Bachelor Thesis by Katharina Maria Mette

Green Technology in Smart Cities

An analysis of what role green technologies can play within climate mitigation and resilience strategies of Smart Cities

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Abstract

Many scholars have pointed out that cities are part of the problem of climate change, but done right, they can also be part of the solution. This paper will build on that assumption and research the role that green technologies can play in climate mitigation and resilience strategies of Smart Cities. To answer this question, first the concept of a sustainable Smart City will be created. In this context, climate mitigation and climate resilience strategies will be explained. Afterwards, the potential and opportunities of green technologies, in these strategies will be outlined. To answer the research questions, this paper conducts a content analysis. Three Smart City concepts and their stakeholders are analysed regarding their use of green technologies in tackling and anticipating climate change. Through the content analysis, a comparison of the stakeholders´ vision and strategies will be possible. This shows the diverse ideas behind Smart Cities and their relationship between climate mitigation and resilience with green technology. The data of the research consists of primary data from the cities´ governments, like (policy) papers, statements, brochures, and informational papers. Due to the urgency of climate change and its impact on cities, where most of the earth´s population lives, the relevance of this paper is high. It comes to the conclusion, that Smart Cities and their strategies are highly individual. The role of green tech divers between the cities and is mostly seen as a tool to achieve better quality of life, push innovation, and keep citizens safe.

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List of Abbreviations

IPCC	Intergovernmental Panel on Climate Change
UN	United Nations
AI	Artificial Intelligence
IoT	Internet of Things
Tech	Technology
UHI	Urban Heat Island

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1. Introduction

Cities around the world, are adopting climate mitigation and resilience strategies to actively fight the progress of climate change and to increase resilience towards future climate crisis. Over the last years, the impact of human-made climate change has become visible in forms of extreme weather phenomenon, melting glaciers, and rising sea levels. As of right now, the consequences of climate change on the safety of the world's population can only be imagined (NASA). This is especially alarming for urban settlements.

"[T]he twenty-first century is frequently referred to as 'the first urban century' or simply 'the urban century'" (Van der Heijden, Bulkeley, & Certomà, 2019). According to the UN, in 2016 around 54,5% of the world´s population lived in urban settlements, a number that is said to climb up to 60% in 2030 (Department of Economic and Social Affairs, 2016). Cities are a vital player in global climate change, as they are a massive producer of CO2 emissions, which also gives them the power to be part of the solution (Magila, Cork, et al., 2018). Scholars in the field of urban governance acknowledge that resilience and mitigation strategies could be the way to use this power (Boyd & Juhola, 2014; World Bank, 2009).

Mitigation strategy aims at actively fighting the progress of climate change, to keep the future impacts of it limited. Where this strategy fails, the second strategy of resilience comes into place. In literature, there are calls for making cities´ mitigation and resilience strategies more flexible (Gersonius, Ashley, Pathirana, & Zevenbergen, 2012). This paper picks this up by concentrating on administrations´ turn towards technological progress to achieve this flexibility. The global increase of Smart Cities and their focus on sustainability underlines this development. In this context, a field that has been around for 40 years, is being reintroduced. "Green technology" describes the technology, that is both environmentally friendly and follows the purpose of tackling or anticipating climate change impacts (Casini, 2017). Different types of AI, the IoT, Big Data and Machine Learning can be referred to as green technologies. In Smart Cities, they often appear in forms of optimized public transport, collecting and processing data, or within smart homes. All of which focus on decreasing the cities emissions and increasing their resilience. This can be an individual topic, for instance, urban settlements near mountain regions might deal with changing perception patterns, whereas coastal settlements might focus on rising sea levels. These cities probably use technologies differently and so far, no literature attempted to collate these different ways. Moreover, there is a gap in the research that is focusing on the practical role and opportunities for green technologies in the context of mitigation and resilience strategies. The theoretical concept of green technologies (Casini, 2017; Laffta & Alrawi, 2018) as well as mitigation and resilience have been extensively discussed (Godschalk, 2003; Lu & Stead, 2013). What this paper is trying to do, is filling the lack of research that examines their relationship and practical implications. It is going to look at the role that green technology has within mitigation and resilience strategies. Therefore, the following research question is stated:

(1) *“What is the role of green technologies in climate mitigation and climate resilience strategies of Smart Cities?”*

To answer the main research question, two sub questions have been formulated. This paper will build a framework, to develop, in combination with documents published by the cities, a deeper understanding of the meaning and significance of green technologies for Smart Cities. This will allow insight into how stakeholders act differently, and it will show best practice patterns. Through this, the research hopes to contribute to an optimization of climate mitigation and climate resilience strategies. Therefore, the following research question has been formulated:

(2) *“What differences can we find in the meaning and significance of green technologies in the Smart Cities?”*

The most important actor in the context of climate resilience and mitigation in Smart Cities are the stakeholders who implement these. Focusing on them is from upmost importance because stakeholders´ engagement is necessary for cities to achieve resilience and approach the uncertain future (Iturriza, Labaka, Hernantes, & Abdelgawad, 2020). To incorporate their role in the research, this paper is interested in how they view the opportunities of green technologies and how this can be seen in their strategies. Through these strategies, they set the goals and future for the entire city, also regarding climate actions. Climate change is an issue that must be addressed now because the consequences could be incisive in the future. Hence, the stakeholder´s view of what green technologies can achieve has a direct impact on the city´s action towards climate mitigation and resilience. There is a gap in the research that acknowledges this importance and focuses on visions that stakeholders have. To research this, the following question is stated:

(3) *"How do Smart City stakeholders envision the opportunities of green technologies for mitigating climate change and for strengthening climate resilience?”*

To answer the proposed questions, an interpretive research is executed. Therefore, concepts of Smart Cities, climate strategies, and green technologies are combined with a content analysis. This was chosen because it allows an in-depth view into the stakeholders' strategies and is not aiming at constructing new theory. Three Smart Cities will be analysed with the help of the concepts to determine the importance of green technologies for mitigating climate changes and building resilience. Hence, documents from the respective stakeholders will be consulted.

In the first part of the following paper, a theoretical framework of a sustainable Smart City that incorporates resilience will be constructed. Moreover, climate mitigation and resilience strategies will be explained within the context of Smart Cities and the theoretical work on green technologies within this will be presented. The theoretical construction will form the basis for a comparison and analysis of the cases. In the second part, the methodological approach of the paper will be elaborated, and a coding scheme will be developed on the constructed theory. In the third part, the findings of the content analysis will be presented and lastly discussed.

2. Theoretical Framework

This chapter aims to combine academic literature on improving the sustainability of Smart Cities with work on green technology and climate strategies. It is organized as follows. First, the work of various scholars on theorizing Smart Cities is discussed. Here one academic stream focuses on the sustainability and resilience components within Smart Cities. Papa et al. highlighted this and developed a flexible concept of Smart Cities that incorporates climate change. Linking to this, climate mitigation and climate resilience strategies are presented, focusing on their role within cities. Finally, Casini´s work on green technology is described. Hereby, it is argued that technology can play a vital role in achieving mitigation and resilience goals. To underline this further, a typology is developed, which categorizes green technologies into different roles they can fulfil within Smart Cities.

2.1. Defining a resilient Smart City

Since the introduction of the term in the 1990s, many papers came up with different definitions of Smart Cities, even though they share the underlying faith in technology and innovation (Cugurullo, 2018). Alberto Vanolo regards the term Smart City to come out of the context of "intelligent cities" and "smart growth" (2013). Capra characterizes Smart Cities by six elements: smart economy, smart people, smart governance, smart mobility, smart environment, and smart living (2014) (Figure 1). The characteristics always have a different degree, making every Smart City unique (Capra, 2014). This paper is concentrating on three characteristics:

Characteristic	Theory	Feature
Smart Economy	Regional Competitiveness	Entrepreneurialism, Innovation, International integration
Smart People	Human and Social Capital	Flexibility, Creativity, Tolerance, Qualification level
Smart Governance	Participation	Transparency, participation in decision-making, quality of political strategies
Smart Mobility	Transport and ICT Economics	Accessibility, ICT availability, modern and sustainable transport systems.
Smart Environment	Natural Resources	Sustainable resource management, Natural attractiveness, Lack of Pollution
Smart Living	Quality of Life	Educational, Cultural and Health facilities, Safety, Housing, Social Cohesion, Tourist attractions

Source: adapted from Giffinger et al., 2007; Caragliu et al., 2011; Vanolo, 2014

Figure 1: The six characteristics of Smart Cities (Capra, 2014, p. 17)

smart environment, smart mobility, and smart living. Cities that focus on these, are focusing on improving their sustainability, their transport systems, and their quality of life.

Becoming one of these cities as well as studying them has become the focus of some stakeholders and scholars. Rjab & Mellouli for instance pick up the sustainability factor and define Smart Cities as a way to "achieve greener, smarter or more efficient cities" (2018, p. 3).

With the focus shifting towards the smart environment characteristic, the idea and theoretical framework of Smart Cities must be extended by the concept of resilience. In this context, resilience can be referred to as “the city’s ability to absorb, adapt, and respond to any changes […]. Therefore, a resilient city is able to withstand the impact of shocks, hazards, and pressures through adaptability or transformation” (Arafah, Winarso, & Suroso, 2018, p. 2). However, it should be noted that economic growth and sustainability are always in a state of conflict within Smart Cities, which makes a sustainable Smart City hard to obtain.

