impact Bilbao.

Finally, based on data gathered by DCP-2050 (2023a), the Energy Sustainability Law 4/2019 of the Basque Country establishes a reduction of 40% in GHG emissions by 2030. The law requires promoting and implementing renewable energies in the public administration sector to reduce dependency on fossil fuels. Basque public administrations must achieve a 60% reduction in energy consumption by 2050, with an intermediate reduction target of 35% by 2030. All administrations are responsible for their buildings and facilities to reach this target. All administrations must generate enough energy by 2030 to cover at least 32% of their energy demand, including thermal and electrical generation systems. Reducing energy use for H/C through refurbishments and integrating renewable heat installations in buildings is a central part of achieving these goals. All purchased electricity is required to be of renewable origin. Also, decree 254.2020 states that public administrations are required to promote studies on centralised energy systems and to improve the energy efficiency of the existing building stock. To develop new buildings, the Energy Sustainability law requires administrations to consider these centralised energy systems for energy supply and the use of renewable energies.

Biscay energy policy

The Basque Country is divided into three provinces with provincial authority. The Biscay provincial authority is situated in Bilbao. In practice, this means residents are subject to four levels of governance: the local Bilbao municipality, the provincial government of Biscay, the Basque government and the national Spanish government.

The Biscay provincial government has formulated the Sustainable Energy Strategy for Biscay 2020 (EESB 2020) based on the previous version of the Basque Energy Strategy (Biscay Provincial Council, 2011). The document details the then-current situation of Biscay energy use, assumed to be 2011, and presents guidelines and a strategic framework to work toward the goals the document has set. As the strategy is based on the Basque Energy Strategy 2020, the document states goals similar to the ones described previously. Furthermore, the document is outdated, with 2020 passing three years ago. The current status of the document, and if an update is in development, is unknown.

Being a lower level of authority, the Biscay province could allow the strategy to be more executive. Though its goals cannot be applied to current energy planning, it is good to note how the document tries to make more workable goals from the more idealistic goals of the Basque Energy Strategy 2020. The document is established in four phases: 1) Reference context, 2) Diagnosis of Biscay, 3) Strategic Framework, and 4) Action plan. Both internal and external participatory processes are interwoven in the four phases. The strategic framework is based on four major strategic guidelines:

1. **Focusing energy policy and action on energy demand.** The document states that Biscay wants an aware and responsible society willing to change energy usage and minimise environmental impact.
2. **To turn the Provincial Council into an agent of reference during the change of the energy model.** The Council of Biscay has a wide range of instruments it can utilise to motivate sustainable behaviour in the energy field.
3. **Making energy a transversal axis of the policies of the Provincial Council.** Making the role of energy explicit in all departments of the provincial government will allow it to have a more direct impact on the change of energy model to which it aspires.
4. **Participate through innovation in the global energy model.** The document's strategic goals aim to position Biscay as a valuable agent in the energy transition worldwide, contributing knowledge and innovation while refraining from damaging the local and global environment.

The strategic guidelines furthermore emphasise the balance between the government, the businesses, and citizens. The aim is to achieve "responsible citizenship", much in line with New Public Management ideals, placing the regional government in an intermediary role between local authority and territorial development. Interestingly, though the scale and timeframe of the document would allow it to be more concrete, the document refrains from doing so. The strategic guidelines could still be relevant if and when an updated document is published.

Local policies and targets

The Bilbao Environmental Strategy 2050 is a strategic document envisioning the transition towards Bilbao as a "sustainable, resilient and healthy city." (Bilbao Municipality, 2020, p.5). The document is established around four main challenges: 1) Carbon-Neutral Bilbao, 2) Resilient Bilbao, 3) Healthy Bilbao, and 4) Smart Bilbao. The first challenge is the most relevant for decarbonising heating and cooling infrastructures. Mirroring the Basque Energy Strategy, the main focus within the Carbon-Neutral challenge is energy efficiency. The actions that contribute to achieving the Carbon-Neutral Bilbao challenge are grouped into six strategic objectives:

1. Electrification and sustainability of mobility.
2. Energy consumption savings in each sector.
3. Increase local energy production.
4. Increase production and use of renewable energies.
5. Enhance CO_2 sinks (such as an increase in greenery).
6. Reduce waste and recycle.

These strategic objectives are further elaborated in strategic actions, though each action remains more of a strategic goal than a concrete plan. The second strategic objective, "Energy consumption savings in each sector", for example, has "Savings within the town hall" and "Savings within the residential sector" as strategic actions. The seeming lack of concrete action is critiqued by Tecnalia (interview 2): "*We have like a long-term vision, but that is very inspirational. That Bilbao will be nearly zero or fully electrified (…) that kind of long-term vision, but we have not much concrete actions in the meantime."*
Reiterated in the Carbon-Neutral challenge is the importance of transport and industry for emissions in Bilbao, as most strategic goals are directed at the mobility and industry sectors. The priority of mobility is visible organizationally by the division of departments in the Bilbao municipality. The topics of sustainability and mobility are paired in one department and headed by the councillor for mobility and sustainability. Heating and cooling can be assumed to not be a priority for the city as, despite the focus on energy efficiency, the decarbonisation of heating and cooling is not mentioned in the document.

The initial Sustainable Energy Action Plan 2020 is a strategic document published in 2012, likely to be developed around the same time as the Biscay and Basque Sustainable Energy Action Plans and in line with those documents (DCP-2050, 2023a). The strategy included various measures to reduce energy use for heating. It focused on the promotion of building refurbishments, the improvement of gas boiler efficiency and the integration of renewable energy. In what way these goals are realised is unclear, though the renovation rate of Bilbao remains low. The strategy included plans for the development of a DHC network in the Bolueta district for up to 1100 households. This plan has not been realised, or the location of the network has been changed to Zorrotzaure island (Oficina contra el Cambio Climático de Bilbao, 2012).

Bilbao is currently developing the Sustainable Energy and Climate Action Plan (SECAP 2030) to follow up on the prior document, which will likely contain more details concerning actions for achieving the energy transition. The document is expected to detail different measures for building refurbishments, feasibility studies for DHC and measures for integrating decentralised decarbonised infrastructure for H/C. However, Tecnalia (Interview 2) states the SECAP will likely be short regarding H/C development in Bilbao: "*Some more concrete actions will appear, but it's quite short. Like, pilot projects for district heating, or how to promote the refurbishment, or some actions. They are more short-term, but for long-term, this is still not clear, the road map. We will not have time this year, probably, to define it very well there."*

The process of planning H/C infrastructure development in the city

The decentralised governance structure of the Spanish state has benefits and challenges for planning H/C infrastructure development in Bilbao. The provinces are responsible for implementing key national energy and climate policies, on which Bilbao depends, and are responsible for authorising power plants and energy networks. The Spanish government is providing funding for energy development (Interview 4). The system has benefits, as the autonomy allows regions and municipalities to work on policy more directly with end-users, allowing for solutions more tailored to local needs. However, the system has its limits. Regarding energy project development, the city requires national certainty regarding energy use (Interview 1). National support can be necessary regarding sustainable energy development, as the city does not have the capability to, for example, significantly reduce the use of natural gas or fund projects for DHC development. Interview 1: "*Sometimes you need the national law that can support, and also inspire, cities to take these kinds of big projects for the city. Of course, developing DHC in a neighbourhood of the city and normally consolidated area is such a big project. So, we somehow need also some certainties in terms of avoiding or banning fossil fuel gas networks".* The national government has established structures to fund these projects and developments (Interview 3). However, more strict national law is stated to be sometimes required to further energy development goals (Interview 1).

The autonomy Bilbao has over its urban planning is stated by Interview 1 to be a benefit that the municipality also wants to apply to the heating and cooling sector. To coordinate the development of sustainable energy, of which heating and cooling will be part, the municipality is developing the Bilbao Energy Agency. This agency is developed in cooperation with the Basque Energy Agency and is expected to consist of 50% municipal and 50% Basque Energy Agency employees. The Bilbao Energy Agency is planned to approach the energy transition in Bilbao as an overseer and coordinator, bringing together different departments and stakeholders in Bilbao to cooperate on the actions set out in the SECAP 2030. With the creation of the Bilbao Energy Agency, it is expected that public-private partnerships on integral energy policy will be easier to create and maintain.

It should be noted that autonomy over urban planning also comes with a risk. Without a national obligation to think about long-term goals, it seems that integrating long-term policy with short-term day-to-day management is a challenge. Tecnalia, as a private stakeholder, is critical of the speed at which Bilbao authorities are moving towards energy policy. *"From what I see from giving support to them is that they are very much in the day-to-day management of city issues. They don't really have much time to think about this long-term period."* The current actions, they state, do not yet reflect the objectives and challenges defined in the Bilbao Environmental strategy. They ask for priority and clarity from the strategy regarding their plans for the development of H/C infrastructure. Interview 2: "*So if they set up their minds, DHC infrastructure for all this, it's complex, but no more complex than the other processes. It will be more simple to do it when you get a clear mandate and vision if it is made a priority."* The general critique of Tecnalia is disputed by the PSOE party (interview 3). However, they repeatedly state that action is necessary now, implying there is not enough currently done to reach the municipality's sustainability goals.

Stakeholder involvement
The key stakeholders involved in the heating transition are displayed in *Table 1.*

Table 1: Key stakeholders involved in the heating transition in Bilbao.

Stakeholder	Description
The Basque Energy Cluster	The Basque Energy Cluster is a non-profit organisation that fosters industrial competitiveness. The Cluster currently comprises 200 businesses and agencies. All further mentioned stakeholders are part of this cluster. (Basque Energy Cluster, n.d.).
Tecnalia	Tecnalia is the largest centre of applied research and technological development in Spain. Their vision is to be agents of both public and private transformation for their adaptation to the challenges of a changing future (Tecnalia, n.d.).
Iberdrola	Iberdrola is a large international energy company. The company has a world-leading role in renewable energy and smart energy grids, anticipating the energy transition. (Iberdrola, n.d.)
Telur Geotermia y Agua	Telur is an energy company specialised in exploiting, evaluating and monitoring groundwater. The company is furthermore responsible for the first closed-circuit geothermal projects with an output of over 1000 kWh in Spain and aims to expand the influence of geothermic energy solutions. (Telur, n.d.)
Sener	Sener is an innovative engineering company specialising in infrastructure, aerospace engineering, energy industries and marine technologies. Their goal is to contribute to social progress through technology. (Sener, n.d.)
Velatia	Velatia is a large international industrial and technological company situated in Biscay. They state sustainability as part of their business strategy, as profitability and responsibility are inseparable. (Velatia, n.d.)
GoiEner	GoiEner is a cooperative project for the generation and consumption of renewable energy. The project aims to restore energy sovereignty: electricity is a basic need which citizens should be able to control themselves. (GoiEner, n.d.)
Basque Energy Agency	The Basque Energy Agency is the energy agency of the Basque Government. Its mission is to propose energy strategies for the Basque Country and participate in developing these strategies. (Basque Energy Agency, n.d.)

The Bilbao Convention Bureau is reportedly optimistic about the cooperation within the Basque Energy Cluster, stating that the Basque Country's energy sector is strong. Interview 4: "*The energy cluster is really efficient in the Basque Country, okay, because they do many things together as a group and they* *work in a coordinated manner."* The improvement of innovation and sustainability seems to be a shared goal among the most significant stakeholders in the Cluster. However, the Decarb City Pipes project (2023a) states the involvement of privately-owned energy companies in the decarbonisation process to be a severe hurdle. The primary goal of each stakeholder company is still their profitability. The activities and goals of the companies may not necessarily align with the decarbonisation visions or social equity. Tecnalia shares this concern; Interview 2 states: "*If we leave it to the market, [the transition] will be slow and socially unequal."* They state that inequalities appear in the Basque country, as wealthier inhabitants are capable of investing in sustainable energies or can make cases to the municipality that they should receive subsidies for renovating their private home, actions that inhabitants of lesser socioeconomic status face more difficulty with. Furthermore, interactions the Decarb City Pipes project (2023a) had with the private sector show a trend in which private companies are counting on integrating a share of hydrogen into the natural gas network. At the very least, the primary interest of private companies in their profitability is a given that should be remembered in public-private partnerships for H/C infrastructure development.

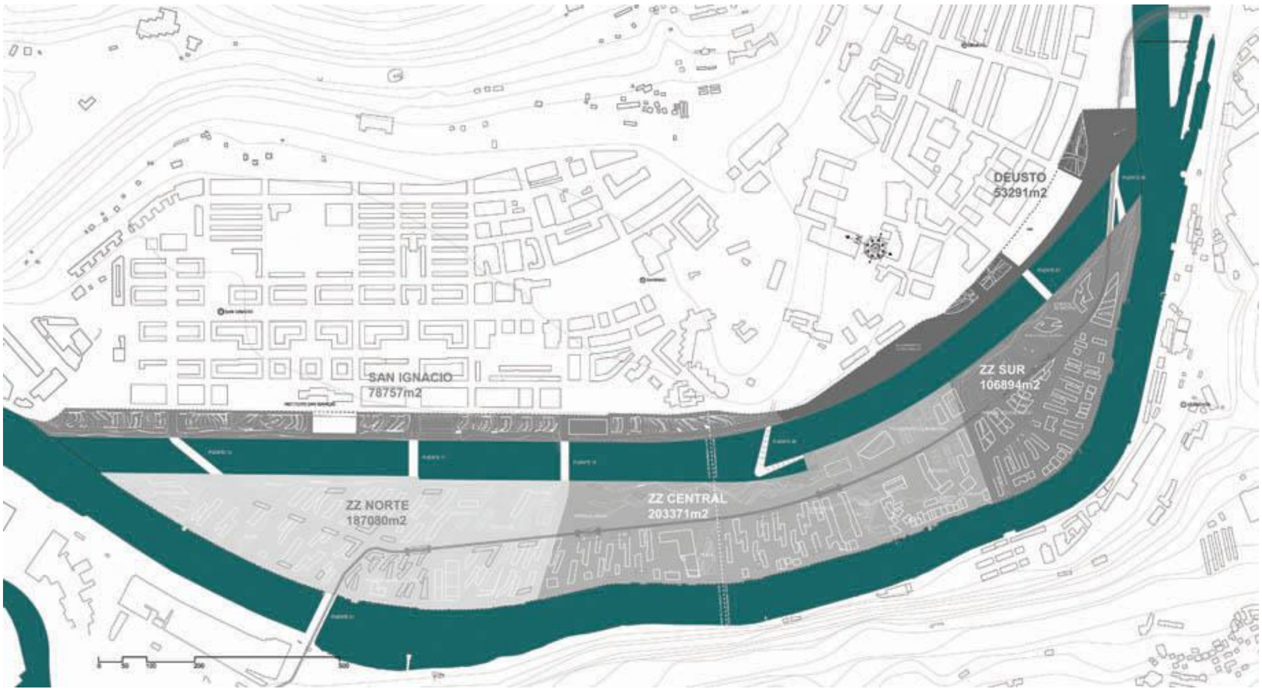
4.1.4 The presence of the projectification phenomenon in Bilbao – Zorrotzaure Island

Bilbao has had a major focus on urban development during the last decades. This can be stated to be a successful effort, as the city has significantly transformed during this time. The liveability of Bilbao has increased in part due to the different projects the city established and relied on. Therefore, the municipality continues to do so, though the priority is stated by Interview 4 to have shifted: "*We leave aside this urban transformation, which is still continuing, but it is not the main priority. The main priority is going to be people. (…) OK, so we want to bring meetings and events to the city in order to transform the city for the benefit of the citizens."* Bilbao increasingly participates in European governance projects to further develop the city and share these results with other European cities. The DCP-2050 project is part of it, though the main urban development project is the ATELIER project, which focuses on the redevelopment of the Zorrotzaure Island brownfield.

