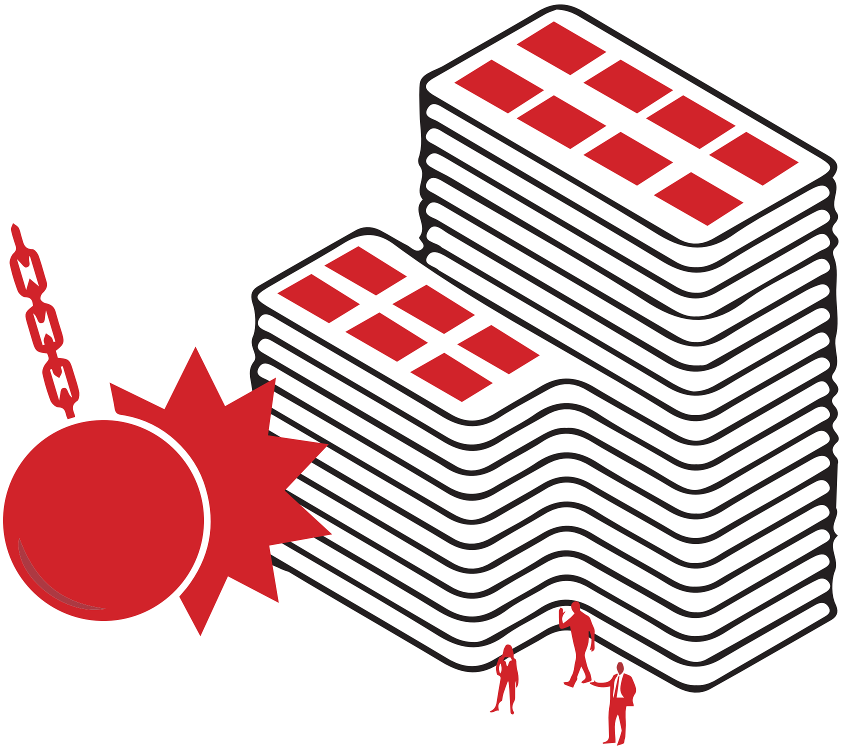


Beyond label C

The proposed policy evaluation of office building adaptation towards nearly zero-energy buildings

Master thesis - Saskia Geerts - TU Delft - June 2019

Beyond label C: The proposed policy evaluation of office building adaptation towards nearly zero-energy buildings

Master thesis
June, 2019

Delft University of Technology
Faculty: Architecture and the built environment
Master track: Management in the built environment

Supervisors
1st mentor: Dr. H.T. Remøy
2nd mentor: Prof. dr.ir. H.J.Visscher
External examiner: Dr.ir. H. Sohn
Arcadis: L. Rodenhuis and B. Karabulut

Author
Saskia Geerts (4280172)
Saskiageerts@msn.com
+31 (0)6 21 39 87 34

Beyond label C

The proposed policy evaluation of office building adaptation towards nearly zero-energy buildings

Contents

Definitions

Office: For this research an office is seen as a building that is built especially for office work and the primary function of the building is dedicated to offices work. Also, monuments are not part of the office definition of this research.

Adaptation: Adaptation is; "any work to a building over and above maintenance to change its capacity, function or performance in other words, any intervention to adjust, reuse, or upgrade a building to suit new conditions or requirements". (Douglas, 2006)

NZEB: The Energy Performance of Building Directives obligates member states to build nearly zero-energy building from 2020 onwards. In the Netherlands NZEB is better known as BENG, Bijna Energie Neutrale Gebouwen. The EPBD defined BENG buildings as: "…a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby'' (EPBD recast, 2010).

Building typology: "The term "building typology" refers to a systematic description of the criteria for the definition of typical buildings as well as to a set of exemplary buildings representing the building types.'' (TABULA, 2012a, p.7)

Preface

During one of my first design projects in architecture, I was surprised by the easiness of designing an environmentally friendly building. Adding solar panels, window shading, high efficient glass, insulation and heat pumps were business as usual. However, in practice, I didn't see all of this happening. Soon I was triggered by the complex nature of the building process, especially when it came down to sustainable buildings. During my internship at the Central Government Real Estate Agency, I experienced this complex nature of sustainable adaptation. How can offices in the inner city, with little roof surface for solar panels become energy neutral? How can the users be accommodated during the adaptation? What is the best way to measure sustainability?
To achieve the climate goals of the Dutch National Climate Agreement, 200.000 buildings need to be adapted each year. This comes down to 1000 buildings each day. These days, a common question from the public is: 'Who is going to pay the bill of these adaptations?' I think, an evident question. Office owners should adapt their houses to label C, in 2030 to label A and in 2050 to nearly zero-energy buildings. But what if they can't pay? What if they don't have the right knowledge? The climate transition not only affect how we should adapt our buildings, it also affects how we life, eat, transport, work and so on. This has direct my interest towards sustainable policies. How can we create policies for a better sustainable environment, while also taking the consequences for the people into account?

This has led me to my graduation topic. I want to contribute to a more sustainable built environment, while taking the consequences for the people into account. To achieve large impact on the energy efficiency of the buildings stock, I focus on the implications of a regulative policy to achieve nearly zero-energy offices. In this master thesis, I want to learn more about the practical implications of NZEB office adaptation and thereby show to complexness of the adaptation of existing buildings towards nearly zero-energy buildings.

I want to thank my both mentors, Hilde Remøy and Henk Visscher, for their feedback and support and giving me the opportunity to get some insight in the research funding process. I also want to thank Leandra, Başak, Jeroen, Simon, Ronald, Victor and all other colleagues from Arcadis. I am really thankful, that they gave me the opportunity to work at their offices and shared their broad knowledge and experiences. Besides, I want to thank Martin Tenpierik, Paula van den Brom, Philip Koppels and Jelger Arnoldussen. I really appreciated all the help I got and the time they took to share their knowledge. Furthermore, I want to thank all the interviewees, that were willing to share their experience and perspectives on the topic. And of course I want to thank my parents Marcel and Irene, my brother Jeroen, Matthijs, Marieke and Anoek and other friends for their support, feedback and valuable distraction during my studies.

Saskia Geerts, Delft, June 2019.

Executive summary

Beyond label C

The proposed policy evaluation of office building adaptation towards nearly zero-energy buildings

Introduction

The built environment consumes almost 40% of the overall energy consumption. Energy is often produced from the conversion of fossil fuels, which result in CO2 emissions, which in turn cause global warming. Therefore, adaptation of buildings towards less energy use is required to mitigate the effects of global warming. Since the adaptation of existing buildings could play a large role in achieving the climate goals, policies are made in order to stimulate these adaptations. The 'Energy Performance of Building Directive' promotes the adaptation of all existing buildings towards nearly zero-energy buildings (NZEB). Currently, offices need to have at least an energy label C by 2023. It is expected that this will increase to label A in 2030 and finally NZEB in 2050. However, the current adaptation rates are too low to achieve NZEB buildings in 2050. Besides, the step-by-step approach from label C to A to NZEB leads to even more pressure to the adaptation sector. If these multiple steps could be skipped, adaptations could be executed more efficient, which reduces costs and time. It could be questioned whether the current policy approach is sufficient to achieve nearly zero-energy offices on time. Therefore, this research will go 'beyond label C' and test an alternative policy of going directly towards NZEB, starting from existing offices with a current energy label G. The research question is as follows: What are the technical, financial, environmental and social implications of the proposed policy requirement of NZEB adaptation of office buildings with a current energy label G? The aim of the thesis is to show the complexity of implementing a regulative policy and thereby giving recommendations for policy makers.

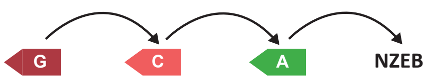


Figure S1: Current step-by-step policy (Author, 2019)

Figure S2: Proposed direct policy (Author, 2019)

Method

To answer the main research question, the following four themes are explored: office stock, energy policies, building adaptation and office owners. To explore the four themes, different methods and techniques are used. The different methods and techniques are framed within an experimental research design. An experimental research design consists of a dependent and an independent variable to indicate the causal relation between the results. The independent variable will be the proposed policy, which influences the office owners, the depended variable. An experimental research design also consist of a control group, which is not exposed to the proposed policy. In this research, the results will be compared to the implications of the current label C requirement, studied by the Economic Institute for buildings (EIB). A literature review, data analysis, calculations and case study interviews are used to execute the experiment. Literature was mainly used to identify a topic and to provide context to the experiment. Data was analyzed to get inside in the Dutch office stock and create office typologies. Calculations were used to calculate the investment costs, energy savings and payback period. Case study interviews were used to find out what the implications for office owners are.

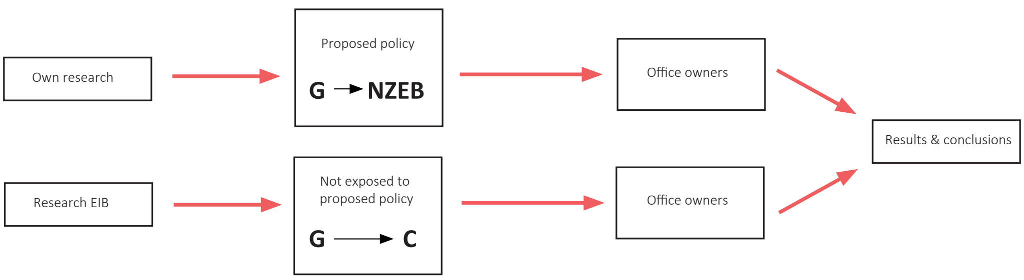


Figure S3: Experimental research design (Bryman, 2016, adapted by author)

Results
In exploring the research question, four main themes were defined. The findings for each theme are summarized.

Office stock: How can office typologies be created, in order to represent the office stock sufficiently for testing the technical consequences of the proposed policy?
The findings from the first theme suggest that the office stock holding a current energy label G can be represented by four typologies. The typologies are characterized by the construction type and compactness. This leads to a compact and non-load bearing, compact and load bearing, non-compact and load bearing and non-compact and non- load bearing type. The typologies are used to execute the calculations of the building adaptation.

Energy policies: How can nearly zero-energy offices be determined? Which other policies have influence on the implementation of the proposed policy?
In conclusion, the findings suggest that the determination method to achieve nearly zero-energy offices consists of three indicators: the maximum energy demand, maximum primary fossil energy use and minimum percentage of renewables. Besides, the provisionary norms for new office buildings can be used to implement the proposed policy, because the norms for new buildings are also applicable for major renovations. The aims from the Dutch National Climate Agreement will largely influence the proposed policy. It is quite certain that the tax for electricity will be lowered and the tax for gas will be increased. The two scenario's, presented in the Dutch Climate Agreement, will be used to calculate the payback period of the implemented measures, needed to comply with the proposed policy.

Building adaptation: What techniques and investments are needed to achieve nearly zero-energy offices? What are the energy savings and what is the payback period?
Technically, existing offices with a current energy label G can be adapted towards NZEB. However, major adaptations are needed. This results in the need for big investments ranging from 353 to 414 euros per square meter. On the other hand, major energy and CO_2 savings are achieved. Adaptation of the entire Dutch office stock will result in 3.1 PJ energy savings and 0.6 to 0.7 CO_2 emission reductions. When looking at the payback period achieved by these energy savings, the payback period is ranging from 22 to 32 years. Next, adaptation from label G to label C is investigated. This requires 39-52 euros per square meter, which will lead to 2.4 PJ energy savings and a payback period of 3 to 4.5 years. The adaptation towards label C lead to 42 MJ savings for each euro invested. For the adaptation towards NZEB this is only 8 MJ. The label C adaptation is approximately 5 times more cost efficient than adaptation towards NZEB.

Owners: What are the implications of the proposed policy for office owners?
Adaptation results in nuisance for the owners because the users need temporary accommodation. Besides, a large share of the office owners will not have the financial possibilities to adapt their building towards NZEB, because the needed investments costs are unreasonable high compared to the rent income. As an alternative, owners will choose vacancy or demolishment. However, for offices located in an increasing office market, the NZEB adaptation is more likely to be feasible. Especially, when technical opportunities arise, such as a nearby datacentre, which can be used for heat waste. The results from the interviews showed that the location, technical opportunities, the personal situation of the investors, the vision of the investor regarding sustainability, the real estate strategy and the possibilities to change the land use plan are important factors that influence the decision making of the office owners.

Conclusion
Technically, the adaptation from label G to NZEB is possible. Financially, the adaptation results in the need for big investment and payback period of more than 20 years. Environmentally, the NZEB adaptation results in large energy and CO_2 savings. Socially, the adaptation results in nuisance for the users and the neighborhood. Office owners have to demolish, sell or leave their building vacant. It can be concluded that the proposed adaptation policy will not lead to the desired effect of nearly zero-energy office buildings because the office owners do not choose to adapt their building but prefer to leave the building vacant or even demolish it. The direct NZEB adaptation requires temporary accommodation and major investments. A large part of the offices will become vacant or demolished, since the adaptation costs are too high compared to the rent values. However, for offices located on locations with high rent levels, the direct NZEB adaptation is more likely to be feasible. Especially, when technical opportunities arise, such as a nearby data center, which can be used for heat waste. Nevertheless, these findings suggest that lots of office owners will not be able to adapt their offices directly towards NZEB. Therefore, it is not possible to generalize such a regulative policy for all offices.

Recommendations
Based on the findings, the following recommendations can be made:

1. Involve office owners when evaluating policies
A policy can be created for a more sustainable future, but without involving the owner, it can lead to negative effects, such as vacancy and demolishment.

2. Focus on the continuation of rent income during policy evaluations
The office owners are most interested in the continuation of rent income, instead of the payback period based on the energy savings, because the payback period is not reliable. It is difficult to estimate the energy prices in the future and often a gap is found between the calculated energy used and the real energy use.

3. Create visions for the future of office locations
Offices in a decreasing office market at industrial locations will not be able to adapt towards NZEB and municipalities are often reluctant to change the land use plan to housing. This will result in lots of vacancy. To overcome this, municipalities can create visions for those locations and thereby be more flexible with changing land-use plans, if it promotes the sustainability of existing buildings.

4. Make use of other policy tools at a differentiated approach
The label C requirement is perceived reasonable by office owners and will result in minor vacancy. On the other hand, to oblige the NZEB regulations for all existing offices, this will result in major vacancy and other negative impacts that will not contribute to a better environment as well. Nevertheless, the case study interviews showed that the adaptation is more likely to be feasible in a increasing office market, such as in the city center of Amsterdam. To conclude, it can be recommended to stick to the label C requirement and use other policy tools to stimulate the adaptation towards NZEB. This stimulation should start at offices that are willing and capable of the adaptation. They can show the advantages, stimulate innovation and hopefully the next group will follow.

Discussion
This study showed that to achieve NZEB offices, it is not possible to simply implement a regulative policy. This chapter discusses the significance of the conclusions of this research within a broader context of energy policies. Lots of challenges, insecurities and innovations are going on in the energy industry, such as the challenge of the distribution and storage of energy, the way of dealing with the gap between theoretical and real energy consumption, the need for technical and process innovations and many more. It even could be questioned whether this whole top down method of compulsory adaptation is the right way of governance. These are all important issues that were excluded from this research but do influence the adaptation of office buildings. Other limitations of the research include the absence of the embodied energy within the calculations, the generalization of office typologies that miss out technical or creative opportunities and the reliability of the database, due to lack of data about renovations.

1

Introduction

1.1 Introduction

This master thesis explores the implications of a proposed policy to achieve nearly zero-energy offices. The introduction chapter described the research background and research questions. First, background information about the energy consumption, energy policies and stakeholders in the office stock is described, leading to a problem statement, an alternative policy and the research questions. The chapter is concluded by the scientific and social relevance.

1.2 Energy consumption in the office stock

The western society depends a lot on energy, especially made from fossil fuels (Dobbelsteen & Tillie, 2011). By using fossil fuels, CO_2 emerges, which impacts global warming. In the Netherlands, only 6,6% of all energy produced is from renewable sources. Comparing to other member states of the European Union, the Netherlands scores the second lowest on renewable energy production (Eurostat, 2017).

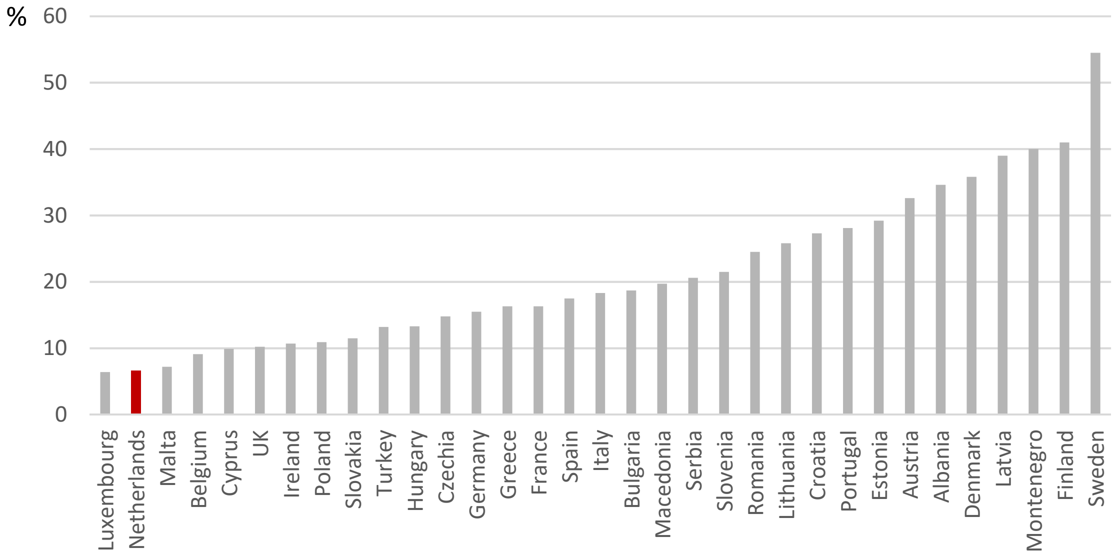


Figure 1.1: Share of energy from renewable sources in the EU Member states (Eurostat, 2017)

Adaptation of office buildings is important to mitigate the effects of global warming. Significantly, the built environment is one of the largest contributors to global warming. It consumes almost 40% of the overall energy consumption in the European Union (EPRS, 2016). Besides, 87% of the building stock needed in 2050 is already built (Wilkinson & Remoy, 2015). Therefore, adaptation of the existing building stock could play a major role in achieving the climate goals. Although only 25% of the European buildings stock is non-residential (BPIE, 2011), it consumes over 40% of the energy consumption (European Commission, 2016). Over a quarter can be assigned to the office stock (BPIE, 2011).

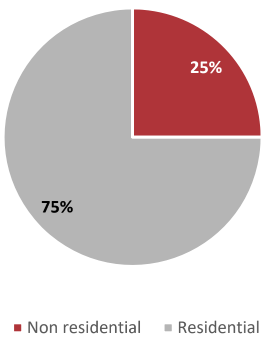


Figure 1.2: Share residential and non-residential in Europe (BPIE, 2011)

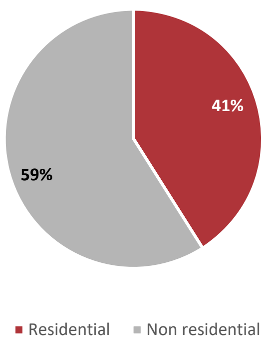


Figure 1.3: Share energy use in Netherlands (European Commission, 2016)

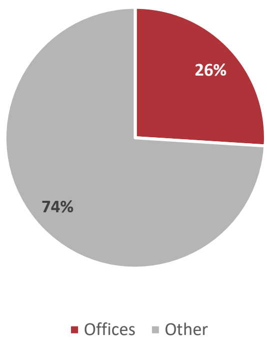


Figure 1.4: Share energy use offices in Europe (BPIE, 2011)

Currently there are over 7 million dwellings and over 1 million non-residential buildings in the Netherlands (CBS, 2019). There are almost 17.000 office buildings, these office buildings are larger than 500 m2 and built after 1950. Figures 1.5 shows the deviation of energy labels within the office stock.

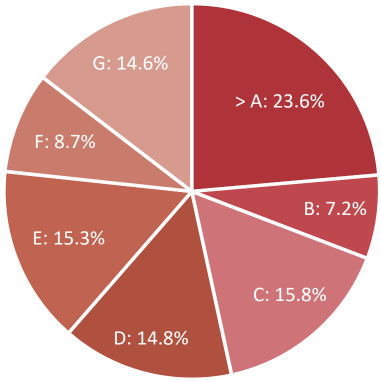


Figure 1.5: Label deviation office stock 2019, based on BAG and label database RVO

The biggest share of the office stock has an energy label A or higher. This looks quite promising. However, these buildings are often recently built and little investments are needed to achieve higher energy labels. The biggest challenge lies in the oldest stock. This part needs major adaptations to comply with current regulations and ambitions.

In order to generalize the adaptation techniques, this research will focus on office buildings with a current energy label G. Adaptation techniques for these office buildings can be generalized because no attention was given to thermal insulation, therefore major adaptation techniques are needed. Offices with a current energy label G can be characterized by single glass, natural ventilation, no or little insulation and are often built before 1975 (Sipma, Kremer & Vroom, 2017). Around 1975, double glass, insulation and mechanical ventilation was introduced. This resulted in major improvements of the energy demand. The use of insulation from 1975 onwards can be traced back to the oil crisis in the 70s. The oil prices increased enormously and resulted in the use of better insulation of buildings (Thijssen, 1990).
The energy efficiency of existing buildings is measured by using the energy index. The energy index is a Dutch energy performance indicator, used for existing buildings. The energy index is connected to an energy label. Table 1.1 shows the different energy labels, their energy index and the theoretical gas consumption. Also, the large improvement of gas consumption between label F and G is seen.

	After 2015	Mean gas consumption [m3/m2]
A	<= 1.20	6.7
B	1.21 – 1.40	9.1
C	1.41 – 1.80	11.2
D	1.81 – 2.10	13.2
E	2.11 – 2.40	16.0
F	2.41 – 2.70	18.6
G	>2.70	28.5

Table 1.1: Energy labels, energy indexes and gas consumption (RVO, n.d.a: Sipma, Kremer & Vroom, 2017)

1.3 Energy policies for existing buildings

To challenge global warming, the Paris Agreement is made during the yearly conference of the United Nations Framework Convention on Climate Change in 2015. At this moment, 180 parties have signed the agreement. This agreement aims to keep the average rise of global temperature below 2° C (UNFCCC, n.d). Also, the Netherlands signed the agreement and responded to it, by the so called 'klimaattafels' [Climate Tables]. This resulted in the Dutch National Concept Climate Agreement, consisting of 600 proposals. The Dutch National Climate Agreement aims to decrease the CO_2-eq emissions with 49% by 2030 with reference to 1990 (Klimaatakkoord, 2018). All greenhouse gas emissions are recalculated to CO_2 equivalenten. In figure 1.6, the greenhouse gas emissions in the Netherlands from 1990 untill 2035 are shown (NEV, 2017). In 1990, the Netherlands used 228 Megaton CO_2-eq. With current policies, the CO_2-eq emission in 2030 should be around 165 Megaton. This means the Climate Agreement will be concerned for the remaining 49 Megaton.

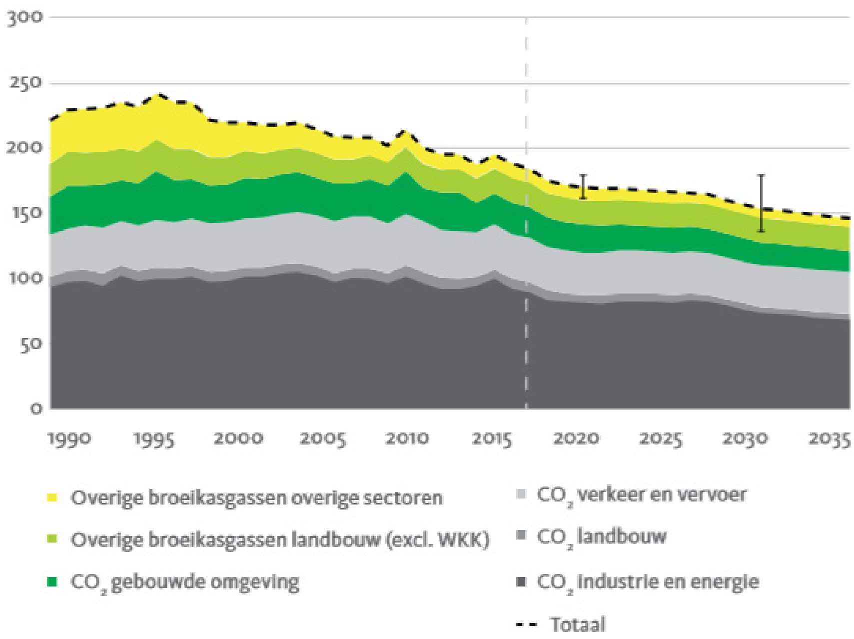


Figure 1.6: Mton CO_2 Equivalents Netherlands (NEV, 2017)

In 2018, a new Climate Act is introduced, that requires the Government to realise policies to reduce 95% of the CO_2 emissions in 2050 (Klimaatwet, 2016). Due to the increasing earth quakes in Groningen, the use of gas fields will be reduced and finally closed by 2030 (Wiebes, 2018). Adapting the existing building stock could play a large role in achieving the climate goals. To achieve the climate goals, major changes need to occur. For example, electricity needs to be produced by renewable sources, buildings need to have high level insulation, make use of heat pumps, connect to district heating and make use of geothermal heating (Ostermeyer et al., 2018).

Since the adaptation of existing buildings could play a large role in achieving the climate goals, policies are made for the existing building stock. The Energy Performance of Building Directive (EPBD) promotes the adaptation of existing buildings towards nearly zero-energy buildings (NZEB). The EPBD is the main policy tool of the European Union for the new and existing building stock. They state that member states should establish a long term-strategy to assist the adaptation of the building stock and promote the cost-effective adaptation of existing buildings into nearly zero-energy buildings (European Union, 2018). Nearly zero-energy buildings are buildings that have a very high energy performance and the nearly zero amount of energy used, is generated to a significant extent by renewable sources (European Union, 2010). Member states should establish norms that indicate cost-effective adaptation of existing buildings (European Union, 2018). Besides, the existing building stock plays an important role in the Energy Efficiency Directive as well. They obligate member states to mobilize investment in renovation of the existing building stock and come up with a long-term strategy (European Union, 2012). In the Netherlands, this resulted in the

Energy Agreement in 2013. The starting point of the Energy Agreement is that building owners should have their own responsibility and interest for energy saving solutions, but they need assistance by doing so. The assistance exists of a combination of awareness and giving information, unburdening and financial support (NEEAP, 2017). However, a formal regulation appeared to be necessary to achieve the energy targets from the energy agreement, because voluntary measures, tax incentives and subsidies were not sufficient. Therefore, the Dutch Government implemented the obligation for offices to have at least an energy label C by 2023. This new legislation is published in 'het Staatsblad' at the 17th of October in 2018 and is regulated by the Dutch building code (Ollongren, 2018). It is expected that this policy will increase to label A in 2030. Another policy for existing buildings is the requirement of having an energy label when selling or leasing a building. This legislation came into force in 2008 (BEG, 2016). One more policy is the 'Activiteitenbesluit milieubeheer'. This policy obligates companies to take energy saving measures with a payback period lower than 5 years (Activiteitenbesluit Milieubeheer 2.6, 2007). Figure 1.7 summarizes the existing policies for offices.