Papa et al. pick resilience up and add it to the existing model of Smart Cities, to frame Smart City´s in the face of climate change (2015). The underlying idea and realization are that Smart Cities offer the opportunity to become more flexible in the face of climate crisis, in order to bounce back from e.g. extreme flooding. Hence, Papa et al. frame the urban system as a cyclical process, based on Learning Capacity, Persistence, Adaptability, and Transformability (Figure 2). This is interesting, as it frames a new concept of Smart Cities in which they are both a solution and a resistance to climate change impacts. Moreover, it gives cities the role of an actor against climate change and they are now able to incorporate mitigation strategies on a whole

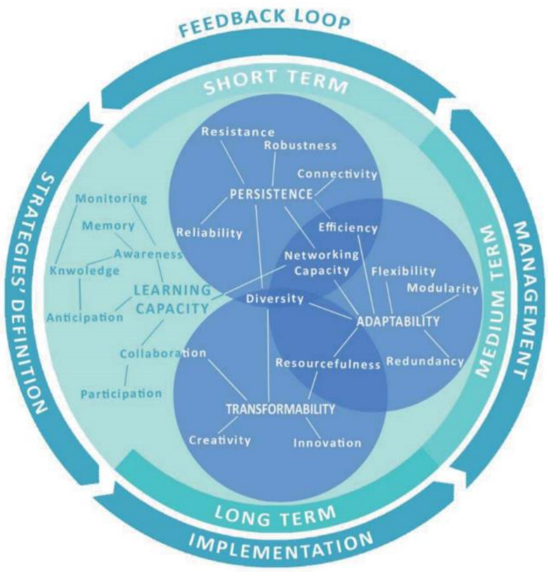

Figure 2 The conceptual model: roles and linkages among the capacities of a Smart and Resilient Urban System in the face of climate change (Papa et al., 2015)

new level. Besides, the model shows the practical implication of resilience through the medium-term strategy of adaptability (Figure 2). All of this gives cities the chance to increase their persistence, through discussions that feedback to the strategies´ definition (Papa et al., 2015). The general concept of a Smart City becomes more flexible (Figure 2).

2.2. The strategies of climate mitigation and climate resilience

This new flexibility allows climate mitigation and resilience strategies to enter Smart Cities, which both offer different opportunities. “Mitigation and [resilience] strategies, although complementary, differ both in their objectives and in their temporal […] scales.” (Galderisi, 2014, p. 48)

On the one side, mitigation strategies are based on the fact, that between 1970 and 2004, global GHG emissions went up 70%. By implementing mitigation strategies in their policy-making, political actors try to reduce these emissions in the long-term (Galderisi, 2014). This often expresses itself through “carbon neutral” strategies, in which cities present ways to reach carbon neutrality within a certain timeframe. Generally, the goal of mitigation is to limit the impacts and intensity of future climate crisis. Instruments of these strategy can be on a large scale, for instance updating building and transport infrastructure towards more energy efficiency. They also occur on a small scale, for example improving a cookstove design to be more efficient (Galderisi, 2014). Summarized, this strategy uses “new technologies and renewable energies [to make] older equipment more energy efficient, or [to change] management practices or consumer behavior” (UN).

On the other side are resilience strategies. They are shifting into focus gradually, as major climate changes are already happening, and global warming is continuing. Simply focusing on mitigation could not be enough, as some researchers argue that the world could have already reached a tipping point (NASA, 2020). By incorporating resilience in their policy-making, actors aim at reducing "the costs of climate change by reducing the damage due to climate change" (Asaduzzaman & Khandker, p. 23). In contrast to mitigation, resilience strategies do not aim at tackling climate change. In becoming more climate resilient, cities anticipate future climate crisis and the following impacts to prepare themselves for them. It is a matter of increasing security, creating emergency plans, and decreasing the likelihood of damage. On the one hand, this refers to damage to infrastructure, for instance buildings, sewers, or data centres. On the other hand, damage refers to human health and life. As climate impacts can be highly specific for different cities, resilience is mostly “defined and implemented at local level” (Galderisi, 2014, p. 48). For instance, resilience strategies in coastal areas might focus on increasing their level of flood protection, while metropolitan cities might focus on collecting and processing air-pollution data. Resilience strategies are often used as flagship projects to improve a city’s image, as the term “resilience” is popular. However, this should not be mistaken as inaction of the city. Even if they use it as a flagship, real measures can follow to improve resilience.

Concluding, both strategies do work best in combination as they complement each other. Mitigating climate change helps reducing resilience measures and resilience measures can step in when mitigation failed.

2.3. The role of green technology within climate strategies

As sketched above, both strategies offer a huge application area for green technology, especially within Smart Cities as they are characterized by technological progress. Technology that is aiming at climate mitigation and resilience can be named "green technology" and has three major fields within Smart Cities: green buildings, smart lighting, smart mobility (Casini, 2017). In cities´ mitigation strategies, green technologies are used in all three fields. In the first, green technologies support energy efficiency in form of cleaner and renewable energy sources, efficient heating systems, and building planning (Casini, 2017). Real-time data processing is used to create digital services for citizens. By providing e.g. a live tracker of a home´s power consumption, the citizens are being navigated towards a more sustainable life. Smart lighting can be achieved by replacing outdated lamps with the newest and smartest technologies. Green technologies help by providing "[r]eal time data capture[d] by the connected lamps[. This] show[s] the public administration information useful on the traffic, […] crowding at the public transport stops, and the availability of parking lots. The control of road lighting […] also help[s] increase[ing] security levels" (Casini, 2017, p. 6). This last field, smart mobility, is mostly achieved by making the public transport sector efficient. Here, green technologies are used in developing and building electric and hybrid vehicles, as well as managing real-time data on traffic (Casini, 2017).

In Smart Cities´ resilience strategies, green technologies offer different opportunities than for mitigation. Regarding green buildings, green technologies can help in making housing more robust against natural disasters. Moreover, it assists stakeholders with incorporating resilience in urban planning and designing emergency plans, by simulating different scenarios. The procession of real-time data is mainly focused on environmental changes in temperature, precipitation, wind, air quality, carbon dioxide, and noise levels. This allows actors in Smart Cities to anticipate changes in the weather early and protect citizens from unhealthy and dangerous environmental circumstances and impacts (Rjab & Mellouli, 2018). One impact could be the rising sea-levels, a phenomenon that is already beyond human control and cannot be reduced through mitigation strategies. Smart City actors use green technologies in flood control systems, water monitoring, and reclamation projects. They offer the opportunity to manage water-level data in real-time, remotely close floodgates, and sent real-time alerts. Precipitation changes could pose another hazard for cities. Through recalculating and redesigning stormwater drainage systems, green technologies can help to tackle this impact (Asaduzzaman & Khandker).

These examples of green technology can be categorized into different kinds of roles that they can fulfil. Stakeholders use green technology with an idea in mind, of what they want to achieve and with a role in mind, of how they regard green tech. The following typology is based on the model by Zand, Solaimani, and van Beers (2015). They established seven roles Information Technology (IT) can have; Information, Communication, Automation, Coordination, Integration, Transformation, and Innovation Role (Zand et al., 2015). Three of these categories are used in typologizing the role of green technology in Smart Cities. The first, Information collecting role, covers all technology that simply aims at collecting data on e.g. water usage, air quality, or the weather. The communication role is linked to the information role, as it covers warning systems, every kind of smart application, or smart home displays. Under the last one, two roles are put together, Automation and Coordination. This category covers every technology that automates processes, coordinates real-time data, creates emergency plans, or observes e.g. traffic.

2.4. Conclusion

In this chapter, it has been argued that green technologies offer great potential for climate strategies within Smart Cities. It was shown that the updated concept of Smart Cities as a flexible and resilient framework offers a great way to combat climate change, especially in combination with mitigation and resilience strategies. To achieve the goals of these strategies, the potential of green technologies has been highlighted. Nevertheless, it has also been shown, how complex and individual Smart Cities are. The scale of their characteristics can differ according to their setting. This also relates to climate strategies and hence green technologies. Every city picks and uses different technologies, depending on their environment. This is in line with the developed typology which showed that the role of green technologies can differ. The presumption was voiced, that metropolitan areas focus on different application areas of green technology than coastal areas. Based on their setting, the vision of the opportunities of green technologies can differ. To answer whether the city´s environment has an influence on the vision of stakeholders for the opportunities of Smart Cities, the following hypothesis is formulated:

H1: Stakeholders deploy green technologies differently, depending on their city´s environmental factors.

It has also been argued, that using both climate strategies simultaneously would be logical. However, it was shown that resilience could be the focus of Smart Cities because climate impacts might be irreversible already and it might be a flagship project for some. To answer which strategy is more focused on, the following hypothesis is formulated:

H2: Smart Cities are more likely to focus on climate resilience strategies.

Lastly, a typology for the role that green technologies can play within Smart Cities has been developed. Moreover, it has been pointed out, that economic growth and sustainability are always in a state of conflict within Smart Cities. To answer, whether stakeholders concentrate more on the economic side of green technology, the following hypothesis is formulated:

H3: Stakeholders focus on the economic role that green technologies can play.

3. Methodology

This chapter aims at providing the research methodology that has been chosen to answer the research questions. In the first part, the case selection is justified, presenting the developed criteria that lead to the case selection. Hereafter, the data collection is explained, meaning what data has been used and how it has been selected. Lastly, the data analysis is presented. Here the use of a content analysis is justified in its use to answer the research questions through the development of a coding scheme.