The ATELIER project in Bilbao is executed through the Zorrotzaure Island urban regeneration project, which entails the redevelopment of the Zorrotzaure brownfield to a mixed land-use residential business district (ATELIER, n.d.). The Zorrotzaure Island lies in the centre of Bilbao, connected to the rest of the city with multiple bridges (Bilbao Ekintza, n.d.). Zorrotzaure is planned to become a place for sustainability, innovation and knowledge. This goal is aimed to be achieved through developing education, integrating sustainable energy technologies, and attracting high-tech businesses to settle in the area (Bilbao Ekintza, n.d.). The project is "*to be used as a framework for deploying and testing new sustainable concepts, principles and solutions that will be used as an example for the whole city*" (ATELIER, n.d.). An example of these concepts: the island is planned to be accessible by zero-emissions vehicles only with an integrated plan for 100% electric public transportation (ATELIER, n.d.).

The district's development is one of two demo districts of the ATELIER project. The Atelier project is an EU-funded Smart City project, a cooperation between the so-named "Lighthouse Cities" of Amsterdam and Bilbao and the participation of six fellow cities to use the results of the project as a framework for their H/C development (ATELIER, n.d.). The ATELIER project focuses on developing citizen-driven Positive Energy Districts (PEDs). A Positive Energy District is defined as an urban neighbourhood with net zero energy import and net zero GHG emissions, working instead to surplus renewable energy production (Urban Europe, n.d.). ATELIER plans to strengthen the local innovation ecosystem and remove social, financial or legal barriers to implementing smart solutions. The PEDs are planned to become engines for later upscaling and replicating solutions, both for the cities participating in the project and for cities beyond the project. Therefore, the ATELIER project can be identified as an experimentative project. Citizen participation is central to the ATELIER project, including residents, local initiatives and energy communities in decision-making. This participation aims to maximise the project's impact (ATELIER, n.d.).

Figure 6: Zorrotzaure Island district division



Source: Zorrotzaure Management Commission, n.d.

Regarding the development of zero-carbon H/C infrastructure, the construction of a three-part 4th generation low-temperature DHC system is integral to the districts' development (Interview 1; Zorrotzaure Management Commission, n.d.). The Zorrotzaure DHC development is divided into the North, Centre and South grids. The DHC is planned to be powered by geothermal and hydrothermal renewable energy to cover the H/C demand. The DHC will be the first significant introduction of a DHC network to Bilbao, and the results of the experimental project can provide the necessary context for eventual future DHC development in the city. The development of the network has completed in the North and South areas, as these previously consisted mainly of industry, making urban regenerative construction easier. It is unclear if these networks are already in use. In the Centre area, development encountered difficulties with private land ownership (Interview 1). Once the situation in the Centre area becomes clearer, development is planned to start there as well. As 500 residents are already living on the island, the buildings they occupy are planned to be connected to the DHC network, and some universities have settled on the island as well (Interview 1).

The Zorrotzaure Island project, combined with the Atelier project, could be stated to be of significant potential for the decarbonisation of the H/C infrastructure of the city. However, it should be noted that the planned urban density within Zorrotzaure Island will be lower than the rest of Bilbao. Furthermore, developing a DHC network in a new development area is more straightforward and different than connecting DHC networks to existing buildings. The development of the DHC network on the island is not representative for H/C infrastructure development elsewhere in the city. The timeline of completion for the project is furthermore still unclear. Tecnalia (interview 2) states that the project, at the very least, is a good experience for the city. Ultimately, the project is still in development, and conclusions about its effectiveness would be premature.

4.1.5 Key challenges for decarbonising H/C infrastructure in Bilbao

Based on the results from the case study, Bilbao faces several key challenges in developing zero-carbon H/C infrastructure in the city. These challenges are categorised into challenges primarily in the social domain and challenges primarily within the technological domain. The challenges in primarily in the social domain are further divided into organisational challenges and financial challenges.

Social domain - Organisational challenges

- *Political commitment and the prioritisation of heating and cooling policy.* As mentioned, Bilbao's low H/C demand compared to other energy sectors means the city is not prioritising the decarbonisation of these infrastructures. This is evident by the sparse mention of energy retrofitting, heat pumps and DHC networks in strategic frameworks on sustainable development. Political support for sustainable measures is focused on mobility, transport and industry, and investments are primarily made focusing on the electrification of the energy supply and development of solar and wind energy generation.
- *Scattered competencies.* The competencies in heating and cooling are scattered across the administration, and until the Bilbao Energy Agency is in operation, the city lacks a designated energy department. This makes it challenging for any department to take the lead on actions (Decarb City Pipes, 2023).
- *A high dependency on the initiative of private regime stakeholders.* The municipality outsources most of its technical knowledge and organisational capabilities to private regime stakeholders. Consequently, the municipality depends on the private sector's initiative and technical capability to enable the transition (interview 2, interview 4). This complicates the installation of decarbonised H/C infrastructure, as the priority of a private regime stakeholder differs from that of the municipality. This means public-private partnerships experience an imbalance in power when mobilising resources to enable the transition.
- *Public opinion.* The public acceptance of the heating transition is a key factor in ensuring citizens and businesses are willing to connect to DHC networks or install thermal insulation or heat pumps. Though Bilbao does not have a DHC network or widespread efforts for the installation of decentralised decarbonised H/C systems to evaluate public opinion on these systems, recent examples in nearby cities highlighted difficulties in convincing residents (DCP-2050, 2023).
- *The ageing Bilbao population.* The Bilbao population is rapidly ageing (Interview 4). Bilbao cannot execute the measures proposed for realising the heating transition in both the private and public sectors if the city does not have the capacity to do so. Though Bilbao has tried solving this issue by attracting young urban professionals to the city, the results of this initiative are unclear.

Social domain - Financial challenges:

- *High upfront costs and long payback periods.* Developing DHC systems and heat pumps is initially a costly investment, even though both technologies generally are economically viable in the long term. Bilbao's payback periods are more extensive than usual, as the heating demand is relatively low. Though the Basque Energy Agency has provided subsidies, it is unknown how well these are used and how the distribution is equalised. Bilbao depends on European and national funding for larger projects, which will be crucial for developing the energy transition in the coming decades.
- *Concerns regarding a just energy transition*. As stated, there are concerns regarding the equality of the energy transition if the transition is left to market incentives. This concern is backed up by a report by the OECD (2022). Spatial disparities are significantly present in income and educational attainment. Adding to that, most of the housing stock has a building

age of over 50 years. There is minor refurbishment of buildings, around 1% of the building stock, unevenly spread across neighbourhoods. In long-term development, the OECD has concerns that the spatial variegation in Bilbao could result in eventual energy inequality.

- *The recent development of the Basque gas network.* The gas network in the Basque Country is a relatively new infrastructure; the network has begun development in the 80s. Gas companies have made significant investments, and are still quite satisfied with their business model (interview 1). The significant recent investments made to construct this network make it challenging for authorities to argue for its decommission so soon (Decarb City Pipes, 2023).

Technological challenges

- *Minimal technical knowledge within the municipality.* Technical knowledge about the developments within the heating sector seems to be, as of yet, relatively absent in Bilbao. Recent cooperation with Tecnalia has aimed to improve the lacking technological knowledge on the municipality's side. Moreover, as stated by the Bilbao Convention Bureau (Interview 4), the city cannot be expected to have all of the technological expertise within the organisation. However, the combination of the lack of technical knowledge and the lack of priority for heating could result in the city facing challenges in the strategy-making process and prove it difficult to attract experts to the municipality.
- *Lack of skilled installers to install decarbonised H/C systems.* Implementing measures for the heating transition depends on the availability of skilled installation companies to install decarbonised H/C systems. These are in short supply in Bilbao. Furthermore, existing installers require upskilling before they can correctly install heat pumps.
- *Lack of expertise.* The city has little experience with different methods of decarbonised heating and cooling, e.g. establishing and managing a DHC network. This aggravates the other mentioned barriers. The ATELIER project can be a great learning experience to tackle this barrier.

4.2 Case study - Bratislava

4.2.1 Introduction

Bratislava is the capital city of the Slovak Republic and the country's political, cultural and economic centre. Following the Soviet Union's collapse during the 1980s and the dissolution of Czechoslovakia in 1992, the Slovak Republic was established on the 1st of January 1993. As such, Bratislava has only relatively recently gained its status as a European capital. The capital borders two sovereign states: the city is located 18 kilometres away from the border with Hungary to the south and bordering Austria directly westwards. The city is situated along the Danube River, bordered by the Little Carpathians mountain range to the north, and stretches across the Záhorská and Podunajská lowlands (Publications Office of the European Union, 2022; World Population Review, 2022).

Bratislava is the largest city in Slovakia, with a population of just under 440.000 in 2022 (World Population Review, 2022). Due to the large number of commuters from the surrounding towns to Bratislava, the city's total population can increase by around 200.000 per workday. The Bratislava metropolitan area consists of approximately 650.000 residents. Bratislava's size is reflected in its prosperity. In 2020, Bratislava ranked as the seventh wealthiest region in the EU regarding regional GDP per capita, surpassing the EU purchasing power standards by 173% (Office K.P., 2020). Though start-ups, businesses and corporate headquarters are expected to continue to locate in the metropolitan region, the city's population is projected to remain relatively stable in the coming decades (Municipality of Bratislava, 2019).

Bratislava's administrative land area is 367,6 km^2, comprising five districts: Bratislava I to V. Bratislava I, Stare Mesto, comprises the old town and is, therefore, the smallest district in both population and area. Bratislava V - Petržalka is the most populous and comprises the largest area (World Population Review, 2022). These districts are further segmented into 17 smaller districts. These former villages were agglomerated into Bratislava as the city rapidly expanded in the last century. The former villages retain much of their autonomy; each district has its own mayor and its own city council (Interview 6).

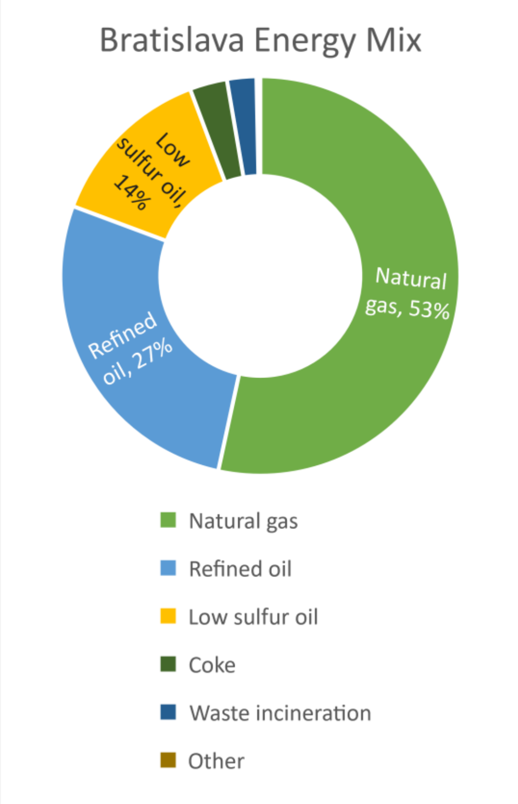
In recent years, Bratislava has established a more proactive approach to the sustainable development goals of the city and the integration of urban planning. Matus Vallo, Bratislava's Mayor since 2018, has been actively pushing for the city's climate ambitions and advocating for net zero greenhouse gas emissions by 2050 (Energy Cities, 2022). The city recently finalised Bratislava 2030, its Sustainable Urban Development Plan. The plan outlines various objectives, including a 55% reduction of greenhouse gas emissions by the end of the decade and specific actions to attain this target. Bratislava's sustainability efforts and strategies have focused on smart city solutions, sustainable transportation, and mobility. Significant attention has been directed towards housing and building refurbishments, waste treatment sectors, stormwater management and green infrastructure throughout the city (Publications Office of the European Union, 2022).

Regarding energy planning, Bratislava 2030 entails the development of a new SECAP 2030 (Publications Office of the European Union, 2022). The city is also committed to conducting analyses of stationary sources of greenhouse gas emissions and establishing robust data-gathering systems to review behavioural changes in energy consumption patterns. Finally, a strategy for renovating the many traditional concrete multi-apartment blocks has been drafted, contributing further to Bratislava's energy planning endeavours (ibid.).

Bratislava remains almost completely reliant on fossil fuel sources for its energy supply. Slovakia is the second most gas-dependent country behind the Netherlands and is still heavily reliant on imported Russian natural gas and oil (Interview 8; Barigazzi et al., 2022). 90% of Slovaks have direct access to natural gas through an extensive pipeline network. Because of the reliance on Russian gas imports, Slovakia's energy landscape has faced significant challenges following the Russian invasion of Ukraine in 2022. The following energy crisis led to a significant surge in gas prices, prompting Slovakia and Hungary to oppose a complete European embargo on Russian oil and gas (Barigazzi et al., 2022). A reduction of Russian gas and oil imports by 90% was agreed upon by the end of 2022. It is difficult to conclude the exact impact of the crisis in Slovakia through conflicting sources and the heavily politicised nature of the energy crisis in the country. With the rapid increase in energy prices, it seems the country has gained a significant awareness of the necessity of the energy transition and, by extension, the heating transition (Interview 8). The national and local policies and strategies are discussed in *paragraph 4.2.3*.

4.2.2 Status quo on heating and cooling in Bratislava

Figure 7: Bratislava Energy Mix 2019



Source: Municipality of Bratislava, 2019

First, the current situation of the heating energy mix and the heating and cooling infrastructure should be assessed. Mirroring the national energy mix, Bratislava's energy mix primarily relies on natural fossil fuels. The city's energy consumption in 2019 is visualised in *Figure 7*; it comprises 53% natural gas, 27% refined oil, 14% low-sulphur oil, and the remaining 6% consists of coal, waste incineration, wood and coke (Bratislava Municipality, 2019).