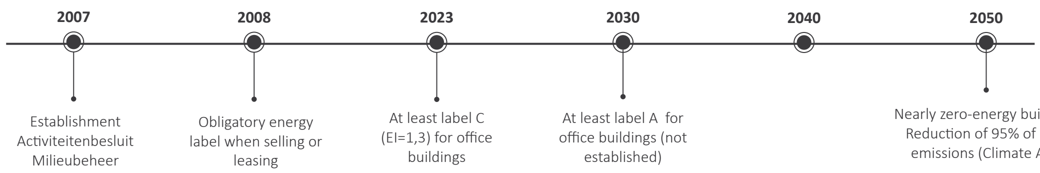


Figure 1.7: Current regulated policies for existing buildings (Author, 2019)

1.4 Stakeholder decision making

To comply with the regulations and to achieve the goal in 2050, adaption of the building stock is needed. Adaptation of a building is complex due to multiple stakeholders with different perspectives. For example, an investor wants a return on investment, while the user wants the adaptation to be in line with the current demand of the market. Moreover, the different stakeholders make decisions at different moments in time and have different levels of impact (Wilkinson et al., 2009). Different perspectives include social, technological, environmental, financial and legislative criteria. Previous studies show that these perspectives are the most important drivers for office adaptation (Wilkinson, 2013). According to Wilkinson (2012) a successful renovation demands that all former perspectives are considered. If policy makers want to influence the nearly zero-energy adaptation of office buildings, they should be aware of the decision-making process of the different actors. The stakeholders in the adaptation process are identified by Douglas (2006), based on Nutt (1993). He identified six groups of stakeholders.

Participant	*Involvement*	*Examples*
Investor group	Those who arrange capital to fund adaptation projects and purchase buildings.	Banks, finance companies, insurance companies, pension funds.
Producer group	Those who design, specify, cost and execute adaptation projects.	Architects, builders, engineers and surveyors.
Marketing group	Those who find users for buildings and buildings for users.	Estate agents and surveyors.
Regulator group	Those who ensure compliance with the statutory requirements.	Building control, fire authority, health and safety executive.
User group	Those who occupy, manage and use the building.	Individual users, Facilities and maintenance managers.
Developer group	Those who undertake some or all of the investor, producer and marketing roles above.	Contractors, development companies.

Figure 1.8: Stakeholders in adaptation process (Douglas, 2006)

This research will mainly focus on the investor group, since they are the owner of the property and therefore primarily affected by the policy requirements. Besides, they have the option to choose what to do with their premises, because adaptation is just one option to respond to the new policy requirements.

Office owners will take other options also into consideration. Other options are:

- Transformation to another use
- Demolish
- Demolish and new built
- Selling
- Leave building vacant (based on Douglas, 2006; Geraedts, van der Voordt & Remoy, 2017)

1.5 Problem definition

The aim of the Dutch National Climate Agreement is to decrease the CO_2 emissions with 49% by 2030 and 95% by 2050. To achieve the goals for the built environment of the Dutch National Climate Agreement, 1,000 buildings need to be adapted each day (Klimaatakkoord, 2018). However, the current adaptation rates of less than 1% per year are too low to achieve the required 2.5% to 3% per year (Ostermeyer et al., 2018). Therefore, it will become a challenge for the construction industry to adapt all buildings on time. The current step by step approach from label C to A to NZEB leads to even more pressure on the construction industry, since the adaptation is divided into multiple adaptation moments. If these multiple steps could be skipped, adaptations could be executed more efficient, which reduces costs and time

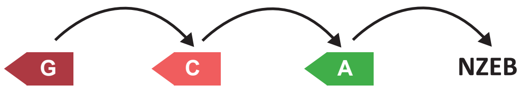


Figure 1.9: Current step by step policy (Author, 2019)

Ouwerkerk (2017) indicates that the step-by-step approach is a 'dead end walk'. If all low hanging fruit is already been picked, there is little investment left to take the step towards NZEB. To achieve label C, an investment of 860 million euros is needed. Seven years later, another 1,4 milliard euros is needed to achieve label A (Arnoldussen et al., 2016). Also, from label A to nearly zero-energy will require big investments. When following this step by step approach, investments can appear to be disinvestments when the next renovation is needed (Ouwerkerk, 2017). However, an advantage of the step-by-step approach is the opportunity to wait for better efficiency of techniques, which will decrease the needed investment costs (Van Hoek & Koning, 2018). Nevertheless, if all building owners wait to renovate towards NZEB, this will not stimulate the scale-up of innovations that are needed to achieve NZEB (Leidelmeijer, de Wildt, Borsboom & van Vliet, 2017).
In conclusion, it could be questioned whether the step-by-step policy is sufficient to achieve nearly zero-energy offices in 2050 because the current step-by-step approach leads to even more pressure on the construction industry. If these multiple steps could be skipped, adaptations could be executed more efficient, which reduces costs and time. Therefore, this research will go 'beyond label C' and test an alternative policy of going directly towards NZEB, starting from existing offices with a current energy label G In figure 1.10 the proposed policy is visualized.

Figure 1.10: Proposed policy (Author, 2019)

1.6 Proposed policy: beyond label C

As described in the former sub-chapter, an alternative policy need to be tested because the current step-by-step approach is not sufficient to achieve the goals for the office stock on time. The proposed policy is therefore a policy that goes directly towards nearly zero-energy offices, in order to execute the adaptations more efficient, which reduces costs and time.

To clarify the proposed policy, it is a regulative policy and forbids office owners with a current energy label G, to use or to start using an office building without complying with the NZEB standards after 2024.

This means, office owners have five years to achieve the NZEB standards. According to Arnoldussen et al. (2016) office owners prefer to have a term of five years and choose their own moment of adaptation instead of the obligation to adapt the building during mutations of the users. It is often thought that the adaptation could best take place during mutations of the tenants because the owners already need to invest and no tenant would be in the building during mutations. Nevertheless, over 60% of the office buildings are multi-tenant buildings. If one tenant leaves, still other tenants will encounter nuisance or needs to be temporarily replaced (Arnoldussen et al., 2016).

Figure 1.10: Proposed policy (Author, 2019)

1.7 Research questions

The aim of this thesis is to provide insight in the complexity of implementing a regulative policy and thereby giving recommendations to policy makers. Consequently, this research will investigate consequences of an alternative regulative policy of going directly towards NZEB. The main research question is defined as: What are the technical, financial, social and environmental implications of the proposed policy requirement of NZEB adaptation of office buildings with a current energy label G?

Technical, financial, social and environmental can be widely interpreted. Therefore, these terms are defined as follows:
Technical: The technical implications will include the techniques needed for office adaptation.
Financial: The financial implications of the policy requirement will involve investment costs, payback period and the implications for the owners.
Social: The social implications will involve the implications for the neighbors, owners and users.
Environmental: The environmental implications contain energy and CO_2 savings.

To find out what the implications are, four important themes will be explored. These themes are: office stock, energy policies, building adaptation and office owners. For each topic, sub-questions are defined. To answer this research question, four themes are explored. First, insight is provided in the current office stock which is used to create office typologies that represent the Dutch office stock, holding an energy label G. Second, the determination method of NZEB offices is explored and other policies that have influence on the proposed policy will be investigated. To find out what the implications of the required adaptation are, the techniques, investment costs and energy savings needed are studied. Last, the implications for the office owners are studied.

Office stock: How can office typologies be created, in order to represent the office stock sufficiently for testing the technical consequences of the proposed policy? (Chapter 3).
- How can an 'office' be defined?
- What parameters should be used when defining typologies?

Energy policy: How can nearly zero-energy offices be determined? Which other policies have influence on the implementation of the proposed policy? (Chapter 4)

- What determination method can be used to determine NZEB offices?
- What other policy tools are available?
- How does the Dutch National Climate Agreement influences policies for the offices stock?

Building adaptation: What techniques and investments are needed to achieve nearly zero-energy offices? What are the energy savings and what is the payback period?(Chapter 5)

- What techniques are available to adapt offices?
- What are the costs of those techniques?
- How much energy will it save?
- What are the payback times of energy neutral adaptations?

Office owners: What are the implications for the owners? (Chapter 6)

- What are their perspectives and how do they make decisions?
- What factors will influence the decision making of the owners?

Conceptual model

Below the conceptual model of the research is presented. This model shows the causal relations between concepts. The proposed policy requirement to directly adapt office towards NZEB will influence the decisions making of the office owners. The decisions of the office owners is based on different perspectives. These perspectives are financial, social, environmental, technical and legislative. Finally, the office owner will make a decision what to do with their property. These decisions are for example: transformation, adaptation or demolishing.

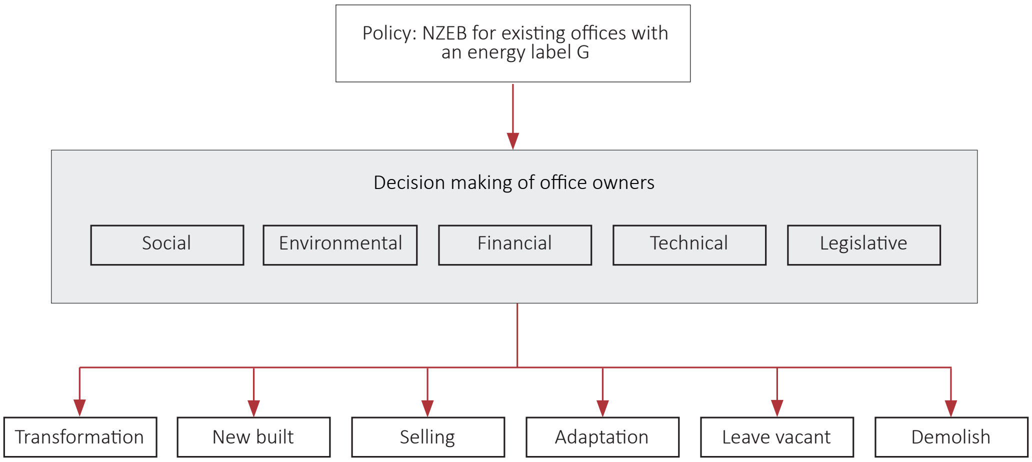


Figure 1.11: Conceptual model (Author, 2019)

1.8 Added value of the research

Scientific relevance

The implications of a required label C and followed by label A is already studied by Arnoldussen et al. (2016). They studied the needed technical measures, invesment costs, energy savings, payback period and the implications for the stakeholders. Their results shows a positive return on investments and 8,6PJ energy savings for the total Dutch office stock. Moreover, the energy saving measures will mainly consist of improvements of installations, this results in little nuisances for the user and the neighborhood (Arnoldussen et al., 2016). However, to achieve NZEB, deep renovations are needed. The implications of adaptation towards NZEB is not researched yet. Consequently, in this research, the implications to go directly towards NZEB will be tested.

In the third chapter of this research, office typologies will be created to test the policy. Already from the 90s, building typologies are created to test policies in the Netherlands. Lots of data and reference buildings are available for the residential building stock. However, data on the existing non-residential building stock is marginal. In the research of Arnoldussen et. al (2016), they used only one reference building to measure the energy savings and the associated costs. This reference building is a mid-sized building of 4320 m2 and three floors high. From the research, it is unclear why this building geometry is chosen as a reference building. According to Raiji, Tenpierik & van den Dobbelsteen (2017) the geometry factors are important to consider, because they can influence the energy use up to 32% and thereby also the investment costs and payback times. Therefore, the geometry factors are important to consider, when using reference buildings. This research will try to add to the existing knowledge by creating office typologies that represent the Dutch office stock, holding an energy label G.

Currently, a lot of development is taking place around policies for energy efficient buildings. For example, in the Netherlands, the energy efficiency for new buildings is now measured by the Energy Efficiency Coefficient (EPC), but from January 2020 onwards, the EPC will be replaced by the nearly zero-energy building regulations (EPG, 2018). Also, the concept of the Dutch National Climate Agreement is presented in 2018 (Klimaatakkkoord, 2018). This research will use the new determination method for buildings and takes account of the aims of the Dutch National Climate Agreement. Thereby this research add to the existing knowledge, since not many researches in the field of energy policies for buildings already took acount of this new measurement method and goals of the Dutch National Climate Agreement.

Social relevance

To challenge global warming, the Paris Agreement is made. This agreement aims to keep the average rise of global temperature below 2° C (UNFCCC, n.d). To keep the average rise of temperature below 2° C, the CO_2 emissions should be reduced. Since the building industry is responsible for a large part of CO_2 emissions, big opportunities for the adaptation of building arise to achieve large savings. This research will test an alternative policy, in order to execute the adaptations more efficient compared to the current policy. This alternative policy seeks to accelerate the process of office building adaptation and thereby contribute to the achievement of the Paris Agreement.

This research could be of relevance for policy makers since it provides insight in the complexity of implementing a regulative policy. This complexity consists of the perspectives of the office owners and techniquel, social, environmental and financial consequences. Insight on these topic can help policy makers to make deliberate decisions or to develop futher research. This research also studied the factors that influence the decision making of office owners, when a regulative policy is enforced. This provides useful insight for the government on the perspectives of office owners. This is of major importance, since it is the public, in this case the office owners, that should implement the policies of the government.

2

Method

2.1 Research themes

With the aim to find out the implications for the policy requirement of NZEB adaptations for existing office buildings, four different themes are explored. The four themes are based on the following subsequent order: First, insight is provided in the current office stock which is used to create office typologies that represent the Dutch office stock, holding an energy label G. Second, the determination method of NZEB offices is explored and other policies that have influence on the proposed policy will be investigated. To find out what the implications of the required NZEB adaptation are, the techniques, investment costs and energy savings needed are studied. Last, the implications for the office owners are studied. Based on this order, the structure of the thesis is divided into the following four themes:

- The office stock
- Energy policies
- Adaptation
- Office owners

Due to this subsequent order, the evaluation of a policy looks like a linear process. However, evaluating a policy is an iterative process. For example, the findings from the office owners will provide feedback for the policy. But also the results from the adaptation will provide feedback for the policy. To explore the themes, different methods and techniques are needed. The different methods and techniques are framed within an experimental research design. This chapter will first explain the experimental research design. Afterwards, the needed methods and techniques are described. Finally, the structure of this thesis is discussed.

2.2 Research design: Quasi-experiment

The research design will provide the framework for the collection and analysis of the data (Bryman, 2016). This research will be an evaluation research of the implications of a proposed policy for the Dutch office stock with an energy label G. This will be indicated as an experiment. According to Bryman (2016), experiments are quite unusual in social studies. However, they are sometimes used to test and evaluate new policies. To test the implications of a proposed policy, the dependent and independent variable are needed, to indicate the causal relation between the findings. The factor that has the casual impact, is indicated as the independent variable and the effect, is the dependent variable. In this study, the proposed policy is the independent variable and the office owners the dependent variable.

To be able to execute an experimental research the independent variable needs to be manipulated, to find out if the NZEB adaptation requirement does have an effect on the office owners. Two groups are formed, one group is 'manipulated' with the proposed policy and the other group is not exposed to the manipulation and functions as the control group. Both groups are observed by their dependent variable: the office owners. Preferably, both groups are randomly assigned, so the only difference between the groups is the experimental treatment.

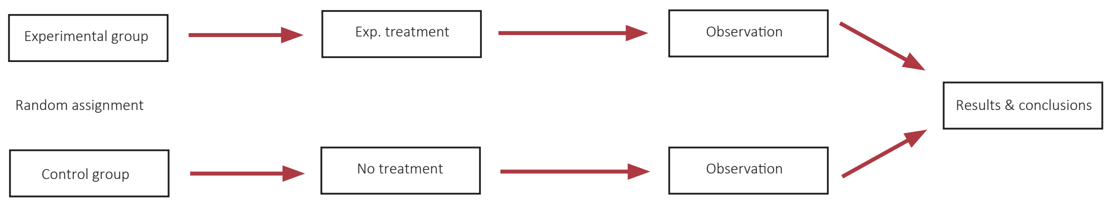


Figure 2.1: Experimental research design (Bryman, 2016, adapted by author)

However, often there are practical difficulties when executing a true experiment. Therefore, Bryman (2016) also draws attention for the 'quasi-experiment', whereas the research design has the characteristics of an experiment, but doesn't fulfill all requirements. In this research, no random assignment of the groups are executed. The control group, will be based on the research of the economic institute for building, EIB. In figure 2.2, the research design for this research is presented.

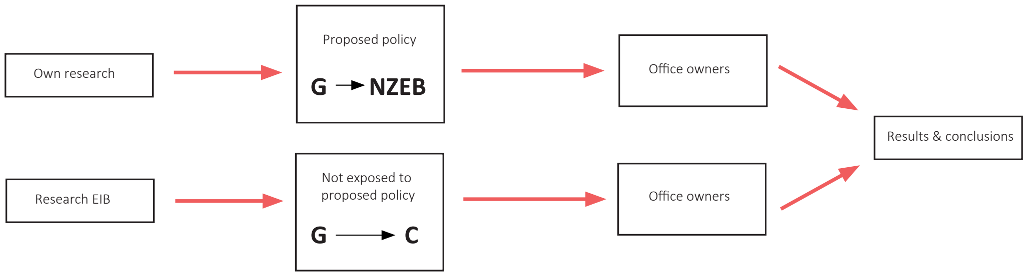


Figure 2.2: Experimental research design (Bryman, 2016, adapted by author)

The findings from the experimental treatment and observations of the implications of the office owners will be used for the results. These will be compared with the results of the research of the EIB. The results will compare the technical, environmental, financial and social implications for the proposed policy and the current policy. The technical, environmental and financial implications will be derived from the experimental treatment. The social implications will be derived from the stakeholder decision making.
Within this research design, different methods and techniques are used. For example, to create office typologies, literature is studied and data on the office stock is analyzed. To manipulate the experimental group, calculations are made to calculate the investment costs and energy savings. The execution of the research design is visualized in figure 2.3.

As presented in figure 2.3, the research design is quite extensive and lots of research on different topics is researched. This was necessary, in order to execute the experiment, since no information was available about sufficient typologies, the needed investment costs, energy savings and payback times. This is evidents, since the revised preliminary NZEB norms, used for this research are just published in 2018. To make the structure more comprehensible and allow the reader to follow the steps made in this research, the research is divided into the four themes mentioned in chapter 2.1. The themes correspond with the phases from the experimental research design. The four themes are indicated in red in figure 2.3.

2.3 Methods and techniques

Literature review

Normally, a thesis consist of more or less the following structure: introduction, method, literature review, results, conclusion and discussion. The literature review is often preliminary to the research as an exhaustive review of the literature in relevant areas. However, a literature review can play different roles in a research (Bryman, 2016). This master thesis doesn't start with a literature review, but the findings from the literature are divided within different themes. The literature review took place simultaneously with the data analysis and case study interviews. The literature helped to focus the quantitative data analyses and this data analyses influenced the literature review as well. For example, the quantitative data analyses showed a lot of old buildings indicated as offices but built as for example churches. Therefore a literature study is executed about the definition of an office building. Such a strategy is often called iterative: (Bryman, 2016) weaving back and forth between different methods and techniques, to finally add to the existing body of knowledge.

Bruce (1994) identified six ways of conceptualizing a literature review. One is the facilitator: '*The literature review can be understood as directly related to the research that is about to be or is being undertaken, the process helping the researcher to identify a topic, support a methodology, provide a context, or change research direction. The review thus helps to shape the course of the student's research*'. In this research, literature was mainly used to identify a topic and provide a context to be able to execute the experiment. Since writing a master thesis is a learning project and new topics were explored in the literature, it also shaped and changed the research direction multiple times.
Due to this learning process, the process of reviewing the literature is an uncertain process of discovery. This results in that you might not always know in advance where it will take you. This type of reviewing the literature can be regarded as a narrative review, which tend to be less focuses and more wide-ranging in scope than systematic reviews (Bryman, 2016).

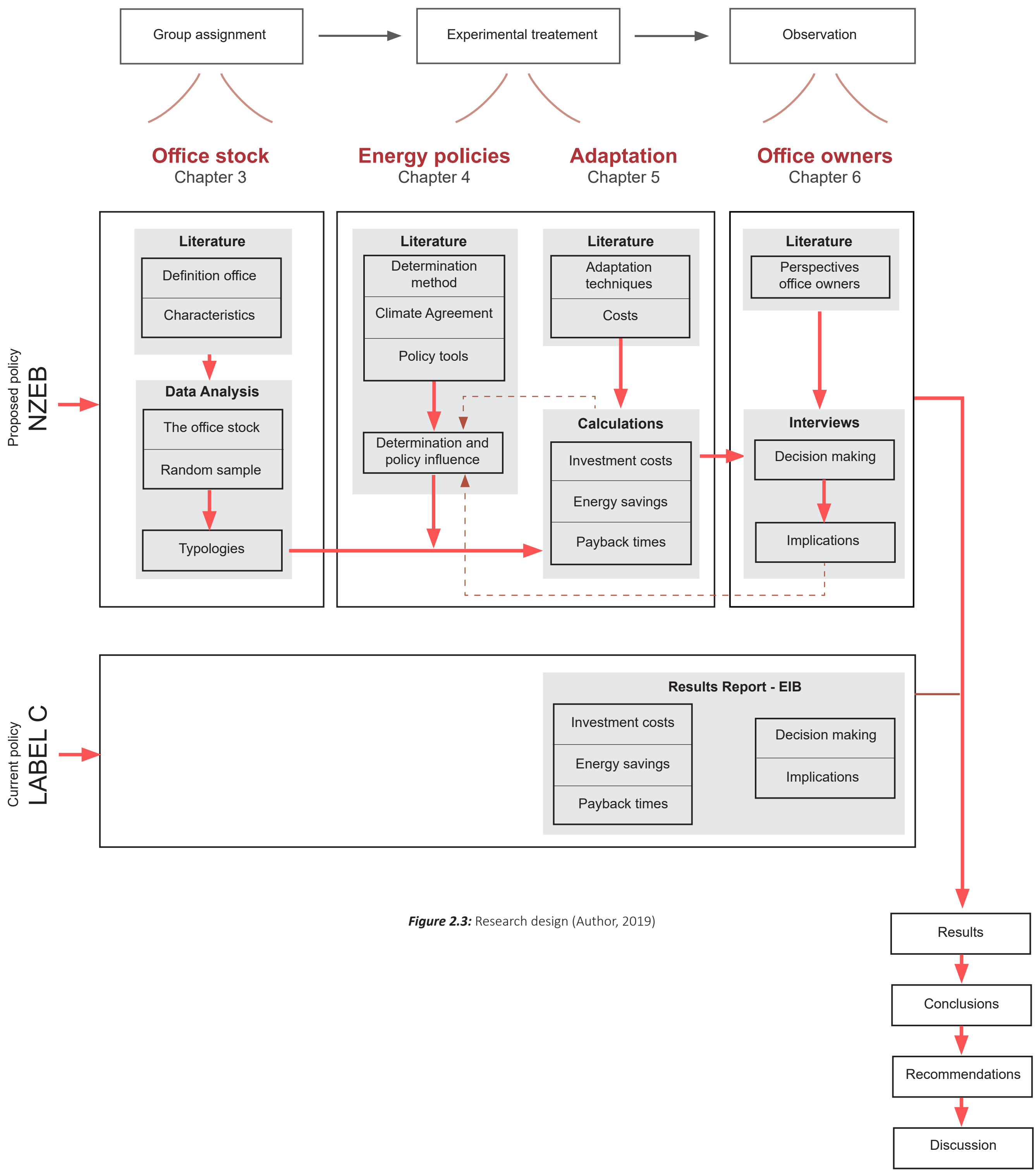


Figure 2.3: Research design (Author, 2019)

Studied literature
Lots of different literature is studied during the literature review, ranging from policy documents from the European Union to study books about building physics. To start the research and find out what policies already exists, mainly documents from policy documents from the Dutch Government and the European Union are studied. To find out how energy efficiency is measured, norm documents of the NEN are studied. To determine what energy saving measures are needed, study books of building physics, written by several teachers from the department of Building Technology of the Faculty of Architecture at the TU Delft are used. Besides, product information from construction suppliers are studied, to indicate the performances of the measures. To calculate the investment costs, building costs databases from Arcadis are used. In addition, master thesis', dissertations, study books and so on are studied as well.

Data analyses
This chapter about the office stock aims to create office typologies in order to test and evaluate the proposed policy. To do this, first literature is reviewed on how an office can be defined and what offices will be subjected to the policy. After that, literature is studied to find out the important characteristics, in order to represent the office stock. To give insight in the existence of these characteristics in the office stock, data is analyzed by means of a random sample.

Used data
In the Netherlands, lots of data on the building stock is available. However, the right data needs to be selected and adapted to make it valuable for this research. To get insight in the Dutch office stock, three databases are used:

- the 'Basis Administratie Gebouwen' (BAG)
- Energy labels
- Monumental lists

The first database used is the BAG. The BAG is part of the Dutch Government System and gives insight in all registered addresses in the Netherlands. The municipalities are responsible for the take up of the data. The data is maintained by the 'Kadaster'. The data is publicly accessible via the 'BAG viewer' and can be downloaded as XML file, which is often used to transfer large datasets. The data gives interesting information of each address. Each address is for example connected to an object, function, building date, municipality and province (Kadaster, n.d.a).
The second database used is the energy label database, maintained by the Dutch Government. Energy labels are required for existing buildings when selling or leasing a building. This legislation came into force in 2008 (BEG, 2016). The Dutch Government maintains databases, with all registered energy labels by certified consultants. The energy labels are connected to a unique address. The databases are publicly accessible via the website of the Government. However, 65 % of the office buildings doesn't have an energy label yet. It could be expected that the current offices with an energy label doesn't represent the total stock, since offices owners with a high energy performance office are expected to apply for a label more frequently. To give an impression about the energy performance of the total office stock, energy labels based on the building age are added, see table 2.1. The labels are added according to the building code which was applicable at that date (Arnoldussen et al., 2016).