3.1. Case selection

The focus of this research is the role of green technologies within Smart Cities. In order to analyse this role, Smart Cities are at the core and a deductive qualitative research was adopted. Qualitative research allows through its flexible approach to create a rich and detailed picture of the context being looked at. Through this, the research will be able to show what numbers are not able to explain, like the conceptual role of green technologies. According to Seawright and Gerring, when a small sample size is used, the usage of a solely random selection process can lead to an unintended introduction of bias. Therefore, they argument for some form of purposive case selection (2008). Based on this, five criteria were carefully chosen on which the cases were selected. Using smart city rankings as a criterion was no option, as every ranking has completely different outcomes. However, they were used as a starting point, to narrow the possible cases down to the ones often mentioned in rankings. After that, cities were chosen by climate mitigation and resilience policies and sorted out by lack of them. Smart City projects that focus on smart homing for example but lack the aspect of smart environment were excluded. Next, due to feasibility, only cities that offer their (policy) papers in English or German were considered. As this paper aims at showing best practices, only leading cities in climate policies were contemplated, meaning that they are actively using mitigation or resilience strategies. As a criterion, belonging to the "C40-network of the world´s cities engaged in mitigation actions" was chosen. Furthermore, the Smart Cities that were chosen, have all been awarded as best practices. Due to the comparative part of this research, cities from different continents have been chosen, to show the diversity of concepts being implemented around the world. Two European cities for example could be part of the mysmartlife.eu initiative, which could lead to similar findings in their interpretation of green technologies. An important criterion that played into the selection process was the availability of data. For that reason, no city from China, a pioneer in Smart Cities, was chosen. Based on all criteria, a small pool of cities per continent was left. Against the background of the scope of a bachelor's thesis, the decision was made that three cases are sufficient to answer the research questions.

The cities Singapore, Copenhagen, and New York were chosen based on the criteria above. All of them have mitigation and adaption strategies, available data in English, are part of the C-40 network, and have been awarded. They were chosen over other cities on their continent because the local governments provide great access to online data.

Singapore won the Smart City of 2018 award (Rohaidi, 2018) and ranked 1st on the IMD Smart City Index 2019 (IMD World Competitiveness Center, 2019). Above that, Singapore is a pioneer in flood control technology and water meter reading systems. Furthermore, Singapore was chosen, because of its unique focus on smart buildings that are built by the public housing association. They are focusing on sustainability and lifestyle, energy use, alarm systems, as well as monitoring heating and water systems (Meckel, 2019).

Copenhagen´s project "Copenhagen Connecting" was awarded the World Smart City Award of 2014. The project is a "concept for a digital infrastructure, that allows for smart city solutions to be easily implemented in the city" (CopenhagenSolutionsLab, 2014), which marks Copenhagen as very interesting for the thesis´ focus on green technology. Their focus on sustainability becomes clear in their "cleantech cluster" which includes the goal of becoming carbon-neutral by 2025 and a commitment to green transportation, bioenergy, and the development of smart grids (Westberg).

New York won Best Smart City of 2016 (Michell, 2016). This award was mainly granted, due to New York´s "Smart + Equitable City" initiative, which focuses on the use of IoT for Smart Buildings/Infrastructure, Transport/Mobility, and Energy/Environment. Especially interesting about New York is its big cleantech start-up scene, which pushes the city as a hub of innovation. Moreover, Mayor Bloomberg already announced in 2009 a transformation of the city towards a green economy (NYCEDC).

The chosen cities provide a levelled ground for comparison. They do differ but are similar in their development which makes the findings not only comparable but also generalizable.

3.2. Method of data collection

Deriving from the nature of the cases, qualitative data from primary sources are used. The data which was chosen was derived from the local governments of the selected Smart Cities. All of them are official governmental papers, brochures, concepts, or initiatives (Appendix C). This kind of data was chosen because it provides first-hand information on how stakeholders regard green technologies and climate strategies. Thus, it is made possible to on the one hand link opportunities that green technologies provide for the specific cities to climate strategies and on the other hand excerpt the significance and meaning that stakeholders attach to these technologies. Lastly, the collected data allows an exact comparison between the three cities.

For the scope of the study, around 19 documents were chosen. As mentioned, they were collected from the cities themselves, in contrast to using second-hand data in forms of e.g. newspapers or studies. This would not have enabled a look into the stakeholders´ minds regarding green technologies. Therefore, the documents were collected from the municipalities' websites and were either found by a google search or through the municipalities´ policy search engines. Due to the fast-moving nature of the Smart City field, rather recent documents were chosen. None of them are older than 13 years, with most of them being from the last five years. Furthermore, climate change is a rapidly changing field as well, which underlines the emphasis on choosing the most recent documents in all cases.

For Copenhagen, six documents have been chosen, the oldest being from 2011 and in the length of 56 to 176 pages. Five of the documents are official papers published by the city and one is a report in cooperation with the London School of economics and political science. For New York, again six documents were chosen, the oldest being from 2007 and in the length of 24 to 445 pages. All documents are official papers, published by the city of New York. For Singapore, seven documents have been chosen. The oldest is from 2016 and they range between two and 56 pages. Four documents are official papers published by the city, one is a media release for smart nation, one a research paper on the smart nation program, and one an extract from the Singaporean website.

3.3. Method of data analysis

The method of analysing and interpreting the data is a content analysis. This method allows a systematic and replicable analysis of large volumes of textual data, in this case, the governmental documents. According to Rose, "it involves the classification of parts of a text through the application of a structured, systematic coding scheme from which conclusions can be drawn about the message content" (2015, p. 1). A content analysis aims at gaining an in-depth understanding of a specific context, which supports this paper´s goal to study the role of green technologies in Smart Cities. According to Burawoy, this type of research is not aiming at generating new theory, but at improving or extending existing ones (1998). This aligns with this paper´s goal to extend the theoretical work of green technologies with practical implications. Besides, the content analysis was chosen because it stays inside the resources of this thesis. Strong points of this kind of analysis are the diverse applicability of it. It is highly flexible and through the use of software programs, in this case, atlas.ti, it is able to cope with large amounts of data.

The content analysis starts "with the identification of relevant concepts and, where appropriate, the formulation of hypotheses in response to the research question" (Rose et al., 2015, p. 3), which has been done in the theory chapter. The next step is identifying the data that will be analysed and unitizing it. From there, the coding scheme needs to be developed, which will be more thoroughly discussed in the next paragraph. In the next steps, the data is collected, and the initial coding is being tested. According to Neuendorf, piloting the scheme is necessary to test its applicability and to optimize it for the analysis (2002). With the adapted coding scheme, the coding and analysis can begin.

To research the role of green technologies in Smart Cities, the chosen documents have been coded to analyse them. The following coding scheme (Appendix A) was developed through an extensive process. First, a provisional scheme was created, based on the theory. After starting coding, some key terms were renamed and some added.

As a basis for the whole analysis, all cities had to be analysed on their approach to being a Smart City. The theory showed how different this can be and how major the impacts can be on e.g. the cities strategies. As discussed in chapter two, only three smart characteristics are from importance and they serve as dimensions in the first coding scheme: Smart environment, Smart mobility, Smart living. The linked key terms are based on the work of Capa and are able to indicate one of the dimensions. For instance, the key terms green space and weather were chosen, because a focus on these clearly show that the stakeholders envisioned their city to be smart when it comes to environmental issues.

Concept	**Dimension**	**Key terms**
Smart City	Smart environment	Water usage
		Green space
		Temperature
		Flooding
		Weather
	Smart mobility	Efficient transport
		Traffic
		Mobility
	Smart living	Education
		Lifestyle
		Health

Table 1 Smart City characteristics

In order to show the opportunities of green technologies within climate strategies, the strategies themselves, and how they are implemented within the cities have to be analysed. Their focus on either one of the strategies can give clues on how they envision the role of green technology, as well as their significance. Therefore, mitigation and resilience serve as dimensions, characterized by three key terms. As mitigation aims at reducing climate change, using e.g. “GHG emission” as a key term, which is a cause of climate change, is very expressive. Resilience aims at being prepared for future climate crisis, so for instance keeping citizens safe through “emergency plans”.

Concept	Dimension	Key terms
Climate strategies	Mitigation	GHG emissions
		Energy consumption
		Carbon neutrality
	Resilience	Reduce damage
		Emergency plan
		Security

Table 2 Resilience and mitigation strategies

In order to analyse the meaning and significance of green technologies within the cities, the theoretical background of green technologies is used. The goal is, to find out how much the cities focus on green technologies and then interpret the citations regarding the meaning that stakeholders give them. Here, Table 1 will be used as a base.

The last coding scheme, Table 3; will tie together the first two. Together with Table 2, the opportunities of green technologies for the different strategies can be presented. All coding schemes together will present the role of green technologies in Smart Cities.

Table 3 is based on the work of Casini. His three deployment areas of green tech serve as Dimensions and his described use of these technologies within these areas serve as key terms.

Concept	Dimension	Key terms
Green technologies	Green buildings	Renewable energy
		energy efficiency measures
		Water meters
		Heating/Cooling efficiency
	Smart lighting	LED lamps
		Connected lamps
		Road lighting
	Smart mobility	public transport
		hybrid vehicles
		Sensors/monitoring
		traffic warning systems

Table 3 Significance of green technologies

3.4. Conclusion

To sum up, this research is focusing on gaining insight into the stakeholders´ views on climate strategies and green technologies. The content analysis will be sufficient to uncover the role that green technologies play within climate strategies of Smart Cities. To get this first-hand insight, the analysis of city documents through the developed coding scheme is adequate. The scheme is split into three parts, allowing an analysis of Smart City characteristics, climate strategies, and the significance of green technologies. The scheme combined with the focus on three Smart Cities allows a comprehensive comparison.

4. Analysis

The purpose of this chapter is to gain a deeper understanding of the threats and changes that climate change proposes for urban areas, in this paper Smart Cities. Therefore, the anticipation of climate change either through mitigation or resilience strategies will be analysed. Through this, differences in the interpretation of climate hazards for different cities will be shown and how this relates to the theory of green technologies, and the circumstances of the city. Furthermore, the focus of the Smart City on different theoretical levels of smartness will be explored. In combination with the results of different usage of green technologies, assumptions can be made about the meaning and significance of green technologies and how this differs between the cities. Based on these findings and in combination with the entire outcome of the analysed data, the main Research Question will be answered.