District Heating and Cooling

Regarding the H/C infrastructure, Bratislava has extensive first and second-generation district heating coverage in the city, consisting of many local networks. For budgetary reasons, these networks have never been physically connected and remain separate island networks (Municipality of Bratislava, 2019; Interview 13). Though not managed by authorities, these networks are formally owned by the corresponding district. The district heating networks are leased to companies to manage the network following a mass privatisation of services after the fall of the Soviet Union. After Slovakia's independence, the district heating networks were modernised using European structural funds and private investments. The current management of the district heating networks is the responsibility of many companies; heat is estimated to be provided by more than 350 licensed companies (Interview 12). The largest provider is the publicly owned company MHTH (Ministry of Finance Heating Company), which controls most heating networks (Interview 7; Interview 12). Due to the organisational and physical fragmentation of the networks, the data on the exact coverage of district heating in Bratislava is unknown. The coverage of district heating is estimated to be around 70%. However, MHTH has stated that the district heating market represents almost 50% of the heating sector in Slovakia and Bratislava (Interview 12).

The unconnected nature of the Bratislava DHC networks results in spatial variegation between the networks. As described by the Bratislava Heating Concept 2019, these district heating networks are relatively old; most, if not all, can be characterised as first-generation or second-generation networks (Municipality of Bratislava, 2019). Low-temperature networks are uncommon. The condition and level of modernisation of the district heating networks in Bratislava vary spatially, dependent on the managing company. For example, "Bratislava East" is a first-generation network, whereas "Bratislava West" operates as a second-generation network (ibid.). The networks are primarily powered by gas, which powers at least 50% of the heating networks (ibid.). When discussing foreseen alternatives to fossil fuel dependency, it seems that waste incineration is how Bratislava aims to transition to more sustainable options. Waste incineration has been projected to account for a third of Bratislava's heat consumption in 2040 (ibid.). This projection is based on pre-energy crisis assumptions, meaning an update on this projection is required.

There is a noticeable trend in heating demand shifting away from the district heating networks in Bratislava. Private developers increasingly establish decentralised heating systems in Bratislava

(Interview 11). These developers either opt not to connect new neighbourhoods in Bratislava to existing district heating networks or to disconnect apartments from the heating network. There are two significant reasons for this shift. First, district heating is unpopular by association with the Soviet regime, sometimes perceived as a vestige of the collectivism of the Communist era (Interview 12, Interview 15). Public opinion on DHC is, therefore, relatively negative. Second, the Slovak Act on Thermal Energy aims to simplify the adoption of local renewable energy sources for heating, which has led to growing investment in decentralised heat pumps (Energie Portal, 2015). Economically, installing a heat pump became cheaper than remaining connected to the district heating network. As networks remain the same size, management costs are spread over a decreasing amount of consumers. This risks a vicious cycle in which networks become increasingly less cost-efficient, and individual options become increasingly appealing, resulting in more disconnections.

Regarding the decentralised heating systems being used, limited information is available. There seems to be a lack of collaboration between the municipality and the electricity company ZSD (DCP-2050, 2023b). Furthermore, individual heat pumps are seemingly unregulated, which risks incorrect installation of heat pumps and can lead to increased long-term maintenance costs (Interview 7; Interview 9). Some industries and households still rely on coke or coal for heating, albeit in small quantities (Bratislava Heating Concept, 2019). The use of wood for heating is more widespread, though the individual usage of unprocessed wood as biomass for heating is associated with pollution risks.

Thermal insulation

Bratislava's built environment urgently requires large-scale renovation, of which thermal insulation is part. Many building envelopes are deteriorating, of which *Figure 8* is an example, though many more have been photographed during the fieldwork of this research. Old outer layers are eroded or have detached from the buildings. The state of the built environment means homes are decreasing in energy efficiency. The potential of energy retrofitting through thermal insulation combined with a renovation of the district heating networks in Bratislava is, therefore, seemingly high, as interview 8 states: "*If they switch to a low-temperature district heating system by renovating all the or majority of the buildings and renovating the district heating system, they could save, I think, of 54% of the fuels.*" The Slovak Republic recognises the necessity of renovations and energy retrofitting, as the country has established a renovation strategy until 2050 (Slovak Ministry for Transport and Construction, 2020).

Figure 8: Deteriorating building envelope in Bratislava

Renovation seems necessary, but the renovation of multi-apartment buildings in Bratislava, which the city primarily consists of, is complicated. A majority vote of 75% of affected residents is legally required for changes – such as renovation – to a multi-apartment building (Interview 15). Though the city has provided a renovation strategy, instruments to establish renovation in apartments seemingly remain lacking. The problem is recognised by the Spatial Planning department of the municipality (interview 6): "*That is what is happening* *to the residential buildings, especially to those built in the communist era. They need this renovation. And, but again, there are no instruments from the city."* Initiatives for energy retrofitting furthermore face a long, elaborate process: the plan for each building renovation requires to go through a 1) territorial procedure, 2) a construction procedure and 3) an environmental impact assessment (EIA). The procedures happen in order, so the first needs to be fully completed before the second can start. Furthermore, the competencies regarding each procedure are distributed among different municipal departments and organisations (Interview 6). Recognising the extensive bureaucracy of the process, amendments to the process are planned to combine the first and second procedures (ibid.).

Despite the difficulty, efforts for renovation have been made. 46,1% of residential housing in Bratislava has been renovated in the last decades (Slovak Ministry for Transport and Construction, 2020). These renovations, however, primarily cover multi-apartment residential buildings. The public sector remains behind on the seemingly ideal renovation rate of 3%; interview 8: "*They are, I think, not meeting [the renovation rates] in the public buildings, or in the public sector in general.*" Furthermore, the quality of the renovations in both sectors is disputed by Interview 8. The quality of the refurbishment is seemingly significantly dependent on cost management, the high initial investment resulting in renovation efforts cutting corners where possible. Interview 8: "*Also, there is a lack of quality of deep renovation. There are a lot of multi-apartment buildings renovated in the last decade. Some insulated only the wall from the north side. Because it was more, the most efficient, with the highest value for money. But they didn't count the factor of, like, if they put bigger insulation, like, more centimetres, they will get much higher energy savings in the short term or long term and so on. Yeah. So there were some... Not good renovations."* This development risks spatial variegation between buildings in building energy efficiency, which can hamper long-term efforts for the decarbonisation of H/C infrastructure.

Composition of the built environment

The majority of buildings in Bratislava are multi-apartment mid-rise flats. Building ownership in Slovakia is high; 91,3% of Slovaks own the house or apartment they live in, compared to the EU average of 69.3%. Similar to Bilbao, renting in Bratislava is unusual. The Department of Spatial Planning in Bratislava (interview 6) describes the situation as challenging, and they state that Bratislava is trying to establish a market with social housing. As of 2020, the share of apartments with regulated rent makes up 1,2% of the housing stock (Liptáková, 2020). A side effect of this development is an above-average share of overcrowded and multigenerational households in Bratislava compared to the EU (ibid.).

Regarding heating, the high amount of private ownership in buildings means individual residents are responsible for their own H/C costs as part of their housing expenses (Liptáková, 2020). Therefore, H/C customers are primarily private housing cooperatives and individual building owners. Most buildings in Bratislava fall under two categories in terms of H/C (Municipality of Bratislava, 2019). The first category of buildings relies on the centralised heat supply of DH networks for heating. The second category of buildings relies on decentralised boilers, both individual and block boilers. The first provides heat to individual low-rise buildings throughout the city, while the latter can provide heat to buildings up to 7-9 apartment blocks (Barco-Burgos et al., 2021; Municipality of Bratislava, 2019). Sometimes, the DH networks are linked with the block boilers. In other instances, heating is exclusively supplied by smaller heating systems based on both block and individual house boilers.

Public opinion and knowledge

Bratislava's political orientation is difficult to assess. The current mayor, Matus Vallo, started his previous term as an independent candidate. He gained a following of experts before his election, with whom Vallo created a development plan for the city called "Plan Bratislava." (Staff C.B.S., 2022b) The group then called themselves Team Vallo, though the name was changed to Team Bratislava for the elections in 2022 (ibid.). The political alignment of Team Bratislava is difficult to assess precisely, as international information about the party is little available. The party's policies seem to place residents' well-being and quality of life as the utmost priority, which could place the party in the progressive central-left of the political spectrum (Team Bratislava, n.d.). The party seems designed chiefly around the personality of Matus Vallo, who is increasingly popular among Bratislava residents. His election in 2018 was secured with 35% of the votes, whereas his re-election in 2022 was secured with 60% of the votes (Staff C.B.S, 2022b). The popularity of Matus Vallo is further reflected in the elections of the district mayors, as interview 7 states: "*His party won with such a landslide. So even in the city districts, just people from his party. So many, many of the districts are actually the same political party as he is.*"

In contrast to the progressive ideals of Matus Vallo, climate change as a motivator for policies regarding the decarbonisation of energy generation seems to have little traction within Slovakia (Interview 12). For Eastern European countries in general, national pride and energy security are more significant levers for the energy transition than the argument of climate change (ibid.). Increasing gas prices for heating are more likely to motivate people towards sustainable H/C (Interview 12, Interview 8). Awareness of the necessity of the change seems to be slowly emerging, with interview 7 stating: "*I think maybe the mentality of this is going away, the replacing of the old gas boilers with new gas boilers*." Furthermore, the private energy sector is a barrier to the transition. Local energy companies seem to have placed the most faith in a renewable or green form of gas, to which biomass, hydrogen or waste incineration is perceived as having great potential (Interview 12; Interview 14). There are strong lobbies for biomass and fossil gas (interview 8). Electrification of H/C through, for example, heat pumps, is perceived as "*a dream*" (Interview 14). It should be noted that these fuels are unsuitable for cooling infrastructures, unlike other sustainable H/C alternatives.

4.2.3 The governance of the heating transition

Legal framework: policies

National policies and targets

Slovakia operates under a dual-state administration system characterised by autonomous regional and local self-government (European Committee of the Regions, 2023). The national Slovak government mainly serves a legislative role, establishing a policy framework for different levels of governance to implement. The country is divided into eight self-governing Regions, each functioning independently under state administrations (Interview 6). The national government distributes taxes across the different levels of governance. The Regions are divided into self-governing municipalities operating independently and under state administration. For Bratislava and Košice, the two largest cities in Slovakia, another layer of governance is added. Both municipalities are subdivided into self-governing districts (ibid.). Each has different competencies, and policies in the Slovak Republic result from cooperation between all layers of governance (Interview 6; Interview 7). This can complicate governance processes, especially in the two larger cities, as policy requires agreement of up to four governance levels.

The national government has developed the Energy Policy of the Slovak Republic (EPSR). The EPSR is a strategic document stating the primary goals and priorities of the energy sector until 2035, with a long-term perspective reaching 2050 (Ministry of Economy of the Slovak Republic, 2014). The EPSR is based on four pillars: 1) energy security, 2) energy efficiency, 3) competitiveness and 4) sustainable energy. The strategy aims to contribute to the sustainability of the Slovak energy sector as an overarching objective, aiming to foster long-term sustainable growth and competitiveness within the national economy. Furthermore, the EPSR emphasises ensuring the reliability and stability of Slovakia's energy supply, promoting efficient energy utilisation at optimal costs, and safeguarding environmental protection. The effectiveness of the EPSR can be questioned regarding the self-government of the different levels of authority in Slovakia. Furthermore, the Slovak national government seems to have a history of questionable policies. Interview 8 states that the different ministries are in little contact with each other, and responsibilities are fragmented. "*For us, it is a big problem to connect the discussion of renovating houses with the discussion of the DHC. Yeah, they are not putting it together, they are not aligned, it's a different Ministry. The Ministry of Transport and Reconstruction has the renovation, but they are mostly focused on building highways. (…) And so, there is a Ministry of Energy who say that: "Okay, but we are on the supply side". So connecting them is a challenge."* Policy on energy, and by extension heating, has been seemingly difficult to control and oversee, and responsibilities for the exact execution of policy are unclear.

Slovakia's current national state is in a state of political crisis. The national government has a long history of corruption scandals on all sides of the political spectrum (Hajdari, 2023). The four-party coalition elected in 2021 lost the support of the libertarian SaS party, losing the coalition its majority within the Slovak House. On the 15th of December 2022, a no-confidence motion against the national government was backed by a majority of the Slovak House (Hajdari, 2023; Henley, 2023). Since the motion's acceptance, Slovakia's political landscape has been increasingly fragmented. The Slovak president Čaputová, whom the Slovak people directly elected for a term of five years and is thus removed from the politics within the house, gave the order for a caretaker government until the next election, scheduled in early 2024 (Dlhopolec, 2023; Henley, 2023)). This caretaker government, however, fell a few months later, and a government of experts is currently running the country (Euronews, 2023). Despite other efforts to avert snap elections, these are scheduled for late September 2023. Concerns rise about the potential election of a combination of the Smer and Hlas parties as the majority within the Slovak House (Henley, 2023). Interview 7: "*It's a lot of populism, of course, it's very influenced by the fact that Slovakia is a very rural country. (…) So many people live in very small villages and, I guess the economic situation is also not good. And stuff like this all just leads to populists, but very like, fascist populism.*" The decline in rural living standards is directly related to the energy crisis, as the price of energy has increased, impacting the rural country significantly (Interview 8).

The national political turmoil has dramatically affected the prognosed major spatial and energy planning legislation shifts. In early 2023, during the reign of the caretaker government, the Slovak Climate Law was introduced (Enerdata, 2023; Interview 8). This law would align Slovakia's emissions target with the EU's target of reducing emissions by 55% by 2030. This legislation furthermore established a goal of attaining carbon neutrality by 2050 (ibid.). Interview 8 states that the law draft was good but also controversial. Interview 8: "*The draft was very good, of the Slovak Climate Law, mostly because it gave responsibilities, and actually even penalties, from the Ministry of Environment to other ministries if they didn't follow decarbonisation pathways. And there was a big backlash from other ministries (…). The goal of the Ministry of Agriculture was to increase animal production, not to decrease livestock, and so on. They now start understanding what the climate goals could mean for them, but they are resisting it. Then the government fell."* Following the law proposal, the proposal was seemingly commented on (Interview 7). The current state of the law following the political turmoil and the fall of the caretaker government is unclear, and its eventual implementation will depend significantly on the outcome of the September election. The country's situation illustrates the significant dependency of the heating transition on political support.

To illustrate the dire Slovak situation, an example is given by Interview 8. Following the energy crisis, biomass use within the country's energy consumption has increased significantly, estimated to have risen to 18% of the share (Interview 8; Decarb City Pipes, 2022). This is stated by Interview 8 to be due to Slovakians not being able to afford gas heating following the high prices and instead opting to cut wood for heat. This increased air pollution significantly, for which the European Commission has sued the Slovak Government. The Ministry of Environment has aimed to reduce biomass burning for heating by providing subsidies for using gas boilers for heat instead. Interview 8 states this subsidy to be the Ministry of Environment's "*Golden Project*".