Building date	Energy label
1900 – 1973	G
1974 – 1981	F
1982 – 1992	E
1993 – 1999	D
2000 – 2003	C
2004 – 2005	B
2006	A
2007 – 2008	A+
> 2009	A++

Table 2.1: Building dates and corresponding energy label (Arnoldussen et al., 2016, adopted by author)

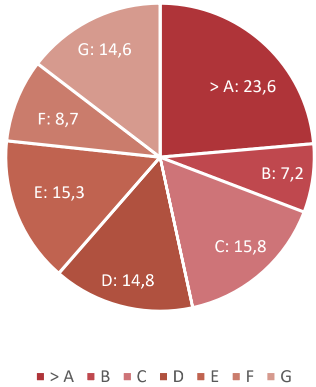


Figure 2.4: Energy label deviation, based on BAG, registered energy labels and added energy labels (Author, 2019)

The third database used is the database that involves all registered listed buildings. However, only 'Rijksmonumenten' are registered. The monuments indicated by the province and municipality are not publicly accessible. The sources and extract dates of the databases can be found in the appendix.

Data analyses

The three database are connected based on their unique address. In this way, the labels are added and the monuments are extracted. The BAG database consists of over 9 million addresses. To handle this amount of data, SPSS is used. After combining the databases in SPSS, analyses could be made. Also, a random sample is taken from the database. SPSS provides a specific tool for a random sample. This means, each building within the stock has a known chance of being selected. The random sample made it possible to find out till what extend the characteristics found in the literature occur within the office stock. The sample is analyzed by means of the characteristics found at street view. The envelope surfaces of the buildings from the sample are calculated by making use of the measurement tool of Google maps and the 'actueel hoogtebestand Nederland' (ahn). The floor area of the buildings was given in the BAG database.

Calculations

To be able to find out the investment costs needed, energy savings and payback times, calculations are made. To determine the energy savings, the energy savings measures found from the literature, are implemented in Uniec 2 software. This software is developed for certified professionals in order to issue energy labels. The results from the Uniec 2 software shows if the implemented measures achieve the NZEB standards and gives indications about the energy use. The investments costs are calculated for each typology defined during the data analysis. After calculating the investments costs and energy savings, the payback times are calculated.
During the calculations, different explorative interviews took place to support the findings from the literature and the calculations. The interviews took place with experts from Arcadis and TU Delft.

Case study interview

'It is essential that industry works together with Government to ensure that policy that is implemented doesn't lend itself to unintended consequences in behavior and instead is carefully aligned to driving real and achievable results throughout the sector.' (Deloitte, n.d.)

This is what is said by Bill Hughes, Managing Director of Legal & General Property, about the effectiveness of energy efficient policies. To test the effectiveness of the policy and find out what the implications for the office owners are, case study interviews will be organized. This research will mainly focus on the perspectives of office owners, since they are firstly affected by the policy requirements and have to make the decision what to do with their real estate. This part of the research focusses on how the proposed policy influences decision making of the office owners. Case studies are used to understand the complexity and particular nature of the case (Bryman, 2016). Case studies will help to define why decisions are made, how decisions are made, how they are implemented and what opportunities and risks are involved during decision-making processes (Yin, 2014). In this research, the complexity and nature will consist of different perspectives office owners and different characteristics of their real estate. The case studies will help to define how the proposed policy will influence the decision making of the office owners. The interviews will be semi-structured interviews and the structure is based on the different perspectives involved in successful office adaptation. The perspectives are social, technological, environmental, financial and legislative. The interviewees will be selected on the cases of the sample that is taken from the G label office stock. However, not all office owners from the sample where able to reach. So the selected cases are not randomly selected.

2.4 Structure of thesis

The following order is typical for the structure of a thesis: introduction, method, literature review, results, conclusion and discussion (Bryman, 2016). However, this thesis consists of four themes that can be regarded as small researches on its own because each theme explores the answer on one sub-question. Therefore, the structure of this thesis is defined by the four themes and the research design. The four themes, office stock, energy policies, building adaptation and office owners are explored in the mid part of this thesis. Each theme ends with an overview of the results and a conclusion on the sub-questions. The four themes, the chapters and the needed methods and techniques are visualized in the research design in figure 2.3. After studying the four main themes, an overview of the results is presented, followed by a conclusion, recommendations and a discussion.

3

The office stock

3.1 Introduction

In this chapter the following sub-question will be answered: How can office typologies be created, in order to represent the office stock sufficiently for testing the technical consequences of the proposed policy? "*The term "building typology" refers to a systematic description of the criteria for the definition of typical buildings as well as to a set of exemplary buildings representing the building types*.'' (TABULA, 2012a, p.7). This chapter aims to create office typologies, representing the office stock. This is important to test and evaluate the effects of the proposed policy during the experiment. The office typologies will be used to calculate the investment costs, energy savings and the payback period. To answer the research question from this chapter, first literature is reviewed to define an office definition for this research. This is needed in order to define which offices will qualify for the proposed policy and consequently, for which offices, the typologies should be created. Second, literature is studied to find out important characteristics in order to represent the office stock. To give insight in the existence of these characteristics within the office stock, data is analyzed. This data analyses starts with providing insight in the total office stock. Afterwards, a random sample is taken in order to define the existence of the defined characteristics, within the office stock. Finally, the results from the literature and data analysis are described. From there on, the office typologies are presented.

3.2 Office definition

In order to create office typologies, first the definition of an 'office' needs to be defined. For this research, an office is seen as a building that is built especially for office work and the primary function of the building is dedicated to offices work. This office definition is chosen to be able to generalize energy efficiency measures. For example, a residential building, but used as an office, will require a different adaptation method. This is evident, since the design of a building is strongly related with its function. For example offices are often designed within a grid of 1.35m, because this allows for efficient office furnishing (Knaack, Klein, Bilow, Auer, 2017). The term office is coming from the Latin word 'officium' and is inherited from the 15th century. It was used to indicate the place were clerks had to do their work. An example is the well known Uffizi in Florence, built in 1560. It was used as accommodation for the city council (de Gunst & de Jong, 1989).

Figure 3.1: Office activities before 1950 (de Gunst & de Jong, 1989)

The office building, as we know it today, doesn't have a long history in the Netherlands. Office work already existed for a really long time, however, it didn't take place in a separate building. Office work was normally performed within the factory building, warehouses or at home. From the beginning of the 20th century, the first separate office existed in the Netherlands. However, those offices looked not like the offices looks like today. The office activities took place in large rooms, with employees sitting on long tables, see figure 3.1. From the 1950s, the offices developed in offices with private rooms, connected with corridor. After the introduction of the air-conditioning and fluorescent lighting, the plan shape of offices was not only limited to natural light and ventilation. As a result, offices with a central core became more popular. Thereby, also open floorplans and flexible ways of working became possible(Van den Dobbelsteen, 2004). Since, offices as we know them today are built after 1950, office built before 1950 will be excluded from this research. Also, monumental offices are not part of this research, as they are subjected to strict rules for adaptation and therefore excluded from the proposed policy. To conclude, for this research an office is seen as an office:

- built after 1950;
- built especially for office work;
- whereas the primary function is dedicated to office work, this will be indicated as larger than 500m2;
- is not registered on the monumental list and
- has an energy label G, due to the focus of the research.

3.3 Characteristics that influences the energy efficiency

This chapter aims to find office typologies that represent the energy label G office stock, like defined in the former sub chapter. Therefore, it is crucial to find out what important characteristics are. To do this, first other researches and policy evaluations are studied, to review how they dealt with building typologies. First the report of DGMR (2016) is studied to find out how they dealt with testing the new NZEB regulations. Following, the report of the Economic Institute for Buildings by Arnoldussen et al., (2016) is retrieved. Also, on European level, building typologies are studied to evaluate European policies (TABULA, 2012a). Afterwards, the applicability of these studies for this master thesis is evaluated. From this review, two important characteristics are defined to classify the building typologies.

Already from the 90s, reference buildings are created to test policies in the Netherlands. Lots of data and reference buildings are available for the residential building stock. However, data on the existing non-residential building stock is marginal. Recently, DGMR (2016) created reference buildings for new residential and non-residential buildings. From 2020 onwards, all new buildings need to comply with the Nearly-Zero Energy Building regulation. To test this policy, reference buildings are created by DGMR, at the request of the Dutch Government. These reference buildings need to represent the current development of building designs (DGMR, 2016). This is evident, since the policy is meant for new buildings built from 2020 onwards.

The Economic Institute for Buildings evaluated the label C requirement for existing offices. To evaluate this policy, they used one reference building. This reference building is a mid-sized building of 4320 m2 and three floors high. To this reference building, they added different technical characteristics, corresponding with different energy labels. The reference building is used to calculate the payback times and the needed measures (Arnoldussen et al., 2016). From their research, it is unclear why this building geometry is chosen as a reference building. According to Raiji, Tenpierik & van den Dobbelsteen (2017) the geometry factors are important to consider, because they can influence the energy use up to 32% and thereby also the investment costs and payback times. Therefore, the geometry factors are important to consider, when using reference buildings.

Another interesting study is the European TABULA project. They recognize the significance of data on the building stock, to test and evaluate policies. Due to the importance of building stock data, the European Typology Approach for Building Stock Energy Assessment (TABULA) project was set up under the Intelligent Energy Europe (IEE) framework. This project focused mainly on residential typologies. This turned out in the formation of residential typologies for 13 different European countries (TABULA, 2012a). Although only 25% of the European buildings stock is non-residential, it consumes over 40% of the energy consumption (Durier, 2013). Therefore, reliable building data of the non-residential stock was seen as significant as well. The TABULA project decided to also study the non-residential building stock. However, only five European countries developed non-residential building typologies. Among those countries, the Dutch stock was not involved. Besides, setting up non-residential building typologies was experienced complex, due to the broad variety in function and their associated characteristics.

In the classification scheme of the non-residential buildings in Germany, they used the following characteristics:

- The utilization of the building;
- The year of construction;
- The compactness or size of the building;
- The technical building equipment (TABULA, 2012b)
- The question if there were already implemented energy saving measures (TABULA, 2012).

Offices with a current energy label G can be recognized by poor insulation and old installations. These offices are mainly built around 1970, when insulation was no part of the façade yet. The windows are mostly made from single glass, no insulation is used, and there is no heat exchange because of natural ventilation (Sipma, Kremer & Vroom, 2017). Since this research only focusses on office buildings with a current energy label G, characteristics like building date, technical building equipment, level of insulation are more or less the same. This is beneficial for the scope of the project, since less typologies will be needed. However, this creates the opportunity to look into the adaptation techniques for label G office more precise. To achieve the NZEB standards, the façade needs major renovations. Therefore, it is important to know if the façade can be replaced in total of needs to be renovated.

According to the literature reviewed, no specific reference buildings for existing offices are created yet. Besides, it would be meaningless to use the reference buildings of new buildings, since the office with a current energy label G are built around 1970 and differ a lot from recently built buildings. The reference buildings used by the EIB, focusses mainly on different technical characteristics of the façade and installations, while only one geometrical form is used. Since this research only focusses on office buildings with an energy label G, the technical building equipment and the façade needs to be replaced anyway to achieve the new NZEB standards and are therefore no meaningful characteristics for this research. The characteristics based on the TABULA project are interesting, since they are used for existing non-residential buildings. However, the utilization the technical building equipment is for office with a current energy label G, more or less the same. The year of construction will not function as a characteristic for this research, since the year of construction of the G labelled offices are already ranging between a small scale. More classes will result in small sample sizes and therefore difficult to generalize. The question if there were already implemented energy saving measures, is evident for this research. Because, the certification of an energy label is at a certain moment in time. This means, if there are already implemented energy saving measures after the certification, this is not seen in the registered energy label. Also, energy labels of office buildings, which don’t have an energy label yet, are added according to their building date. If there are already implemented energy saving measures, these buildings will be beyond the scope of this project, since they require less energy saving measures than the adaptation from G to NZEB. Therefore, first the database needs to be cleaned up. Also, the compactness of the building, is still important, since it influences the energy efficiency and is applicable for existing office buildings. Therefore, the compactness will form the first characteristic, concerning the office typologies for this research. Another important characteristic for this research will be the construction type. In order to know if the façade could be replaced or needs to be renovated, it is important to understand the construction types of office buildings. For this research the following to characteristics will be used:

- Compactness
- Structure

To understand how these characteristics can be classified within the office stock, literature is reviewed on each characteristic. The literature studied is mainly based on study books, used in the bachelor of architecture at the TU Delft during the building physics courses. Also, papers from researchers from the Building Technology master track are studied.

Compactness

First of all, the compactness characteristic needs to be classified within the office stock. According to Raiji, Tenpierik & van den Dobbelsteen (2017), the plan shape and plan depth are important influencing geometry factors of the energy efficiency of a building. Regarding these geometry factors, the new norms for Nearly-Zero Energy Buildings, are differentiated according to the geometry ratio. The geometry ratio, determines the compactness of a building. The geometry ratio is introduced, because it appeared to be too difficult to comply with the norms for certain building types. For example, a 'patio bungalow', has a large envelope surface in comparison with the floor area.

Figure 3.2: Example patio bungalow (BP Architectuur, n.d.)

To classify the compactness within the office stock, the classification from the NZEB regulations will be used. The compactness is measured as Als/Ag. This is the envelope surface divided by the floor area. The NZEB indicator makes a distinction between a compactness factor below 2,2 and above 2,2. The value of the first NZEB indicator is determined by this compactness factor (LenteAkkoord, 2018).

Als/Ag ≡ (Envelope surface)/(Floor area) ≡Compactness ratio

Below, two examples of buildings are presented. The first is compact, the second is not compact. They both have the same square meters of floor area, however, the envelope surface is way larger at the second example. Due to the large envelope surface, lots of heat is lost via the façade.
The compactness can be defined by dividing the envelope surface by the floor area. The distinction is made between a compactness factor below and above 2,2.

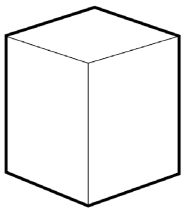


Figure 3.3: Example Compact building (Author, 2019)

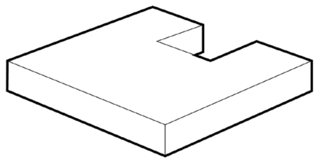


Figure 3.4: Example non compact building (Author, 2019)

Structure

To be able to know if the façade could be replaced or needs to be renovated, it is essential to know whether it is technically possible to replace the façade or not. It is only possible to replace to façade, if the façades is non-load bearing. Already before the 18th century, architects were trying to design non-load bearing facades. They wanted to separate the functions of the wall. They tried to distinguish bearing, sealing and light transmission within the wall. However, there were technical limitations to separate the load bearing structures from the other functions. Nevertheless, it has become possible to separate the façade from the structure. This is possible, when the bearing function is accommodated by columns, while the façade is connected to this structure (Knaack, Klein, Bilow, Auer, 2007).

To understand the structure of the façade, three different types of structures can be distinguished.

- Solid construction (massieve bouwwijze)
- Discs construction (schijvenbouwwijze)
- Frame construction (skeletbouwwijze)

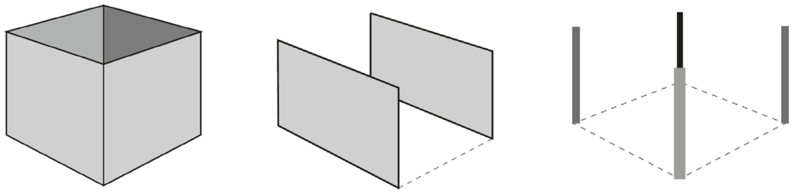


Figure 3.5: Solid, disc and frame construction (Author, 2018)

At the solid construction, the roof connects all walls and all the walls bear the roof. The discs construction consist of two opposite located walls. The roof is connected to these two walls and spanning in one direction from wall to wall. The frame construction consist of load bearing columns. The columns bear the roof. The great advantage of frame construction is the possibility to create big openings in all directions. This gives the opportunity to create open floor plans (Meijs & Knaack, 2010). Important to mention, the construction of a building could also be a combination of types of the structure. For this research the dominant structure of each building is chosen. According to de Gunst & de Jong (1989), a frame construction was often used to build offices to create flexibility within the plans.

However, traditional office buildings were approximately the same size as normal dwellings. Therefore, also the structure was comparable with traditional dwelling structures(de Gunst & de Jong, 1989). Traditional buildings can be defined as buildings with load bearing facades of masonry, concrete or limestone bricks (Thijssen, 1990). The facades were made of stone, which was most of the time load bearing. The 'modern' offices are way bigger in scale and the façade is normally not load bearing. Also stone materials are less used, since this is too heavy for the scale of the modern office buildings (de Gunst & de Jong, 1989). The image below shows the development of the façade structure of stone facades (Rentier, Reymers & Salden, 2001). Due to the energy crisis in the 70s, the energy prices increased. This resulted in the use of better insulation of the facades (Thijssen, 1990). The traditional load bearing facade can be recognized, as a façade made from stone materials with relatively small openings in the façade.

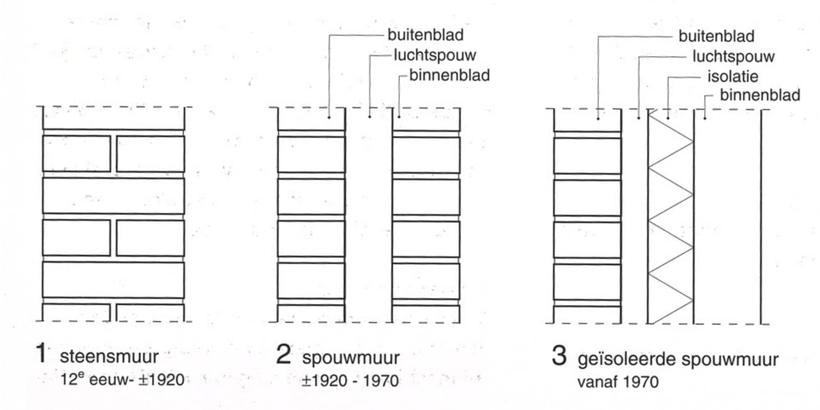
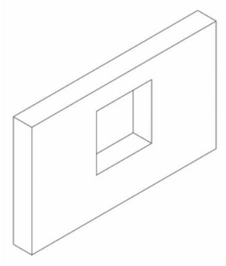
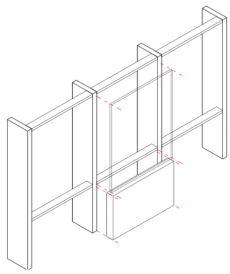
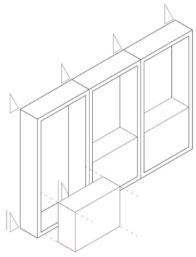


Figure 3.6: Development of stone facades (Rentier, Reymers & Salden, 2001)

Also, three types of façade structures can be distinguished.

Solid wall	Post and beam facade	Curtain wall
		
Solid walls are part of the main structure of the building. Windows are made, by making use of lintels. Solid walls are often made from masonry, limestone or concrete.	The post and beam façade consist of posts, spanning from floor to floor. The posts are linked by vertical beams. The posts provide support for the cladding, self-weight and wind forces. The post and beam façade only bears its own weight and can be replaced by a new façade (Knaack, Klein, Bilow, Auer, 2017).	Structures, in which the facades hangs from the roof, can be regarded as curtain walls. The construction is independent from the buildings' main structure. Therefore it can be replace by a new façade (Knaack, Klein, Bilow, Auer, 2017).
Load bearing	Non- load bearing	Non-load bearing

The construction characteristic can be classified by a non-load bearing wall and a load bearing wall. This can be recognized by the construction type and façade type.

3.4 Results

Literature

This chapter aimed to find out how office typologies can be created, that represent the office stock holding an energy label G. In exploring the research question of this chapter, first the definition of an office is discussed. The finding from the literature suggest that an office, as we know it today, is built after 1950. In addition, the design of the building is strongly connected to the function of the building. In order to generalize the measures to adapt the building, only offices, that are especially built for office work and the primary function is dedicated to office work, are taken into account. Also monuments require different adaptation techniques and are therefore excluded from this research.

To be able to create office typologies, two characteristic that influence the adaptation came out of the literature to be most suitable for the office adaptation towards NZEB. These characteristics are: compactness and structure type. The compactness can be classified by dividing the envelope surface by the floor area. The distinction is made between a compactness factor below and above 2,2. The construction characteristic can be classified by a non-load bearing wall and a load bearing wall. This can be recognized by the construction type and façade type.

Data analysis

According to the findings from the literature, office like we know them today, are built after 1950. When looking at the database, still 23,6 % of the office buildings are built before 1950. This are almost 13.000 office buildings. This substantial part of the office stock will be removed from the database, since it does not correspond with the office definition defined above. To test if these 13.000 office buildings are indeed no offices as defined, a random sample of six buildings from the 13.000 office buildings is taken. The results below were found. These buildings are built as residential buildings, but used as an office. The findings from this sample correspond with the literature found.

Figure 3.7: 'Offices' built before 1950 (Google Street View)

Concerning the office definition of this thesis, there are almost 17.000 offices in the Netherlands, whereas 14,6% has an energy label G. In figure 3.8 the deviation of energy labels within the office stock is presented.

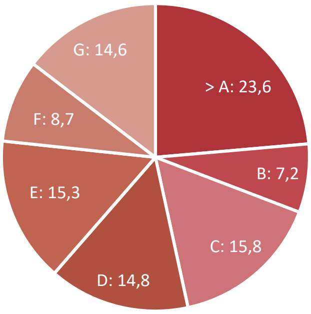


Figure 3.8: Energy label deviation, based on BAG, registered energy labels and added energy labels (Author, 2019)

In order to classify the building stock by the characteristics defined above, a probability random sample is taken from the office stock with a current energy label G. The sample is selected by the sample command of SPSS. Each building within the stock has therefore a known chance of being selected. The first thing needed, was to clean the database by removing offices that are for example already renovated. When analyzing the sample, the results showed that only 46% is useful for this research. The other 54% appeared to be already renovated, transformed to residential buildings and also some errors were found in the BAG database. At the website of the Kadaster, which maintains the BAG database, it is stated that errors in the database occur. It is possible to report the errors by means of special forms (Kadaster, n.d.b).

	Frequency sample [N]	Percentage [%]
Office	32	46
Non relevant offices	38	54
Total	70	100

Table 3.1: Results clean up database (Author, 2019)

The relevant offices are classified within the four types defined in subchapter 3.3. The average compactness is calculated within the sample by making use of the formula defined in 3.3. The structure is defined based on the characteristics of the façade and the construction. From there on the amount of offices within each type is defineBelow the results are presented.

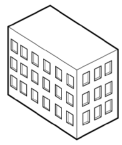
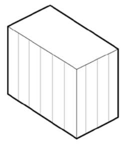
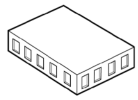
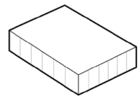
				
Compactness	Compact	Compact	Non compact	Non compact
Average compactness	1.37	1.37	2.55	2.55
Structure	Load bearing	Non-load bearing	Load bearing	Non-load bearing
N	8	15	5	2
%	27	50	17	7

Table 3.2: Results characteristics within sample (Author, 2019)

3.5 Conclusion: office typologies

This chapter aimed to create office typologies, in order to test the implications of NZEB adaptation. The findings showed two important characteristics: compactness and structure. From there on, four different types are created. The four typologies are classified within the office stock according to the random sample. The typologies are presented in table 3.3.
The typologies are presented by different dimensions of the building. This is important to be able to calculate the investments costs and energy savings. Resulting from the findings from this chapter, the four types in table 3.3 will be used to test the proposed policy. The measures and investments costs needed for the adaptation of these types will be presented in chapter 5.

	Type 1	**Type 2**	**Type 3**	**Type 4**
Compactness	Compact		Non compact	
Structure	Load bearing	Non-load bearing	Load bearing	Non-load bearing
Als/Ag	1,37	1,37	2,55	2,55
Ag [m2]	1080	1080	1550	1550
Als [m2]	1480	1480	3960	3960
OF [m2]	302	302	384	384
NBS [m2]	360	360	1500	1500
NFS [m2]	454	454	576	576
NRS [m2]	360	360	1500	1500
Sample [N]	8	15	5	2
Frequency [%]	27	50	17	7
Total [m2]	952.812	1.786.523	595.508	238.203

Table 3.3: Final office typologies (Author, 2019)

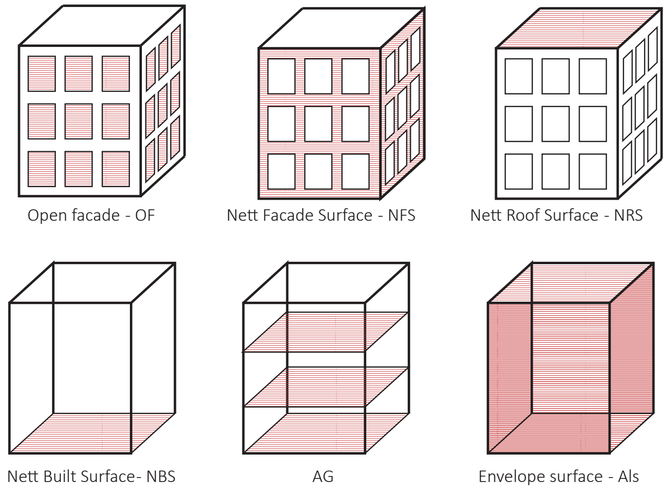


Figure 3.9: Different surface types (Author, 2019)

4

Energy policies

4.1 Introduction

This master thesis test the implications of a regulative NZEB policy for existing offices with a current energy label G. To evaluate this policy, it is important to understand how nearly zero-energy offices can be determined and which other policies have influence on the implementation of the proposed policy.
Therefore, this chapter aims to answer the following sub-question: How can nearly zero-energy offices be determined? Which other policies have influence on the implementation of the proposed policy? To anwer these questions, first literature about the determination of energy efficiency for buildings is explored. Afterwards, literature is studied on policy tools and overview of the aims of the Dutch Climate Agreement is presented that influences the proposed policy. This chapter ends with a conclusion.

4.2 Determination of energy efficiency for buildings

Development of measurement methods

In order to determine the needed measures and investments cost for the NZEB adaptation, a measurement method is needed. To define the measurement method used for this research, literature is reviewed on how energy efficiency is measured. Currently, major changes are going on in the development of measurement methods of energy efficient buildings. From 1 January 2020, the energy efficiency of buildings will be determined by the NTA 8800. To understand these changes, the evolvement towards this method will be explained. Energy labels, the energy index, the energy efficiency coefficient are used to indicate the energy performance of a building. But when is which indicator used and how are these measured? To get an impression of the differences between those indicators, table 4.1 is made.