Generally, every section is structured the same way. First, the findings for all cities are presented, which occur in two forms. On the one hand, basic numbers on how often certain key terms occurred. On the other hand, the interpretation of the citations linked to key terms. After that, the findings are compared and interpreted.

4.1. Meaning and significance of green technologies

To gain insights in the different meaning and significance that green technologies have in the cities, Table 3 and Table 1 are used. The latter shows the cities´ focus on either smart living or smart environment/mobility. The first shows how often green technologies are named as an instrument.

Copenhagen

Green technology

Regarding the frequency of "green technology" key terms, the analysed documents show that the legislators of Copenhagen concentrate on “smart mobility” four times more than on “green buildings”. “Smart lighting” comes up extremely rarely and then it mostly co-occurs with “housing/buildings”.

Within the strongest dimension “mobility”, the focus is on “public transport” whereas “hybrid vehicles” and “sensors/monitoring” are from no importance. The ambitions regarding the public transport sector are clearly stated; extension and optimization. Green technology is used in the real-time processing of bus data for digital signs at bus-stops, as well as for online journey planners. Moreover, the intelligent procession of radio and GPS technology is used to enable “traffic controllers to keep lights green if buses are approaching” (The City of Copenhagen, 2014, p. 11). In general, “monitoring/ sensor technology” is a relatively new field for Copenhagen, using it mostly at bus stops and air pollution measurements. One big application of sensor technology and intelligent software is in sewer pipes, more precisely in their control mechanisms. The whole sewer network is linked to weather radars so that they can prepare for example for heavy rainfalls. Through this, the risk of flooding can be reduced and water quality improved. Copenhagen is planning on extending sensor tech to (smart) buildings.

The second focus is on the dimension “green buildings”. Here the focus is heavily on “heating/cooling efficiency”, as the city expects an increased energy use in this field. Copenhagen has introduced district heating a long time ago to counteract the high energy expenditure. This technology uses the thermal heat from waste management and through the thermodynamic technology of district heating, energy efficiency was improved a lot. At this moment, cooling is not a big concern for Copenhagen, but stakeholders anticipate that it will be. Therefore, they started to develop district cooling networks, which “take advantage of seawater as well as excess heat for absorption chillers from the combined heat and power network.” (London School of Economics and Political Science, 2014, p. 90) The key term “renewable energy” comes up half the times as often as the first. Here technology is mostly seen as a way to make buildings more carbon-neutral and create new jobs. The focus is on both solar energy and biogas. The key term “energy efficiency measures” occurs rarely, but it often co-occurs with the “housing/buildings”. The focus is on “[r]emote meter reading[s] of heat consumption [to] identify plants with unusually high consumption.” (London School of Economics and Political Science, 2014, p. 32)

Smart City

Copenhagen´s focus as a Smart City lies on the characteristic "smart environment". Within this dimension, the variables "weather" and "water usage" are most prominent, “green space” and “flooding” only come up half as often and “temperature” is rare. Copenhagen is a coastal city, so they (already) must deal with an increase of rainwater, stormwater, and consequently flooding. Therefore, they put great focus on their "water usage". The city has advanced wastewater management and is adapting its sewers to future precipitation changes. Moreover, stakeholders developed their own cloudburst management in form of cloudburst pipes and roads to manage the rainfall. On top of that, "a new hydraulic model will be prepared for use in connection with implementation of the 300 cloudburst management projects" (The City of Copenhagen, 2015, p. 18). Another method that is popular in Copenhagen is "green spacing" to manage stormwater and big masses of water. Stakeholders name three advantages of this. First, green roofs and walls help to slow down the rainfall and reduce the risk of flooding. Second, green and blue landscaping helps to improve the liveability of the city and helps clean the air. Lastly, retention/green roads help to store and retain masses of water. A small concern for the city of Copenhagen is rising "temperatures" and thus UHI. This problem will not occur soon, but the municipality wants to be prepared for the hotter summers and is starting to use existing resources to create data sets on temperature and weather patterns.

The second characteristic that Copenhagen concentrates on, even though it is significantly less important, is “smart living”. The variable “housing/buildings" plays the biggest role. Even though the rise of groundwater and sea level is not seen as an urgent thread for Copenhagen's housing, this will change over the next century. The stakeholders make it clear, that they want to take action early to cut even greater financial losses later. In line with that, they say that climate-proofing existing buildings is often more expensive than building new ones, which is why new buildings are supposed to have "build in options for upgrades that can then be decided upon at a later time" (The City of Copenhagen, 2011, p. 68). The analysis makes out two big focuses within in “building/housing” variable. On the one side, water-proofing the basements and sewers against future rainfalls (e.g. through backwater values) and on the other improving the energy efficiency. “40% of Denmark´s CO2 emissions come from buildings” (The City of Copenhagen, 2014, p. 34), which is why existing technical solutions for new and retrofitting buildings are to be used. (Figure 3) The variable “health” plays a vital role as well, although it comes up thrice times less often. “Health” can be made out as a factor that is often in the awareness

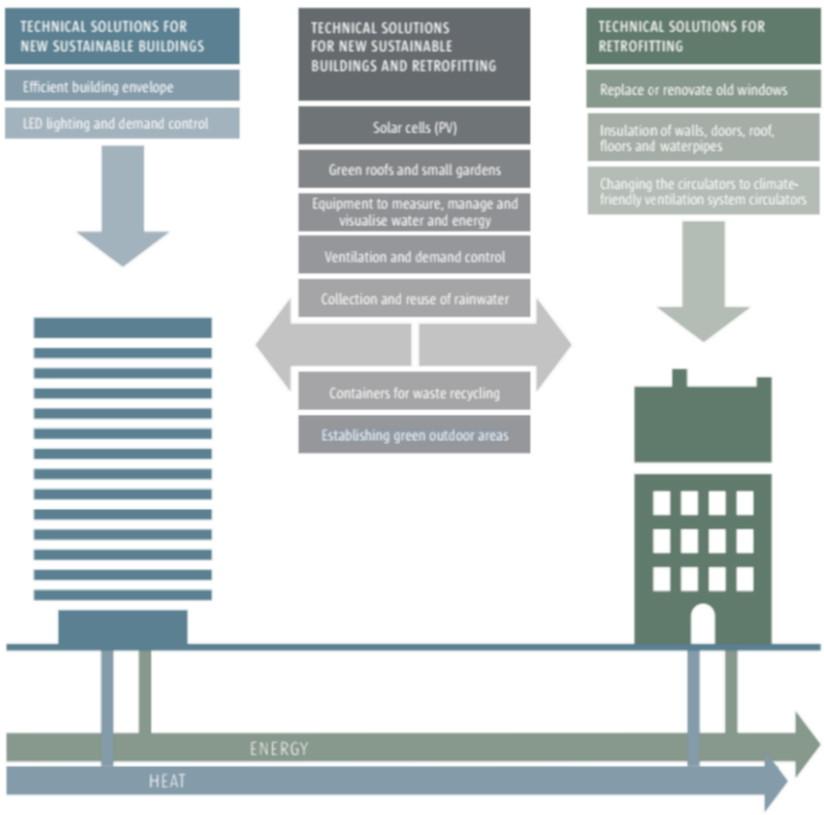

Figure 3 Copenhagen builds and retrofits the sustainable way (The City of Copenhagen, 2014, p. 34)

and is being considered on multiple levels. It has a high co-occurrence with “traffic” and “green space”, because clean air leads to improved health in both humans and biodiversity.

The third characteristic “smart mobility” comes up half as often as “smart living”. Copenhagen focuses on “traffic”, in terms of the reduction of congestion to achieve time efficiency and better liveability. As mentioned before, the stakeholders hope to improve health through the consequently lower noise and pollution levels. Furthermore, the analysis shows that this is supposed to improve Copenhagen´s quality as a business location (e.g. shorter times for freight transport).

New York

Green technology

The analysis of the New York documents shows a clear focus on improving “green buildings” and “smart mobility” infrastructure through green technology.

Within the Dimension “green buildings”, the emphasis equally lies on improving “renewable energy” and “heating/cooling” systems. A big issue for stakeholders is both the extreme heat due to the density of buildings and the extreme cold of the snowy winters. “Heating/cooling efficiency” is recognized to be in the way of cutting emissions and becoming carbon neutral. To counteract that, city buildings are to be retrofitted and insulated. However, the documents show no real solution approach. They do acknowledge the danger of power outages, which especially in hospitals could lead to no air condition for critical patients. A hands-on solution that the city deploys in buildings, is the water meter reading system. It “is one of the largest IoT deployments in the city. Since 2009, it has saved residents tens of millions of dollars by connecting them to water usage data online.” (City of New York, 2015, p. 6) (Figure 4) The second key term “renewable energy” is supposed to be achieved, through the instalment of solar panels and emancipation from fossil fuels towards clean electricity resources. “This means the deployment of wind, both upstate and offshore, as well as solar power.” (OneNYC 2050, 2017, p. 13) Improving electric energy storing is from importance as well, as it is linked with greening and improving the grid.

The green technology of "smart lighting" seems to play little role in the city. "LED lamps" and smart lighting systems are recognized to be important for retrofitting buildings and cutting emissions and costs. However, "connected lamp" systems are not even mentioned.