Regional policies and targets

Though part of the governance structure, the regional government of Bratislava is stated to be relatively weak in its competencies regarding spatial planning, instead often complicating the municipality's work (Interview 6). Furthermore, the relationship between the regional and national authorities and the Bratislava municipality seems complicated. Interview 7 states: "*From what I understand, the city administration is not really friends with the regional administration, and also not with the government.*" The majority within the regional parliament is the liberal group, with the Regions governor a centre-rightwing politician from the Slovakian SaS party (Juraj Droba // ECR Group in the European Committee of the Regions, n.d.). It is important to note that the SaS party is stated to reject strict solutions to climate change (Clean Energy Wire, n.d.). As these contrast the ideals in affiliation with Team Bratislava, the relationship is likely to be a little stiff.

Because of the region's limited role in spatial planning, energy planning on the Bratislava Regional level is unclear. The self-government of the municipality of Bratislava seems to benefit the city's autonomy on urban planning, as Team Bratislava has pushed for developments seemingly in contrast with the views of the Region's governor and parliament majority. This autonomy would therefore benefit the city's energy planning by extension. The exact implications of how the Region's governor's views on energy impact the municipality's policy remain unclear, though it is likely of lesser impact.

Local policies and targets

Residents of Bratislava are subject to four levels of governance:

1. The national government, which is primarily responsible for legislation and taxation.
2. The autonomous regional government with its competencies.
3. The self-governing municipality with its competencies.
4. One of the 17 self-governing city districts with its competencies.

Policy from any level of governance can be arduous; each level must intensively cooperate. In a way, the municipal government level of Bratislava functions like a regional government. The city districts are stated to have considerable autonomy, causing problems in coordination and coherence at the city level (Interview 6; Interview 7; Publications Office of the European Union, 2022). Political contestations and impasses between the city and the districts are stated to have been or are still common occurrences (Interview 6). Furthermore, in Bratislava, the city districts do not always identify as part of the city. There can be significant differences between the character of the city districts. For example, the Spatial Planning department (interview 6) states on the district of Čunovo, a district on the southernmost border of Bratislava: *"Like this here in the south, Čunovo, the people living there, when I meet them, they identify themselves as inhabitants of Čunovo, not Bratislava. They have this rural structure, rural character*." The governance system in Bratislava and Košice has been criticised by the European Commission, which has deemed the structure insufficient and has issued two advisory reports on good governance for both regions (Council of Europe, 2023). Current cooperation with the city districts seems to have improved, supported by the landslide victory of Team Bratislava. Most city district mayors stem from this party, improving the relationships between the city and its districts (Interview 6; Interview 7). However, this cooperation seems primarily motivated by this incidental political alignment, and the sustainability of the collaboration is unsure.

To simplify the urban development process, the Bratislava municipality has created a spatial plan to which the city districts are obliged (Interview 6). The plan stems from 2007 and is stated by Interview 6 to be created in cooperation with the city districts. The plan is a strict legislative document, leaving little room for flexibility should a city district want to develop another function than assigned by the plan. Both the municipality and the city districts seem unsatisfied with the process of urban planning the spatial plan dictates, as the Spatial Planning department (ibid.) has stated there are at least nine packages of amendments to the spatial plan either prepared or in preparation. The role of the legislative function of the state seems to hinder this process, as the legislation on urban planning is stated to be complicated (Interview 6; Interview 7). The state recognises the complexity of the process, as the state has been trying to issue both a new spatial planning law and a construction law to speed up the developmental process. These laws are stated to be valid from April 2024, though it is unclear if and how the current political situation has impacted these laws. The Spatial Planning Department is critical of how the law could impact urban development (Interview 6): "*We don't even think the state is prepared for that. (…) They want to have one IT system, everything should be in it and everything should go quick. So, we will see how it will work."* How this plan is amended can significantly influence how energy planning works in the city. The (re-)development of both DHC systems and outside units of decentralised H/C systems is regulated by this spatial plan (ibid.).

Bratislava has a sustainable urban development strategy: Bratislava 2030 (Municipality of Bratislava, 2022). The strategy is an integrated document with three parts: a vision, an analytical part, and a strategic part. The main aims of Bratislava 2030 are 1) Bratislava as a city created for people and by people, 2) Bratislava as a healthy and lively city, and 3) Bratislava prepared for future challenges. The latter aim states that the city's infrastructure should not only meet the standards of the 21st century but the needs of the future as well (ibid.). The specific goals of "Bratislava prepared for the challenges of the future" mention climate adaptation and the integration of renewable sources in the energy mix instead of fossil energy sources. Visions for decarbonisation are not explicitly mentioned in the document. When asked about the current situation on climate mitigation in Bratislava, interview 7 replied: "*There is not much in Bratislava*. *(…) In terms of mitigation, we are now dealing with this problem that there used to be an energy department in the past, though they weren't really doing much of an energy strategy. They were more like, you know, collecting the electricity bills. (…) And now, we don't have a department, this is lacking, we don't have any energy managers or anyone who would do some mitigation strategy in terms of energy.*" The city plans to create a climate office with similar positions and responsibilities to the Bilbao Energy Agency (Interview 7). The climate office's exact starting date and capabilities are not yet clear. Finally, Bratislava is planning a SECAP, which can be beneficial to furthering climate mitigation actions in the city (Publications Office of the European Union, 2022; Interview 7).

Regarding the planning of H/C infrastructure, the municipality has developed the Bratislava Heating Concept (Municipality of Bratislava, 2019). This heating concept is based on a previous iteration of the Thermal Energy Concept in 2007, deemed to need an update after changes in legislation and the introduction of the Slovak Energy Policy. The goals of the document are sixfold:

1. To ensure the reliability and safety of the heat supply.
2. To ensure economy with the production, distribution and consumption of heat, based on the principle of sustainable development.
3. To ensure environmental protection.
4. To ensure the production of energy from waste.
5. To ensure compliance with the goals of the Energy Policy of the Slovak Republic.
6. To ensure compliance with the legislative regulations in the energy field.

The goals do not mention a decarbonisation effort, though both the EU policy and legislation on the decarbonisation of heating systems are mentioned in the introduction. The Heating Concept gives an overview of Bratislava's heating situation. The document primarily focuses on the maintenance of the current heating infrastructure, the efficiency of energy use and the renovation of buildings. However, the heating concept does provide three scenarios that reach 2040 for the future development of heating in Bratislava.

1. The first scenario assumes the current development of the existing heat infrastructure, assuming the usage of natural gas distribution networks to meet heating demand. This scenario is based on the current trends within the Bratislava heating market. The scenario assumes 40% of the heating consumption will be provided by natural gas, 20% from other (likely fossil) sources, and 40% by sustainable heat suppliers (sustainably sourced DHC, block boiler plants and local heating pumps). The heat consumption from industry is assumed to be provided by gas boilers. Consumption in the residential and tertiary sectors is assumed to be provided by sustainable heat suppliers where possible; otherwise, a gas connection is assumed. The potential for energy savings in energy efficiency will be evenly spread over time up to 2040.
2. The second scenario similarly assumes the current heat infrastructure's projected development. The scenario differs from the first in assuming the increase in consumption will partly be covered by heat from Waste Incineration Heat production in the city. The heat not currently used for electricity generation will be supplied to the Central Heating Supply. The potential for energy savings in energy efficiency will be evenly spread over time up to 2040.
3. The third scenario assumes a change in the city's heat infrastructure development. The scenario assumes the renovation of the DH networks, with current infrastructure being updated to 4^{th} generation systems, combined with smart city concepts. This change cumulates in the simultaneous use of DH networks, centralised heat sources and individual heat sources of self-consumers. The installation of the systems is assumed to be evenly distributed over time until 2040. The scenario assumes that objects of heat consumption will be connected to the DH networks, through which they can redistribute excess heat. The increase in heat consumption will be provided by 40% natural gas, 20% by other fuels, and 40% by sustainable supply. Bratislava identifies this scenario as the most preferable scenario, though notably, it does not provide a way to decarbonise the heating systems.

How the third scenario should be achieved is divided into four a four-stage framework, each stage taking five years, until 2040. The first stage describes preparatory and explorative actions to further work towards the scenario, including developing a concept for using renewable energy sources in city buildings and implementing the first part of energy-saving projects. The second to fourth stages are more general goals designed to be worked out later. The steps are stated as an overall process that the city should follow closely.

Though the document is thorough, the current situation regarding heating in Bratislava is uncertain. First, while the process was planned to take place across all sectors, the process is stated to proceed often *without* the direct influence of the city of Bratislava (Municipality of Bratislava, 2019). This brings the plan into question, for the municipality does not actively pursue its goals and assumptions. Though calculated, the document incorrectly assumes heating systems will stay or be connected to the district heating networks, as current trends illustrate a different situation. The document assumes heat pumps will become more integrated into the city's building stock. The document assumes the integration of excess heat back into the district heating networks. It assumes the district heating networks can be upgraded to 4th-generation DHC systems combined with the concepts of smart city management. Furthermore, the accessibility of the information in the document itself can be stated to be complicated and confusing, often lacking a clear overview and purpose. Interview 7 names the 2019 Heating Concept: "*the horrible document".* The document's disregard for strategic plans aiming for decarbonisation has not been well-received, and the current situation of the plans following the energy crisis is uncertain. Stakeholders state they require more strategic leadership from the city regarding developing decarbonised H/C infrastructure (Interview 11; Interview 13).

The process of planning H/C infrastructure development in the city
The process of planning H/C infrastructure development in Bratislava is complex. A multitude of factors hinder the process in the city. First, as described, no dedicated department within the city is specifically responsible for energy planning. The city faces significant capacity problems, both financially and in human capital (Interview 7; Municipality of Bratislava, 2022). Instead, relevant responsibilities for H/C are fragmented across multiple actors and departments (Interview 11). Additionally, the energy sector in Bratislava is predominantly privatised, and consequently, authority over energy planning and H/C networks is limited at the city level (Municipality of Bratislava, 2014; 2019). Companies seem to have different approaches on whether and how Bratislava should proceed towards decarbonising heating and cooling (Interview 12; Interview 13; Interview 14). These company differences could result in spatial variegation of H/C supply, potentially increasing energy poverty in the long term. The creation of the Climate Office in the city might provide a way to guide the development of decarbonisation efforts, though this remains uncertain.

Furthermore, as the municipality struggles with funding, the city's involvement in sustainable energy planning is often extrinsically motivated by being awarded EU funding (Municipality of Bratislava, 2022). The city's ability to increase its municipal revenue is limited, as approximately 80% of Bratislava's income is governed by the Slovak Republic state and is beyond the city's control (ibid.). The city's main source of funding, the share of personal income tax, is only 14% of the national total. Moreover, the city does not receive any portion of corporate taxes. Therefore, the city's economic success is not reflected in its municipal budget. Additionally, the city experiences a high level of public debt, the threshold of which cannot be exceeded, limiting the city's ability to take loans. In being allocated EU funding, the city aims to open possibilities for sustainable urban development. Examples of these projects include the DCP-2050 project and the ATELIER project, the latter of which the city participates to gain knowledge about the possible development of its own PEDs in the future (ATELIER, n.d.). The city has also recently been approved as a beginner city participating in the EU's 100 climate-neutral and smart cities by 2030 mission (Publications Office of the European Union, 2022). As highlighted by Matus Vallo and the director of the responsible municipal department (Decarb City Pipes, 2022; Euractiv, 2022), these EU projects enable Bratislava to serve as an experimentation and innovation hub for the transition towards climate neutrality. However, there are risks regarding reliance on these projects, which are often temporary and location-specific, as these are not a replacement for a comprehensive city transition strategy to urban H/C development. Finally, Bratislava primarily participates in these projects as a learning city, as the capacity problems within the municipality do not enable the city to participate fully. While the required knowledge is gained, the urban development necessary remains behind.

Stakeholder involvement
The key stakeholders involved in the heating transition are displayed in **Table 2** on the next page.

Table 2: Key stakeholders involved in the heating transition in Bratislava.

Stakeholder	Description
The Slovak Innovation and Energy Agency	A contributory governmental organisation established by the Ministry of Economy of the Slovak Republic, tasked to inform, educate, monitor and evaluate, support energy efficiency and innovation and participate in international cooperation.
Energy Centre Bratislava	NGO aimed at promoting and supporting rational energy usage and energy efficiency.
Slovak Gas Industry SPP-Distribúcia MH Teplárenský Holding (MHTH)	Bratislava's Heat Company & Distribution Service Operator. A state-level and publicly-owned gas company.
Veolia Energia Slovensko Group	Major Slovak energy company group, consisting of many companies, focused on providing heat and energy, waste management and water management.
SLOVNAFT	International oil refinery, focusing on production, warehousing, wholesale and retail sales and distribution, providing oil as a fuel to Slovakia.
Termming, a.s.	A regional thermic management company operating in many districts of Bratislava and the region.
Engie Group	International energy company group, with many associated companies operating in Slovakia.

Given the municipality's limited strategic governance capacity, as a result of both limited personnel and the described governance issues, the decarbonisation of heating and cooling has been delegated to voluntary private utility providers (Bratislava Municipality, 2019; Interview 11). These competitors vary in their levels of commitment to the transition and differ in their proposed technical solutions and spatial domain. Furthermore, cooperation with the private sector has not yet been formalised. As of this moment, public-private partnerships occur on an ad hoc basis. Currently, the city looks to the private sector to address climate change adaptation and specifically provide the technical direction to guide the heating transition (Publications Office of the European Union, 2022; Interview 10). The concerns regarding the priorities of private companies stated in the Bilbao case also apply here. When asked about the opinion of other stakeholders on the high upfront investments of DHC systems, Interview 8 states: "*I think they are very reluctant, especially due to the inflation.*" Policies will probably have to be put in place to increase the incentive for the development of DHC, as this motivation is seemingly not yet present within the heating market.

4.2.4 The presence of projectification in Bratislava - organisational complexity

Bratislava is a city of projects on ideas and possibilities; projects for its urban development remain behind. Bratislava participates in a wide variety of different visionary projects planning for the future of the city; examples include the ATELIER project, the DCP-2050 project, the Bratislava Plan, the creation of the SECAP, the Bratislava 2030 Strategy, and the 100 Climate Neutral Cities. However, these projects are not followed up with significant visible plans or actions in urban development. The follow-ups mentioned in the strategies primarily exist of assessments, feasibility studies, and explorations of possibilities. The ATELIER project is explicitly a project in which the city can learn from the projects in Bilbao and Amsterdam, which does not provide a way in which Bratislava can directly apply these lessons for its own H/C urban development. The responsibilities for the execution of the created concepts for H/C development are fragmented and unclearly distributed over the private sector, different levels of governance and within the municipal organisation itself. Interview 7: "*The city administration really doesn't have power over the heating systems."* This results in the responsibility for the execution of the transition primarily being the responsibility of the private sector and the residents. This is accurately seen in residents moving away from district heating networks in favour of decentralised options, as the large-scale networks are not viable to rapid change, but the individual household is. It seems that when the transition becomes the responsibility of residents, residents will make choices for options that provide swift solutions for the most individual benefit.