Indicators	Building type	Applicability	Norm	Future norm
Energy efficiency Coefficient (EPC)	New	Building code, till 1 January 2020	NEN 7210	NTA 8800
Energy index (EI)	New and existing	Label C (EI 1,3) for offices before 2023. Required label when selling or leasing, applicable for housing associations and commercial buildings.	NEN 7210	NTA 8800
Energy label	New and existing	Required energy label when selling or leasing for home owners	NEN 7210	NTA 8800
NZEB	New	From first of January 2020 all new buildings need to be BENG building.	NTA 8800	

Table 4.1: Overview of energy efficiency measurement methods (RVO, n.d.e;n.d.f; NTA 8800; NEN 7210)

All three indicators are adopted in the NEN 7120 (RVO, n.d.e; RVO, n.d.f). However, they are used in different situations and for different regulations. For example, the EPC is used for new buildings and regulated by the building code. The Energy Index (EI) is used for new and existing buildings (RVO, n.d.e). The energy label is a simplified version of the energy index. The energy label is based on 10 building characteristics, while the energy index is based on 150 characteristics (RVO, n.d.f). An energy label is required when selling or leasing a building (BEG, 2016). The simplified energy label for the buildings of home owners will be sufficient. However, housing associations need to have an energy label based on the energy index. The energy index also indicates the amount of renting points, which determines the maximum renting prices (RVO, n.d.f). The same counts for offices owners. The label C requirement for office owners actually holds a minimum energy index of 1.3 (Ollongren, 2018). However, these indicators will be replaced by the ‘Energie Prestatie Gebouwen, EPG’, from January 2020 onwards.

The new measurement method

Due to the aims of the Energy Performance of Building Directive (EPBD), member states should establish a new method to calculate the energy performance of buildings. According to the EPDB, member states should establish a long-term strategy to assist the adaption of the building stock and promote the cost-effective adaptation of existing buildings into nearly zero-energy buildings (NZEB). Nearly zero-energy buildings are buildings that have a very high energy performance and the nearly zero amount of energy used, should be generated to a significant extent by renewable sources (European Union, 2018). The focus of this definition lays at the 'nearly zero-energy used'. In former definitions, a building could achieve high energy efficiency standards, if the building consume a lot of energy and generate this energy by renewables. Due to the definition of nearly zero-energy buildings, the building needs to be adapted as well, instead of only adding solar panels. To achieve nearly zero-energy buildings, a measurement method and norms should be established. Members states are themselves responsible to establish a measurement method and norms. These norms can be differentiation for different building categories. In Annex 1 of the EPBD, they provide a common general framework for the calculation of the energy performance of buildings (European Union, 2018).

In 2015, the former Minister Blok indicated that a new transparent and easy to implement measurement tool was needed to respond to the demands of the consumers. The consultancy agency Nieman gave the advice to come up with one measurement method instead of multiple measurement methods. Also, they advised to align the introduction of this method with the new NZEB regulations from the EPDB (Blok, 2017). The first version of the new method was ready in 2018. This method is defined in the 'Nederland Technische Afspraak' NTA 8800. The NTA 8800 will thereby replace the NEN7120. The first version of the NTA8800 can be used to study the financial feasibility of the NZEB regulation for new buildings (EPG, 2018). A big difference between the EPC, EI and the EPG is that the EPC and EI have no dimensions and the EPG will be measured in kwh/m2.year.

The NTA 8800 can be used for new and existing buildings, as well as for residential and utility buildings. The measurement method for these types is almost the same. The NTA 8800 measured the energy efficiency according to three indicators (NTA 8800). The following three indicators are used:

1. The maximum energy demand in kWh per square meter usable area;
The first indicator consist of all the energy that is needed to cool and heat the building. The quality of the building envelope is an important factor for this indicator.

2. The maximum primary fossil energy use in kWh per square meter usable area;
Indicator two will be calculated according to the sum of heating, cooling, moisturize, lighting, ventilators, demoisturize, warm tap water and auxiliary energy. The energy produced by renewables can be deducted from the primary energy use.

3. The minimum percentage of renewable energy;
This percentage is based on the part of renewable energy use compared with the primary energy use. The renewables should be generated on the building plot. However, there are some exceptions. For example, when the main heat pump is located outside the plot, but delivers renewable heat to the building. To be able to take renewable energy measures outside the building plot in account, a certificate according to NEN 7125 is needed.

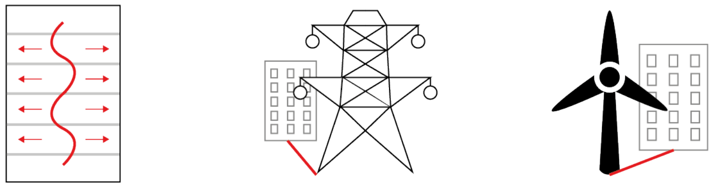


Figure 4.1: Visualized BENG indicators (Author, 2019)

NZEB norms

The first regulation, that will use three indicators of the NTA 8800, will be for new buildings. According to the EPDB, from 31st December 2020 onwards, all new buildings need to be nearly zero-energy buildings (European Union, 2010). According to article 2,10 of the EPDB, the NZEB requirements for new buildings are also applicable for buildings that need major renovations. According to article 2:10, a major renovation of a building is:

a) when the total costs of the renovation are higher than 25% of the value of the building, excluding the value of the ground, or
b) more than 25% of the surface of the building envelop is renovated.
The member states can choose if they implement option a or b (Europese unie, 2010).

As explained in chapter 3, offices holding an energy label G can be recognized by poor insulation and old installations. The windows are mostly made from single glass, no insulation is used, and there is no heat exchange because of natural ventilation (Sipma, Kremer & Vroom, 2017). If offices with a current energy label G need to be nearly zero-energy buildings, major adaptation of the building envelop is needed. Therefore, the NZEB norms, defined for new buildings, will also be applicable for the major adaptation of existing office building, holding an energy label G.

The aim of the Dutch Government, is to already apply these new norms from the first of January 2020 onwards. Therefore, provisory norms are published in November 2018. There are two moments left for market parties to react on the current norms. Afterwards, the norms will be definitely determined. The current norms for new offices are:

BENG 1 [kWh/m2.year]	BENG 2 [kWh/m2.year]	BENG 3 [%]
Als/Ag <= 2,2 = 90 Als/Ag => 2,2 = 90 + 50 (Als/Ag – 2,2)	50	30

Als = envelope surface in m2
Ag = usable area of the building in m2

Table 4.2: Provisional BENG norms (LenteAkkoord, 2018)

The first indicator will be determined according to the compactness of the building. The compactness can be calculated according to the envelope surface and the usable area of the building (LenteAkkoord, 2018). After publishing the new norms, a big discussion started within the politics and the industry. The new norms would be not ambitious enough in corresponding with the old norms (LenteAkkoord, 2019). For example, the first indicator is changed from 25 to 90 kWh/m2.year. This big difference can be explained by the change of the definition of the first NZEB indicator. In the new determination method, a fixed norm for ventilation is used. This results in a higher demand, since heat recovery is not taken into account. Due to all these differences, it is difficult to compare the former NZEB norms with the new ones (Van der Loos & Kuijpers- van Gaalen, 2019). How the final norm will look like and when they will be published is not clear yet.

4.3 Policy tools

This research, will test a regulatory policy. However, a policy is often a mix of different tools to achieve the intended goal (Adams and Tiesdell, 2011; European Parliament, 2016). In order to reflect on the proposed policy, it is important to understand the different tools. When not all barriers can be removed with a regulatory policy, other policy tools can be used to support the policy.

Vedung (1999) distinguishes three types of policy instruments: regulation, economic and information instruments. The basis of this distinction is the level of authorities force. Moving from restraining regulation, to incentive based economic policy, to the lowest degree of persuasive forces like information instruments. Regulations are measures undertaken by the government, that demands certain objectives rules. If the rules are not followed, negative sanctions will follow. Economic regulations are incentive based and consist of handling out or taking back material resources in money or in kind. Economic tools make certain actions often cheaper or more costly. Information covers 'attempts at influencing people through knowledge transfer, communication of reasoned argument, and moral suasion (Vedung, 1992, p.2)'. At the request of the Policy Department of the European Parliament, a research about the various policy options to boost the energy efficiency renovation of buildings has been carried out. Corresponding with Vedung they classified the following policy tools: regulatory, financial and fiscal and information campaigns and labeling (European Parliament, 2016). Meijer, Straub and Mlecnik (2018) did research about the stimulation of home owners to take energy saving measures. In their research, they made a division of four different policy instruments: regulatory, economic, organizational and communicative. This categorization adds the organizational instrument to the instruments defined by Vedung. The organizational policy instruments aims to streamline the organization of the process. For example to guide different stakeholder perspectives in an office adaptation. To get a better understanding, what these policy tools include, some examples are presented in table 4.3.

Categories	Examples
Regulatory	Laws, rules, specific exceptions, etc. These are used to force owners to comply with certain demands. An example of a regulatory policy is the requirement for office to have at least an label C by 2023.
Economic	Economic policies could be subsidies or taxes. Subsidies are there to create incentive for owners to take certain measures, they wouldn't take if there were no subsidies. Taxes can be used as a disincentive, where for example higher energy consumption leads to higher prices.
Organizational	Since office adaptations are complex due to the involvement of multiple stakeholders, another policy tool could be to streamline the organizational process of the adaptation. Especially when the office is located in the inner city, where also lots of neighbours are involved.
Communicative	Communicative tools are used to enlarge the awareness and knowledge about sustainable offices adaptions. It can provide technical, financial and practical information. This can be achieved by for example information campaigns

Table 4.3: Examples policy tools (Meijer, Straub and Mlecnik, 2018; European Parliament, 2016, adapted by author)

Also Adams and Tiesdell (2011) made a deviation in policy tools, by which governments can intervene in markets to create more sustainable places. They made the distinction according to their impact. Their fourfold classification consist of shaping, regulating, stimulating and capacity building instruments. This classification can be compared with the classification of Meijer et al. (2018). It is important to understand that creating more sustainable places, will normally require a combination of these policy instruments. A policy is essentially a political decision, instead of a technical effort (Adams and Tiesdell, 2011). These policies normally consist of packages of policy instruments to support certain public objectives. Also the report of the European Parliament (2016) recognized the importance of policy packages that consist of a combination of mandatory and voluntary schemes. Nonetheless, it should be acknowledged that if the results are not achieved, voluntary measures can become mandatory measures.

This research will focus on a regulative policy. However, it does not exclude other policy tools. It is important to keep the other policy tools in mind, when evaluating the results of the experiment. A regulative policy cannot overcome all barriers, therefore a policy is often a mix of different instruments. Besides, the Dutch politicians are working on a Climate Agreement and lots of new policies will exist in the future that will influence the office stock as well. In the next sub chapter an overview of the current ambitions from the climate agreement will be presented.

4.4 Dutch Climate Agreement

In 2015, 192 countries signed the well-known Climate Agreement of Paris. The agreement aims to keep the global temperature below two degrees Celsius. The Netherlands signed this agreement and thereby responded to it by the so called 'klimaattafels' [Climate Tables]. These tables consisted of different companies and organizations, in order to discuss about measures to diminish the CO2 emissions. This resulted in the Dutch Concept Climate Agreement, consisting of 600 proposals. The Dutch Concept Climate Agreement aims to diminish the CO2 emissions with 49% by 2030 with reference to 1990 (Klimaatakkoord, 2018). Besides, according to the new Climate act, over 95% of the CO2 emissions should be reduced in 2050 (Klimaatwet, 2016). For this sub chapter, the Dutch Concept Climate Agreement is studied and some important aims that will influence the office stock as well, are presented below.

Standardization

An important part of the Dutch Concept Climate Agreement is the built environment. For the built environment the aim is to reduce the CO2 emission with 3,4 Mton in 2030. 1 Mton will be dedicated to utility buildings. To achieve this, different proposals are made. The proposals for the utility buildings are focused on standardizations towards 2030 and 2050. Before the first of July in 2019, a concrete target will be determined to achieve before 2030. This target will be evaluated in kwh/m2.year and will focus on decreasing natural gas use. Besides, a legal standard will be in force for the energy efficiency for buildings in 2050. This norm will be in force from the first of January 2021 and will be differentiated for different building types. This norm will be determined by the NTA 8800 (Klimaatakkoord, 2018, p.38C1). The progress towards the target for 2030 will be monitored by the municipalities, every 4 years. If the progress is not enough, obligatory requirements can become in force. Currently, the measurement of energy efficiency is based on theoretical energy consumption. If it appears to be easier to evaluate the real energy consumption, the real energy consumption will be a part of the evaluation (Klimaatakkoord, 2018).

Neighborhood approach

An important part of the Dutch Concept Climate Agreement for the built environment is the 'wijkgerichte aanpak' [Neighborhood approach]. The municipality will play an important role in this approach. Together with the inhabitants and the building owners, they will decide the best approach for the neighborhood. For each neighborhood, the approach can differ. Heating districts is for example a measure that can be implemented on the level of the neighborhood (Klimaatakkoord, 2018). It is expected that also companies will be connected to the heating districts in the concerned neighborhood. This will result in 0,1 to 0,2 Mton CO2 savings for utility buildings (PBL, 2019).

From SDE+ to SDE ++

An interesting subsidy tool is the SDE+ subsidy. This subsidy is created for companies and non-profit organizations, who are going to invest in renewable energy. Every year the Government makes a budget available, this year the budget is 5 milliard euro. However, this subsidy is meant for the production of renewable energy. Therefore, this subsidy will not be available for the renovation poor insulated façades (RVO, n.d.c). Nonetheless, according to the coalition agreement, this subsidy will change to the SDE++. From 2020, it will focus on the CO2 reduction instead of renewable energy production. Therefore, also the renovation of poor insulated façades will qualify for this subsidy (Wiebes, 2018b). Just like the SDE+ subsidy, the SDE++ subsidy will only count for commercially viable technologies and needs to be scalable. The techniques with the most cost effective CO2 reduction will be the first to qualify for the subsidy, to stimulate the competition to reduce CO2. The subsidy is temporary. The subsidy will for example decrease in time or will stop after a while. The temporality of the subsidy is important to only stimulate future proof techniques. Future proof techniques will after a while also be able to be implemented without subsidy (Wiebes, 2018b). According to the Concept Climate Agreement, SDE+ subsidy will be available for sustainable heat sources. However, it is unclear if the subsidy will actual be available. According to the assessment of the Concept Climate agreement by the PBL (2019), it is still unclear which types of projects will be eligible for the subsidy. Other available subsidies are the EIA and ISDE. The ISDE is for companies as well as for individuals. The ISDE is applicable for heat pump, solar boilers, biomass boilers and pellet stoves. In 2019, 10 million euro is available. It is not possible to obtain SDE, EIA and ISDE subsidy at the same time.

Energy tax
The Government wants to stimulate the efficient use of energy, by making use of energy tax. The tax for electricity will be lowered and the tax for gas will be increased. Besides, for self-produced renewable energy, no tax will be applicable. The increasement of the energy bill should stimulate building owners to use less energy and take energy saving measures. The Dutch Climate Agreement presents two different scenarios:

1. Increase of gas tax with +1 cent, running from 2020 till 2029 in combination with an increase of tax relief of max 65 euro's for the first four years. After that, the electricity price will decrease with 0,5 cent until 2030.
2. Increase of gas tax with +4 cents and an increase of tax relief of max 65 euro's, from 2020 till2024. After that, the gas tax will increase with +1 cent until 2030. The electricity price will decrease with 0,5 cent until 2030 (Klimaatakkood, 2018).

Both scenario's will influence the payback times of energy saving measures.

Assessment of Dutch Climate Agreement
The Netherlands Environmental Assessment Agency (PBL) and the Netherlands Bureau for Economic Policy Analysis (CPB) presented their assessment of the Dutch Concept Climate Agreement on the 13th of March 2019. They assessed if the measures from the agreement will be enough to achieve the goals and what the costs of these measures are. The PBL concludes: the measures will not be enough to reach the goals. Besides, not all measures could be analyzed, since they were not clearly defined. If the measures from the agreement will be implemented, the CO_2 emissions will decrease between 43 and 51 percent. This means, if everything from the agreement will succeed, the goals will be achieved. However, this chance highly unlikely (PBL, 2019). According to the CPB the agreement will result in a 0,5% loss of the Dutch GDP (CPB, 2019a).

The ambitions from the Dutch Climate Agreement are not established yet. However, it is important to keep in mind, that for example the neighborhood approach will also play an important role on the energy efficiency of offices. Also subsidies and tax incentives will have an impact on the adaptation of the office stock.

4.5 Results

In exploring how nearly zero-energy offices can be determined, the findings showed that this can be determined based on three indicators: the maximum energy demand, maximum primary fossil energy use and a minimum percentage of renewable energy production. The determination method is fully described in the NTA 8800. Nwe offices will achieve the nearly zero-energy standard if they achieve a maximum of 90 kwh/m2/year for the first indicator, 70 kwh/m2/year for the second indicator and 30% of renewables is generated. The norm for the first indicators, can differ because the norm will be adjusted according to the compactness of the building. These norms are established for new buildings. However, these norms are also applicable for major renovations.
In exploring other policies that may have an influence on the implementation of the proposed policy, the literature indicated that a regulative policy is often combined with other policy tools. Other tools can help to overcome barriers that are not covered with the regulative policy. For example, the Dutch Climate Agreement presented two scenario's for increasing tax on gas and lowered electricity prices. The increase of tax for gas will influence the success of the proposed regulative policy: if gas is more expensive, adaptation can become more beneficial. Furthermore, most aims of the Dutch Climate Agreement are not clearly defined yet. It is not defined what the exact standardization norms for existing buildings will be, there are doubts about the right measurement method to monitor the progress and it is not clear how large the contribution of the neighborhood approach will be.

4.6 Conclusion

This chapter aimed to find out how nearly zero-energy offices can be determined and which other policies have influence on the implementation of the proposed policy. In conclusion, the findings suggest that the determination method to achieve nearly zero-energy offices consists of three indicators: the maximum energy demand, maximum primary fossil energy use and minimum percentage of renewables. Besides, the provisionary norms for new office buildings can be used to implement the proposed policy for existing offices with an energy label G, because the norms for new buildings are also applicable for new buildings. The aims from the Dutch National Climate Agreement will largely influence the proposed policy. It is quite certain that the tax for electricity will be lowered and the tax for gas will be increased. The two scenario's, presented in the Dutch Climate Agreement, will be used to calculate the payback period of the implemented measures, needed to comply with the proposed policy. Other policy tools should be kept in mind, since a policy often consist of packages of different instruments.

5

Building adaptation

5.1 Introduction

This chapter will explore the technical, financial and environmental implications of the building adaptation. This chapter aims to find the adaptation techniques, needed investment costs, energy savings and payback periods for the four different typologies defined in chapter 3. These findings are crucial, to find out how office owners will respond to the proposed policy.
First literature is reviewed on the available adaptation techniques. From there on, the associated costs are calculated based on the existing cost database from Arcadis. After determining the adaptation techniques, the energy savings will be calculated by using 'EPC-software'. The payback period can be calculated according to the investments costs and the monetary savings that results from the energy bill. After exploring the implications of the proposed policy, a sub-chapter is dedicated to the findings of the implications of the label C requirement. These findings are based on the existing report of the Economic Institute for Buildings. The energy savings and the payback period will be calculated based on the needed techniques and investments costs. However, some extra background knowledge is needed to execute the calculations. Therefore, both sub-chapters will start with an exploration of existing knowledge. Each sub-chapter also ends with a presentation of the findings. After exploring each sub-chapter, an overview of the results is presented. After that, conclusions are made.

5.2 Adaptation techniques

To find out the needed adaptation techniques, literature is reviewed. First, a strategy to define the needed adaptation techniques needs to be defined. Afterwards, the needed measures will be presented based on study books of building physics, written by several teachers from the department of Building Technology of the Faculty of Architecture at the TU Delft. Besides, product information from construction suppliers are studied, to define the performances of the measures.

Adaptation strategy

This research will focus on existing offices with a current G energy label. The adaptation techniques will be based on the reduction of building related energy, since these type of energy is used in energy efficient policies for buildings. Technical deficiencies of old office buildings is often present at the building physics and building service installations of the building. Leakages and poor insulation can be found in the façade. The building services are often inefficient. This leads to low user comfort and high energy demand and thus high operational costs (Ebbert, 2010). Energy saving strategies are challenging, since lots of design variable are fixed, such as the plan shape and the building orientation (Raiji, Tenpierik & Dobbelsteen, 2017). To adapt these buildings to NZEB buildings, the buildings need to be adapted. The NZEB norms are based on the Trias Energetica. The Trias Energetica is a three step approach to improve the energy efficiency of buildings. This approach was designed by TU Delft Emeritus Professor Kees Duijvestein, in 1979. He came up with the following three steps:

1. Reduce the demand for energy
2. Use fossil energy as efficient as possible
3. Use sustainable energy sources

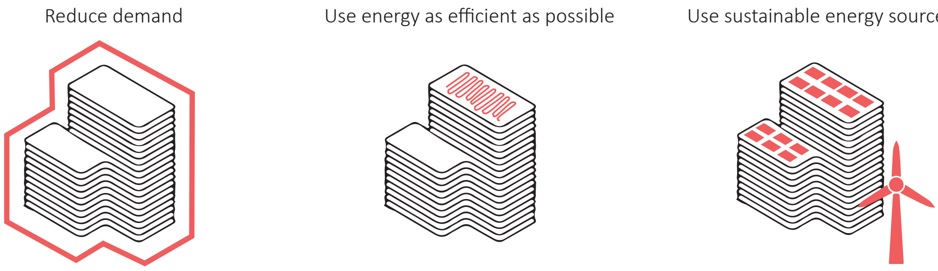


Figure 5.1: Trias energetica (Author, 2019)

The focus of the Trias Energetica is the climate design and the energy efficiency of the building, instead of only focusing on generating renewable energy. Only when the design has minimized the heat and cooling demand, the focus should be on renewable energy sources (Attia, 2018). To reduce the demand, the façade can be adapted. To use fossil energy as efficient as possible, the inefficient installations needs to be replaced. Finally, renewable energy possibilities on site can be considered. Following the Trias Energetica, the adaptation strategy will be:

- Adapt the façade
- Replace inefficient installation
- Generate renewable

Adaptation techniques

Following the adaptation strategy, the needed techniques to achieve NZEB are studied. Literature is studied on highly energy efficient adaptations. To test if the techniques achieve the NZEB standards, Uniec software is used.

Below different energy efficient adaptation techniques are presented. Two different façade types are used. This selection of the two types is based on the typologies of chapter 3.3. The distinction between the façade types, is the construction type. For example, if the façade is load bearing, it is not possible to replace the façade, but needs to be renovated.

Adapt façade

When the façade is not load bearing, it can be removed and replaced. The new façade should meet the energy efficiency standards for BENG buildings. If the façade is load bearing, the façade can't be replaced, but needs to be renovated. Below the measures needed are presented.

Roof and wall insulation	Lots of heat loss is due to bad insulated roofs. Therefore, roof insulation is really important. Each 25th year, the roof of buildings need maintenance. This is an efficient moment to add insulation to the roof (Arnoldussen et al., 2016). The roof insulation needs at least a heat resistance of 6,0 m²K/W. The walls need at least a heat resistance of 4,5m²K/W (NEN, 2014). Insulation with a high thermal conductivity can be used. For example RockFit Mono, which has an ʎ-value of 0,035 W/m.K (Rockwool, n.d.).
HR+++ glass	U: 0,4 W/m²K, ZTA: 0,45
Window frames	For the calculations the Venta Aluminum window frame is used. This frame has an U-value of 0,72 W/m²K (Venta, n.d.).
Automatic outside shading	To prevent heat inside during the summer, shading is a good solution. Especially movable shading is recommend, because it will not prevent heat in the winter. High efficient outside shading will lead to a ZTA of 0.15. Inside shading will only achieve a ZTA of 0,40. For the renovation towards energy neutral, automatic outside shading with a ZTA of 0.15 is chosen (Van der Linden et al., 2011).
Seal off gaps and cracks	Besides highly insulated glass, the openings and connections within the façade are really important to prevent heat loss. Therefore, double or triple seals are used to seal of the cracks. In the energy efficiency calculations this is measured in dm3/s per m2. To achieve energy neutrality the airtightness should be around 0,15 dm3/s per m2 (DGMR, 2017).

If the façade is load bearing, the façade can't be replaced, but needs to be renovated. However, it should meet the same standards to achieve the NZEB standards. To achieve this, cavity and outside wall insulation will be used. When renovating the façade, also the windows and the window frames can be replaced, shading will be added and the gaps and crack will be sealed.

Cavity and or outside wall insulation	The load bearing facades are often made with a cavity. This gives the opportunity to add insulation inside the cavity. However, to reach to minimum requirement of 4, 5m²K/W, also insulation outside the wall is needed. Rockwool, with a thermal conductivity of 0,035 W/m.K can used for both options (Rockwool, n.d.).

Outside wall insulation was often used to renovate poorly insulated facades. According to Rentier, Reymers and Salden (2001), outside wall insulation is the best solution to improve the heat resistance of a façade. Great advantages of outside wall insulation are:

- The insulation is placed on the cold side of the structure, this means less building physic issues will occur, such as thermal bridges, moist troubles and condensation.
- The thickness can be determined by the demanded heat resistance.
- There is a great variety of lay-outs.
- It results in little nuisance for the users.
- A badly maintained façade gets a new look

Outside wall insulation can be combined with cavity insulation. Cavity insulation will result in a higher thermal value, since it will decrease the convection within the cavity. Besides, it is a highly cost-effective measure. The investments are little, while it results in large energy savings (Van der Linden & van den Ham, 2015). Normally a cavity is used to be able to ventilate and drain moist and vapour (Rentier, Reymers & Salden, 2001). Therefore, it is often said that cavity insulation will result in moist troubles. However, according to van der Linden & van den Ham (2015), this is not the case. If the cavity insulation is implemented correctly, the insulation will not allow moist within the cavity. Ventilation of the cavity is therefore not necessary anymore.

<u>Replace inefficient installations</u>

Daylight depending light	With this installation, the amount of artificial light will be adapted to the amount of daylight.
Pulse- or (timed) lighting sweep	This system gives the opportunity to turn off all lighting in the building at once, therefore also the light that is unnecessarily turned on, will turn off.
LED lights	Replacing current lighting with energy efficient LED lighting (Yanovshtchinsky, Huijbers & van den Dobbelsteen, 2012).
WKO and heat pump	When changing the boiler, it could be replaced by a hybrid or all electric heat pump with a 'WKO'. A WKO stores heat in different ground layers and is often combined with a heat pump. The heat pump can also make use of the heat and cooling of the air. According to the Netherlands Enterprise Agency it is a sustainable way of cooling and heating with low exploitation costs (RVO, n.d.g).