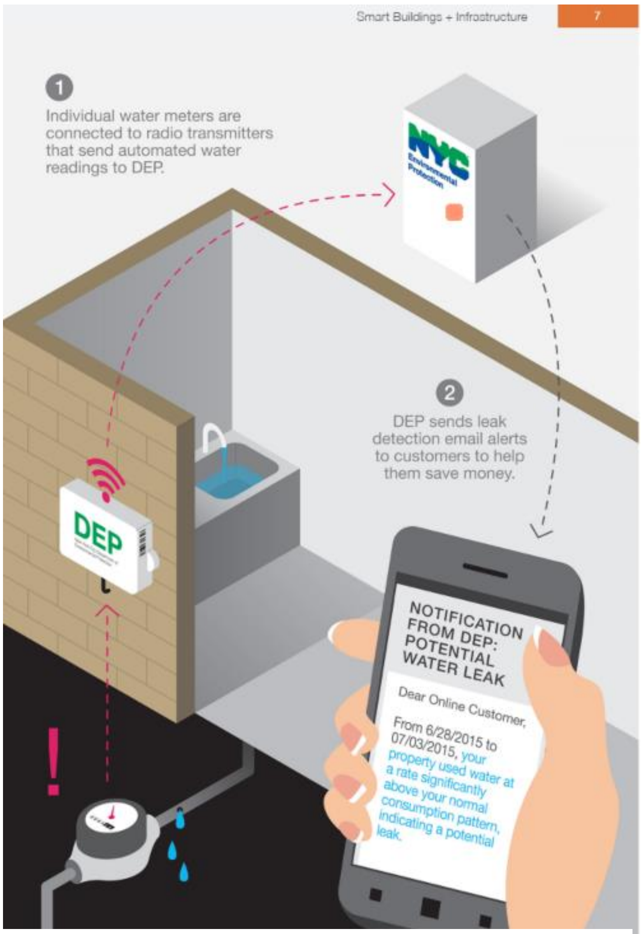

Figure 4 Wireless Water Meters (City of New York, 2015, p. 7)

In terms of "smart mobility", the analysis shows nearly an equal focus on "sensors/monitoring", "hybrid vehicles" and "public transport". The latter uses technology in "City buses and traffic lights with real-time sensors that prioritize bus transit through signalized intersections." (City of New York, 2015, p. 10) This is achieved through "Transit Signal Priority (TSP), an urban traffic management system that improves the efficiency and dependability of bus mass transit. A bus equipped with the in-vehicle TSP system requests priority service as it approaches an intersection and can change the normal signal operation to improve the flow of bus traffic." (City of New York, 2015, p. 10) The other key term "sensors/monitoring" shows the deployment of different kinds of green technology in many areas. As mentioned, it is used in water meter reading systems and the "Midtown in Motion" project (real-time traffic information). Besides these, the technology is used in hardening the fuel infrastructure and support post-emergency restoration through "automated sensors and other information technology (IT) systems that will monitor the operational status of these facilities." (City of New York, 2013, p. 11) To ensure the health and safety of the citizens, data-driven air quality management practices and "PowNYC" are used. The latter "is a public-facing web app that allows city residents to monitor snow removal progress in real time." (City of New York, 2015, p. 21) Interesting is the cities engaged approach to use sensors and monitoring in combination with resilience strategies. "Emerging sensor technology, along with supporting data infrastructure, enables data-driven asset management, allowing the City to be proactive rather than reactive to problems as they arise." (OneNYC 2050, 2017c, p. 8) The figure shows examples of how green technology is employed within the city's everyday life. (Figure 5)

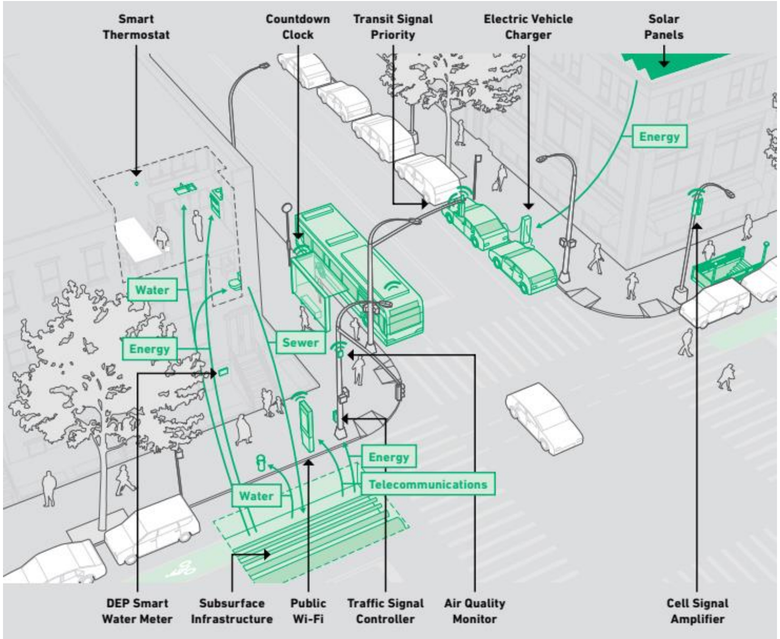

Figure 5 A connected City (OneNYC 2050, 2017c, p. 8)

Smart city

The focus in New York is very clearly on “smart environment” and “smart living". The biggest concern that the stakeholders address is “flooding”. There is a huge awareness about the thread through water masses, especially due to past catastrophes like hurricane Sandy. The analysis shows a big co-occurrence of “flooding” with both “housing/buildings” and “security”. The latter is composed of measures to strengthen critical infrastructure, and the first is about floodproofing buildings through e.g. elevations or improved sewer systems. Especially buildings on the coastal line, which is very long in New York (figure 6), are in the focus. Commissioned studies and risk assessments/future scenarios led to a coastal protection strategy. It is comprised of coastal edge elevation, minimizing upland wave zones, floodwalls, levees, local storm surge barriers, and a general improvement of design and governance in the coastal area. Another big concern is "water usage". To save money, the city introduced an automated water meter reading system in 2009. Moreover, the analysis shows a big concern to harden the wastewater infrastructure against future climate changes, as well as to achieve "net-zero energy for treatment of wastewater by 2050." (OneNYC 2050, 2017, p. 16) It

Figure 6 New York City´s coastline: Now and Then (City of New York, 2013, p. 39)

becomes apparent, that past natural disasters have led to huge concerns about future weather changes: “[As] climate change continues to worsen, we can expect more powerful and destructive storms that will threaten residents, communities, and our economy” (OneNYC 2050, 2017, p. 23). Like the weather, temperatures are expected to become more extreme, which is why the city is already launching programs like “CoolRoofs” to counteract UHI. Moreover, the climatic changes will impact the already critical air quality. Urban air monitoring programs and a data-driven air quality management practice are supposed to reduce pollution and increase the citizens' health. This is in line with the "green spacing" through the expansion of green streets, "people priority streets" and greenway paths for cyclers. The key term “green space”, came up extremely rarely.

The second big dimension “smart living” is mainly concerned with “housing/buildings”. Here, the co-occurrence with “LED lamps” is extremely high, as they are seen as a way to cut emissions and save money. However, the biggest issue is to protect buildings from floods. With the big goals to make them resilient against any kind of natural disaster, many measures are being taken. Watertight windows and doors are installed, elevations are made, external flood barriers are built, and sewers are upgraded. The key term “health” came up three times less than “housing/buildings”, and is focused on inequality, heat, and air pollution-induced health problems and traffic fatalities. "By the 2050s, New York City will be hotter than ever before. Average temperatures are expected to increase by up to 5.7 degrees Fahrenheit, and many more New Yorkers may die each summer from intense heat than the 130 who die annually today." (OneNYC 2050, 2017, p. 6) This is why there is a big focus on making hospital infrastructure climate crisis-proof.

The dimension “smart mobility” plays nearly no role. It came mostly up under “traffic” and focuses on reducing congestion and emissions through real-time traffic information. Furthermore, the city has a traffic safety program, “Vision Zero”. Lastly, data show the goal to achieve an efficient traffic transit system, which makes sense, as New York is completely dependent on (public) transport.

Singapore

Green technology

The analysis shows an even focus on “green buildings” and “smart mobility” within the concept of green technology. Singapore sees itself as a leader in the smart home industry and shows this for instance through its creative approach to renewable energies. Due to their "small size, urban density, low wind speeds, relatively flat land, and lack of geothermal resources" (National

Climate Change Secretariat, 2016, p. 4), they are investing in research to improve renewable energy options for buildings, besides solar panels. One way, which also aims at "energy efficiency", is waste-to-energy plants. To achieve efficiency in the industry, energy efficiency schemes for companies were developed, which range from financing to incentives. A big issue in Singapore is the tropical weather and hence the “cooling” of buildings. Through automated cooling systems, they try to unite cooling with energy efficiency. Another issue in this area is the cooling of data centers. Again, Singapore counts on research to develop new green tech: "Research is also being carried out to assess how "direct liquid immersion" technologies can be used to remove heat from computers, such as servers in data centres. This is more efficient than air cooling, especially for large servers, and has the potential to significantly reduce energy consumption in data centres.” (National Climate Change Secretariat, 2016, p. 37) Lastly, Singapore is using green technology in form of water meters.

The second dimension "Smart mobility" is focused on "sensors/monitoring" and the data shows a wide deployment area. Light sensors across the city are used to display energy consumption. The processing of "real-time energy usage and costs, alert residents to high energy use, and offer energy-saving tips" (National Climate Change Secretariat, 2016, p. 22). Moreover, sea surface temperatures are getting monitored and in public spaces temperatures and humidity which can then activate e.g. smart fans. In general, the focus is on smart homes, and Singapore is motivated to enhance their IoT and sensor networks.