The current H/C regime in Slovakia is not easily transitioned from heating with fossil fuels to decarbonised H/C systems. Despite the high potential of centralised infrastructure, the private sector seems to refrain from investing in renovating the extensive district heating network. Interview 8 states: "*For example, the heating industry is always mentioning those [DHC systems] of the fourth generation, but they never say how to get there. And they are just mentioning that somebody in Western Europe is doing it. That we are aware of it. But when you ask them what steps they would like to do, they don't specify anything."* When asked why they think that is, they state: "*I think a very big part of the Slovak Economy is built on, I would say "cheap" now in brackets, fossil fuels from Russia. (…) Yeah, political connections to Russia, it was much easier to do that.*" The political ties to fossil fuel providers are furthermore stated to hinder progress. Interview 8: "*Also, there were some corruption scandals related to the coal industry in Slovakia. Also, for example, the national state fossil gas company owned the biggest geothermal source in Slovakia, maybe even the biggest in Central Europe, even in Europe, possibly. And now, after 30 years, they are constructing. But clearly their incentive was to sell fossil gas rather than construct the technologically more advanced and more difficult geothermal*." Interview 13 states that Energy Company Veolia has tried installing geothermal heat pumps, but the Ministry of Living Environment rejected the company's proposals. Interview 8 further states that the national government had put a stop status on solar power and wind power, prohibiting the connection of new sources of above 10 kilowatt-hours. This measure has as a consequence that Slovakia currently ranks the lowest in the EU in terms of electricity share produced from solar and wind sources.

Interview 8 further shares their concerns about the development of sustainable heating and cooling in Slovakia; they describe the current state of heating and cooling projects in Slovakia:

> "*I haven't mapped it properly in all the cities, but there could be some locally owned companies, some, also, private companies run it, sometimes municipalities, and so on. Yeah, but I think that awareness of mayors and the local people that they could participate on the energy transformation and be energy self-sufficient, or at least increase their self-sufficiency, is very low. So there are few, few projects. I think we counted two or three good projects, which we made a small short documentary about, two or three municipalities which renovated their buildings and used some heat pumps. But nothing like, uh, district heating network system, maybe the first good attempt is that Bratislava is trying to consolidate it, and is part of the Decarb City Pipes project. But, yeah, there is still a weak potential."*

The governance complexities, fragmented responsibilities, and technological disparities in the heating transition refrain Bratislava and Slovakia from positioning themselves to further heating and cooling projects in urban development. Projects for renovation and energy retrofitting have slowly made sure renovations have been done in a share of the building stock, but as stated, their quality remains questionable. If Bratislava aims to develop itself as a sustainable city, following up on visions with tangible projects for urban development seems necessary, though many challenges bar this development.

4.2.5 Key challenges for zero-carbon heating and cooling in Bratislava

Bratislava faces several key challenges in decarbonising the city's H/C infrastructure. These challenges are listed below in different categories.

Social domain – Organisational challenges

- *The governance structure.* The primary challenge within Slovakia's governance is the described complex decentralised governance model. Responsibilities and competencies for H/C infrastructure are fragmented between the different layers, and developing policy is complicated. The Centre of Expertise for Good Governance is finalising policy advice to change this governance situation. They would see the municipality as a strategic coordinator or mediator across the 17 districts, which aligns with other interviews' statements on the governance situation (Council of Europe, 2023; Interview 6, Interview 8; Interview 13). However, it is questionable if this solves the issue, as the core problem of coordinating 17 self-governing local authorities within *one* city of 450.000 residents is not resolved. Current H/C development projects are possible through incidental political alignment, which could prove unsustainable in the long or short term.
- *Political unrest at the national level.* The Slovak's current national political status is an example of the political dependency on the heating transition. Political unrest and instability within the national government withhold necessary legislative reforms and reduce trust between authorities on every level and between authorities, stakeholders, and citizens. Corruption scandals and lack of national political motivation to provide an effort regarding sustainable energy (and H/C infrastructure) make local initiatives for experimentation and innovation with H/C infrastructure vulnerable.
- *The limited control of authorities over district heating networks.* The city has little control over the district heating networks, which could hinder policies and initiatives to redevelop the district heating networks to fourth-generation DHC systems.
- *Public opinion on decarbonising H/C.* The primary reason for transitioning towards decarbonised H/C infrastructure is energy security, which can be attributed to the significant dependency on Russian oil and gas within the Slovak energy mix. Like Bilbao, natural gas was long seen as an affordable, reliable and relatively eco-friendly way to keep homes warm. Furthermore, climate mitigation as an argument only rarely gains leverage, and the extensive DHC coverage is unfavourably associated with the previous communist regime. Involving citizens and building owners, which constitute more than 90% of the building stock, the transition is reportedly "very complicated" in Bratislava (Interview 7).
- *Uncoordinated private development.* Private developers are not stimulated to develop sustainable heating alternatives, instead opting for known solutions in gas boilers. They are stated to be unsure about DHC development and tend to fear greater expenditure (Interview 14). The market instead opts for decentralised alternatives despite the present infrastructure, as these are safer investments. Similar to Bilbao, the high upfront investment costs present a significant barrier.
- *The dependency on the initiative of the Slovak energy sector.* Current regime actors in the Slovak energy market primarily rely on natural gas as an energy source for their profitability. These actors are necessary for transitioning to a decarbonised H/C infrastructure, countering their private interest in their current profitability. This significantly influences the possibilities within Bratislava to transition towards decarbonised H/C infrastructure.

Social domain – Financial challenges:

- *Limited financial capabilities.* A significant barrier to executing a policy is the limited way the Bratislava municipality can use its strong economy to its advantage. The city cannot solely rely on its funding schemes. Therefore, the city partly relies on EU funding, which results in the following challenge.

- *A low allocation of EU funding due to the high GDP of the region.* Bratislava's funding structure means the city relies on European project funding for urban development. First, such project funding often prioritises one-off innovative or experimental pilot projects. Second, due to the region's high GDP, the region is in a disadvantaged position for allocating European funds (Municipality of Bratislava, 2022). EU funding is prioritised to regions with a below-average GDP per capita, meaning Bratislava is only entitled to draw on a fraction of the allocated funds. Unlike other high-GDP metropolitan regions, this low allocation is not compensated by higher own revenues due to the funding structure.
- *Unclear strategy on the economic viability of the heating transition.* The economic viability of the heating transition is dependent on two key factors: financial incentives and the mobilisation of financial institutions dedicated to energy efficiency (Municipality of Bratislava, 2022). There is, however, no investment strategy for an ongoing climate action plan. The Slovak Republic has only recently started estimating the investment requirements for climate action, and in part due to the national political unrest, subsequent policies remain unclear (Interview 11).

Technological challenges

- *Minimal technical knowledge and staff capacity within the municipality*. Bratislava possesses relatively little technical knowledge within the municipality, limiting its possibility of drafting new policies decarbonising H/C infrastructure. Interview 7 admits they do not possess the technical knowledge, stating there are few in the municipality who do. "*Everyone cares about energy and wants to do something about energy, and suddenly there are not enough people to do it. (…) We have this one technical guy that I talked about, but he in no way wants to do strategy or management."* The absence, or removal, of a dedicated energy department in the municipality poses a challenge. The municipal organisation lacks sufficient knowledge of technical development in the heating transition. The municipality primarily outsourced the technological problems to the private sector, making it almost fully dependent on these sources for its actions on H/C policy. This is identified by Interview 8 as an issue: "*There is a big problem with data at the local level. There is not enough data. Like, the municipalities don't know so much about it, and there was a strong tendency for privatisation of services. So now it's a question of what is in the hands of the city municipality or the state sector.*" Technical knowledge of energy, heating and cooling is primarily held by private developers, who themselves conflict with their visions of how to proceed (Interview 12; Interview 13; Interview 14). Knowledge from other cities going through a similar phase in the transition, e.g. Vienna or Bilbao, can provide insight into possibilities for the city, but cannot secure their information is helpful to the specificities of Bratislava's situation.

Pandora's H/C box

As can be observed in the case study on Bratislava, strategy-making on H/C policy and legislation in Slovakia is a difficult process. The heating transition in Slovakia is highly politically dependent, and contemporary political crises harm progress towards the decarbonisation of H/C infrastructures. In addition, it seems touching the topic of heating and cooling is difficult in Slovakia, even for energy experts. Trying to change the Slovak heating sector has high risks and political implications and little political revenue. Interview 8: "*Everybody is worried to touch the heating sector, even all the relatively good experts in energy, like the former minister of energy was a relatively good energy expert. He was afraid to open the Pandora's box of district heating and heating...*" Pandora's box of H/C development seems to consist of both legislation and governance issues, as well as a consequence of the strong privatisation in the country. When asked if the reason for this Pandora's box was the heating sector's complexity, Interview 8 states: "*Yeah, yeah, and I think a lack of research and development and progressive companies*. *(…) The private sector is not that developed in these technologies. There is a strong lobby for, for example, waste incineration, but there is not a strong lobby for geothermal or for low-temperature DHC systems. There is almost no private sector push for that. There is no, I haven't met with a company which will be pushing for industrial-scale heat pumps. So there are some associations for heat pumps, for heating and cooling in general, but mostly they focus on individual heating and cooling. So, it's a shame, but there is a strong lobby for biomass, a strong lobby for fossil gas, yeah, and so on.*"

4.3 Bilbao and Bratislava - Similarities and differences

The cities of Bilbao and Bratislava are different in many aspects. First, Bratislava has extensive DH coverage connected to the built environment, primarily consisting of multi-apartment blocks. Heating in the city has long been a priority, and the primary provider of heating is a public company. Bilbao has not had heating or cooling as a priority in the city and thus has little experience in the field, only currently developing their first DHC network. Second, the governance structure in Bratislava means the city has little financial capability, making the municipality more dependent on EU and national subsidies and political support. Bilbao is more in control of its finances, allowing for more urban development, and works closely with the Basque Government and the Basque Energy Agency for grants and subsidies. Third, Bratislava's gas supply is wholly dependent on Russian imports, which, due to current events, has made the city's energy supply vulnerable and accentuated energy poverty in the poorer regions of Slovakia. Bilbao's energy supply depends on gas from Algeria and LNG imports worldwide, meaning the city's energy supply is less vulnerable, if still dependent on external sources. Fourth, the Basque Government has established the Basque Energy Agency, which provides management and insight into the Basque Country's energy use and development. A similar agency is being planned in Bilbao. Slovakia has no such agency, and the fragmentation of responsibilities combined with the privatisation of resources means data on energy use and development is lacking. It is unsure if the Bratislava Climate Office, when instigated, will be able to provide this data. Finally, the climate in the cities is different, impacting their heating needs. Bilbao's temperate climate results in payback periods on sustainable heating system installation, both in supply and demand, which are unusually long. Bratislava's payback periods can be assumed to be shorter, as the city experiences a need for heating for around six months per year, and current technologies are outdated and energy-inefficient.

However, in essence, many problems the cities face in their aim to decarbonise H/C infrastructure can be categorised similarly. Regarding challenges in the social domain, both cities i) face problems in capacity, ii) experience complexities through the high amount of residential ownership, iii) face complex governance processes with fragmented responsibilities, iv) experience difficulty with high upfront investment costs, v) are highly dependent on regime actors in the private sector to facilitate transition policies, vi) are highly dependent on political support for the drafting and implementation of energy policies and vii) prioritise heating over cooling, despite increasingly experiencing warmer temperatures. Regarding challenges in the technical domain, both cities face significant uncertainty regarding the technological viability of H/C infrastructure in their cities. They furthermore experience difficulty with a lack of technical knowledge about these systems on the municipal level, complicating the drafting of applicable strategic frameworks and policies for their decarbonisation.

Considering these challenges, the heating transition can be assumed to be a similarly vulnerable process in both cities. The implications of these results on the relevant literary concepts are discussed in the following chapter.

5. Discussion

In this chapter, the main findings of the empirical study are reflected upon, connecting these to the literature review. The four-track approach by Albrechts will be used as a framework to which the strategy-making process for decarbonised H/C infrastructure of both cities is analysed, using the 15 strategic criteria.

5.1 The long-term vision – the integral importance of clarity

When analysing both case studies on their strategic goals for H/C infrastructure development, the integral importance of the *clarity* criterion becomes apparent. It can be argued that both cities currently refrain from clear strategic goals for decarbonising their H/C infrastructure.

In Bilbao, strategic goals for energy retrofitting are listed throughout the different strategic documents aiming for environmental sustainability. Bilbao continuously aims to create strategic goals that can be easily communicated. The main challenge of "Carbon-Neutral Bilbao" is such an example. To expand, the challenge is centred around six strategic objectives, designed to be clear and encompass the main strategic goal of "Carbon-Neutral Bilbao". For example, the third strategic objective, "increase local energy production, " is concise and easily communicated. Another example can be found in the general vision of Bilbao 2050: "Bilbao as a sustainable, resilient and healthy city." This vision is clear in its communication: Bilbao is aiming to reduce its environmental impact, the city wants to be prepared for the future, and focuses on quality of life of its citizens. In this way, Bilbao's long-term vision of the city can be identified as clear.

However, the strategic frameworks for decarbonisation in Bilbao currently refrain from formulating clear strategic goals for decarbonising its H/C infrastructure. The strategic goals focus on reducing energy consumption and increasing renewable energy production and use. It is unclear what that means for energy retrofitting efforts in the H/C sector. This can be attributed to the contemporary lack of knowledge about H/C infrastructure in the city. Decarbonising H/C infrastructure has not been a priority in the city compared to decarbonising the major energy demand of the mobility and industrial sector. This knowledge is slowly gained through urban experimentation, of which the ATELIER project on Zorrotzaure Island is an example. Still, without significant knowledge about the effects of centralised and decentralised decarbonised H/C options in the Bilbao climate, it is challenging to formulate strategic goals for decarbonising H/C infrastructure in Bilbao. Therefore, the strategic goals for the decarbonisation of H/C infrastructure currently remain unclear.

Bratislava's long-term strategic goals are similar to the general vision of Bilbao, though applied to the timeframe of 2030. Its strategic goals consist of "Bratislava as a city created as a city for people and by people", "Bratislava as a healthy and lively city", and "Bratislava prepared for future challenges". Again, these long-term visions can be identified as clear and easy to communicate. Bratislava aims to create a city where its people's quality of life and active participation is the focus while increasing its resilience to face future challenges. The difference in the way these goals are formulated already showcases a difference in priority between the cities. Where Bilbao aims to be "sustainable", Bratislava aims to be "prepared". The absence of clear visions for decarbonisation within the Bratislava 2030 strategic goals should not come as a surprise.