Renewable sources

Solar panels	Solar panels create energy from solar power. The panels are easy to implement on site. For the calculations Astronergy asm6610m 300 Wp panels from the Uniec 2 database are used.
District heating	According to the Dutch climate agreement for the built environment, the heat companies will realize sustainable heat sources, such as geothermal energy, waste heat, solar heat, bio mass, power to heat and sustainable gasses. The climate agreement also indicates that it is needed to subsidize the unprofitable part. Besides, these sources should be taken in account with relevant policies such as the BENG regulation. For offices, to make use of this sustainable sources, they should be connected to the district heating (Climate agreement C1, 2018).

The district heating is not used in the energy efficiency calculations. However, it is an important measure in the Dutch Climate Agreement. Also the NTA 8800 will take account of district heating in the BENG calculations. The share of renewable sources of the heating district can be deducted from the primary energy use. However it is unclear what the share of renewables will be of the heating districts (PBL, 2019). Therefore, it is difficult to determine what the influence of heating districts will be. So, in this research, heating districts will not be part of the adaptation.

Results

This sub chapter aimed to find the adaptation techniques needed for the adaptation towards NZEB. Therefore, the adaptation strategy of the Trias Energetica is used. From there on, the adaptation techniques are determined. Table 5.2 presents the adaptation techniques according to the adaptation strategy.

Adapt façade	Replace inefficient installations	Generate renewables
Roof and wall insulation	Daylight depending light	Solar panels
HR+++ glass	Pulse- or (timed) lighting sweep	District heating
Replace window frames	Led lights	
Automatics outside shading	WKO and heat pump	
Seal off gaps and cracks		
Cavity and or outside wall insulation		

Table 5.1. Results NZEB adaptation techniques (Based on findings author, 2019)

The table shows the techniques needed to achieve NZEB. The techniques are mostly focused on reducing the demand for energy. The techniques are used to calculated the needed investments costs and achieved energy savings.

5.3 Investment costs

The needed measures to achieve the NZEB standards require certain investment costs. To calculate the investment costs, several costs databases from Arcadis are used. Also, short interviews with experts from Arcadis are performed, to support the findings from the calculations.

Calculating investment costs

In order to calculate the investment costs, the different costs within the total investment costs must be understood. Investment costs for the adaptation of buildings can be divided into five different types of costs:

- Direct costs
- Indirect costs
- Additional costs
- BTW

Direct costs, are the costs for labor, construction, demolishing, installations, terrain design and so on. Indirect costs are the general implementation costs and the profit and risks. The additional costs are the costs for the client, such as, consultancy costs and the costs for the utility connection. BTW is value-added tax and is currently determined at 21% (Arcadis, 2016).

To determine these costs, indicators from the report 'Investeringskosten maatregelen utiliteitsbouw 2016' are used. These indicators are based on a reference building and are indicated in euro per square meters. The price level of these indicators are determined in 2016. The indicators contain: building costs, indirect building costs and additional costs. However, taxes are excluded and need to be added. This chapter aims to find the implications of the proposed policy. This means, the investment costs need to result from the proposed policy. Therefore, the regular maintenance costs are deducted from the total investments. This will result in the additional costs needed for NZEB adaptation. The maintenance costs are calculated according to 'Vormfactoren & kostenkengetallen, 2017' (Arcadis, 2017).

Results

Table 5.2 shows the investment costs for each measure and building type. Also the average price per square meter is calculated.

Measure	Surface	Investment	Types			
		€/m2	1	2	3	4
Roof insulation Rc 6	NRS	71	€ 25.560,00	€ 25.560,00	€ 110.050,00	€ 110.050,00
Floor insulation Rc 3,5	NBS	20	€ 7.200,00	€ 7.200,00	€ 31.000,00	€ 31.000,00
Outside wall insulation Rc 4,5 + plaster	NFS	130	€ 59.020,00		€ 74.880,00	
Cavity insulation 200mm Rc 5,7	NFS	14	€ 6.356,00		€ 8.064,00	
Replace facade panels RC 4,5	NFS	202		€ 91.708,00		€ 116.352,00
Windows U=0,8 + window frames 0,72	OF	389	€ 117.478,00	€ 117.478,00	€ 149.376,00	€ 149.376,00
Automatic sun shading ZTA 0,15	OF	108	€ 32.616,00	€ 32.616,00	€ 41.472,00	€ 41.472,00
80% wtw Luka D	AG	19	€ 20.520,00	€ 20.520,00	€ 29.450,00	€ 29.450,00
Heat pump 100 KW	AG	98	€ 105.840,00	€ 105.840,00	€ 151.900,00	€ 151.900,00
Insulation of pipes	AG	1	€ 1.080,00	€ 1.080,00	€ 1.550,00	€ 1.550,00
LED	AG	25	€ 27.000,00	€ 27.000,00	€ 38.750,00	€ 38.750,00
Daylight depending light	AG	4				
Pulse- or (timed) lighting sweep	AG	1	€ 1.080,00	€ 1.080,00	€ 1.550,00	€ 1.550,00
Solar panels 300wp Roof	m2	237	€ 21.330,00	€ 21.330,00	€ 24.885,00	€ 24.885,00

Total [€]	€ 425.080,00	€ 451.412,00	€ 662.927,00	€ 696.335,00
Incl btw [€]	€ 463.337,20	€ 492.039,08	€ 722.590,43	€ 759.005,15
Total [€/m2]	429,0159259	455,5917407	466,1873742	489,6807419
Maintenance [€/m2]	€ 75,70	€ 75,70	€ 75,70	€ 75,70
Additional costs [€/m2]	€ 353,32	€ 379,89	€ 390,49	€ 413,98
Total [€]	€ 381.580,66	€ 410.282,54	€ 605.254,66	€ 641.669,38

Table 5.2: Investment costs for NZEB adaptation (Calculations made by author, based on database of Arcadis

The findings indicate that the investment costs for the different typologies ranges between €353 and €414. This difference can be traced back to the compactness and structure characteristics. Typology 1 and 2 are both compact and have relatively less façade surface. The costs for adapting the façade are therefore lower for typology 1 and 2 than for 3 and 4. Also a difference can be found at the construction type. The replacement of the total façade is more expensive, than the renovation of the existing façade. Therefore the non-load bearing typologies 2 and 4 are more expensive. The findings suggest, that the adaptation costs from energy label G towards NZEB are ranging between €353 and €414. In addition, there is a significance difference among the different typologies. The findings are important to execute the experiment. To find out what the implications of the proposed policy for office owners are, the office owners need to know the needed investment costs.

5.4 Energy savings

This subchapter aims to find out the energy savings due to the adaptation. Based on the literature and factors discussed in the following paragraph, the energy savings can be calculated First, the existing literature and factors available for calculating energy saving will be presented. After that, the results will be discussed. The energy savings will be presented in peta joules and in CO2 emissions

Calculating energy savings after adaptation

To calculate the energy savings after the adaptation, the energy consumption before the adaptation and after the adaptation needs to be determined. The energy consumption before the adaptation will be determined based on the theoretical energy consumption, researched in the report of Simpa et al. (2017). The energy consumption after the adaptation, will be determined after implementing the energy saving measures in the Uniec2 software. The energy savings will be the saved energy of the adaptation of the total office stock holding a current energy label G.

Energy savings=energy consumption before adaptation-energy consumption after adaptation

The aim is to calculate the total energy savings. Therefore, the gas and electricity use is summed up. To be able to do this, the gas use is converted to primary energy gas. Therefore the gas use is multiplied with the energy gauge of gas: 35,17 MJ/m3.

Primary energy gas [MJ] = Gas use [m3/m2] * [35,17 MJ/m3] (Majcen & Itard, 2014).

To get an impression of the scale of the energy savings, the energy savings will be compared with the aims of the Dutch Climate Agreement. The Dutch Climate Agreement aims to have a CO2 reduction of 3,4 Mton for the built environment in 2030. 1 Mton will be dedicated to utility buildings. To achieve this, different proposals are made. To be able to calculated the energy savings to CO2 reduction, the CO2-emmision factor is used. The factor is determined by Agentschap NL, PBL, ECN and CBS. The CO2-emmision factor is 0,68 kg/KWh (CBS, 2017).

Results

Energy consumption before adaptation

Based on the existing literature and building stock defined in chapter 3, the findings suggest an energy consumption of 3,8 PJ by the office stock with a current energy label G. Table 5.3 presents the energy consumption of the office stock with a current energy label G before the adaptation took place.

Gas [m3/m2]	28,5
Primary energy gas [MJ]	1002
Electricity [MJ]	48
Total energy use [MJ]	1050
Square meters [m2]	3.573.045
Total [PJ]	3,8

Table 5.3: Results energy use before adaptation (Author, 2019)

Energy consumption after adaptation
Table 5.4 shows the energy consumption after the adaptation. First the energy consumption is calculated for each type separately. Afterwards they are summed up according to the square meters available at each type. The findings show an energy consumption after adaptation of 0,7 PJ.

	Type 1	Type 2	Type 3	Type 4
Square meters [m2]	952.812	1.786.523	595.508	238.203
Energy use [MJ/m2]	190	190	198	198
Total [MJ]	181.034.301	339.439.313	117.910.498	47.164.199
Total type 1-4 [MJ]	685548310,7			
Total [PJ]	0,7			

Table 5.4: Results energy use after adaptation (Author, 2019)

Energy savings
The findings suggest energy savings of 3,1PJ for the NZEB adaptation of the total office stock with a current energy label G. A distinction is made between NZEB buildings that make use of fossil fuels and NZEB buildings that uses green energy. If the energy used, would be from sustainable energy 0,7 Mton CO2 would be reduced. This means, with the proposed policy already 60% to 70% of the aim from the Dutch Climate Agreement is achieved. This amount is substantial, especially because this results from only the adaptation of office buildings with a current energy label G.

	NZEB	NZEB
	Fossil energy	Green energy
Energy savings [PJ]	3.1	3.1
Energy savings [kWh]	852,050,572	1,042,480,659
Reduction CO_2 emissions [Mton]	0.6	0.7

Table 5.5: CO_2 savings (Author, 2019)

5.5 Payback period

This subchapter will explore the payback period resulting from the office adaptation. In order to calculate the payback period, first the operating and income expenses will be studied according to existing literature. The existing literature, together with the results from the energy savings will form the basis to calculate the payback period. Afterwards, the results will be presented.

Operating expenses
When exploring the financial implications of the NZEB adaptation, the operating expenses are of major importance. Operating expenses are expenditures to operate the building and keep it in good conditions (Ling & Archer, 2013). According to Eichholtz, Kok & Quigley (2010), energy represents 30% of the operating expenses. Besides, energy is the most manageable operational costs of an office building (Eichholtz et al., 2010).
To find out if the operating expenses are out of control, the operating expense ratio (OER) can be calculated. The OER is the ratio between operating expenses and the effective gross income. The greater the OER, the larger the operating expenses consumes the effective rent income. Knowledgeable investors are aware of healthy ratio's (Ling & Archer, 2013). Thus, if the operating expense are lowered by the energy saving measures, the OER will be lower and more interesting for investors. However, this depends on the proportion of property-level operating expenses paid by the tenant. This proportion varies from gross lease to triple net lease. In a gross lease, the owner is responsible for all the operating expenses. In a triple net lease, the owner is not responsible for any operating expenses. In between the triple net lease and gross lease are the net and net-net leases (Ling & Archer, 2013).

The decrease of energy costs, can be indicated in payback times. This approach divides the total investment costs by the yearly payment reduction. This short literature review on the influence of energy saving measures on the operation costs, supports the importance of calculating the payback times for office owners.

Energy prices

The payback period is calculated according to the financial saving on the energy bill. The energy savings are highly depended on the energy prices. The starting point for the energy prices, are the current prices in 2019. In 2019, the energy prices already increased enormously. The energy prices are three times higher than was expected by the Government. This increasement is mainly due to the increase in oil prices and taxes. In 2019, 47% of the total energy bill consists of taxes (CBS, 2019). These taxes are used to subsidize sustainable energy initiatives. Besides, as explained in chapter 4, the Dutch Climate Agreement wants to stimulate electricity use and doesn't want to stimulate gas use. Therefore they give two different scenarios:

1.Increase of gas tax with +1 cent, running from 2020 till 2029 in combination with an increase of tax relief of max 65 euro's for the first four years. After that, the electricity price will decrease with 0,5cent until 2030.

2.Increase of gas tax with +4 cents and an increase of tax relief of max 65 euro's. from 2020 till2024. After that, the gas tax will increase with +1 cent until 2030. The electricity price will decrease with0,5 cent until 2030 (Klimaatakkoord, 2018).

These two scenarios are used to calculate the payback period of the NZEB adaptation.

Operating income

Besides the payback times due to the energy savings, the security of rent income is of major importance to adapt the building or not. For example, the municipality of Vancouver aims to have energy neutral buildings by 2020. The responses are positive, because the adaptation costs are relatively low comparing with the value of the building (Rompa, 2016). The investments needed for label C are reasonable in comparison with the average rent price of €134 per m2 per year. However, offices located in bad lettable areas and with low rental prices, will already have troubles to achieve the label C requirement (Arnoldussen et al.,). There is a big difference in rental prices in relation to the location. For example in Old-South in Amsterdam the average rental price is 360 euro/m2/year. In Bargermeer in Emmen, the average rental price is 23 euro/m2/year. Besides, in 2017, the rental prices are decreased with 0,4% in Emmen (Cushman and Wakefield, 2018). Common lease terms for offices are 5 to 10 years. Shorter than 3 years is not often seen, because they do not deliver sufficient time for the owner to amortize the costs (Ling & Archer, 2013). According to a study of the ING and the University of Maastricht, an energy efficient office building increases the value with 9%. Also, the rent levels will increase with approximately 10% (ING, 2017). When calculating the payback period, the increasing rent levels are not taken in account, since it is difficult to generalize the increasement of rent levels, because this will vary between different locations.

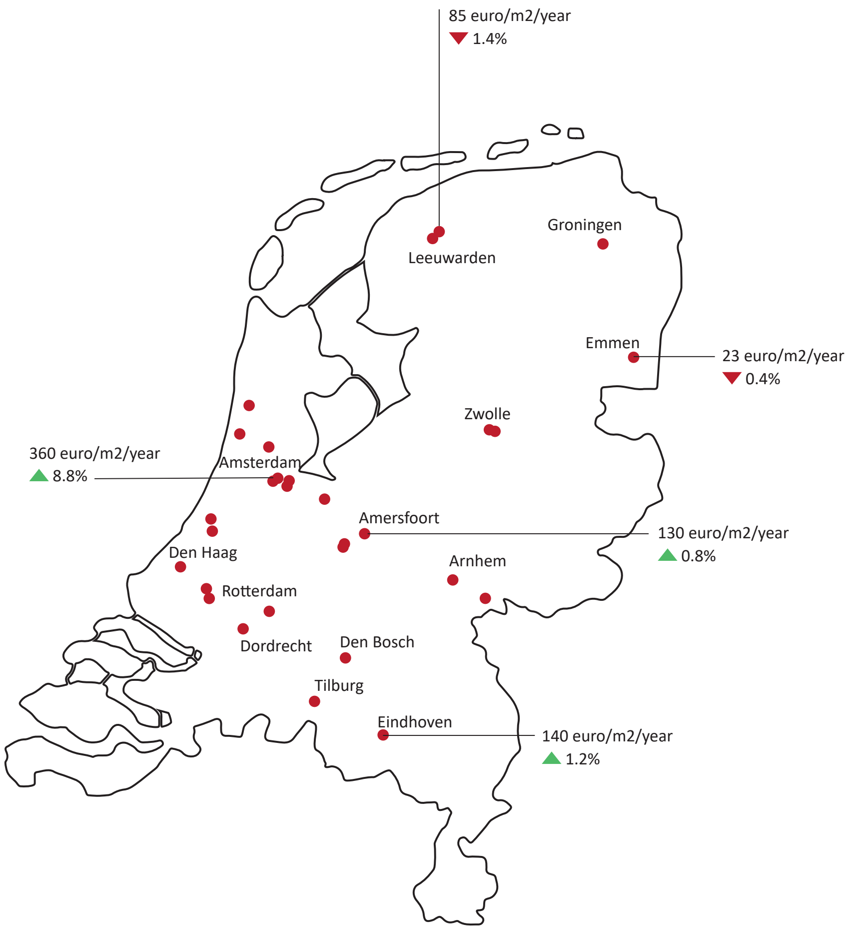


Figure 5.4: Locations and rental prices of sample (Author, 2019)

Results

The literature emphasized the importance of the operation costs. Energy represents 30% of the energy expenses and is the most manageable operation expenses. Adaptation of the buildin can lead to the decrease of operational costs. Due to this decrease of costs, the investments can be paid back. Therefore, the payback period is calculated for the NZEB adaptation. Tale 5.5 presents the payback period of the investments needed for NZEB adaptation. The findings suggest that the payback period vary from 22 to 32 years. The deviation within the payback periods can be explained by the different typologies and there associated costs. Also a deviation is seen between the two scenarios of the climate agreement. The shorter payback period for scenario two can be explained by the increasing price for gas.

		Type 1	Type 2	Type 3	Type 4
	Investment costs [€/m2]	€ 406,13	€ 432,70	€ 443,30	€ 466,79
1	Pay back times [years]	26	28	30	32
2	Pay back times [years]	22	23	24	26

Table 5.5: Payback times (Author, 2019)

The findings are relevant for the office owners because of their lease terms. Common lease terms for offices are 5 to 10 years. Shorter than 3 years is not often seen (Ling & Archer, 2013).

5.6 Results Label C requirement

5.2 to 5.5 shows the needed techniques, investment costs, energy savings and the payback period that results from the adaptation toward nearly zero-energy offices. In this chapter the results form the adaptation towards label C will be summerized. This can be regarded as the results from the control group. An experimental research design often contains a control group, which is not exposed to the proposed policy. In this research, the results will be compared to the implications of the current label C requirement, studied by the Economic Institute for buildings. The implications of a required label C is already researched by Arnoldussen et al. (2016). Their findings will be summarized in this subchapter.

Techniques
The techniques needed will mainly consist of improvements of installations. However, to achieve label C for offices with a current energy label G, also cavity insulation and the replacement of glass is necessary. The techniques needed to achieve an energy label C, has a high 'no-regret' characters and will not interfere with other possible energy saving measures in a later stage.

Investment costs
The investments costs to achieve the label C requirement for office buildings with a label G are ranging between 39 and 57 euro per square meter.

Energy savings
The label C requirement results in 8,6 PJ for the total office stock. The adaptation of only the offices with a G label, results in 2,4 PJ savings. The savings for only the G label offices are significant, since larger savings are achieved when adapting from a low energy label. The adaptation also lead to 0,4 Mton CO2 savings

Payback period
The payback period from label G to label C is considered 3 to 4,5 years. The needed investments are called 'reasonable' in comparison with the average rent income.

Overview results
Table 5.6 presents the overview of the results from the report, that tests the implications of the label C requirement for offices. These results are significant for this research, in order to compare these results with the findings from the proposed policy requirements.

Techniques	Mainly replacement of installations and glass. Also cavity insulation is necessary
Investment costs	39-57 €/m2
Energy savings	2,4 PJ
Payback period	3 – 4,5 years

Table 5.6: Overview results label C requirement (Arnoldussen et al., 2016)

5.7 Overview results

This chapter explored the technical, financial and environmental implications of the building adaptation towards NZEB. This chapter aimed to find the following implications of office adaptation towards NZEB:

- adaptation techniques;
- needed investment costs;
- energy savings;
- and payback times.

Besides, it summarized the main findings from the report of the Economic Institute for Buildings, who researched the implications of the adaptation towards label C. Table 5.7 present the main findings of this chapter.

	NZEB	**C**
Adaptation techniques	Major renovations, including the replacement or major adaptation of the façade.	Mainly replacement of installations and glass. Also cavity insulation is necessary
Costs	353 – 414 €/m2	39-57 €/m2
Energy savings	3,1 PJ	2,4 PJ
CO_2 savings	0,6 – 0,7 Mton CO_2	0,4 Mton CO_2
Payback period	22 – 32 years	3 – 4,5 years
Cost effectiveness	8 MJ/€	42 MJ/€

Table 5.7: Overview results NZEB and label C (Calculated by author, 2019; Arnoldussen et al., 2016)

As table 5.7 shows, the implications of the NZEB adaptation differ substantially from the label C adaptation. To achieve the NZEB standards, major renovations are needed, large investments are needed and large energy savings are achieved. To achieve the label C requirements, mainly replacement of installations is needed, the investment costs are substantially lower and also large energy savings are achieved. To indicate the cost-effectiveness of both policies the results in MJ for each euro invested is calculated as well. The NZEB policy shows for each euro invested, 8 MJ is saved. The label C requirement shows a larger cost effectiveness of 42 MJ saving for each euro invested.

5.8 Conclusion

The findings from this chapter showed the needed techniques, investments costs, energy savings and the payback period for the adaptation towards nearly zero-energy buildings. Technically, existing offices with a current energy label G can be adapted towards NZEB. However, major adaptations are needed, often including the replacement of the facade, the installation of a heat pump and adding solar panels. This results in the need for big investments ranging from 353 to 414 euros per square meter. On the other hand, major energy and CO_2 savings are achieved. Adaptation towards NZEB of the entire Dutch office stock with a current energy label G will result in 3.1 PJ energy savings and 0.6 to 0.7 CO_2 emission reductions, which is already 60-70% of the aims of the Dutch Climate Agreement for utility buildings 2030. This is a huge part of the aims of the Dutch Climate Agreement, since this 60-70% is already achieved by only adapting office buildings with a current energy label G. If all utility building would be adapted towards NZEB, the aims for 2030 would be largely exceeded. The investment can be payed back by the savings on the operational costs, of which the energy represents 30% of the total operational costs. When looking at the payback period achieved by these energy savings, the payback period is ranging from 22 to 32 years. The large range between the payback periods can be explained by the different typologies and the two scenario's for the increasing tax on gas and lowered prices for elektricity, of the Dutch Climate Agreement.
Next, to compare the findings with the label C requirement, adaptation from label G to label C is investigated. This requires 39-52 euros per square meter, which will lead to 2.4 PJ energy savings and a payback period of 3 to 4.5 years. The adaptation towards label C lead to 42 MJ savings for each euro invested. For the adaptation towards NZEB this is only 8 MJ. To conclude, the label C adaptation is approximately 5 times more cost efficient than adaptation towards NZEB. The findings from this chapter will be used to present to the office owners, in order to find out what the implications of the proposed policy for the office owners are.

6

Office owners

6.1 Introduction

It is essential to involve stakeholders, when testing the effectiveness of the proposed policy, to ensure the policy doesn't lend itself to unintended consequences (Deloitte, n.d.). Therefore, this chapter aims to find out what the implications of the proposed policy for the office owners are by means of case study interviews. The following research question will be answered: What are the implications of the proposed policy for office owners?
This chapter focusses on the office owners, since they have to decide what to do with their property after a policy is enforced. This chapter provides the observation part of the experimental research design, explained in the method section. This observation consists of how the compulsory NZEB adaptation will influence the office owners. For this observation, case study interviews are used. But first literature is studied to provide background knowledge. This background knowledge consists of the perspectives of financers and offices owners. Also an overview of different owners within the office stock is presented. Afterwards, the results of the case study interviews are discussed. In order to find out if the implications leads from the proposed policy, the results will be compared with the results of the label C requirement.

6.2 Perspectives

Before starting the case study interviews, some background knowledge about the office owners is important, to evaluate the results. The focus of this research will be the office owners, since they are firstly influenced by the policy and have to make the decision what to do with their real estate. In addition to the office owners, financers are important as well. Because, an investor often uses a loan from financers, due to risk diversification, financial leverage and the advantage of tax deductibility of mortgage interests (Koppels, 2019). Therefore, first a short overview of the perspectives of financiers and office owners are discussed.

<u>Financers</u>
The energy performance of buildings is important for financers to approve for financing or not. Due to energy performance obligations, the depreciation of badly performing buildings will be accelerated. This will influence the terminal value of the building and therefore led to insecurity on the real estate market (Arnoldussen et al, 2016). For example, the ABN Amro has a required paragraph for sustainability in the valuation report of real estate. A higher energy label results in a favorable valuation of the building and led to a better risk profile. Therefore, the finance of the ABN Amro will be cheaper for sustainable buildings. Also the ING puts requirements for the energy performance of buildings. From 2017 onwards, the ING only finances buildings with a better energy label than C. Building with a lower energy label than C, require an action plan to improve the sustainability of the building to be able to acquire new financing (KPE Morel, 2018).

To standardize energy efficient mortgages, the Energy Efficient Mortgages Action Plan (EeMAP) is set up. This project is funded by the European Commission's Horizon 2020 Programme. The EeMAP aims to incentivize owners to upgrade the energy efficiency of their assets or to obtain an energy efficient buildings. This initiative is also based on the belief that better energy performing buildings have a better risk profile. However, according to a study of the EeMAP project, there is no secret formula yet to calculate the energy efficiency into the real estate value. Nevertheless, the energy efficiency will contribute to the long term value and preservation of the asset, which results in the reduction of the risk. Besides, energy efficiency upgrades are often combined with an overall improvement of the building (Hartenberger, Lorenz, Sayce & Toth, 2017). However, according to a study of the ING and the University of Maastricht, an energy efficient office building increases the value with 9%. Also, the rent levels will increase with approximately 10% (ING, 2017).

<u>Owners</u>
Real estate owners can be divided in three types of owners: owner-developer, owner/occupier and the owner investor. Owner developers are also knows as value add investors. They focus on adding value of existing buildings or land to sell the property after development. Owner investors leases their real estate to generate money. Owner investors can be divided into institutional investors and private investors. Institutional investors manage capital for pension funds and insurance companies. Pension funds and

insurance companies often invest a part of their capital in real estate to spread risks. Institutional investors are professionals in their field. They are especially organized as investors companies and have therefore a large amount of expertise. Institutional investors are mainly interested in new buildings with reliable leas contracts (Gelinck & van Zeeland, 2010). According to Buck Consultants International (2011) institutional investors are aware of the possibilities of sustainable real estate. Most of them have statements on sustainability, such as CO2 footprints in their yearly reports. For institutional investors this is important due to image, value increase, lower energy costs for tenants, less vacancy, higher rent levels and less environmental impact. Unlike institutional investors, private investors have no knowledge about real estate and their perspectives are only financial. They can invest in real estate themselves, by buying, maintaining and leasing a building. However, private investors can also take part in listed funds, also known as 'commanditaire vennootschappen'. Funds are relevant for private investors, since the risks are spread and the maintenance is done by professionals. Normally, the investors don't take part in the shareholders meeting, unless the promised yield is not achieved (Gelinck & van Zeeland, 2010).