The data shows little significance of the last dimension “smart lighting".

Smart City

Singapore is focusing on the “smart environment” dimension, closely followed by the “smart living” one. “Smart mobility” on the other hand, plays no role. The analysis shows a big concern about “temperature”, “water usage” and “weather”, as wet seasons are going to become wetter and dry seasons drier. However, the biggest concern is extreme rainfalls, which leads to flooding and can damage technological infrastructure. Singapore is defined by coasts and the coastal areas are not high above the sea level. In the 1960s and 1970s, the island state had to fight major flooding, which led to heavy investments “in drainage, bringing down the number of flood-prone areas significantly” (Ministry of the Environment and Water Resources, 2016, p. 16). Due to climate change, Singapore is hardening its structure further, e.g. through floodwalls and its reclamation projects must be at least four meters above sea level. Rising "temperatures" and the associated risks are taken very seriously. Especially dry spells and the "health" risks (heat stress) are a big problem. “The increased risk of heat-induced and vectorborne illnesses can cause [citizens] to fall ill more frequently” (Ministry of the Environment and Water Resources, 2016, p. 7). Besides, food and drinking water security are in danger and the danger through fires increases, while forests are declining. Regarding "water usage", the data shows a big focus on sewers and managing wastewater, especially in case of flooding. That is, why the city has a stormwater management system. Another issue is the improvement of efficiency for used water treatment. Taps and urinals for example are being water fitted to make them more efficient. To ensure sufficient drinking water, water conservation programs are being created and the "Four National Taps" is working on diversifying water supplies and expanding the source capacity. “Green spacing” has little significance in the data, the biggest concern is about protecting biodiversity, conserving mangrove trees, and expanding cycling spaces. In general, the analysis shows a big concern about the impact that climate change will have on the operation of e.g. telecommunication, power, or transport, compared to the other cities.

In the analysis, the second dimension “smart living” shows an equal concern about “housing/buildings" and "health". The latter focuses on heat-induced illnesses and the general effects of rising temperatures on health. To tackle this, the city develops a "heat index and advisories for the public" (Ministry of the Environment and Water Resources, 2016, p. 31). Besides, food and water supplies are being strengthened. In "buildings/housing", the key idea is to achieve energy efficiency through smart home technology and to climate-proof buildings. The "BCA's Green Building Masterplans aim to reduce carbon emissions and increase sustainability in Singapore's buildings. Recognising that tenants consume about 50 per cent of energy in a commercial building." (National Climate Change Secretariat, 2016, p. 16)

Lastly, “smart mobility” is solely focused on “efficient transport”. Again, measures to achieve energy efficiency are key. However, issues about flooding of underground stations are a big concern, as well as raising coastal roads.

4.1.1. Conclusion

The analysis shows a different approach that stakeholders take towards green technology. Copenhagen wants to be seen as “green”, which impacts their way of including green technology in their city. New York is big on using green technology in collecting data, but it has not found its way into new yorkers’ everyday life. Singapore on the other hand is achieving this with no problem. The Hypothesis (H1) made in chapter three can be supported, that the stakeholders deploy green technologies differently depending on their city´s environmental factors. This will also get clear in the following.

For Singapore, the significance of green technology is extremely high, merely by the geographical and historical situation. Due to their lack of space, they try to find smart solutions and historically, Singapore has always been a pioneer technological breakthrough. They are focusing on research and innovation to level out their natural disadvantages e.g. in the renewable energy sector. Singapore clearly wants to be a pioneer, which increases the significance of green technology for them. Moreover, smart tech does not only have meaning in their industry, it has arrived in the every-day life of citizens through smart home applications. The concern about their citizens' health is high and stakeholders are turning to green tech for help.

For New York, green technology has significance in a field that plays little role in Singapore. Within the transportation sector, it does not only help to make transport more efficient, but it allows stakeholders to make public transport more convenient for users. This focus makes absolute sense, as New York is massively dependent on their working transport system. Significance of green technology in buildings is on the rise, the stakeholders´ motivation is clear, but the conditions are completely different than for Singapore. For the stakeholders in New York and Copenhagen, it is politically not as easy as for Singapore to expand new smart technology. New York focuses a lot on sensor technology to collect data and provide real-time services. Moreover, stakeholders seem to attach meaning to green technology to be a guide and tool to become more resilient (e.g. the use of AI in future assessments). Green technology is supposed to help making New York "healthier", through better air quality or fewer traffic fatalities.

Copenhagen is a bit different. It seems, that they are still trying to figure out their meaning of green technologies that fit their "green city" image, hence all their green space/green road projects. They do see it as a great business opportunity, a way to save money and as a way, similar to New York, to increase their flexibility and resilience. In general, the significance of green technology is lower compared to the other cities, as Copenhagen uses many "older" technologies like district heating. Moreover, they focus a lot on alternative methods like retention roads, expanding cycling, or their cloudburst management. However, their motivation to achieve new things, like the water meters, is extremely high and stakeholders acknowledge the high significance that green technologies can have for buildings.

4.2. Opportunities of green technologies for climate mitigation and climate resilience

This section will build on the previous but specify the findings on both mitigation and resilience strategies. The findings will show what opportunities green technologies offer for both strategies and how different the focus is in different cities. To gain insight, Table 2 is used to determine which strategy is more important in which city. The interpretation of citations of Table 3 will lead to the input about the opportunities.

Copenhagen

The data analysis shows a huge emphasis on “climate mitigation strategies” in Copenhagen. Variables from both dimensions co-occur throughout all documents, but this is mostly due to Copenhagen´s constant assurances that they want to be proactive.

Within mitigations strategies, “carbon neutrality” has a big significance. Stakeholders declare that their goal for the city is to become carbon neutral by 2025. Besides the carbon-neutral goal, the documents show a huge awareness of “GHG emissions”, especially when it comes to health impacts. With the objective to cut emissions, the data shows that the main goal is to create economic green growth. To achieve this objective, a clear strategy can be recognized. Due to its huge contribution to emissions, the focus is on expanding the “public transport” and “cycling” sector. The variables "efficient transport" and "public transport" co-occurred often, showing the ambitions to cut congestions, improve road space, and improve (public) transport. The second part of the strategy is Buildings. The goal is to make them more energy-efficient, especially through tools like district heating.

The analysis shows an equal focus on all three variables within the Dimension “resilience”. “Reducing damage” is focused on harm through massive volumes of water. This will be achieved through "relieving the pressure on the sewer network" (The City of Copenhagen, 2015, p. 6). Huge investments are required, but the city seems confident that it will repay itself through the reduced damage.

Figure 7 Green Roads (The City of Copenhagen (2015, p. 29)

The co-occurrence with the variable “weather” and “water usage” make Copenhagen’s strategy to reduce the scale of future climate events truly clear. Warning systems for rain are used, the establishment of watertight basements, sandbags, and the adaptation of public spaces so that they can store rainwater. The latter is in line with the strategy to use the “greening of the city’s surfaces as an effective way of lowering the city’s surface temperatures and contributes to reducing the [UHI]” (The City of Copenhagen, 2011, p. 43) The analysis also shows specific “emergency plans”. Copenhagen makes use of the hydraulic functions of retentions spaces and green roads to store big volumes of water (Figure 7). Moreover, they developed their own cloudburst management systems. These consist of cloudburst retention spaces/parks, cloudburst pipes and cloudburst roads, roads that can handle rainwater in case of cloudbursts, and bring it e.g. into the harbour. Moreover, there are emergency plans to deal with damage to buildings in case of heavy rainfalls. Lastly, the analysis showed a big concern about floods, which is why the key term “security” covers Copenhagen´s strategy of establishing dikes, building above sea level, locally adapting the sewer capacity, and expanding the local management of stormwater.

New York

The data shows a twice as high focus on “mitigation strategies” than on “resilience strategies”. Within the first one, the focus is almost exclusively on "GHG emissions". New York wants to "reduce greenhouse gas emissions by 80 percent by 2050 relative to 2005 levels" (City of New York, 2015, p. 12) and they have a clear strategy on how to achieve this. The biggest focus lies on cutting emissions in buildings, by making them as efficient as possible. The co-occurrences with "transport" and "cycling" point to multiple city projects, like "Midtown in Motion", which help cutting emissions through an efficient transport sector. Another method that is presented is the shift towards renewable energies in forms of e.g. rooftop solar panels. In line with this is the task, to expand grid-scale energy storage. Lastly, the data show a confident outlook on the opportunities of green spacing. Next to the goal to cut emissions, the goal to become “carbon neutral” by 2050 is relatively insignificant within the analysis. To achieve this, the city acknowledges, that it “will require a radical shift to end [the] reliance on fossil fuel.” (OneNYC 2050, 2017, p. 10) This is underlined by the huge co-occurrences with “renewable energies” and “public transport”, which show the goal to create jobs through the mitigation strategy. However, one could point out, that the whole strategy is built around the goal to save and make money.

“Resilience strategy” is presented as especially important. Within the strategy, the clear focus lies on “emergency plans”. Stakeholders present multiple plans, like the “building emergency plan” and the “Climate adaptation Roadmap”. The latter is based on scientific studies and future scenarios and is supposed to visualize and prioritize future climate hazards. Moreover, the NYC app provides advice on emergency plans in general. The data show a big co-occurrence with both “flooding” and “weather”, which showcase the focus on increasing the availably of deployable floodwalls, levees, permanent floodwalls, and pipe treatments to prevent backflows. Another big focus is on “health”, especially through evacuations of medical buildings like hospitals. The key terms “reduce damage” and “security” are insignificant. The latter mainly consists of real-time alert systems and hardening the infrastructure against flooding, whereas the first is concerned about reducing the health damage through heat and the property damage through flooding.