Without clear decarbonisation visions, strategic goals for decarbonising the H/C infrastructure in Bratislava also remain absent. This is reiterated in the Bratislava Heating Concept 2019; the six strategic goals refrain from explicitly mentioning decarbonisation. The ideal visionary scenario of the concept assumes the city will only be able to provide 40% of its H/C infrastructure with sustainable sources, primarily from waste heat incineration, a heat source already present in the city. Furthermore, these ideals are part of a “possible scenario”, mentioned only at the very end of the extensive document. The unclarity towards its strategic decarbonisation approach heavily limits the way in which the city can progress towards decarbonising its H/C infrastructure.

When examining both case studies, it seems the unclarity of the long-term visions on H/C decarbonisation is partly the result of the socio-technical heterogeneity of the heating transition. The visions on H/C development in both cities, or absence thereof, reflects the described issues with socio-technical heterogeneity in the literature review. Bilbao faces difficulty as the city lacks up-to-date knowledge about how decarbonised H/C infrastructure can be applied to the city context, preventing the city from formulating clear strategic goals. Bratislava faces difficulties in organisational complexity and its limited capacity that prevent the municipality from developing clear strategic goals. When analysed through the strategic criteria, the issues with socio-technical heterogeneity are further emphasised. As municipalities depend on the extent to which key stakeholders are involved, their presence or absence can significantly influence the municipality’s technological and organisational knowledge of the transition, which is explored further in *Paragraph 5.3.* The influence of the socio-technical heterogeneity is further accentuated as the unclarity of strategic goals could also result from challenges in the compatibility of the strategic framework with the socio-technical environment, the way political support is present, or a lack of focus on key concepts. The uncertainty resulting from the socio-technical heterogeneity of the transition has a significant influence, and, therefore, both cities refrain from developing clear strategic goals for H/C decarbonisation.

The clarity criterion for the *long-term vision* can be considered integral to the quality of strategic frameworks for H/C decarbonisation, as it influences how many other criteria can be met. For example, without a clear strategic goal envisioning decarbonised H/C infrastructure, the motivational impact of the strategy is likely to remain limited, the degree of risk is more difficult to assess, the workability is reduced, and it is unclear to what degree the strategic goals are appropriate in light of the resources available. To illustrate, the impact of a lack of a clear long-term vision is evident in the lack of strategic direction in the Bratislava case. It appears that the clarity criterion is interdependent with how other criteria are met, and meeting this criterion is crucial in meeting the others. This is explored further in the following paragraphs.

5.2 The short-term and long-term actions – projectification and creating trust

When analysing how the short-term and long-term actions on developing H/C decarbonisation are conceptualised and executed in both cities, the projectification phenomenon's influence on building trust in strategic frameworks becomes clear. Furthermore, these actions greatly influence most strategic criteria, illustrating their interdependence in strategic frameworks for H/C decarbonisation.

Bilbao can be identified as a city in which the phenomenon of projectification is significantly present. Furthermore, the city has used the positive aspects of projectification to its advantage. The city has historically relied on projects to ensure its previous long-term vision of transitioning away from its heavy industry, enabling significant urban development in a relatively short time. Therefore, the concept of creating trust through short-term actions in solving problems is visible in the city's development. This is best illustrated through the following quote from Interview 4:

“*Initially people didn’t understand that such a thing could take place. But little by little, there is a moment when the city started to observe the development (…) so people, little by little started to understand that something important was going to happen. Yeah. And there was a, I think there was a good communication policy, so that it was very important that local people understood the importance of this transformation. This was also in connection with the fact that all the major projects* *in the city turn into reality and the local population started to believe in the politicians started to believe in the projects. And, so that, there was a good atmosphere, to go ahead with difficult projects.*"

Allowing these projects to take shape and ensure urban development allowed for trust in the process and support for more projects, creating a cycle that encouraged development towards long-term action. In this way, the projectification phenomenon can be observed as the pragmatic answer to organisational complexity it can be.

Perhaps because of this, Bilbao can be seen to rely on projects for its H/C infrastructure development as well. As stated, the city must learn more about how different decarbonised options can impact the city before creating long-term strategic goals. The city's answer to that problem is participating in the ATELIER project, which is a great example of how projectification has impacted the operation of the municipal organisation and how urban experimentation influences eventual socio-technical regime change. First, the ATELIER project developing the Zorrotzaure Island is a way to reduce the organisational complexity of the heating transition by physically shaping and experimenting with a possible solution outside of the municipal organisation. The project's outcome is certain to provide more insight into future H/C development in the city. Furthermore, the project can be identified as a politically safe way in which the city can create short-term action to work towards its strategic sustainability goals. The Zorrotzaure Island was already a brownfield in need of urban redevelopment. The project creating the PEDs on the island is politically attractive in Bilbao and showcases the city government's proactive role in innovation with relatively little risk. To reiterate the point made in the literature review, there is little reason to be against furthering urban development through a low-risk, innovative, and experimental project, especially if that is the agreed-upon strategic focus of the city.

However, the negative aspects of the projectification phenomenon still apply to the ATELIER project. It is debatable if the project's outcome on H/C infrastructure can be "*used as a framework for deploying and testing new sustainable concepts, principles and solutions that will be used as an example for the whole city*", as stated by the ATELIER website (2023, n.d.). Creating new and innovative infrastructure in an area used for redevelopment is significantly easier than applying the same infrastructure to the centuries-old and heritage-protected city centre. The experiment cannot guarantee socio-technical regime change, as its outcomes are difficult to upscale. Furthermore, the ATELIER project is removed from the municipal organisation, accentuating difficulties with knowledge distribution about the project results and the tension between the project and the non-project part of the organisation. The ATELIER project remains an episode in the long-term development of decarbonised H/C infrastructure in Bilbao, and its short-term nature can prove to be hard to translate to the long-term necessary actions to decarbonise the H/C infrastructure of the entire city. It should be noted that this might change with the introduction of the SECAP once that document is finished. The tension between the influence of the projectification phenomenon and the utilisation of strategic spatial planning for long-term H/C development mentioned in the literature review is visibly present in Bilbao.

Contrary to Bilbao, the projectification phenomenon remains relatively absent in Bratislava. It seems to be present to some extent, as can be seen in the effects of "Plan Bratislava". It seems the short-term actions following the election of Matus Vallo, likely in the form of projects, have had the trust-creating effect Albrechts theorised. The party has increased its support immensely during the previous term, as Matus Vallo had a landslide victory in the last elections. Therefore, Vallo's ambitions for sustainable development can count on increasing support from the population.

Regarding developing H/C infrastructure, the Bratislava Heating Concept 2019 includes short-term and long-term actions. This four-stage action plan was to be applied to the development of H/C infrastructure until 2040. As it is a good example of how the city formulates short- and long-term actions, this action plan is outlined in **Table 3**.

Table 3: The 4-stage plan of the preferred scenario from the Bratislava Heating Concept (2019).

Stage	Steps	Timeline
Stage 1	The development of a concept for the use of renewable energy sources in the buildings.	2019 - 2025
	Preparation of energy audits of buildings owned by the city.	
	Possibilities of using combined production of electricity and heat in buildings (CHP-plants).	
	Implementation of the first part of energy saving projects	
	Creation of a fund for the development of renewable energy sources in the city.	
	Carrying out the passporting of heat distributions and calculating the necessary investment in the distribution systems in individual districts of the capital.	
	Prepare the introduction of energy management in individual city districts in cooperation with the energy management department of the municipality.	
	Preparation of material that would contain the measures by which the city, in cooperation with the city districts, wants to achieve and adequate and transparent heat price for consumers.	
Stage 2, 3 and 4	The implementation of other parts of energy saving projects	Stage 2: 2025-2030 Stage 3: 2030-2035 Stage 4: 2035-2040.
	Preparation and implementation of projects for the supply of development and transformation sites with heat, in the scope of the 2nd stage.	
	Preparation and implementation of projects for the use of renewable energy sources, including the gradual transformation of the central heat supply so that the use of renewable heat sources is not an obstacle to its continued operation.	
	In the case of the feasibility of the intention to transfer the heat output of the ZEVO OLO central heat supply, (ZEVO = waste-to-energy facility, OLO = waste incineration) as to the central heat supply confirmed feasibility study, the implementation of the connection of ZEVO OLO, as to the central heat supply system "East" and the supply of the heat produced in ZEVO to the central heat supply system.	

The use of this action plan is questionable. These actions were stated to proceed often *without* the direct influence of the municipality. Furthermore, it seems these actions did not meet the flexibility criterion, as the impact of the energy crisis has made many short-term actions infeasible, and the remaining reliance on the "preferred scenario" of the city on gas usage has become an obvious weakness. However, what to do instead is heavily contested, and short-term strategic actions towards decarbonising H/C infrastructure remain mostly absent.

Despite the projectification phenomenon's negative connotation, the absence of the phenomenon in Bratislava can be identified as a challenge to developing decarbonised H/C infrastructure. Through significant organisational complexity within the municipal organisation, with the cooperation of regime stakeholders, and in managing 17 self-governing city districts, significant urban development regarding H/C infrastructure remain stagnant. Responsibilities are fragmented and unclearly distributed. The flexibility of the organisation and the spatial plan for urban development is very limited, limiting the possibility of initiatives and implementing projects. Small spatial changes face long bureaucratic processes. Consequently, stakeholders have much discussion about how to go about the long-term actions contributing to decarbonised H/C development. This is not followed up with short-term actions without clarity in these long-term actions. There seems to be an urgent need for sense-making within the municipal organisation, and politically safe developments can further unify urban development in the 17 districts to reflect the development of the entire city.

The presence of the projectification phenomenon in both cities is twofold. On the one hand, the phenomenon can have a significant positive impact on the implementation of strategic frameworks for decarbonising H/C infrastructure. Utilising projects as short-term actions for long-term urban H/C development raises trust in the process. This seems to influence criteria 2,5,6,8,12,13, and 14 positively. Using short-term projects to increase the trust in strategic leadership raises the motivational impact of the H/C strategies. Furthermore, this can impact the workability of the strategic framework and can increase the focus on key concepts. Apart from co-dependent criteria, projects as short-term actions address more criteria of strategic frameworks. Projects are created appropriately in light of the resources available, can more accurately assess the degree of risk, and can involve key stakeholders in the long-term process. On the other hand, the negative aspects of the phenomenon remain a significant threat to long-term development and should be accounted for when developing a strategic H/C framework. A strategic H/C framework should consist of both short-term and long-term actions.

5.3 The contact with stakeholders – organisational complexity

Analysing the contact with stakeholders is done through the eighth criterion, the extent to which key stakeholders are involved in the strategy-making process. Though a single criterion, as described in the literature review, the transition is primarily, if not wholly, dependent on public-private partnerships for achieving its goals. The described actor interactions and perceived barriers in the literature review are present in both case studies.

In Bilbao, the organisational complexity of the heating transition is apparent, with many actors, organisations and networks having stakes in its development. The primary stakeholders necessary to decarbonise the city's H/C infrastructure are companies within the Basque Energy Cluster. This consists of giant international energy companies, like Iberdrola, innovative companies, like Telur, and research and development centres, like Tecnalia. The Bilbao Convention Bureau is reportedly satisfied with the strength of the Cluster. Though cooperation within the Cluster seems strong, they remain privately interested. In particular, big international energy companies like Iberdrola are socio-technical regime actors disinclined to rapid change. To reiterate the quote from Tecnalia (Interview 2), a company part of the Cluster: "*If we leave it to the market, [the transition] will be slow and socially unequal.*" The Cluster operating as a strong group can demotivate new entrants to the energy market. Therefore, the paradoxical situation described by Reda et al. (2021) can be observed in Bilbao: the city is committed to climate mitigation goals, while the city's energy companies are both innovating and contributing to reinforcing the regime structures that undermine the city's targets. The high sunk costs in the relatively recently developed gas network in the Basque Country will disincline the incumbent energy companies to invest in decarbonisation.

However, the need for public-private partnerships to transition remains, as Bilbao already struggles with its organisational capacity. The municipality has relatively little technical knowledge about developments in the heating sector and lacks the staffing to execute its short-term and long-term actions. Consequently, the municipality is majorly dependent on the goodwill and initiative of the private sector (Interview 2, Interview 4). Therefore, involving key stakeholders in the strategy-making process is of integral importance. A tension in power relations between these stakeholders and the municipality can be observed, as the paradoxical situation on decarbonised H/C infrastructure development depends on those inclined to keep the regime in place. The relatively low priority of decarbonising H/C infrastructure in the municipality accentuates this tension and is likely to influence the capability of the municipality to transition significantly.

The organisational complexity of the transition is accentuated in Bratislava. The municipality does have good relations with publicly owned MHTH and seems to be in good contact with the major private companies in the city, like Veolia (Interview 7). However, the H/C sector in Slovakia contains large energy companies that fully rely on natural gas distribution for their revenue. Changing the socio-technical regime of which 91% is dependent on gas distribution is an immensely difficult process, as described by the previously mentioned quote from Interview 8: "*the national state fossil gas company owned the biggest geothermal source in Slovakia, maybe even the biggest in central Europe, even in Europe, possibly. And now, after 30 years, they're constructing it. But clearly their incentive was to sell fossil gas, rather than construct the technologically more advanced and more difficult geothermal*." Again, the paradoxical situation Reda et al. (2021) described is clear. The high investments necessary to change the socio-technical regime in Slovakia disincentivise incumbent energy companies to invest in these technologies. It is, therefore, no surprise that Interview 8 dubs the Slovak H/C sector a "Pandora's box".

Similar to Bilbao, Bratislava also faces significant challenges in its organisational capacity. The tension in power relations between the private sector and the public sector can be observed here in a more significant way. The municipality reiterates that they lack sufficient knowledge of the heating transition (Interview 7). They state their desire to hire someone with this knowledge but also their uncertainty if they find someone: "*I'm not the one who will bring the solution, as I said, I'm not a technician. (…) We're always talking about the lack of energy managers. (…) So, the thing is, will we find someone to do this?*" Interview 8 further reiterates this argument when discussing the expert knowledge within Slovak municipalities: "*They seem to support the energy transformation, but they lack expert capacities*." Municipalities are limited by their knowledge and capacity and express their uncertainty regarding the best way to proceed. Interview 7: "*So from a non-technological point of view, you're also very insecure that like some things that you are trying to push for maybe are not good.*" Reiterating the lack of a long-term vision, these uncertainties limit how strategic frameworks can involve stakeholders in the process of strategy-making. This culminates in a significant challenge. Bratislava depends on reaching its yet unclear goals on large socio-technical regime actors that are very much disinclined to change their profitable infrastructure.