Owner occupiers uses their own real estate. Real estate is not their primary task and therefore they are often less aware of sustainability (Buck Consultants International, 2011). However, companies with a highly societal responsible image are interested in sustainable buildings. Besides, lower energy bills is also an incentive for implementing sustainability (Arnoldussen et al, 2016). Another important real estate owner and occupier is the Real Estate Government. Due to their socially responsible character, their perspectives are not only financial.

Below the deviation of different types of owners within the total office stock and the G label office stock is presented. Notably, the G label office stock consist mainly of companies/institutions and private investors. To find out, what the perspectives of these owners are, how they make decisions and how these are implement, case study interviews are executed.

Owners		% total *	% label C	N
Owner and user	Central Government Real Estate Agency	7	0	0
	Companies and institutions	29	54	15
Owner investor	Institutional investors	13	0	0
	Private investors (cv, bv, fondsen)	50	46	13

Table 6.1: Deviation ownership (Buck Consultants International, 2011; own sample, 2019)

6.3 Case study interviews

From the literature review, different types of office owners with different perspectives were recognized. For example, the owner and user has more interest in the suitability for the function of the office buildings than a private investor. The office owners interviewed for this research are selected from the random sample. The selection is based on the different type of office owner and the responses of the interviewees. The case study interviews aim to reveal the factors that influence the decision making of the owners, when the proposed policy would be in force. To test this, the owners need to be 'manipulated', as explained in the experimental research design. The manipulation, is the context that will arise from the proposed policy. These are: the needed techniques, investment costs, energy savings and the payback period. This context will be presented to the interviewees, to find out how this will influence their decision making process.

Case 1	Private investor	Dordrecht	April 26, 2019
Case 2	Investor and user	Molenaarsgraaf	April 29, 2019
Case 3	User and developer	Amersfoort	May 6, 2019
Case 4	Investor and developer	Emmen	May 10, 2019
Case 5	Investor and user	Rotterdam	May 14, 2019
Case 6	Investor and developer	Huis ter Heide	May 15, 2019

After the results from the case study interviews, an overview of the results from the label C requirements will be presented. These results are based on the existing research of the Economic Institute for Buildings.

6.4 Results

Results proposed policy

Case 1: private investor

Dordrecht
Building date: 1982
BVO: 3653
Registered energy label: Yes, valid until 2026
Compactness: 1,25
Facade type: Non load bearing
Tenant:
Owner: Private owners

Figure 6.1: Case 1 (Google Street View)

The building is located just outside the inner-city of Dordrecht and build in 1983 as a Governmental building for the UWV. In 1995 the UWV moved and the Governmental Real Estate Agency sold the building to four private investors. For this case study interview, one of the private investors is interviewed. They bought the building as an investment for their pensions. According to one of the owners, in the period they bought the building, people didn't want to be depended on institutions. Therefore, they used a building as a pension fund. Besides, they had their own construction company and were used to deal with buildings and with businesses themselves. They knew it was a good investment, since Jeugdzorg was already interested in the tenancy of the building. In addition, the construction of the building was robust, there were possibilities to expand and a large parking space was included. After Jeugdzorg moved, the building was vacant. The owners had the idea to transform the office into housing. However, the municipality refused to change the land-use plan. The owners contacted a vacancy manager to maintain the vacant building. The first two floors were used by creative small companies and the upper floors were used by anti-squat. To make the office ready for anti-squats, the owners had to invest a lot of money. After a while, the municipality decided that the anti-squat had to be removed. According to the owner, this was inconvenient, since they just had invested in the building, especially because the owners were already quite old. The owners of the building did the management and the financing themselves until the building became vacant. They made their own asset management plan. Every time the building needed maintenance, they considered to take energy saving measures, which were applicable at that time. However, for a long time it was unclear what the purpose of the building was going to be, therefore it was difficult to do investments. This year the building is sold to a private developer. The developer will partly demolish the building and partly transform the building into housing. The office owner is quite happy with this deal. Because of his age, he was happy to get rid of the building and in addition they made a fair deal with the developer (personal communication, April 26, 2019).

Figure 6.2: Interior case 1(Author, 2019)

In this findings from this case study showed that the legal, financial and personal perspectives were the most important drivers to take decisions. The case to adapt the office building towards energy neutral was not applicable, since there was no demand for offices, the land use plan didn't change and the owners were already on a certain age, they decided to sell the building. This case study shows that also the personal situation of an office owner can play a role in decision to adapt or not. It also showed that the possibility to invest depends on the future of the building. Since it was unclear what the purpose was going to be, no investments were made.

Case 2: Investor and user

Molenaarsgraaf
Building date: 1962
BVO: 768
Registered energy label: No
Compactness: 1,16
Facade type: Load bearing
Tenant: Single
Owner: Owner and user

Figure 6.3: Case 2 (Google Street View)

The office building in Molenaarsgraaf was a former municipal building. The building is built on top of a canal. This was exactly in the middle of two districts. The municipality sold the building to an insurance company. The insurance company moved in 2004 and sold the building to the current users. For this interview one of the shareholders of the b.v. is interviewed.

For the consultancy company, this location was perfect. They are located outside the ring of Rotterdam, have no traffic jams and the locations is cheap. The location is not of major importance since, most of their employees are working at the office of the client. Currently, they are in the middle of the process to adapt the office building towards label C. For the owners, trust was important in selecting a party to do the adaptation. One of the owners of the holding, consulted the architect from his own private house. The architect recommended a construction company, that was able to give advice on the adaptation towards energy label C.
They are quite happy with their building and its cheap location and therefore it is important that the investment will lead to a continuation of the use of the building. They are not interested in possible pay-back times of the energy bill. If the investment costs are too big, they will look for better options. Such as, hiring an office building somewhere else and sell the office building to the municipality to demolish it. The interviewee assumed that the neighbors will be happy if the building will be demolished, since it blocks the view towards the water for some neighbors. However, the interviewee also mentioned that if all offices should be energy neutral, also other offices will ask for higher rents, in order to finance the adaptation. If they should adapt their building towards energy neutral they will consider heat pumps that make use of the water below the building. However, he doubts if the municipality will provide permits to make use of the water. Also, he prefers to wait until techniques are more efficient. In addition, they don't have the urgency to be a frontrunner. For them, the exploitation costs and the suitability of the place to work, is most important (personal communication, April 29, 2019).

In this case study the financial perspectives is the most important factor in the decision to adapt the building. If the investments costs are too big, they would look for other options. Besides, the continuation of the use of the building is important because they are very happy with the building and the location.

Case 3: User and developer

Amersfoort
Building date: 1977
BVO: 3218
Registered energy label: Yes, valid until 2016
Compactness: 1,37
Facade type: Non load bearing
Tenant: Not for profit organization
Owner: Municipality of Amersfoort

Figure 6.4: Case 3 (Google Street View)

The former Court in Amersfoort is built in 1973 and sold by the RVB to the Municipality. However, this was done by an a-b-c contract. The Municipality of Amersfoort bought it from the RVB but will sell is afterwards to a not for profit organization. This organization wants to accelerate sustainable initiatives. They had the aim to transform the old court building into the first climate neutral building of the Netherlands. The municipality of Amersfoort was fond of the idea and therefore they decided to sell the building to them with the abc-contract. The director of the organization was fiercely against the demolishment of the old building, he said: 'demolishing is never a sustainable solution'. Therefore he also displaced the energy label in his office without any shame.

To be able to buy the building, the not for profit organization had to make a design and a business case. They made a design that was just like 'tomatoes in a greenhouse'. They designed a big façade around the old building and aimed to generate an oversupply of energy to also compensate the footprint from the adaptation process. According to the owner, the building would have been the first building with a climate neutral WWF certificate. However, they didn't have financial capacity themselves, therefore they decided to cooperate with a local developer. The building is located next to the central station of Amersfoort. They created a business case, with a yield of 7,5%, tax benefits and even made contracts with potential tenants. According to the organization, the developer deceived him on the day of the sale. The developer and financer had already made other plans with an architect to demolish the building and build commercial dwellings. This would result in a yield of 20%. They were not amused and stopped the collaboration. The project failed and currently the building is almost totally vacant. Only the not for profit organization is renting one floor. Right now, the municipality of Amersfoort is looking for a new municipal building and made plans to build a new building at the location of the old court building (personal communication, May 6, 2019).

This case is quite unique, since the party that has the exclusive right to buy the building was not financially involved in the project. Their main perspective was to achieve a sustainable building. The owner of the not for profit organization showed that they were able to create a business case to make this old building not only NZEB, but even climate neutral. However, the developer and financer are not interviewed for this case study.

Case 4: Investor and developer

Emmen
Building date: 1971
BVO: 1125
Registered energy label:
Compactness: 1,41
Facade type: Non load bearing
Tenant: Multi
Owner: Private owner and developer

Figure 6.5: Case 4 (Google Street View)

The building in Emmen is located at an industrial area. It was bought by a private investor and developer in 2004. The building was deteriorated and needed renovation. Therefore, the current owner renovated the building, by replacing the windows and the old installations. The building has no registered energy label, but the owner thinks the renovation has led to at least an energy label C.

The private investor owns real estate in the north of the Netherlands. They own buildings in Haren, Assen and Emmen. Currently, the owner is trying to sell his buildings. He doesn't see any future in the commercial real estate market, due to the market, the financers and the prevailing climate policies. According to the owner, financers doesn't provide loans anymore in the north, except from Groningen and Zwolle (personal communication, May 10, 2019). Also, the demand for commercial real estate in Emmen is decreasing (Cushman and Wakefield, 2018). The owner also wants to sell the case study building, he tried to change the land-use plan to be able to sell it for a reasonable price. He thought student housing would be a good opportunity, since the location is close to the Stenden University of applied sciences. However, the municipality didn't want to change the land-use plan. Following, Remoy and Van der Voordt (2014), shows that big legal risks for office adaptation to another use are the requirements of the zoning plan and the building code. Also, Douglas (2006) states that full agreement with the building code is especially difficult for older assets.
The current users of the building are happy with their office because the rents are low and the interieur of the office is modern. According to the owner, when the rents would increase due to adaptation costs, the users would not able to rent the office anymore. A user on the south axes, who is able to pay a rent of around 400 euro's per m² is probably also able to pay 450 euro's per m². If the rents from the case study building should increase from 45 to 65, this would definitely be a problem for the users. The interviewee owns multiple buildings and assumed that all this buildings would comply with label C. Small adaptations to his buildings will be no problem, since he always has a buffer for unexpected maintenance. Nevertheless, he thinks that lots of small real estate investors in the north would be affected by the label C requirement and will go bankrupt. Buildings will be sold for low prices and if possible, transformed. Also, he called the adaptation costs toward NZEB irresponsible. He thinks it is unwise to invest in the office market anyway. In general he thinks the climate policies are poorly considered. Policy makers have no idea about the real consequences. They think that real estate investors are rich, however the interviewee would definitely not agree (personal communication, May 10, 2019).

This findings from this case study interview shows the perspective of a real estate investor in a decreasing office market. Due to the low rental prices, the investment costs to achieve NZEB, are according to the investor in Emmen, irresponsible. He is trying to sell his buildings, but therefore he wants to change land-use plans to transform office buildings into dwellings. This should result in a better terminal value. However, for the case study building this is a problem, since the office is located on an industrial area and the municipality didn't want to change the land-use plan.

Case 5: Investor and user

Rotterdam
Building date: 1991
BVO: 24.455
Registered energy label: Yes, valid until 2020
Compactness: 0,74
Facade type: Non load bearing
Tenant: Single
Owner: Owner and user

Figure 6.6: Case 5 (Google Street View)

The office building in Rotterdam, is a large data center combined with an office building. The building has a registered energy label G. For this case study interview, a senior corporate real estate manager and a product manager 'hard services' are interviewed. The real estate portfolio of the interviewed company can be divided into two types, offices and shops. They own around one third of their real estate, the other part is leased. To make decisions within their portfolio, they look at the match between supply and demand, depending on the location, scale and the characteristics of real estate. Also, the energy policies will influence the decision making concerning their real estate. Are they going to renovate the building? Or upgrade it towards the lowest minimum? According to the interviewees, it is all about balancing the issues. On one hand, they have sustainable ambitions. On the other hand, adapting all offices towards NZEB at any costs, would not be a wise decision. For example, if an adaptation towards C is around 300.000 euro's and towards A 1.000.000, they will look if the sale value will bridge the gap of 700.000 euro's. The outcome doesn't directly influence the decision, however they are still a commercial company with commercial perspectives. Nevertheless, they don't have to make a certain yield, like private investors. Besides, the interviewee mentioned that the adapting towards NZEB would be more expensive than is indicated in this research, since they have to find temporary accommodations for the users. This will results in much higher cost.

Up until now, the office building in Rotterdam not adapted towards a more sustainable building, this was mainly due to a lack of vision for the location. They didn't know what to do with the building, because part of the office was empty. They thought about leasing a part, however this was difficult due to security reasons. The interviewees mentioned that they look at each location for specific solutions. For example, for the building in Rotterdam they are thinking of using waste heat from the data center, change the roof and add solar panels to it. Another interesting case is the office building in the northern part of the Netherlands. This building is part of three office buildings. One of them is vacant and holds an energy label in the range of G to E. They thought of different business cases, but this is difficult because of the location and the challenging characteristics of the building. They considered changing the land-use plan and lease the building to startups and scaleups. However, there is no sufficient market for this at the location. Based on the plan shape, the building was suitable for dwellings. However, they needed to sell the building for almost nothing, since the transformation costs are that high, that there is no money left to buy the building. Besides, it will costs a lot of money to divide the three buildings into two. The buildings are like Siamese twins because the buildings are physically connected and the installations and the parking garage are shared. According to the interviewee the adaptation of office buildings towards NZEB, is only possible during a major renovation and if there are possibilities to increase the square meters of the building and thereby increasing the rent income(Personal communication, May 14th 2019).

The findings from this case study interview showed the perspective of a user and owner of a real estate portfolio. This interview showed the importance of the specific circumstances of the location, for the possibility to adapt the building or not. They indicated that they are balancing different issues and want to make 'wise' decisions. A major issue would be the need for temporary accommodation during the adaptation. This will result in large investments and nuisance for the users ans business. Also, the real estate strategy is of major importance in the decision to adapt a building or not. However, it is difficult to prospect what the future of the business and the market will bring and thereby it is difficult to make such big investments.

Case 6: Owner and developer

Huis ter Heide
Building date: 1987
BVO: 1176
Registered energy label: Yes, valid until 2021
Compactness: 1,89
Facade type: Non load bearing
Tenant: Multi
Owner: Owner developer

Figure 6.7: Case 6 (Google Street View)

The office building in Huis ter Heide is bought in 2017 by a private owner and developer. company has a strong entrepreneurial characters. Where big investors will never take the risk, they see an opportunity to create value. For example, they bought several vacant office buildings, they renovated them and currently all those office buildings are rented out. Their investment strategy is depending on the location, type of real estate and the market trends. Part of their investments are 'value add' investments: investments with the purpose to add value to the building. They also have lots of attention for the potential tenant. They are willing to think along with the potential tenant and adapt the building to their needs where possible. They own around 25 office buildings in the region of Utrecht. They are responsible for their own asset and property management and therefore want to be at close proximity to the locations. They expect that around nine buildings will not comply with the label C requirement for 2023. One of them is the office in Huis ter Heide. For them, the most important factor, that influences the decision making, is the real estate strategy. Does the building has a future? Do they want to keep the building, transform or even sell it? The building in Huis ter Heide is bought in 2017. When they bought the building, it was still vacant and they knew it would be a challenge to add value to the building. They first focused on finding new tenants, and they did. Now they are considering what to do with the building. Technically the building is suitable for major adaptation. However, they questioned whether the location is future proof as well. To be able to adapt their office buildings to NZEB, the future value of the location is important.

This can be seen in one of their projects in the city center of Amsterdam. This project consist of an old office renovation towards a new modern office, with high sustainability standards. Concerning the planned renovation, the office is future proof for 2050. When looking at the of the location, the decision to renovate this building future proof for 2050, was more easy to take, than the renovation of an office at the boarder of a high way. When the interviewee looks at the costs to comply with NZEB, she indicates that the difference with C is evident. They would ask themselves, if they would be willing to invest such an amount in the office in Huis ter Heide, since the rent levels are relatively low, comparing with the rent levels in Amsterdam. It is therefore necessary to weigh up carefully between investments costs and rent levels. For the building in Huis ter Heide, label A is more reasonable and financially possible, according to the interviewee (personal communication, May 15, 2019).

The findings from this case study interview showed the importance of the location for the decision to adapt the building. Besides, they showed that creativity, careful attention for the building, the potential tenant and its location are important to add value to real estate. The costs to adapt the office building in Huis ter Heide towards NZEB are probably too high to invest in . Especially, because it is difficult to invest for such a long period, when the future of the location is unclear.

Results label C policy

The Economic Institute for Buildings, explored the implications for the office owners of the label C requirement. They interviewed multiple office owners. Their findings suggest, that the first thing owners would ask is: does the building has a future? This is crucial since it will determine if the investment would be paid back or not. Their study indicate that investment costs are reasonable in comparison with the average rent prices. However, the investment costs are unreasonable for offices located at bad locations, with low rents. The investment costs for these offices are relatively high in comparison with the rent income. They expect that the affected stock will be 0,9% of the total stock.

The implications for the stakeholders of the label C requirements are reasonable. 0,9% of the total stock needs to be sold, demolished or leave vacant. Due to the 'no regret' character and relatively low costs of the adaptation towards C, most office owners will be able to adapt the buildings towards C. Besides, as explained in chapter 5, no temporary accommodation is needed for the users, since the adaptation consist mainly of the replacement of installations (Arnoldussen et al, 2016).

6.5 Conclusion

This chapter aimed to answer the following research question: what are the implications of the proposed policy for the stakeholders? The findings suggest that the proposed policy will result in a reconsideration of the future of the building. When reconsidering the future of the building, they can choose to adapt the building, demolish, sell, built new or leave vacant. There is a variety of factors that influence this decision. For example, the possibilities to change the land use plan can be a decisive role in the decision to adapt the building or not. If there is no demand for offices, but there is a demand for housing, transformation could be a solution. However, it is difficult to change the land use plan in industrial areas, which are often not suitable for living. Other factors such as the technical situation of the building, the legal challenges, the vision of the investor and the real estate strategy can also play an important role. Table 6.2 summarizes the factors that influence the decision making of stakeholder, due to the proposed policy.

Perspective	Factor that influence decision making in adaptation
Financial	Real estate strategy/ future value Possibilities to change the land use plan (legal)
Technical	Technical opportunities
Social	Accommodation during adaptation The age of the investor
Environmental	Legal requirement Personal motivation

Table 6.2: Factors that influence decision making (Author, 2019)

Adaptation towards NZEB result in nuisance for the owners because the users need temporary accommodation. Besides, a large share of the office owners will not have the financial possibilities to adapt their building towards NZEB, because the needed investments costs are unreasonable compared to the resulting rent income. In addition, it is often unclear what the future of the location will bring. Therefore, office owners in decreasing markets are not willing to do large investments, concerning the long payback period. As an alternative, owners will choose vacancy or demolishment and no adaptation of the building will take place. However, for offices located in an increasing office market, the NZEB adaptation is more likely to be feasible. Especially, when technical opportunities arise, such as a nearby datacentre, which can be used for heat waste. The results from the interviews showed that the location, technical opportunities, the personal situation of the investors, the vision of the investor regarding sustainability, the real estate strategy and the possibilities to change the land use plan are important factors that influence the decision making of the office owners.
The findings from both the label C and NZEB requirement showed the importance of the location in the decision to adapt the building or not. However, the biggest difference between the label C and NZEB requirement, is that the policy towards NZEB needs major renovations, requires temporary accommodation and a much bigger investment.

7

Results

7.1 Introduction

This chapter will present an overview of the results of the former chapters. The main research question of the master thesis was:
What are the technical, financial, social and environmental implications of the proposed policy requirement of NZEB adaptation of office buildings with a current energy label G?

To answer this question, this research was divided into four themes, each providing a different sub-question. The four themes and their sub-question were as follows:

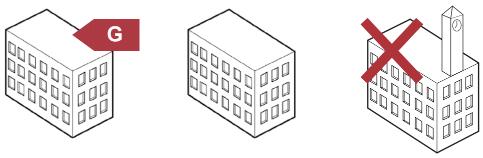
- **Office stock**: How can office typologies be created, in order to represent the office stock sufficiently for testing the technical consequences of the proposed policy?
- **Energy policies:** How can nearly zero-energy offices be determined? Which other policies have influence on the implementation of the proposed policy?
- **Building adaptation**: What techniques and investments are needed to achieve nearly zero-energy offices? What are the energy savings and what is the payback period?
- **Office owners**: What are the implications of the proposed policy for office owners?

The results of each theme are already presented at the end of each chapter. To give an overview of all results, they will be visually summarized at the next page.

The first research question aimed to find office typologies that represent the Dutch office stock. The results started with an office defintion for this research, followed by a data analyzes of the total stock and finally suggesting four different typologies, visualized in the figure. The second theme aimed to find out how NZEB offices can be determined and which other policies have influence on the implementation of the proposed policy. The findings showed, that the proposed policy should be determined according to three indicators, based on the NTA 8800. The norms needed to achieve are corresponding with the norms for new buildings, since they are also applicable for major renovations. The aims of the Dutch Climate Agreement will largly influence the implementation of the proposed policy. The typologies, the determination method and the aims from the Dutch Climate Agreement are used to find out the technical, financial and environmental implications of the proposed policy for the different typologies. The results are the needed techniques, investment costs, energy savings and payback period. The results are shown in the figure. These implications provided the context for the interviews with the office owners. The fourth theme aimed to find out the implications for the office owners. A large part of the office owners will not be able to adapt their building towards NZEB, because the needed investments costs are unreasonably high compared to the resulting rent income. This will, in turn, result in vacancy or demolishment of buildings and building adaptation will not take place. At the bottom part of the figure, also the results from the label C requirement are presented in order to compare the results of the NZEB adaptation. The adaptation towards label C, requires minor adaptation, little investment costs and relatively large energy savings. According to the owners, the investment costs are reasonable and most adaptations will take place.

Office stock

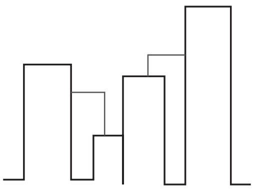
Chapter 3



Energy label G

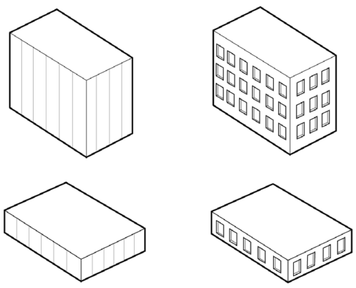
> 500 m2
> 1950

No monument



17.000 offices

14,6 % Label G
7.8 million m2
with label G



Energy policies

Chapter 4

NZEB

1. The max. energy demand
   < 90 kWh/m2.year
2. The max. primary fossil energy use
   < 50 kWh/m2.year
3. The min. % of renewable energy
   > 30%

Two scenario's for energy tax and elektricity prices:
1. increase gas tax with +1 cent, decrease electricity price with 0.5 cent
2. increase gas tax with +4 cent, decrease electricity price with 0.5 cent

NZEB

LABEL C

LABEL C

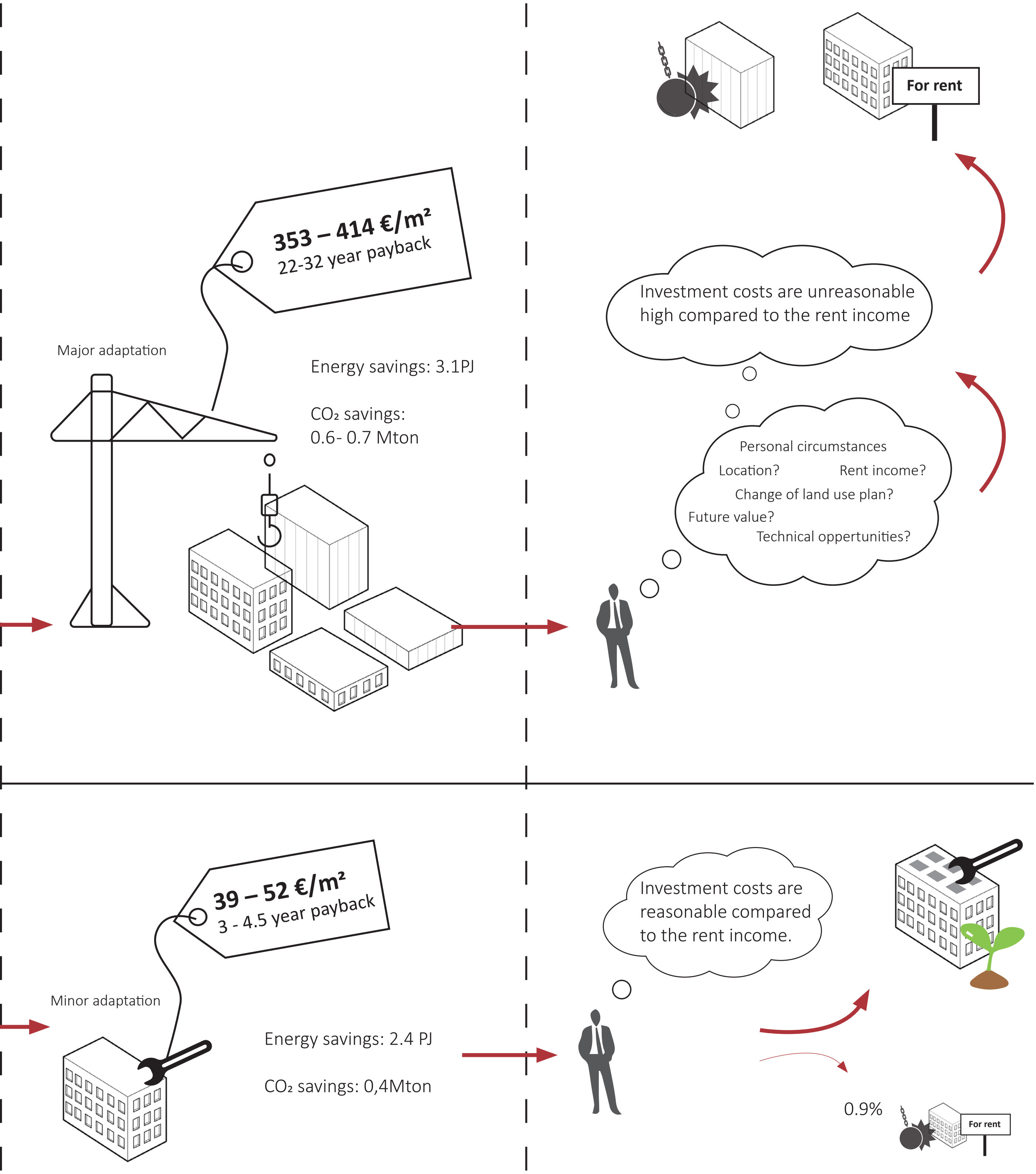
From the 1st of January 2023 onwards, it is forbidden to start using or to use an office building with a lower energy label than C (=EI 1,3)

Building adaptation

Chapter 5

Office owners

Chapter 6



8 Conclusions

8.1 Introduction

According to the Dutch National Climate Agreement, the Netherlands must reduce 95% of its CO2 emissions by 2050. Since the building industry is responsible for a large part of CO2 emissions. The 'Energy Performance of Building Directive' promotes the adaptation of all existing buildings towards nearly zero-energy buildings (NZEB) before 2050. However, the current adaptation rates are too low to achieve this on time. Besides, the current step by step approach from energy label C to A and from label A to nearly zero-energy leads to even more pressure on the adaptation sector. If these multiple steps could be skipped, adaptations could be executed more efficient, which reduce costs and time. This research started with the question whether the current step by step policy is sufficient to achieve these goals on time. However, a policy requiring direct adaptation towards nearly zero-energy offices has never been tested. Therefore, this research aimed to test the implications of going directly towards NZEB. To test this proposed policy, four sub-questions have been defined, each relating to a different theme. First, insight is provided in the current office stock which is used to create office typologies that represent the Dutch office stock, holding an energy label G. Second, the determination method of NZEB offices is explored and other policies that have influence on the proposed policy will be investigated. To find out what the implications of the required adaptation are, the techniques, investment costs and energy savings needed are studied. Last, the implications for the office owners are studied.