Singapore

The analysis shows a twice as high focus on climate mitigation than on climate resilience strategies. Within “mitigation”, the awareness on “GHG emissions” is huge (figure 8). Especially the role of the industry and its big energy consumption is recognized. The strategy lies in cutting energy use and therefore emissions in the power generation sector and the industry. This is linked to the key term “energy consumption”, which shows a big effort to educate households on their energy consumption and how they can become more efficient. The data show a small sign of "carbon neutrality", but the text showcase four strategies that Singapore employs for this goal. First, improving the energy efficiency e.g. through retrofitting buildings, secondly, reducing carbon emissions from power generation, thirdly, developing and demonstrating cutting-edge low-carbon technology, and lastly, responding to challenges of climate change through unity.

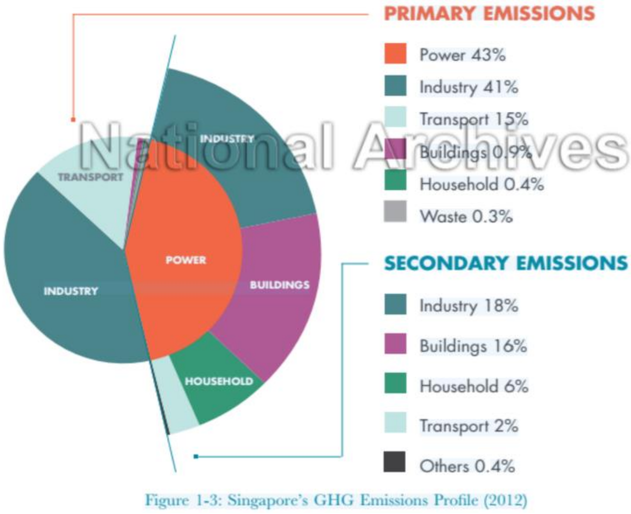

Figure 8 Singapore’s GHG Emissions Profile (2012) (National Climate Change Secretariat, 2016, p. 19)

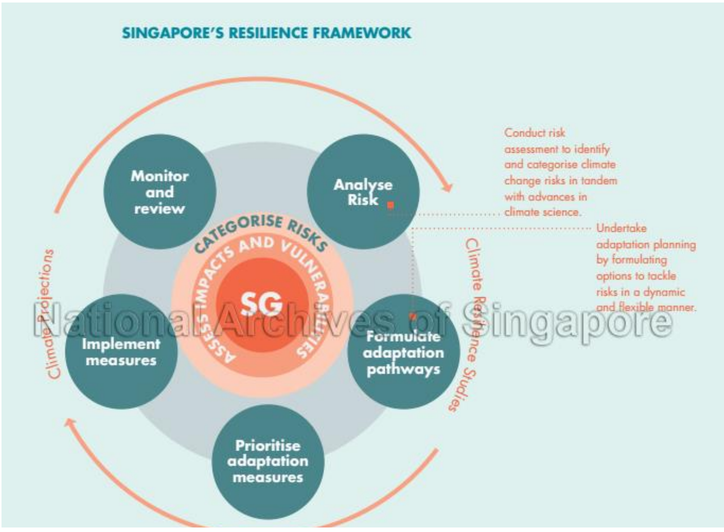

Figure 9 Singapore´s Resilience Framework (Ministry of the Environment and Water Resources, 2016, p. 9)

The focus within the “resilience” strategy is on "security" and "reducing damage": "To adapt to the impacts of climate change, we have developed a range of adaptation measures, designed with the protection of Singapore and Singaporeans in mind." (National Climate Change Secretariat, 2016) Therefore, Singapore developed a resilience framework (figure 9). Within “reduce damage”, the co-occurrence with “flooding” and “temperature” is very high, because the damage through flooding and the heat stress on the information system must be reduced. Within "security", the co-occurrence with "buildings/housing" is high, because their safety is endangered through high temperatures and strong winds, as well as through flooding. The strategy here is to inspect infrastructure regularly and raise coastal roads, reclamation levels, and floodwalls.

4.2.1. Conclusion

In chapter two, it was assumed that all cities put more emphasis on resilience than on mitigation strategies (H2). However, this section has shown a clear focus in all three cases on climate mitigation strategies. This can be explained on the one hand through the cities goal of becoming carbon neutral. On the other hand, Resilience is often seen as a flagship project and as something that is important, but one has still time to expand it in the future. Due to the similar focus on mitigation, similarities in how the stakeholders envision opportunities for green technologies can be recognized, which can form the basis of best practices. However, differences have been shown as well.

Within climate mitigation strategies, all three analysed cases show a focus on sensor-based technology. They all recognize the opportunity that they offer to save emissions and achieve energy efficiency. Two deployment areas can be accounted for. On the one hand, real-time data processing is used in transportation in forms of digital signs or traffic signals to achieve less congestion and an efficient way of driving (e.g. TSP and Midtown in Motion in New York). On the other hand, water meter reading systems are used to save residents money, achieve efficiency, and also involve citizens through the visualization. Another way that green tech is used to save energy is through applying it to buildings (e.g. solar panels, lighting) and making them into “smart homes”. An interesting way to make heating and cooling more efficient is demonstrated by Copenhagen. Their use of thermal heart from waste management through thermodynamic technology is named district heating and contributes a great deal in achieving energy efficiency. At the moment they are working on district cooling networks, which would be especially interesting for Singapore. They on the other hand are leading in the field of smart lighting. Their 3M Channel Lighting System is presented as an innovative way to save energy by "using proprietary films that capture and reflect light from LEDs to illuminate a room”. All three cities regard green technologies in the same way when it comes to mitigation strategies: they are supposed to make procedures more (energy, water, etc.) efficiency, which than in turn is supposed to help mitigate climate change.

Within climate resilience strategies, the cities show different approaches to how they envision green technology use. Copenhagen is focused on managing water masses with the opportunities that green technology offer. Their intelligent sewer pipes are linked to the weather radars and can react to e.g. heavy rainfalls. Moreover, they deploy retention spaces with their smart hydraulic functions are able to deal with excess water masses. On top of that, they have their own cloudburst management, which is partly supported by smart technology features. The warning system for rain/weather is based on real-time data procession and serves to protect the citizens. Both Singapore and New York use this technology in different forms, but with the same goal in mind. New York extended it through real-time alert systems. Besides, they developed a feature in their app, which advises on emergency plans. This is in line with their overall aim of using green technology to protect their citizen, especially their health. Their smart air pollution monitoring shows that. Singapore has a similar approach, as they too see opportunities for improving their citizens' health and safety in tech. Through their automated cooling systems, mostly in public spaces, green technology helps in reducing heat stress. Moreover, Singapore´s awareness is big on the effect heat can have on technological equipment, which is why they try to use green technology in removing heat from servers, etc. ("direct liquid immersion").
All three cities see the opportunities of green technology in keeping their city and its citizens safe, they just envision it in different fields. Copenhagen focuses on managing water, whereas New York and Singapore focus on improving the general health of their population.

4.3. Role of green technologies in climate mitigation and resilience strategies

This section aims to combine the outcomes of the last sections to determine, how the role of green technologies differs in the cities. Therefore, the findings of significance and meaning will be combined with coding scheme three and the typology from chapter two (Appendix B).

For Singapore, green technology is a pioneer project and they focus a lot on innovation. Green tech is playing a role in every-day life and it is integrated into the life of every citizen. The typology shows that green tech plays the role of automating and coordinating. For instance, their cooling systems in public spaces are automated. However, the typology shows, that it is impossible to attribute one role for one city. Singapore is using green technology in their communication and their information collecting role, a focus is hard to pin down. For New York, the focus is a bit clearer on communication. Through their different apps and the water meter system, they use green technology mostly in its communication role. As mentioned before, this makes sense, as New York is focused on transportation and collecting data. Even if they use green tech more for climate mitigation strategies, they are working towards expanding it to resilience measures, especially when it comes to buildings. New York and Copenhagen have the similarity, that they see green technologies to save money and expand the economy. Singapore on the other hand is more concerned about expanding research. Copenhagen is not as far as the other cities. Their focus is, like New York, on mitigation strategies, but they see the opportunities green technologies offer for resilience. They focus on the role of automation and coordination, but on a different level than Singapore. Automation is used in the sewer and transportation system.

Lastly, the assumption that Stakeholders focus on the economic role that green technologies play can be supported partly (H3). It has been shown that all three cases focus on different economic factors, for instance, research is increased in Singapore whereas New York and Singapore widely focus on saving money and boosting the city’s economy. However, in none of the cities is the economic role predominant.

4.4. Conclusion

This chapter aimed to answer the three research questions about opportunities, meaning, and role of green technologies. They all were sufficiently answered. The significance is highest in Singapore and lowest in Copenhagen. Moreover, the different opportunities that green technologies offer for mitigation and resilience were extensively presented. Lastly, the differences in both the meaning and the role of green technologies have been illustrated.

5. Conclusion

The goal of this research is to answer the research question about what role technologies play within climate mitigation and resilience strategies of Smart Cities. A specific role cannot be generalized. Every city uses green tech differently. As already marked in the theory, Smart Cities are very individual and guided by their environment. The research supports this, as Singapore is focusing on heat-induced problems, Copenhagen and New York more on weather-induced ones. Green technology plays an economic role in all three cases. Again, the focuses are quite different. Singapore regards green tech as a research field whereas the other two cities see its economic role in saving money and expanding business.