Analysing the dependence of both cities on the initiative and capacity of their major energy stakeholders points to one of the most significant challenges to the strategy-making process for decarbonising their H/C infrastructure. These stakeholders must be involved in the strategy-making process to change the socio-technical regime. At the same time, their current business model is dependent on the socio-technical regime remaining in place. That, combined with high-upfront costs linked to niche experimentation and large-scale infrastructural change, limits the participation of these stakeholders in the transition and therefore limits how the transition can take place. To answer this paradox, it seems authorities increasingly rely on citizen initiative to change market demand.

5.4 The basic process with citizens – a sense of urgency

Albrechts' theory on the four-track approach idealised citizen involvement in major decisions, making the strategy-making process highly inclusive. Albrechts idealised an interactive process in which citizens understand different points of view and build their intellectual capacity to influence all tracks of the four-track approach. Interestingly, though this process is the cornerstone of Albrechts' theory, how this process is done is not part of the 15 literary criteria for strategic frameworks. Through analysis of both case studies, this process is described regarding the strategy-making process for H/C development.

In Bilbao, the degree of citizen involvement in the strategy-making process for decarbonising H/C infrastructure remains unclear. Citizen support is, however, integral to the success of the transition. Most citizens in Bilbao own their houses and live within a multi-apartment building, which means consensus with the citizens is required to decarbonise H/C infrastructure. However, the priority in H/C development is little felt among citizens. Though the energy prices have increased following the energy crisis, the stable supply of gas to the Basque Country and the little urgency for decarbonised H/C infrastructure have not had a motivating impact. The socio-technical landscape remains relatively stable, and therefore individual citizens are limitedly looking for opportunities in socio-technical regime change. Renovating buildings from an energy point of view is not perceived as a must by residents. Climate mitigation and decarbonisation efforts have not been perceived as vital by most Bilbao inhabitants. The Basque Energy Agency, therefore, subsidises renovation projects by promoting safety and accessibility as levers instead. Thermal insulation has seemingly the most potential in Bilbao. Initiatives for heat pumps face difficulty, as almost 40% of the building stock is subject to heritage protection, and installing heat pumps elsewhere in multi-apartment buildings requires consensus among residents. There is not enough sunshine in the region to justify solar instalments, and individual geothermic installations remain undiscussed as options. Therefore, how citizens are expected to decarbonise their H/C systems remains relatively unclear, playing back to the mentioned challenges regarding unclear long-term visions.

In Bratislava, it is clear that citizen involvement in the strategy-making process is very limited. The municipality has little control over its heating systems, and involving citizens in city policy is reportedly "very complicated in Bratislava". However, the immense economic impact of the energy crisis on Slovakians does mean citizens feel the urgency to move away from the city's gas-dependent infrastructure. The lack of a clear strategy or vision for decarbonising the H/C infrastructure in the city, or even an energy department in the city, means citizens are taking the initiative themselves. This can backfire significantly, illustrated by the increase in unprocessed biomass use following the surge in gas prices in January 2022. Interview 8 describes a dire situation where desperate people use anything they find to stay warm: "*They are turning [gas boilers] off and heating with locally sourced wood in a legal or illegal way. Sometimes even burning plastics and old textiles, old furniture and so on. So they are really paying with their own health instead of money for heating. (…) So that is very problematic from the air pollution side."* Refraining from involving the citizens in the strategic process, or even involving the citizens in energy management, can seemingly have drastic unforeseen consequences.

Unfortunately, without the city, or even the national government, providing strategic guidance or taking initiatives in decarbonisation, it becomes the individual responsibility of the citizens to decrease their reliance on expensive gas-intensive H/C infrastructure. This seemingly results in individuals moving away from the present district heating infrastructure. This negatively influences the city's potential to renovate its extensive district heating networks to 4th generation DHC networks. However, a widespread instalment of heat pumps in Bratislava risk increasing the buildings' electricity use significantly. The thermal insulation in the city faces issues in quality, and multi-apartment buildings not yet refurbished legally require a 75% agreement of tenants before renovations can take place. The H/C market in Bratislava is increasingly heterogeneous and, therefore, increasingly complex. Through these developments, the transition in Bratislava can be stated to currently be out of the municipality's control, and it is unclear if and in what way the municipality plans to regain this control. A strategic process for the future of H/C development in the city will require direct citizen involvement to reduce the impact of current developments.

The sense of urgency for decarbonising H/C infrastructure within the city influences the basic process with citizens. Where decarbonisation efforts remain less urgent, citizens primarily refrain from active participation in the decarbonisation process. Where decarbonisation efforts are urgent, citizens will take the initiative with or without the guidance of the municipal or national authorities. However, if the municipality does not guide citizens about this urgent development, it could negatively influence how the transition happens.

5.5 Examining the usefulness of the 15 strategic criteria

Analysing strategic H/C development with the four-track approach and the 15 strategic criteria makes it apparent that the strategic criteria have different priorities regarding strategic frameworks for H/C development than the four-track approach. Albrechts (2004) emphasises the constantly changing nature of a strategic framework, to which the *long-term vision* and *long-term and short-term actions* are equally important as the *contact with stakeholders* and *the basic process with citizens*. Achieving a strategic goal is a dynamic and creative process under constant change. Therefore, Albrechts continuously emphasises the significance of the high degree of trust between the different parties. This is reiterated when examining the *contact with stakeholders* and *the basic process with citizens* in both case studies, as demonstrated in *Paragraphs 5.3* and *5.4*. Bilbao and Bratislava face difficulty in this process, significantly influencing how both cities can transition their H/C infrastructure to decarbonised systems. Difficulties in this process limit how windows of opportunity for the heating transition can be taken advantage of and socio-technical regime change realised.

When examining the 15 strategic criteria as part of the strategic framework for H/C, this emphasis on trust is noticeably absent. The strategic criteria mostly apply to track 1, the long-term vision, and track 2, the long-term and short-term actions. When applied to these tracks, their co-dependence is clear. However, their use seems mostly reserved for the framework itself, as they limitedly include how the process with stakeholders and citizens is guided. Without criteria for this process, it seems the use of the strategic framework as a guiding document for infrastructural change remains limited. This is visible in both case studies, as Bilbao and Bratislava face significant challenges to realising the heating transition in contact with regime stakeholders and the basic process with citizens.

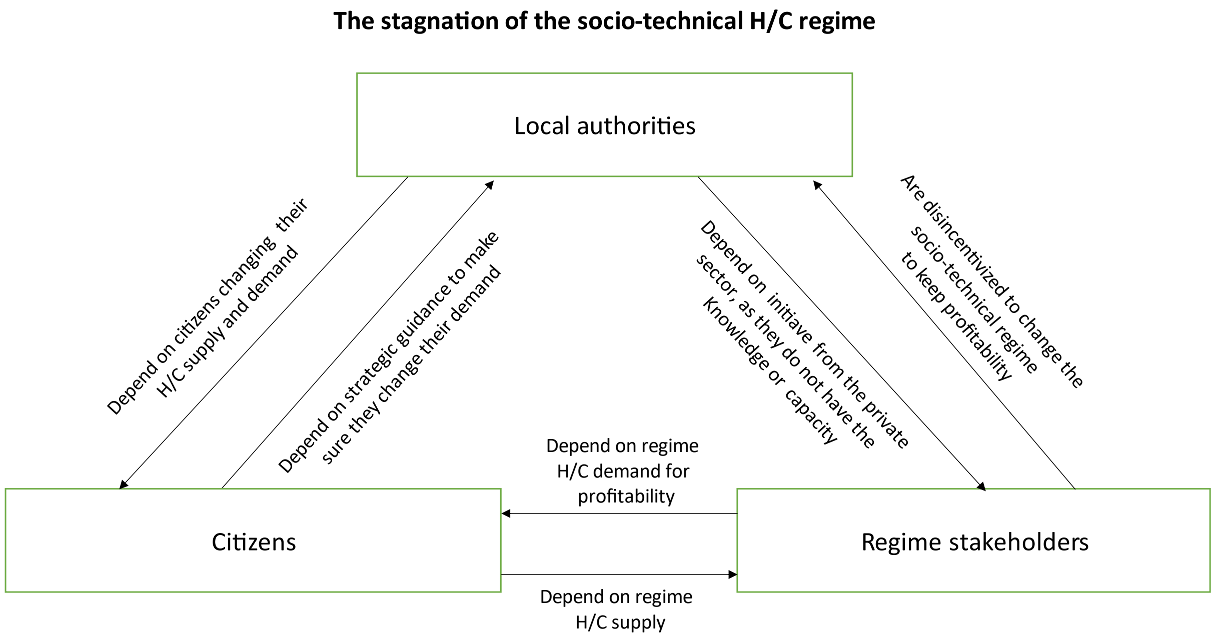
5.6 Inherently unmanageable

Finally, the *wicked* nature of the heating transition described in the literature review is apparent in both case studies. The decarbonisation of H/C infrastructure is an ambiguous goal, subject to constant change, and is associated with strong moral, political and professional issues. Both cases struggle with the transition's uncertainty, complexity and socio-technical heterogeneity. Limited municipal capacity and knowledge reduce the capability of municipalities to push for changes in the socio-technical landscape. This is stated by Tecnalia (Interview 2): "*It's a problem with many municipalities that they don't have this [technological] expertise in hand*." And reiterated in the Bratislava municipality (Interview 7): "*So from a non-technological point of view, you're also very insecure that like some things that you are trying to push for maybe are not good."* Continuous technical development further complicates the issues with knowledge about the technological part of the transition (Interview 9). Increased heterogeneity in technology inevitably increases the heterogeneity in the organisational aspect, severely limiting the capabilities of both municipalities to create clear strategic frameworks.

Furthermore, the heating transition's dependency on political support is observed in both cities as a significant factor. Political support and initiative are integral to the transition's success. In Bilbao, though political support to decarbonise is present, decarbonising H/C infrastructure is a small issue compared to decarbonising the energy demand of the city's industry and transport sectors. This is illustrated by how the city council has divided priorities, combining sustainability issues with mobility (Interview 3). Without the decarbonisation of H/C infrastructure as a political priority, the socio-technical landscape in the city remains stable, and windows of opportunity for regime change remain limited. On the other hand, political unrest in Slovakia significantly limited how Bratislava can use windows of opportunity. The energy crisis in Slovakia had a significant impact on the socio-technical landscape. In this way, it could have been a window of opportunity in which Bratislava could have incorporated citizens in the transition process and jumpstarted its transition to decarbonised H/C infrastructure. Instead, as national political support and strategic guidance have fallen short, it has remained in its socio-technical regime. When applied to the contextual aspects of the strategic framework, the sociopolitical context seems most integral to facilitating strategic frameworks that aim to decarbonise H/C infrastructure.

Finally, the dependence on the regime stakeholders for socio-technical change is a paradox, confirming the theory by Reda et al. (2021). The current socio-technical regime can be identified to be in its *stagnation* phase. Regime stakeholders are primarily motivated to keep the regime unchanged as long as possible while also being integral to facilitating regime change as quickly as possible. Both case studies illustrate the challenges that arise from this dependence on private sector interest, as described in paragraph 5.3. Authorities rely on citizens changing their H/C demand to facilitate regime change and make the private sector cooperate. However, without a sense of urgency and strategic guidance through the transitions' socio-technical heterogeneity, this risks uncoordinated and, in the Bratislava case, even harmful development. This results in a triangle of socio-technical stagnation, limiting how windows of opportunity can be utilised. Citizens look to authorities for guidance to facilitate socio-technical change and look to regime stakeholders for their supply in H/C infrastructure. Authorities are limited in their organisational capabilities and look to the regime actors for initiative and look to the citizens to change their H/C demand to accelerate these initiatives. Regime stakeholders are disinclined to any change in the regime unless forced to by significant pressure from the socio-technical landscape, e.g., through significant changes in citizen H/C demand. These tensions are displayed in *Figure 8.*

Figure 9: The stagnation of the socio-technical H/C regime



This is emphasised by the lack of a "right" way for decarbonised H/C development, creating high uncertainty surrounding the heating transition. Authorities are unsure of what policy they should push, as pushing for the wrong H/C infrastructure might have detrimental unintended consequences in the long term. Therefore, it can be concluded that this socio-technical transition towards a regime of decarbonised H/C infrastructures is still in its *establishment* phase, and large investments in time and monetary resources will be required to move towards the *expansion* phase.

6. Conclusion

Transitioning towards decarbonising a city's heating and cooling infrastructure is an incredibly complex process. Many technological and organisational challenges are faced by authorities aiming to change their socio-technical heating regime. To improve the understanding of this topic, this research was centred around the question: *"How can cities address the challenges in their strategy-making process for decarbonising their heating and cooling infrastructure?"* To chart these challenges, this research conducted a multi-case study on Bilbao and Bratislava. Through analysing of the results of both case studies, this chapter aims to provide an answer to the research question.

The main challenge to the strategy-making process for decarbonising H/C infrastructure identified by this research is the high degree of uncertainty resulting from the socio-technical heterogeneity of the heating transition. This research identifies the transition to still be in its *establishment* phase. This can be seen through the rapid technological developments in the H/C infrastructure sector, containing innovations in centralised and decentralised H/C systems paired with investments in thermal insulation. Massive investments in and experimentation with these innovations are required to ensure the transition moves to its *expansion* phase; however, as the options to decarbonise increasingly diversify, what and whom to invest in remains unclear. This results in a high degree of uncertainty, which is characteristic of the establishment phase.

This uncertainty has a major effect on *long-term vision* and *the short- and long-term actions* of the four-track approach to strategy-making. The clarity of the *long-term vision* is impaired by the socio-technical heterogeneity, as this results in uncertainty about what technologies to apply in what context. Municipal organisations lack the technical knowledge and organisational capacity to address this heterogeneity issue and therefore refrain from formulating clear long-term strategic goals for decarbonising H/C infrastructure. This unclarity negatively influences how other strategic criteria can be met. Without a clear long-term vision, the motivational impact of the strategy is likely to remain limited, the degree of risk of the strategic goals more difficult to assess, and the workability reduced. Furthermore, this results in the strategic framework being unclear to what degree its strategic goals are appropriate in light of the resources available. The clarity of the long-term vision is an integral part of enabling the use of strategic frameworks. Its current unclarity in both case studies limits how their frameworks can be utilised for changes in the socio-technical landscape and to act on windows of opportunity. Without a clear long-term vision, the *short- and long-term* actions for decarbonisation of H/C are complicated to formulate, further hampering the effectiveness of the strategic framework and increasing organisational complexity. To reduce the impact of this uncertainty, authorities need to gain technological knowledge and organisational capacity, which is realised through the paradoxical dependency on regime stakeholders.