8.2 Conclusions on the sub-questions

Office stock: How can office typologies be created, in order to represent the office stock sufficiently for testing the technical consequences of the proposed policy?
Data on the building stock is important, in order to test and evaluate policies. To test the proposed policy, office typologies are created. The findings from the first theme suggest that the office stock holding a current energy label G can be represented by four typologies. The typologies are characterized by the construction type and compactness. The compactness and construction type highly influences the energy efficiency and the adaptation method of the office building. The typologies are used to execute the calculations of the building adaptation.

Energy policies: How can nearly zero-energy offices be determined? Which other policies have influence on the implementation of the proposed policy?
In conclusion, the findings suggest that the determination method to achieve nearly zero-energy offices consists of three indicators: the maximum energy demand, maximum primary fossil energy use and minimum percentage of renewables. Besides, the provisionary norms for new office buildings can be used to implement the proposed policy for existing offices with an energy label G, because the norms for new buildings are also applicable for major renovations. The aims from the Dutch National Climate Agreement will largely influence the proposed policy. It is quite certain that the tax for electricity will be lowered and the tax for gas will be increased. The two scenario's, presented in the Dutch Climate Agreement, are used to calculate the payback period of the implemented measures, needed to comply with the proposed policy. A policy often consists of packages of different instruments. Therefore, the evaluation of this regulative NZEB adaptation is in reality often supported by other policy tools such as: giving information, streamlining the organizational process, tax incentives or subsidies. This research will only take account of a regulative policy and the scenario's of the Dutch Climate Agreement for energy prices. However, it is important to keep the other policy tools in mind when evaluating the proposed policy.

Building adaptation: What techniques and investments are needed to achieve nearly zero-energy offices? What are the energy savings and what is the payback period?
Technically, existing offices with a current energy label G can be adapted towards NZEB. However, major adaptations are needed, often including the replacement of the facade. This results in the need for big investments ranging from 353 to 414 euros per square meter. On the other hand, major energy and CO2 savings are achieved. Adaptation of the entire Dutch office stock will result in 3.1 PJ energy savings and 0.6 to 0.7 CO2 emission reductions, which is already 60-70% of the aims of the Dutch Climate Agreement for utility buildings 2030. When looking at the payback period achieved by these energy savings, the payback period is ranging from 22 to 32 years. Next, adaptation from label G to label C is investigated. This requires

39-52 euro's per square meter, which will lead to 2.4 PJ energy savings and a payback period of 3 to 4.5 years. The adaptation towards label C lead to 42 MJ savings for each euro invested. For the adaptation towards NZEB this is only 8 MJ. The label C adaptation is approximately 5 times more cost efficient than adaptation towards NZEB. It can be concluded that the label C requirement is more cost-efficient.

Office owners: What are the implications of the proposed policy for office owners?
Adaptation result in nuisance for the owners because the users need temporary accommodation. Besides, a large share of the office owners will not have the financial possibilities to adapt their building towards NZEB, because the needed investments costs are unreasonable compared to the resulting rent income. In addition, it is often unclear what the future of the location will bring. Therefore, office owners in decreasing markets are not willing to do large investments, concerning the long payback period. As an alternative, owners will choose vacancy or demolishment and no adaptation of the building will take place. However, for offices located in an increasing office market, the NZEB adaptation is more likely to be feasible. Especially, when technical opportunities arise, such as a nearby datacentre, which can be used for heat waste. The results from the interviews showed that the location, technical opportunities, the personal situation of the investors, the vision of the investor regarding sustainability, the real estate strategy and the possibilities to change the land use plan are important factors that influence the decision making of the office owners. The findings from both the label C and NZEB requirement showed the importance of the location in the decision to adapt the building or not. However, the biggest difference between the label C and NZEB requirement, is that the policy towards NZEB needs major renovations, requires temporary accommodation and a much bigger investment.

8.3 Overall conclusion

After providing the conclusions on each sub-question an overall conclusion will be presented. The main research question was as follows: What are the technical, financial, social and environmental implications of the proposed policy requirement of NZEB adaptation of office buildings with a current G label?
The findings are ordered according to technical, environmental, financial and social implications and are summarized in the table 8.1.

	From G to Energy neutral	From G to C
Technical	To achieve NZEB, existing techniques can be used It involves major renovations, often including the replacement of the façade A heat pump is needed to achieve NZEB	Mainly replacement of installations The replacement of glass and cavity insulation is often also necessary
Environmental	Adapting the total office stock with a current energy label G will save 3,1 PJ energy This results in 0,6 – 0,7 Mton CO2 savings, which is 60 to 70 % of the goal of the Dutch Climate agreement for commercial buildings in 2030 Offices will become vacant or demolished. This means lost of scarce materials and environmentally not desirable	Adapting the total office stock with a current energy label G will save 2,4 PJ energy This results in 0,4 Mton CO2 savings, which is 60 to 70 % of the goal of the Dutch Climate agreement for commercial buildings in 2030 Depending on gas

Financial	The adaptation costs are ranging between 353 and 414 euro per square meter The payback periods ranging between 22 and 32 years, depending on the energy prices and taxes. For each euro invested, 8 MJ is saved During the adaptation, temporary accommodations is sometimes necessary. This results in the increasement of costs.	The adaptation costs are ranging between 39 and 57 euro per square meter The payback periods ranging between 4 and 4,5 years, depending on the energy prices and taxes. For each euro invested, 42 MJ is saved
Social	Major nuisance for users. Major vacancy/ demolishment of office buildings with a G label. Especially in peripheral industrial areas Office owners go bankrupt Difficult to find cheap office locations for small companies.	Little nuisance for users 0,9% vacancy.

Table 8.1: Technical, Financial, Environmental and Social implications(Author, 2019)

Technically, it can be concluded that existing offices with an energy label G, can be adapted towards NZEB. The techniques needed do already exists. However, major renovations are needed. This means that for example the whole façade needs to be replaced and a heat pump is necessary to achieve the NZEB standards. When adapting towards label C, only the replacement of installations, replacement of glass and cavity insulation is needed. Socially, this will result in less nuisance for the users. Environmentally, the adaptation of the Dutch office stock towards NZEB will result in 3.1 PJ energy savings and 0.6-0.7 Mton CO2-emission savings nationally. This is already 60- 70% of the climate goals for all utility buildings for 2030. On the other hand, when adapting the office stock towards label C, 2,4 PJ is saved. Environmentally, the demolition of office buildings is also not desirable, since it will result in loss of scarce materials. Financially, adapting towards NZEB will costs around 353-414 euros per m2. This is six times as high as adapting towards label C. The adaptation towards label C result in 42 MJ savings for each euro invested. For the adaptation towards NZEB this is only 8 MJ. In other words: adapting towards C is more cost effective than adapting towards NZEB. Environmentally, the demolition of office buildings is also desirable, since it will result in loss of scarce materials. Socially, the direct adaptation policy towards NZEB leads to nuisance for the users because the users need temporary accommodation. Besides, a large part of the office owners will not be financially able to adapt their building towards NZEB, because the needed investments costs are unreasonable compared to resulting the rent income. Office owners will go bankrupt and small companies will experience difficulties to find cheap office space.

Based on the conclusion of the main and sub-questions, it can be concluded that the direct adaptation policy will not lead to the desired effect of nearly zero-energy office buildings. The direct NZEB adaptation requires temporary accommodation and major investments. A large part of the offices will become vacant or demolished, since the adaptation costs are too high compared to the rent values. However, for offices located in an increasing office market, the direct NZEB adaptation is more likely to be feasible. Especially, when technical opportunities arise, such as a nearby data centre, which can be used for heat waste. Nevertheless, these findings suggest that lots of office owners will not be able to adapt their offices. Therefore, it is not possible to generalize such a regulative policy for all offices. The following chapter will present recommendations for policy makers.

9 Recommendations

9.1 Recommendations

The aim of this thesis was to show the complexity of implementing a regulative policy and thereby giving recommendations for policy makers. This complexity can be seen at the decision making process of the owners. The office owners make decisions based on different factors that will determine if they will adapt their building or not. For example, the location is an important factor in the decision to adapt the building. The rent income vary significantly among locations. Within the research sample, the rent income ranges between 23 and 360 euros per square meter. An office located at a location with a rent income of 360 euros per square meter yields a higher return after adaptation than an office building with a rent value of 23 euros per square meter. Therefore, it is difficult to generalize a regulative policy for all office owners. Based on the findings of this research, the following recommendations can be made:

1. Involve owners by evaluating policies
Through this research, it has been demonstrated that the involvement of owners when evaluating new policies is of major importance. A policy can be created for a more sustainable future, but without involving the owner, it can lead to negative effects, such as vacancy and demolishment.

2. Continuation of rent income
Policy evaluations should mainly focus on providing continuation of rent income instead of sufficient payback periods, based on the energy savings. According to the case study interviews, the owners of offices are most interested in the continuation of rent income, instead of the payback period. Also, the calculated payback period is not reliable, since it is difficult to estimate what the energy prices in the future will be. Besides, it is difficult to estimate what the actual savings are after the adaptation, since the actual energy use can differ from the calculated energy use. This will highly influence the payback times.

3. Creating visions for the future of office location
Regulative climate policies for offices will lead to the early depreciation of offices since it cannot be used without adaptation. Especially offices in decreasing office markets at industrial locations will be affected. Since the demand is decreasing, the rents are low and it is insecure whether or not the offices will be rented out after adaptation, office owners will not be able to make large investments for adaptation. If the land use plan could be changed to housing, investments could be more interesting, if the housing market at that location is increasing. According to the interviewees, municipalities are often reluctant to change the land use plan at industrial areas. However, regulative climate policies will result in vacancy at industrial areas. To overcome this, municipalities should already think ahead of the future of offices locations. They can create visions for those locations and thereby be more flexible with issuing permits and changing land-use plans, if it promotes the sustainability of existing buildings.

4. Make use of other policy tools at a differentiated approach
The findings suggest, that it is not possible to generalize the proposed policy for the total office stock. Therefore, ideally a differentiated ('tailor made') policy would be most appropriate. However, the implementation of such a policy is very difficult and guidelines should be made to make the division within a differentiated policy. It is evident that the location factor should play a role in this division, as this strongly influences the rental prices per square meter and therefore the payback time of investments. The investment costs for office adaptation are more or less the same within the country. However, the rent income can differ enormously.
Nevertheless, it could be questioned whether differentiated regulative policies will be possible to organize. The label C requirement will be more easy to generalize on a national level because the adaptation costs towards C are more or less reasonable for each location, In fact, the average renovation costs for adaptation towards label C can be compared with the regular maintenance costs. To conclude, to oblige the NZEB regulations for all existing offices, this will result in major vacancy and other negative impacts that will not contribute to a better environment as well. Nevertheless, the case study interviews showed that the adaptation could be possible in the city centre of Amsterdam. Therefore, it can be recommended to stick at the label C requirement and use other policy tools to stimulate the adaptation towards NZEB. This stimulation should start at offices that are willing and capable of the adaptation. They can show the advantages and hopefully the next group will follow.

10 Discussion

10.1 Introduction

This study showed that to achieve NZEB offices, it is not possible to simply implement a regulative policy. Therefore this chapter discusses the significance of the conclusions of this research within a broader context of energy policies and sustainability. Several topics will be discussed, which give a substantial impression of the complexity of the implementation and success of an energy policy for the existing building stock.

10.2 Challenges for energy policies for existing buildings

The conclusions of this research suggest, that it is not possible to simply implement a regulative policy to achieve nearly zero-energy offices. To achieve a nation-wide NZEB office stock goes beyond the adaptation on building level. For example, the electricity used in this buildings must be produced from renewable sources, requiring a transition in the electricity sector as well. The aim of the Dutch Climate Agreement is to produce 70% of all electricity needed from renewables in 2030. In addition, heat companies will develop sustainable heat sources, such as geothermal energy, waste heat, solar heat, bio mass, power to heat and sustainable gasses. For offices, to make use of this sustainable sources, they should be connected to the district heating (Klimaatakkoord, 2018). However, also in the energy industry, there are major issues to tackle. One example of an issue for the electricity sector is the distribution and storage of energy. Moreover, the sector is faced by an everlasting discussions about biomass, nuclear energy and the Not-In-My-Backyard syndrome for wind farms. These are all important issues that were excluded from this research but do influence directly or indirectly the built environment.

As indicated in the introduction, the current renovation rates are too low to achieve the renovation rate required to achieve nearly zero-energy buildings in 2050. To respond to this challenge, the Dutch Government will launch an innovation program, to advance industrial approaches to bring down the costs and accelerate the renovation capacity. This can be achieved by standardization, digitalization, prefabrication and automation (Ostermeyer et al., 2018). If the costs of these techniques will decrease, it will largely influence the results from this research. For example, the payback period will be much shorter and investors would probably be more willing to invest in the adaptation when the renovation costs decrease. To achieve nearly zero-energy buildings, often the installation of heat pumps is needed. However, heat pumps are still quite expensive. According to Mulder, Bonte, Kalkman & Smit-Rietveld (2017), the prices of heat pumps will be comparable with the current CV and HR boiler, if the supply will be corresponding with the supply of the conventional boiler. Also Diederik Samson, who chaired the Climate Table about the built environment [Klimaattafel gebouwde omgeving], argued that heat pumps will in the future be cheaper and more efficient (Winterman, 2018). However, according to the chairperson of the largest heat installation supplier of the Netherlands, Remeha, this is not the case. Heat pumps are already produced in enormous amounts, since the techniques is the same as for air conditioners (Reijn, 2019). These arguments show that the reduction in costs of heat pumps is highly contested, but will also influence the feasibility of NZEB adaptation.

There are discussions about how to measure the energy efficiency of a building. Several studies indicate a big gap between the theoretical energy consumption and the real energy consumption of a building (Macjen, 2016; Simpa, Kremer & Vroom, 2017). The NZEB indicators are calculated based on the characteristics of the building. According to Simpma, Kremer & Vroom (2017), the calculated energy consumption can be three times higher than the real energy consumption. Therefore, it could be questioned whether it is sufficient to use the theoretical energy consumption for energy policies for buildings.

Another important issue is the governance of the whole climate transition. It could be questioned whether this top down-method of regulation policies is sufficient for such a big transition. According to Rotmans (2019), the climate transition is the biggest challenges we have ever faced. He argues, that the transition starts with engaging large amounts of people. Currently, there is little support from the public. 80% believes more should be done to tackle climate change. However, when it comes to willingness to bear the needed measures, 80% opposes. This reluctance will be even bigger if the Government implement compulsory measures in a centralistic way. However, there is differentiated support, because some municipalities and neighbourhoods are already frontrunners. He argues to begin by implementing measures at frontrunner areas. This allows the Government to show the advantages to the greater public and slowly expand to less willing neighborhoods. This differentiation in policy deployment is found in this thesis as well, as a differentiation based on the rent levels at different locations.

To conclude, lots of challenges, insecurities and innovations are going on in the energy industry. These are all important issues that were excluded from this research but do influence the adaptation of office buildings. Besides, the challenges described above are not a complete list of challenges, however it gives a substantial impression of the complexity for the field of energy policies for existing buildings.

10.3 Limitations

This master thesis is focused only on the energy savings during the operation of the building. However, buildings consume energy throughout their whole life cycle. The energy consumption of a building can be divided into six stages:

- extraction of raw materials;
- production of materials and components;
- transportation;
- construction;
- operation;
- demolition (Konstantinou, Cukovic Ignjatovic & Zbasnik-Senegacnik, 2018).

The results of this master thesis suggest that often the facades needs to be replaced. According to Hildebrand (2012), the façade contributes around one third of the total embodied energy of the structure. It can be concluded that the building adaptation will consume more energy than is indicated in this research, when taking the whole life cycle into account. Therefore, it is difficult to compare the findings with label. To achieve label C, less raw materials are needed, but during operations more energy is consumed.
Another limitation, is the generalization of the office typologies and thereby the generalization of needed techniques. Almost each office building is different and requires different adaptation techniques. Due to this generalization, the possibilities of creativity and technical opportunities are excluded. Also, some limitations can be found in the used database. For example, energy labels according to the building date are used to add to the office buildings without an energy label. This way of adding energy labels is limited, since it is unclear if the building is already renovated or not. Besides, six case study interviews are executed. The outcomes might have been different if more case study interviews were executed.
Moreover, as explained in chapter 4, other policy tools are available to support the direct adaptation towards NZEB. Giving information to office owners could for example help to leverage the technical opportunities. Or subsidies could help to decrease the investment costs. However, this research focussed on the implications of a regulative policy and therefore other policy tools are excluded from the research. Nevertheless, future research could help to get insight in the effects of other policy tools to achieve NZEB office adaptation.

References

Activiteitenbesluit Milieubeheer 2.6. (2007). Retrieved from: https://wetten.overheid.nl/BWBR0022762/2019-01-01

Adams, D. & Tiesdell, S. (2012). Shaping Places: Urban Planning, Design and Development. London: Routledge. 24.

Arcadis. (2016). Actualisatie investeringskosten maatregelen EPA-Maatwerk-Advies: Bestaande utiliteitsbouw 2016. Retrieved from: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/technieken-beheer-en-innovatie/investeringskosten-energiebesparende-maatregelen

Arcadis. (2017). Vormfactoren & Kostenkengetallen & Assets 2017. Retrieved from: https://www.arcadis.com/media/6/B/C/%7B6BCE6385-98BA-4DC0-A023-C2A305C4D720%7DBrochure%20Vormfactoren%20en%20Kostenkengetallen%20Assets%202017.pdf

Arnoldussen, J., van Zwet, R., Koning, M. & Menkveld, M. (2016). Verplicht energielabel voor kantoren. Retrieved from: https://www.eib.nl/pdf/verplicht_energielabel_voor_%20kantoren.pdf

Attia, S. (2018). Net Zero Energy Buildings (NZEB)- Concepts, Frameworks and Roadmap for Project Analysis and Implementation. Hull, Canada: Elsevier.

BEG (2016). Besluit Energieprestatie Gebouwen. Retrieved from:https://wetten.overheid.nl/BWBR0023734/2016-07-01.

Blok, S.A. (2017). 30 196. Duurzame ontwikkeling en beleid [Letter of Government]. Retrieved from: https://zoek.officielebekendmakingen.nl/kst-30196-485.html#ID-791585-d36e381

BPIE. (2011). Europe's buildings under the microscope. Retrieved from http://bpie.eu/wp-content/uploads/2015/10/HR_EU_B_under_microscope_study.pdf

Buck Consultants International. (2011). Doelgroepenonderzoek segmentatie duurzaamheid Nederlandse kantorenmarkt. Retrieved from: https://www.rvo.nl/sites/default/files/bijlagen/Rapport%20doelgroepenonderzoek%20segmentatie%20Duurzaamheid%20Nederlandse%20Kantorenmarkt.pdf

Bruce, C. S. (1994). 'Research Students' Early Experiencesof the Dissertation Literature Review', Studies in Higher Education, 19(2): 217– 29.

CBS. (2017). Rendement en CO2 emissie elektriciteitsproductie 2015. Retrieved from:https://www.cbs.nl/nl-nl/achtergrond/2017/06/rendementen-en-co2-emissie-elektriciteitsproductie-2015

CBS. (2019). Energierekening 334 euro hoger. Retrieved from: https://www.cbs.nl/nl-nl/nieuws/2019/07/energierekening-334-euro-hoger

CPB. (2019b). CPB Infographic Doorrekening ontwerp-Klimaatakkoord. Retrieved from: https://www.cpb.nl/sites/default/files/omnidownload/CPB-Infographic-Doorrekening-ontwerp-Klimaatakkoord.pdf

Cushman and Wakefield. (2018). Nederland compleet, januari 2018, Kantoren- en bedrijfsruimtemarkt. Retrieved from: www.cushmanwakefield.nl/nl-nl/research-and-insight/2018/nederland-compleet-januari-2018

De Architect (2018). Winy Maas: 'De traditionele gevel verdwijnt'. Retrieved from: https://www.dearchitect.nl/techniek/artikel/2018/01/winy-maas-de-traditionele-gevel-verdwijnt-101186688

De Gunst, D.D. & de Jong, T. (1989). Planning en ontwerp van kantoorgebouwen. Delft, The Netherlands: TU Delft.

De Jonge, H. (2017). Real Estate Management: Adding Value [PowerPoint Presentation]. Retrieved from: https://brightspace.tudelft.nl/d2l/le/content/49531/viewContent/680352/View

Deloitte UK. (2014). Carbon Penalties and Incentives report. United Kingdom, Deloitte Real Estate.

Deloitte UK. (n.d.). Carbon Penalties and Incentives report. Retrieved from: https://www2.deloitte.com/ uk/en/pages/real-estate/articles/carbon-penalties-and-incentives-report.html

DGMR. (2016). Referentiegebouwen BENG. Retrieved from: https://www.rvo.nl/file/referentiegebouwen-bengpdf

DGMR. (2017). Luchtdicht gebouw in zeven stappen. Retrieved from: https://www.aannemervak.nl/wp-content/uploads/2017/12/Luchtdicht-gebouw-in-zeven-stappen.pdf

Dobbelsteen, A. van den, & Tillie, N. (2011). Energetic Urban Planning- A novel approach to carbon neutral cities. SB11 Helsinki World Sustainable Building Conference.

Douglas, J. (2006). Building Adaptation. Oxford, United Kingdom: Butterworth Heinemann.

Durier, F. (2013). Initiatives in support of efficient buildings: the role of industry. Retrieved from: http://www.buildup.eu/en/practices/publications/initiatives-support-efficient-buildings-role-industry

Eurostat. (2017). Renewable energy statistics. Retrieved from: https://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics

Ebbert, T. (2010). Re-face, Refurbishment strategies for technical improvement of office facades [Dissertation]. Delft University of Technology, Delft.

Energieneutraal. (2014). In van Dale online Dictionary. Retrieved from: https://www.vandale.nl/zoeken/o/zoeken.do

EPG. (2018). NTA 8800 ten behoeve van vaststelling BENG-eisen. Retrieved from: http://www.gebouwe nergieprestatie.nl/nta-8800-ten-behoeve-van-vaststelling-beng-eisen/

European Parliament and the Council of the European Union. (2010). DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings (recast)

European Parliament. (2016). Boosting Building Renovation: What potential and value for Europe. Retrieved from: http://www.europarl.europa.eu/RegData/etudes/STUD/2016/587326/IPOL_STU(2016)587326_EN.pdf

European Commission. (2012). Roadmap 2050. Policy, (April), 1–9. https://doi.org/10.2833/10759

European Commission. (2016). EU Buildings Database. Retrieved from: https://ec.europa.eu/energy/en/eu-buildings-database

European Union. (2012). Betreffende energie-efficiëntie, tot wijziging van Richtlijnen 2009/125/EG en 2010/30/EU en houdende intrekking van de Richtlijnen 2004/8/EG en 2006/32/EG, (L 315/1),1–56.

European Union. (2010). Richtlijn 2010/31/Eu Van Het Europees Parlement En De Raad, 2010(juni), 13–35.

European Union. (2018). Amending Directive EPBD. Retrieved form: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L0844&from=EN

Gelinck, S. & van Zeeland, H.H. (2010). Transformatiewijzer: van kantoor naar woonruimte: perspectief, financiën en regelgeving. Delft: SBR.

Geraedts, R.P., Van der Voordt, D.J.M. and Remøy, H.T. (2017). Conversion Meter. A new tool to assess the conversion potential of vacant office buildings into housing. Conference paper. International Conference on Advances on Sustainable Cities and Buildings Development. Porto, Portugal, 15-17 November 2017. 12 pp

Hartenberger,U., Lorenz, L., Sayce, S. & Toth, Z. (2017). Creating an Energy Efficient Mortgage for Europe, Mortgage lending valuation and the impact of energy efficiency: an overview of current practices. Retrieved from: https://eemap.energyefficientmortgages.eu/wp-content/uploads/2018/04/EeMAP-Technical-Report-on-Mortgage-Lending-Valuation-and-the-Impact-of-Energy-Efficiency.pdf

Hildebrand, L. (2012). Embodied energy in façade design. Retrieved from: https://repository.tudelft.nl/islandora/object/uuid%3A15b40e6f-cad1-48b2-9ca0-daf04e27b161?collection=research

ING. (2017). ING en Universiteit Maastricht: Verduurzamen Kantoorpanden leidt tot 9 Procent Waardestijging. Retrieved from: https://www.ing.nl/nieuws/nieuws_en_persberichten/2017/04/ing_en_universiteit_maastricht_verduurzamen_kantoorpanden_leidt_tot_9_procent_waardestijging.html

Itard, L., & Majcen, D. (2014). Relatie tussen energiegebruik en CO2-uitstoot van Amsterdamse corporatiewoningen.

Kadaster. (n.d.a). Basisregistratie adressen en gebouwen. Retrieved from: https://zakelijk.kadaster.nl/basisregistratie-adressen-en-gebouwen

Kadaster. (n.d.b). BAG terugmelden. Retrieved from: https://zakelijk.kadaster.nl/bag-terugmelden

Knaack, U., Klein, T., Bilow, M. & Auer, T. (2007). Facades, Principles of Construction. Berlin, Germany: Birkhäuser.