Generally speaking, all cities focus on the role that green technologies can play within mitigating climate change and achieving carbon neutrality. Using green tech to make procedures (water etc.) more energy efficient is the focus of all cities. However, differences were found in the role stakeholders attribute to green technologies. For Singapore, green technology plays the role of improving the citizens' everyday life, while also functioning as flagship and supporting their position as a pioneer. For them, they offer great opportunities to solve the problems they have due to geographical space. New York seems to attribute green technology the role of achieving climate mitigation goals. For a megacity like them, green technologies offer huge opportunities to solve transportation and pollution problems. Using them, New York is making its public transport system more user-friendly. Lastly, for Copenhagen, the role is harder to pinpoint, as the significance of green tech is lower than for the other cities. They are still trying to figure out how to use green technologies and keep their "green" image. Therefore, green tech plays mostly the role of automation and coordination. Moreover, Copenhagen uses green technologies to underline their aspiration to be proactive.

An interesting finding is that even though all cities use green technologies to become more climate resilient, the focus is overwhelmingly on mitigation strategies. This paper struggles to find a reason for this. A possibility is, that the fatal impacts of climate change are still in the future so mitigation actions are more urgent. Another could be, that New York and Copenhagen are just getting started using green technology and the first logical focus is on mitigation strategies. A further finding is, that green technology is not regarded as the solution for climate change. All cities deploy many other methods, besides technological ones. For instance, Copenhagen is focusing on green spaces and roads to deal with major flooding. New York is reclaiming wetlands and Singapore is raising its coasts.

As already elaborated, this research is in line with the literature highlighting the individual character of Smart Cities. Capra makes it clear within his theocratization of Smart Cities, that the smart characteristics always have a different degree making the application of green technologies unique as well (2014). The analysis of the climate strategies also shows, that even though mitigation is the focus, both strategies should be used in combination. This is in line with Galderisi stating that mitigation and resilience are complementary but differ in their objectives and scales (2014).

This research must reflect upon some of its limitations. Qualitive primary data cannot be analysed statistically which makes it hard to get clear findings. This is emphasized through the limited number of cases looked at in this paper. The research tries to counter this, with the careful selection of these cases, trying to get a global view on green technologies in Smart Cities. Another weakness of the data that should be considered is the source of the data. When it comes to governmental projects that are connected to a lot of prestige, like Smart Cities, using primary data can be problematic. These documents were made for the public with a focus on self-portrayal, which could lead to biases coming in the research. However, the scope of this paper does not allow in-depth interviews with stakeholders or a field analysis of the cases. Therefore, the researcher trusts the honesty of the stakeholders in their publications and keeps the possibility of biases in mind. Further research could pick this up and conduct interviews with Smart City stakeholders to deepen findings on the research question of this paper. Another topic, building on this research´s topic, could be to research the effectiveness of green technologies to achieve the goals of climate mitigation and resilience. Lastly, the question about the focus on mitigation could be studied, as this research struggled an to find an answer.

The findings of this research can be translated into practical implications, which are presented in form of best practices. The following technologies stood out during the analysis and could act as inspiration for other stakeholders to make their city more efficient and resilient. The first being sensor-based technology, especially Singapore's. Through lighting sensors across the city, general energy consumption is being displayed. Not only does this catch people's attention to the topic, but it generates a shift of behaviour. This shift is supported by their applications which use real-time data on energy usages and costs. This gives citizens a great incentive to get active against climate change themselves. The second is New York´s TSP (Transit Signal Priority). This urban traffic management system improves the efficiency of bus transportation, making public transport more reliable and more attractive. Furthermore, it allows the city to work towards the goal of cutting emissions. Lastly, Copenhagen is using smart sensor technology in sewer pipes. The sewer management is improved by linking the control mechanisms to weather radars so that they can automatically open and close in case of extreme rainfalls etc. This does not only reduce the risk of flooding but also improves general water quality.

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7. Appendix

Appendix A: Coding Scheme explained

Concept	Dimension	Key terms
Smart City	Smart environment	*Water usage*; this includes the treatment of wastewater, sewers, rainwater catchment areas, groundwater and drinking water
		Green space; this includes green roads, parks, pedestrian zones, biodiversity and waldsterben
		Weather; mainly about rain, precipitation, storms and wind
		Temperature; this includes heat, Urban Heat Islands and air quality
		Flooding; does not fall under weather, because of its importance on its own
	Smart mobility	*Efficient transport;* means the quality of infrastructure and roads
		Traffic; means the efficiency of traffic e.g. due to congestions
		Mobility; means the opportunities to be mobile within the city e.g. car parks and cycling
	Smart living	*Buildings/Housing*; all about building infrastructure, especially about smart home
		Lifestyle; everything connected to free time, comfort and accessibility
		Health; about human health (e.g. traffic fatalities, heat stress) and health infrastructure

Concept	Dimension	Key terms
Climate strategies	Mitigation	*GHG emission;* includes any kind of emission
		Energy consumption; includes any consumptions form industry to households
		Carbon neutrality; is mainly about the goal to become carbon neutral, carbon footprint or carbon neutral technologies
	Resilience	*Reduce damage;* mainly covers warning systems and insurance
		Emergency plan; every kind of plan and evacuations, dams, roads for water etc.
		Security; covers the anticipating of crisis e.g. flooding

Concept	Dimension	Key terms
Green technologies	Green buildings	*Renewable energy;* every measure to achieve cleaner energy (e.g. solar panels)
		energy efficiency measures; every measure from industry to household to become more energy efficient
		Heating/Cooling efficiency; every measure to optimize heating and cooling systems
		Water Meters; every water meter reading technology
	smart lightning	*LED lamps;* every technology to make lighting more efficient
		Connected lamps; the technology of connected lamps
		Road lighting; everything about traffic and road lighting
	Smart mobility	*public transport;* every technology to optimize the public transport sector

		hybrid vehicles; every measure to increase the usage of hybrid/electric vehicles
		Sensors/Monitoring; every sensor technology (e.g. traffic warning systems)

Appendix B: Typology

	Copenhagen	New York	Singapore
Information collecting role	1.real-time processing of bus data for digital signs at bus-stops 2. “[r]emote meter reading[s] of heat consumption [to] identify plants with unusually high consumption.”	1.monitioring status of facilities 2.air quality monitoring	1.monitoring of sea surface temperatures 2.monitroing of temperature and humidity in public spaces
Communication role	1.use of real-time data for online journey planners	1.Water meter reading system for citizens 2.Midtown in Motion 3.PowNYC	1.Water meter reading system for citizens 2. Light sensors across the city are used to display energy consumption 3. “real-time energy usage and costs, alert residents to high energy use, and offer energy-saving tips”
Automation and Coordination	1.use of real-time data for keeping bus lights green 2.intelligent sewer pipes 3.district heating 4.district cooling	1.solar panels 2. use of real-time data for keeping bus lights green (TSP)	1.renewable energies (e.g. waste to energy plants) 2.”direct liquid immersion” 3.automated cooling in public spaces 4. 3M Channel Lighting System

Appendix C: Documents for the Analysis

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Appendix D: Data from atlas.ti

Smart City characteristics

.	Copenhagen Gr=1552; GS=6	New York Gr=3732; GS=6	Singapore Gr=239; GS=7	Total
● **Flooding** Gr=1537	13	1507	17	1537
● **Green space** Gr=58	27	23	8	58
● **Temperature** Gr=134	9	101	24	134
● **Water usage** Gr=384	65	293	26	384
● **Weather** Gr=182	52	105	25	182
● **Efficient transport** Gr=20	8	6	6	20
● **Mobility** Gr=2	2	0	0	2
● **Traffic** Gr=164	39	125	0	164
● **Health** Gr=334	20	292	22	334
● **Housing/Buildings** Gr=998	73	902	23	998
● **Lifestyle** Gr=13	3	8	2	13
Smart environment Gr=2157; GS=5	149	1932	76	2157
Smart living Gr=1320; GS=3	95	1179	46	1320
Smart mobility Gr=186; GS=3	49	131	6	186
Total	604	6604	281	7489

Climate mitigation and resilience strategies

.	Copenhagen Gr=1552; GS=6	New York Gr=3732; GS=6	Singapore Gr=239; GS=7	Total
● Energy efficiency measures	15	17	26	58
● Heating/Cooling efficiency Gr=117	73	42	2	117
● Renewable energy Gr=96	41	41	14	96
● Water Meters Gr=11	1	6	4	11
● Connected lamps Gr=0	0	0	0	0
● LED lamps Gr=36	23	11	2	36
● Road lighting Gr=12	1	9	2	12
● Hybrid vehicles Gr=29	5	20	4	29
● Public transport Gr=532	492	31	9	532
● Sensors/Monitoring Gr=59	7	27	25	59
Green buildings Gr=273; GS=4	129	102	42	273
Smart lighting Gr=48; GS=3	24	20	4	48
Smart mobility Gr=616; GS=3	504	75	37	616
Total	1315	401	171	1887

Significance of green technologies

.	Copenhagen Gr=1552; GS=6	New York Gr=3732; GS=6	Singapore Gr=239; GS=7	Total
● **Energy efficiency measures**	15	17	26	58
● **Heating/Cooling efficiency** Gr=117	73	42	2	117
● **Renewable energy** Gr=96	41	41	14	96
● **Water Meters** Gr=11	1	6	4	11
● **Connected lamps** Gr=0	0	0	0	0
● **LED lamps** Gr=36	23	11	2	36
● **Road lighting** Gr=12	1	9	2	12
● **Hybrid vehicles** Gr=29	5	20	4	29
● **Public transport** Gr=532	492	31	9	532
● **Sensors/Monitoring** Gr=59	7	27	25	59
Green buildings Gr=273; GS=4	129	102	42	273
Smart lighting Gr=48; GS=3	24	20	4	48
Smart mobility Gr=616; GS=3	504	75	37	616
Total	1315	401	171	1887