The paradoxical dependency on regime stakeholders to facilitate socio-technical regime change has a major influence on cities aiming to decarbonise their H/C infrastructure. The current socio-technical regime is in the *stagnation* phase. In the current socio-technical regime of H/C infrastructure, regime stakeholders are invested in the regime remaining unchanged. Their priority as private stakeholders is their current profitability, e.g., through selling natural gas, which depends on using current H/C infrastructure. They are disinclined to take the initiative enabling the transition unless forced to by significant pressure from the socio-technical landscape. Therefore, local authorities look to citizens to change their H/C demand and establish pressure from the socio-technical landscape on the stakeholders to change the socio-technical regime. However, citizens depend on the regime actors for their supply in H/C. Furthermore, the socio-technical heterogeneity of the heating transition makes initiative as an individual a difficult, lengthy process that can have major unintended negative consequences if not done properly. Therefore, citizens depend on authorities for guiding policy. However, as described, authorities themselves struggle with the uncertainty of the socio-technical heterogeneity, as whatever policy they decide to push can also have detrimental unintended consequences in the long term. This creates a triangle of stagnation, where all tensions between the different groups currently maintain the socio-technical regime of the H/C infrastructure. This severely limits how cities can ensure the decarbonisation of their H/C infrastructure and is therefore identified as the main challenge to the strategy-making process for this infrastructure.

This research aimed to chart the projectification phenomenon as a possible major challenge to the heating transition. In a way, the projectification phenomenon does pose a significant challenge to the long-term, large-scale development the transition requires. The Bilbao municipality can be seen to rely on temporary projects for its H/C infrastructure development, illustrated by the ATELIER project redeveloping the Zorrotzaure Island brownfield. It is debatable if the project can achieve its desired outcome of being an example for the whole city, as developing 4th generation district heating in an urban redevelopment area is a significantly easier process than decarbonising H/C infrastructure in the centuries-old, heritage-protected city centre. The project results will be difficult to scale up to the rest of the city. Furthermore, the project is removed from the municipal organisation, accentuating difficulties with knowledge distribution about the project results and the tension between the project and the non-project part of the organisation. The ATELIER project is an experimental episode in the long-term development of the heating transition in the city and can prove to be hard to translate to the long-term necessary actions to decarbonise the H/C infrastructure of the whole city.

However, when a strategic framework for the transition takes the phenomenon into account, the projectification phenomenon can also be identified as an opportunity to counter the challenges identified with the socio-technical heterogeneity of the transition. First, as the transition is still in its *establishment* phase, experimental urban projects like the ATELIER project are necessary to further knowledge about new technologies and to keep innovating. These urban experiments provide knowledge about how different technologies behave in different contexts and might provide new ways to use windows of opportunity when these arise. Furthermore, urban projects are visible ways in which short-term actions can occur, improving the trust in the long-term process and strategic leadership, which is integral to the transition's success. Additionally, using short-term projects to further development goals for decarbonising H/C infrastructure can positively influence 6 of the 15 strategic criteria. Their visibility and their purpose for sense-making can i) increase the motivational impact of strategic frameworks for H/C decarbonisation, ii) can impact the workability of these frameworks, iii) can more accurately assess the degree of risk, iv) can increase the focus on key concepts, v) can assess the appropriateness of strategic goals in light of resources available, and vi) can involve key stakeholders in the process. Finally, as the current socio-technical regime remains stagnant, the pragmatic solutions the phenomenon poses to organisational complexity may provide some leverage to instigate change. An experimental urban project with new H/C infrastructure containing little political risk and reducing organisational complexity might provide a way in which cities can slowly understand how to change the socio-technical landscape or act on a window of opportunity if the landscape undergoes sudden change (e.g., the energy crisis).

Finally, there are a few ways this research identifies how cities can improve their strategy-making process for transitioning to decarbonised H/C infrastructure. Analysed through the four-track approach, it can be concluded that the strategy-making process is a never-ending development structured around processes with citizens and key stakeholders. Based on this process, clear long-term visions on the development of H/C infrastructure should be constructed, the essence of which should continuously be reflected in the long-term and short-term actions of the municipality. These strategic frameworks should include innovation and urban experimentation to further development towards a new socio-technical regime in which decarbonised H/C infrastructure is the status quo. Furthermore, using the strategic framework as a guide towards development can provide clarity in taking advantage of windows of opportunity. The strategic framework envisioning the decarbonisation of H/C infrastructures is a continuous collaborative process between regime actors, authorities and citizens, with clear long-term goals and visible indicators of progress.

In conclusion, this research has identified uncertainty as a result of socio-technical heterogeneity as the major challenge to the heating transition in cities. The transition is characterised by organisational and technological complexity. It is a disruptive and heavily contested *wicked problem* with many unintended consequences to well-intended choices. It is a paradox, dependent on regime stakeholders to change that from which they profit. Going beyond this wicked problem will require clear, visible and strategic long-term leadership, coupled with accepting uncertainty and embracing urban experimentation. There is no “right” way to ensure the decarbonisation of heating and cooling infrastructure. No strategy will provide the perfect solution. We must move forward anyway.

6.1 Recommendations for future research

The integrated nature of the challenges within the heating transition means future interdisciplinary research would benefit the understanding of the topic. The scientific disciplines of political science, technological H/C development, economics, law, communication studies and public administration are examples of relevant disciplines. Using the new perspectives from interdisciplinary research could create a better understanding of the complexities and intricacies of the heating transition. A few recommendations in which to visualise future research are stated below:

- Future research could review the heating transition using a multi-level governance framework. The execution of the H/C policy is reliant on the cooperation of all governance layers. Research using this framework can illuminate the intricacies and difficulties experienced when applying national decarbonisation strategic frameworks to the local context.
- Future research could review the 15 literary criteria within different strategies, analysing how these apply to the strategic framework as a continuous process with stakeholders and citizens. These tensions could be reviewed within different sustainability strategies or developments requiring long-term solutions.
- Future research could critically review heating and cooling technologies and technological development through a technical or literature review. This could help in decisions on different sustainable heating technologies and provide some guidance in the complexity of heterogeneous heating networks.
- Future research on the legislative side of heating and cooling development could shed much-needed light on the legislative complexities within the heating transition. Interrelated regulations on these technologies have remained an unexplored topic within this thesis.
- Future research could incorporate interdisciplinary research with communication sciences, reviewing how strategies are communicated within the organisations drafting the strategies and to affected residents.
- Future research could review the influence of the projectification phenomenon on strategic frameworks more thoroughly, examining its effect on urban governance and how its positive and negative influences can be incorporated into long-term urban development.

- Future research could review the development of the heating transition in medium-sized cities and smaller towns, where H/C demand and urban density affect viable heating strategies differently.
- Future research could review the just development of the heating transition, as spatial variegation in heating technologies could risk an unjust transition and eventual energy poverty in less socioeconomically wealthy areas.
- Future research could review the heating transition and energy transition as a whole through a political framework. The high political dependency of the transition means reviewing the intricacies of the politics behind the transition can be vital to our understanding of it.
- Future research could review the heating transition through an economic framework, as the economic feasibility of different H/C systems plays a vital role in its development.

6.2 Policy recommendations

Possible policy recommendations on heating and cooling are stated below:

- It is recommended to prioritise heating and cooling in sustainability strategies and policies and develop clear long-term strategic goals. It is furthermore essential to recognise the neglect of cooling in policy, as the importance of zero-carbon cooling is expected to increase dramatically as a means of climate adaptation.
- Focusing on the process with citizens and stakeholders to create the strategic framework for H/C development is recommended to build trust and understanding in key stakeholders and the general population. Use strategic H/C plans to communicate clearly to residents the effects of your policy and the impact that will have on residents; use strategic goals to make sure residents understand why changes are happening. Ensure residents keep being positively engaged in the developments regarding the decarbonisation of H/C infrastructure.
- A proactive role of authorities in developing strategic frameworks for the decarbonisation of heating and cooling infrastructure is required. More insight into the heating transition's multi-level governance aspect can show how this role is best divided among governance levels.
- It is recommended to recognise that a solution will never be perfect. No strategy will account for everything; no decision will include everyone. Therefore, though it is important to discuss policies and recommendations thoroughly, it is also important to move beyond stagnation. Furthermore, it is recommended to recognise that not all strategic goals will likely be met and that continuously aiming for achieving all is more important than the actual achievement.
- As the quality of installations can vary greatly, it is recommended to refrain from cutting corners, as these will increase long-term costs and reduce climate mitigation potential.
- Attracting new people to the municipal organisation is recommended to broaden capacity in expertise and the general workforce. Recognising the municipality cannot be expected to possess the entirety of technical heating and cooling knowledge; the municipal organisation should possess some expertise on heating and cooling to better strategic frameworks on H/C.
- It is recommended to refrain from complete reliance on waste incineration as a permanent way of sustainable heating. Waste incineration can provide a transitory heat source, but the practice becomes unsustainable as waste production is planned to be reduced. Furthermore, it cannot provide a means of sustainable cooling.
- To communicate the development of the strategic framework, it is recommended to use urban developmental projects to indicate progress visibly. This furthers understanding of and trust in the strategic goals within the population.
- Using urban experimentation with different solutions and communicating their results with other cities is recommended. The ATELIER Project is an example of directly communicating the development of experimentation with partner cities.

- Finally, it is recommended to recognise the economic viability of ensuring the transition to sustainable heating is already beneficial. Though the stagnation of the current regime complicates proactive investment, refraining from investing is likely to increase the total costs of investment significantly. Investment in sustainable sources will pay itself out. It is also recommended to examine taxation and financing regulations, as these will be integral in the economic development of the heating transition.

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8. Appendix

Appendix A – Interview guide

Introduction: 5 minutes

- Introduction of the researcher and the topic of the research.
- Explanation of how the interview contributes to the research.
- Obtain consent for recording the interview anonymously and using interview data

Part 1: The heterogeneity of the heating transition: what is the situation surrounding the heating and cooling transition in your city? - 15 minutes

- What is your role in the heating transition?
- Who are the different stakeholders that are important in the transition in your city?
- In what way are buildings in your city mainly heated and cooled?
- What role do renewable energy sources play in the existing energy mix for heating? How do you envision a change in this energy mix?
- What are the key options for sustainable heating and cooling in your city?
- What kind of DHC can you envision for your city?

    - At what temperature (high or low) and at what scale do you envision DHC being developed?
    - How are decentralized heat sources, such as heat pumps, integrated with DHC ?
    - In what way do you see potential in DHC as a sustainable heating solution for your city?
    - In what way do you see potential in decentralized heat sources, such as heat pumps, as a sustainable heating solution for your city?
- How is demand-side management promoted for reducing energy consumption in your city?
    - Is the insulation of one's home promoted?
    - Is reducing overall energy use by lowering temperatures promoted?
    - In what way are trade-offs necessary between energy efficiency and the development of DHC ?
    - In what way do you see potential in demand-side management as a sustainable heating solution for your city?
- What would you describe as the main challenges to the heating transition?
    - What is the relationship between relevant stakeholders?
    - Where does the funding for the heating transition come from?

Part 2: Projectification: in what way does the municipality rely on projects in their long-term vision? - 15 minutes

- How does [your project] contribute to the heating transition in your city?
    - In what way is your project held accountable by/to the municipality?
    - How is your project funded?
    - How does your project align with expectations from your client/the municipality?
    - What is the goal of your project?
    - What will be the impact when the project is finished?
    - In what way does your project innovate regarding the heating transition? Regarding policy, or regarding technology? What are the benefits and challenges of this innovation?
- How is the output of [your project] distributed or communicated across the municipality?
- What other key projects are currently happening in your city regarding the heating transition? What timeframe do these projects have?
- Have you seen an increase in the number of projects in your municipality? If so, why do you think that is?
- In what way do you think your municipality is open to change?
    - Do you think new initiatives in policy would be readily accepted? And new developments in technology?

Part 3: Strategic spatial planning: does the long-term vision of the municipality work? – 15 minutes

- What is your view on the long-term vision of the municipality on the heating transition? Do you agree, or do you disagree? On what points?
- The scientific literature on urban planning lists 15 criteria of urban strategy. In what way do you think the construction of the long-term vision of the heating transition upholds the following criteria?
    - Is the goal of the heating strategy clear in its development?
    - Does creating the heating vision have a motivational impact on you to work towards the heating goals?
    - In what way is the heating vision made to be internally consistent?

    - In what way is the heating vision made to be compatible with the environment of your city?
    - In what way is the heating vision made to be appropriate in light of the resources available in your city?
    - What degree of risk is associated with creating the heating vision?
    - To what extent is the strategy made to match the personal values of key figures, like the mayor, the council, or energy companies?
    - To what extent are key stakeholders involved in the creation of the strategy? And to what extent are citizens involved?
    - Are senior-level managers actively involved in the process?
    - Do you think the time horizon of the heating transition is manageable?
    - In what way is the heating transition made to be flexible?
    - Do you think the finalized heating strategy can be translatable to practice?
    - Is there a clear focus on key concepts within the heating vision? And is that carried over to practical actions?
    - Is the leadership behind (the construction of) the vision trusted and committed to the goals of the vision?
    - In what way is the heating vision made to be politically realistic?
- In what way has the municipality (already) made an effort to achieve the vision?
    - In what way is the budget reserved for actions following the vision?
    - In what way is the organization adapted to the vision? Are there changes happening in the municipal organization?
    - In what way is achieving the vision a priority in the municipality?
- How do the municipality's current actions reflect the long-term vision for the heating transition?

Part 4: End note: Things that came up, and what would you do? Is there anything else? – 5 minutes

- In what way would you change the vision of the municipality for the heating transition if you had the possibility? (shortage in labor?)
- Is there anything else you want to add to this topic?

Appendix B – Coding themes and sub-themes

Name	Description	Files	References
Autonomy		5	10
Bureaucratic issues		8	30
Bilbao Energy Agency		2	9
Climate office Bratislava		1	2
Inter-department connection		5	12
Slovak Governance		2	15

Name	Description	Files	References
Capacity		3	5
Equipment		1	1
Human capital		7	9
Knowlegde		6	22
City transformation		6	10
Urban development		3	6
Cooling		2	2
Cost management		7	26
Decarb City Pipes info		1	2
Relations with other cities		5	9
Roadmap-outlook		1	1
District heating		7	42
Energy		6	25
Electricity		3	7
Gas		5	13
Geothermal		2	4
Heat		1	3
Hydrogen		2	2
Nuclear power		1	3
Flexibility		5	7
Heating analysis		3	14
Heating demand		5	15
Retrofitting		6	19
Recycling		1	3

Name	Description	Files	References
Weather conditions		3	4
Heating technology		4	13
Biomass		4	7
Boilers		4	5
Development		1	6
Heat pumps		5	9
Waste incineration		3	7
Installers		4	8
Local specific conditions		4	12
Long-term goals		7	19
City Vision		6	15
SECAP		4	8
National policy		6	18
Regional policy		3	5
Political alignment		8	25
Pollution		1	1
Projects		7	27
Experimentation		2	3
Zorrotzaure		2	2
Regulation		8	28
Spatial Plan		1	12
Residents		9	24
Citizen participation		8	20
Responsibility		9	25

Name	Description	Files	References
Spatial variegation		4	8
Stakeholders		9	36
Communication		5	8
Examples		6	10
Strategy		6	27
Transition management		6	10