Klimaatakkoord. (2018). Ontwerp van het Klimaatakkoord. Retrieved from: https://www.klimaatakkoord.nl/klimaatakkoord/documenten/publicaties/2018/12/21/ontwerp-klimaatakkoord

Klimaatwet. (2016). Retrieved from: https://www.tweedekamer.nl/kamerstukken/wetsvoorstellen/detail?cfg=wetsvoorsteldetails&qry=wetsvoorstel%3A34534

Koppels, P. (2019). Real Estate Finance 3 [PowerPoint Presentation]. Retrieved from TU Delft Brightspace: https://brightspace.tudelft.nl/d2l/le/content/35593/viewContent/576509/View

Konstantinou, T., Cukovic Ignjatovic, N. & Zbasnik-Senegacnik, M. (2018). Energy. Retrieved from: https://repository.tudelft.nl/islandora/object/uuid%3A320f4b29-235d-4355-913f-2b07f0d5d44c?collection=research

Lawson, B. (2006). How designers think, the design process demystified. Amsterdam: Architectural Press.

Leidelmeijer, K., de Wildt, R., Borsboom, W. & van Vliet, M. (2017). Monitoring energiesprong, Kosten van Verduurzaming van Woningen. Retrieved from: https://www.rigo.nl/wp-content/uploads/2017/11/kosten-verduurzaming.pdf

LenteAkkoord. (2018). Initiatiefnemers Lente-akkoord onderzoeken mogelijke impact definitieve BENG-eisen. Retrieved from: https://www.lente-akkoord.nl/initiatiefnemers-lente-akkoord-onderzoeken-mogelijke-impact-definitieve-beng-eisen/

LenteAkkoord. (2019). Concepteisen Beng kunnen ambitieuzer. Retrieved from: https://www.lente-akkoord.nl/opinie-concepteisen-beng-kunnen-ambitieuzer/

Ling D. C. and Archer W. R. (2013). Real Estate Principles: A Value Approach. New York, NY: Mcgraw-Hill Education

Majcen, D. (2016). Predicting energy consumption and savings in the housing stock [Docteral thesis]. University of Technology, Delft.

Meijer, F., Straub, A., & Mlecnik, E. (2018). Consultancy centres and pop-ups as local authority policy instruments to stimulate adoption of energy efficiency by homeowners. Sustainability (Switzerland), 10(8). https://doi.org/10.3390/su10082734

Mulder, G., Bonte, C., Kalkman A. & Smit-Rietveld, C. (2017). Roadmap Warmtepompen. Retrieved from: https://www.topsectorenergie.nl/sites/default/files/uploads/Urban%20energy/publicaties/TNO%20TKI%20Roadmap%20warmtepompen%202017.pdf

NEEAP. (2017). Vierde Nationale Energie Efficientie Actie Plan voor Nederland, (april).

NEN. (2018). NTA 8800, Energy performance of buildings- Determination method. Delft: NEN connect.

NEN. (2004). NEN 2916, Energy performance of utility buildings- Determination method. Delft: NEN connect.

NEN. (2012). NEN 7210, Energy performance of buildings- Determination method. Delft: NEN connect.

NEN. (2014). 1 januari 2015: aanscherping EPC en hogere Rc-waarden. Retrieved from:https://www.nen.nl/NEN-Shop/Bouwnieuwsberichten/1-januari-2015-aanscherping-EPC-en-hogere-Rcwaarden.htm

Nutt, B. (1993) The Adaptive Reuse of Buildings, Paper presented at a Conference on Building Refurbishment. London: Publisher Unknown.

Meijs, M. & Knaack, U. (2010). Bouwdelen en verbindingen. Amsterdam, The Netherlands: SUN.

Ollongren, K.H. (2018). Besluit van 17 oktober 2018, houdende wijziging van het Bouwbesluit 2012 betreffende de labelverplichting voor kantoorgebouwen [Letter to parliament]. Retrieved from: https://zoek.officielebekendmakingen.nl/stb-2018-380.html

Ouwerkerk, E. (2017). Verplicht Energielabel C voor Kantoorgebouwen Stelt als Maatregel Niets Voor. Retrieved from: https://fd.nl/opinie/1192059/verplicht-energielabel-c-voor kantoorgebouwen-stelt-als-maatregel-niets-voor#

Oranje, J. (Stage manager). (2019, 13th May). Het grote Europese lijsttrekkersdebat. Nieuwsuur, Hilversum: NPO.

Ostermeyer, Y., Camarasa, C., Saraf, S., Naegli, C., Jakob, M., Visscher, H. & Meijer, A. (2018). Building Market Brief The Netherlands. Retrieved form: http://cuesanalytics.eu/wp-content/uploads/2018/10/181023-CK-BMB-BMB_NETHERLANDS-DEF-CIE-Edition.pdf

PBL. (2019). Effecten ontwerp Klimaatakkoord. Retrieved from:https://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2019-effecten-ontwerp-klimaatakkoord_3619.pdf

Raiji, B., Tenpierik, M. & Dobbelsteen, A. (2017). Early-Stage Design Considerations for the Energy-Efficiency of High-Rise Office Buildings. Sustainability, 9(4), [623]. DOI: 10.3390/ su9040623

Reijn, G. (2019). De duurzame warmtepomp goedkoper? 'Dat gaat echt niet gebeuren'. Retieved from: https://www.volkskrant.nl/economie/de-duurzame-warmtepomp-goedkoper-dat-gaat-echt-niet-gebeuren~b9b2896f/?utm_campaign=shared_earned&utm_medium=social&utm_source=email

Remoy ,H. T. & van der Voordt, D.J.M. (2014). Adaptive reuse of office buildings: opportunities and risks of conversion into housing. Building Research & Information 42(3), 381-390.

Rockwool. (n.d.). RockFit Mono. Retrieved from: https://cdn01.rockwool.nl/siteassets/rw-bnl/downloads-nl/downloads/technische-productbladen/gevel/technisch-productblad-rockfit mono-nl.pdf?f=20190228102426

Rompa, I. (2016). Nederlandser zetten zich in voor groen Vancouver. Duurzaam Gebouwd, 15, 75-77.

Rotmans, J. (2019, June 5). Governance klimaatbeleid. At rondetafelgesprek Tweede Kamer [Video debate]. Retrieved from: https://debatgemist.tweedekamer.nl/debatten/governance-klimaatbeleid

RVO. (n.d.a). Energie index. Retrieved from: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels-gebouwen/bestaande-bouw/energie-index

RVO. (n.d.b). Energieprestatie (EPC). Retrieved from: https://www.rvo.nl/onderwerpen/duurzaam ondernemen/gebouwen/wetten-en-regels-gebouwen/nieuwbouw/energieprestatie-epc

RVO. (n.d.c). SDE. Retrieved from: https://mijn.rvo.nl/sde

RVO. (n.d.d). Algemene begrippen. Retrieved from: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels-gebouwen/algemene-begrippen

RVO. (n.d.e). Verschil Energie-Index (EI) en Energie Prestatie Coëfficiënt (EPC). Retrieved from: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels-gebouwen/bestaande-bouw/energie-index/verschil-energie-index-en-epc.

RVO. (n.d.f). De Energie-Index en het Energielabel. Retrieved from: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels-gebouwen/bestaande-bouw/energie-index/verschil-energie-index-en-energielabel

RVO. (n.d.g.) Duurzaam ondernemen, warmte en koude opslag. Retrieved from: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/warmte-en-koudeopslag.

Sipma, J. (ECN), Kremer, A. (CBS), & Vroom, J. (CBS). (2017). Energielabels en het daadwerkelijk energieverbruik van kantoren, 89.

TABULA. (2012a). Typologie Approach for Building Stock Energy Assesment. Main results from TABULA project. Retrieved from: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/tabula_final_report_en.pdf

TABULA. (2012b). Typology Approaches for Non-Residential Buildings in Five European Countries- Existing Information, Concepts and Outlook. Retrieved from: http://episcope.eu/fileadmin/tabula/public/docs/report/TABULA_TR3_D9_NonResidentialBuildings.pdf

Thijssen, C.C.F. (1990). Technische kwaliteit van etagewoningen [Docteral thesis]. University of Technology, Delft.

UNFCCC (n.d.). What is the Paris Agreement? Retrieved from: https://unfccc.int/process andmeetings/the-paris-agreement/what-is-the-paris-agreement

Van der Linden, A.C., Erdtsieck, P., Kuijpers-van Gaalen, I.M., Zeegers, A. & Selten, T.A.J. (2011). Bouwfysica (7th ed.). Amersfoort, The Netherlands: ThiemeMeulenhoff.

Van der Linden, A.C. & van den Ham, E.R. (2015). Feiten en fabels na-isoleren van spouwmuren. Retrieved from:

https://www.weston.nl/Files/webentity/NewsItem/feiten-en-fabels-na-isoleren-van-spouwmuren/feiten-en-fabels-over-spouwmuur-na-isolatie_oktober-2015.pdf

Van den Dobbelsteen. (2004). The Sustainable Office [Docteral thesis]. University of Technology, Delft.

Van der Loos, R. & Kuijpers – van Gaalen, I.M. (2019). BENG is verander, maar wat betekent dat nu echt? Tvvl Magazine, 1, 46-49.

Van Hoek, T. & Koning, M. (2018). Klimaatbeleid en de gebouwde omgeving. Retrieved from: https://www.eib.nl/?s=klimaatbeleid+en+de+gebouwde+omgeving

WCED. (1987). Report of the World Commission on Environment and Development: Our Common Future. Retrieved from: http://mom.gov.af/Content/files/Bruntland_Report.pdf

Weijer, H. (2019). De lange weg van de nieuwe 'BENG'-rekenmethode NTA 8800. Tvvl Magazine, 1, 44-45.

Wiebes, E. (2018). Kamerbrief over gaswinning Groningen. Retrieved from: https://www.rijksoverheid.nl/documenten/kamerstukken/2018/03/29/kamerbrief-over-gaswinning-groningen

Wiebes, E. (2018b). Kamerbrief over verbreding van de SDE. Retrieved from: https://www.rijksoverheid.nl/documenten/kamerstukken/2018/11/26/kamerbrief-over-verbreding-van-de-sde

Wilkinson, S. (2012). Analysing sustainable retrofit potential in premium office buildings. Structural Sur vey, 30(5), 398–410. https://doi.org/10.1108/02630801211288189

Wilkinson, S. (2013). Sustainable Urban Retrofit Evaluation. Retrieved from: https://www.researchgate.net/publication/280628530

Wilkinson, S., James, K., & Reed, R. (2009). Delivering sustainability through the adaptive reuse of com mercial buildings: the Melbourne CBD challenge. Proceedings of the Pacific Rim Real Estate Society 15th Annual Conference, (June 2008), 1–19. https://doi.org/10.1675/1524-4695(2008)31

Wilkinson, S., & Remoy, H. (2015). Sustainability and Office To Residential Conversion Adaptation in Sydney ., (Bullen).

Winterman, P. (2018). Met 10.000 euro kunnen Nederlands al flink besparen. Retrieved from: https://www.ad.nl/politiek/met-10-000-euro-kunnen-nederlanders-al-flink-besparen~a23fbcc8/

Vedung, E. (1999). Constructing effective Government information campaigns for energy conservation and sustainability: Lessons from Sweden. International Planning Studies, 4(2), 237-251, DOI: 10.1080/13563479908721737

Venta. (n.d.). Raam en deursystemen, Venta. Retrieved from: https://nl.aluk.com/nl_ve/producten/raam-en-deursystemen/venta

Yanovshtchinsky, V., Huijbers, K. & van den Dobbelsteen, A. (2012). Architectuur als Klimaatmachine. Amsterdam: SUN.

Yin, R.K. (2014). Case Study Research, Design and Methods (4e ed.). Los Angeles, CA: SAGE Publications.

Images

Recticel insulation (n.d.). Retrieved from: https://www.recticelinsulation.com/be-nl/home?utm_source=Livios&utm_medium=Website&utm_campaign=Editorial-de-efficientste-manier-via-je-buitenmuur

Forum Rotterdam. 2017. Retrieved from: https://nieuws.top010.nl/forum-rotterdam.htm

Kadaster (n.d.) Retrieved from: https://www.kadaster.nl/

RVO (n.d.) Retrieved from: https://www.rvo.nl/

Cultureel Erfgoed (n.d.) Retrieved from: https://www.cultureelerfgoed.nl/

BP Architectuur (n.d.). Retrieved from: http://www.bpa-zwolle.nl/startpagina/projecten/patio-bungalow-zwolle/

Appendix B

B.1 Reflection

The method

The biggest challenge during my research was the lack of information about office typologies and investment costs for nearly zero-energy adaptation. Due to this lack of information, I wanted to create my own typologies and calculate the investment costs myself. This required exploring new techniques and software programs such as SPPS and Uniec2. In order to calculate the investment costs, I also needed to know more about the technical aspects of building adaptation. Therefore, I studied several books of the department of Building Technology. Because of my eagerness, I also dived in the policy documents of the Dutch Climate Agreements, several European Directives and norm documents, such as the NTA 8800 and NEN7120. Due to my enthusiasm to dive in all these topics, I was a bit drowned in all information and had difficulties to write down everything I studied properly. If I had to do this thesis over again, I would have focused on the implications for the office owners. I would not calculate the investments costs myself, but use literature to find out what plausible costs are. Investment costs for the adaptation towards nearly zero-energy for existing office buildings is not calculated yet by other researches, but literature can help to give an indication of these costs. This indication would have been sufficient to find out what the implications of a direct NZEB policy for the offices owners are. If I would have narrowed down my graduation topic like explained, I expect that my structure was more clear and consistent. However, I would not have learned that much about all those topics I studied.

Feedback from mentors and others

During my thesis, I received a lot of feedback from my mentors and colleagues from Arcadis. This feedback was always very useful. The feedback was often given like questions and why I made certain choices. Therefore, I needed to give clear argumentations for my choices and stay critical about my own work. I have learned that although you receive feedback, you still have to make your own choices. Sometimes you also don't need to use the feedback, as long as you have a good argument why you didn't use it. This is exactly how I dealt with the feedback during my elective at complex projects and during design project in my bachelor. However, I could have asked for more feedback from others. As explained, I had difficulties with structuring all the information I researched. It could have helped to ask more people to read though the parts I wrote, since it was sometime difficult to oversee everything myself.

Reflection on topic

My personal aim for this thesis was to develop more knowledge about the practical implications to achieve nearly zero-energy adaptation, while considering especially the perspectives of the stakeholders. Regarding the results of this thesis, I developed another opinion about the role of the Government in the climate transition. First, I was surprised by the label C requirement, since it sounds not ambitious. However, my thesis showed, that simply implementing a more ambitious regulative policy will not directly lead to the desired results. A regulative policy should be carefully considered and is only possible when it can be generalized for the office stock. This is difficult, since every building and office owner is different. To achieve nearly zero-energy offices, I think the Government should not take up a top down centralistic approach, but use other policy tools to achieve nearly zero-energy offices. As a consequence, I think great opportunities arise for architects and consultants. They can develop business models to specific cases and try to add most value to buildings and thereby create the opportunity to invest more in sustainability. From the interviews, I also experienced that not all office owners are concerned with climate change or have much knowledge about sustainable adaptation. Therefore, I think consultants and architects should take up an active approach to develop business cases and contact building owners to look for the most beneficial opportunities to sustainably adapt their buildings. The Government should focus more on rewarding and stimulating these kind of projects instead of implementing regulative policies, followed by a fine, when the office owner doesn't fulfill the requirement. Indeed, rewarding good behavior is always more helpful than punishing bad behavior.

Added value of the research
The results of this thesis could be off relevance when policy makers will develop the aims and goals from the Dutch Climate Agreement. For buildings, the Dutch Climate Agreement focusses on standardization. They will develop concrete targets that buildings should achieve before 2030. The progress towards the target for 2030 will be monitored by the municipalities, every 4 years. If the progress is not enough, obligatory requirements can become in force. However, this study shows it is not possible to simply implement norms for buildings. The adaptation of buildings need to be supported by the building owners as well. For office owners, to make the decision to adapt a building, is influenced by lots of different factors. For example, the rent income is an important factor in the decision to adapt, which differs enormously within the country. This makes it impossible to set standards for all building in the Netherlands. Therefore this study shows to policy makers of the climate agreement that policies should stimulate office owners at a differentiated approach. This stimulation should start at offices that are willing and capable of the adaptation. They can show the advantages and hopefully the next group will follow.

Relation between graduation topic and master track
I think my graduation topic is closely related to the master track. In the Real Estate Management course of this master track, students learn the importance of the fit between demand and supply. We are living in an ever changing environment, where technological innovation, globalization and urbanization asks for different types of real estate and influences the market. Since real estate is static and the demand is ever changing, there is a continue mis match between supply and demand. This mis match can also be seen in this research. The current supply is the office building with an energy label G, the current demand is the NZEB requirement.

Another important topic of the Real Estate Management department is scenario planning. Scenario planning can help to explore the future demand in order to be more prepared for the changing demand. Scenario planning could also be off relevance for the office owners, which were interviewed for this research. The office owners often reconsidered the future of the building, before deciding to invest in the building. The future of the building is important for the stability of rent income to be able to earn back the investment costs. However, it is of course very difficult to consider the future of the building, they indeed don’t have a crystal ball. To explore the future mismatch, ‘scenario planning’ is used. This helps to be more prepared for the changing demand in the future. For example, if the results from the scenario planning indicate the possibility for a rising student population in the neighborhood, the investor could consider this during the adaptation and already talk with the municipality for the possibilities to change land use plans.

B.2 BAG sources

Below the differences sources used for the database are presented.

- BAG: https://nlextract.nl/downloads/
  Date: 01-01-2019

- Label database RVO: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/hulpmiddelen-tools-en-inspiratie-gebouwen/ep-online
  Date 01-01-2019

- Monumentendatabase: https://cultureelerfgoed.nl/node/1341
  Extract date: 18-02-2019

B.3 Sample

In this appendix, information about the sample used in this study is presented.

Amsterdam
Building date: 1993
BVO: 944 m_2
Registered energy label: Yes, valid until 2023
Compactness: 1,93
Facade type: Non load bearing
Tenant: Multi tenant building (11)
Owner: Private owner

Amsterdam
Building date: 1963
BVO: 3.289 m_2
Registered energy label: No
Compactness: 1,67
Facade type: Non load bearing
Tenant: Single
Owner: Private owner

Amsterdam
Building date: 1950
BVO: 11.229 m_2
Registered energy label: No
Compactness: 1,67
Facade type: Load bearing
Tenant: Multi (52)
Owner: Private owner

Amsterdam
Building date: 1968
BVO: 5.005 m_2
Registered energy label: No
Compactness: 1,00
Facade type: Non load bearing
Tenant: Multi 42
Owner: Private owner

Arnhem
Building date: 1967
BVO: 1700 m_2
Registered energy label: No
Compactness: 2,42
Facade type: Load bearing
Tenant: Single
Owner: Owner and user

Dordrecht
Building date: 1982
BVO: 3653
Registered energy label: Yes, valid until 2026
Compactness: 1,25
Facade type: Non load bearing
Tenant: -
Owner: Private owners

Den Bosch
Building date: 1979
BVO: 1260
Registered energy label: Yes, valid until 2025
Compactness: 2,16
Facade type: Non load bearing
Tenant: Single
Owner: Owner and user

Zwolle
Building date: 1988
BVO: 2380
Registered energy label: Yes, valid until 2027
Compactness: 0,94
Facade type: Load bearing
Tenant:
Owner: Unknown

Eindhoven
Building date: 1977
BVO: 3156
Registered energy label: Yes, valid until 2019
Compactness: 1,05
Facade type: Non load bearing
Tenant: Multi
Owner: Municipality of Eindhoven

Leeuwarden
Building date: 1968
BVO: 4608
Registered energy label: No
Compactness: 1,10
Facade type: Non load bearing
Tenant: Single
Owner: Private owner

Emmen
Building date: 1971
BVO: 1125
Registered energy label:
Compactness: 1,41
Facade type: Non load bearing
Tenant: Multi
Owner: Private owner and developer

Leiden
Building date: 1950
BVO: 6554
Registered energy label: Yes, valid until 2025
Compactness:
Facade type:
Tenant: Multi
Owner: Municipality of Leiden

Huis ter Heide
Building date: 1987
BVO: 1176
Registered energy label: Yes, valid until 2021
Compactness: 1,89
Facade type: Non load bearing
Tenant: Multi
Owner: Private owner developer

Hoogezand
Building date: 1961
BVO: 899
Registered energy label: Yes, valid until 2028
Compactness: 1,77
Facade type: Load bearing
Tenant: Single
Owner: Private owner

Amersfoort
Building date: 1977
BVO: 3218
Registered energy label: Yes, valid until 2016
Compactness: 1,37
Facade type: Non load bearing
Tenant:
Owner: Municipality of Amersfoort

Bussem
Building date: 1970
BVO: 1887
Registered energy label: No
Compactness: 2,76
Facade type: Load bearing
Tenant: Single
Owner: Owner and user

Heemskerk
Building date: 1950
BVO: 1303
Registered energy label: No
Compactness: 2,35
Facade type: Non load bearing
Tenant: Multi
Owner: Private owner

Rijswijk
Building date: 1971
BVO: 13.250
Registered energy label: Yes, valid until 2020
Compactness: 0,62
Facade type: Non load bearing
Tenant: Multi
Owner: Private owner

Heiloo
Building date: 1970
BVO: 1.370
Registered energy label: No
Compactness: 3,19
Facade type: Load bearing
Tenant: -
Owner:-

Leeuwarden
Building date: 1965
BVO: 5736
Registered energy label: No
Compactness: 2,39
Facade type: Load bearing
Tenant: ?
Owner: Private owner and user (?)

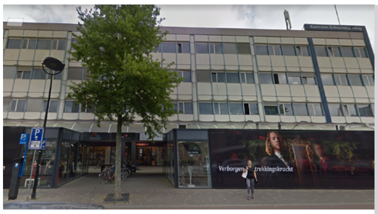
Molenaarsgraaf
Building date: 1962
BVO: 768
Registered energy label: No
Compactness: 1,16
Facade type: Load bearing
Tenant: Single
Owner: Owner and user

Rotterdam
Building date: 1991
BVO: 24.455
Registered energy label: Yes, valid until 2020
Compactness: 0,74
Facade type: Non load bearing
Tenant: Single
Owner: Owner and user

Rotterdam
Building date: 1956
BVO: 5.544
Registered energy label: No
Compactness: 0,86
Facade type: Load bearing
Tenant: Multi
Owner:Municipality of Rotterdam

Sassenheim
Building date: 1972
BVO: 3.715
Registered energy label: No
Compactness: 2,46
Facade type: Non load bearing
Tenant: ?
Owner: Akzo Nobel

Terneuzen
Building date: 1959
BVO: 3.992
Registered energy label: No
Compactness: 2,51
Facade type: Load bearing
Tenant: ?
Owner: owner and user



Tilburg
Building date: 1965
BVO: 6.538
Registered energy label: No
Compactness: 1,05
Facade type: Non load bearing
Tenant: Multi
Owner: Unknown

Zaandam
Building date: 1965
BVO: 1.321
Registered energy label: No
Compactness: 1,59
Facade type: Load bearing
Tenant: Multi
Owner: Private owner

Zeist
Building date: 1970
BVO: 10.858
Registered energy label: Yes, valid until 2025
Compactness: 1,27
Facade type: Load bearing
Tenant: Multi
Owner: Private owner

Zevenaar
Building date: 1957
BVO: 13.554
Registered energy label: No
Compactness: 1,23
Facade type: Load bearing
Tenant: Single
Owner: Owner and user

Zwolle
Building date: 1960
BVO: 4.505
Registered energy label: No
Compactness: 1,29
Facade type: Non load bearing
Tenant: Multi
Owner: Private owner

B.4 Uniec calculations

In this appendix, the summaries of the calculations in Uniec 2 are presented. Two calculations for the two different building shapes are made. No distinction is made between the load bearing facade and the non load bearing facade, since they have to achieve the same standards for the facades. Therefore, the calculations are the same.

Summary calculation compact

Uniec 2.2

STUDIEBEREKENING

0,44

Jaarlijkse hoeveelheid primaire energie voor de energiefunctie		
verwarming (excl. hulpenergie)	$E_{H;P}$	14.126 MJ
hulpenergie		11.706 MJ
warmtapwater (excl. hulpenergie)	$E_{W;P}$	9.87[illegible] MJ
hulpenergie		0 MJ
koeling (excl. hulpenergie)	$E_{C;P}$	50.[illegible] MJ
hulpenergie		0 MJ
zomercomfort	$E_{SC;P}$	[illegible] MJ
bevochtiging	$E_{hum;P}$	0 MJ
ventilatoren	$E_{V;P}$	63.[illegible] MJ
verlichting	$E_{L;P}$	263.961 MJ
geëxporteerde elektriciteit	$E_{P;exp;el}$	0 MJ
op eigen perceel opgewekte & verbruikte elektriciteit	$E_{P;pr;us;el}$	207.100 MJ
in het gebied opgewekte elektriciteit	$E_{P;pr;de;el}$	0 MJ

Oppervlakten		
totale gebruiksoppervlakte	$A_{g;tot}$	1.080,00 m²
totale verliesoppervlakte	A_{ls}	1.368,00 m²

Elektriciteitsgebruik		
gebouwgebonden installaties		44.939 kWh
niet-gebouwgebonden apparatuur (stelpost)		37.843 kWh
op eigen perceel opgewekte & verbruikte elektriciteit		22.472 kWh
geëxporteerde electriciteit		0 kWh
TOTAAL		60.310 kWh

CO_2-emissie		
CO_2-emissie	m_{co2}	12.690 kg

Energieprestatie		
specifieke energieprestatie	EP	192 MJ/m²
karakteristiek energiegebruik	E_{Ptot}	207.055 MJ
toelaatbaar karakteristiek energiegebruik	$E_{P;adm;tot;nb}$	378.907 MJ
energieprestatiecoëfficiënt	EPC	0,438 -
energieprestatiecoëfficiënt	EPC	0,44 -
E_{ptot} / $E_{P;adm;tot;nb}$ (Bouwbesluit)		0,55 -
E_{ptot} / $E_{P;adm;tot;nb}$ (energielabel)		0,40 -
energielabel nieuwbouw utiliteit		A+++

Onderstaande BENG Indicatoren zijn berekend conform de Handreiking BENG gebaseerd op de NEN 7120. Vanaf 20 november 2018 is het duidelijk dat deze indicatoren en de voorlopige BENG eisen uit 2015 achterhaald zijn. Zie ons artikel `Nieuwe BENG eisen bekend`. Wij raden ten sterkste af om met onderstaande informatie te rekenen en kunnen geen helpdesk vragen over deze eisen beantwoorden, aangezien wij ons richten op de BENG eisen conform NTA 8800 en de bijbehorende software Uniec 3. De enige reden dat wij deze resultaten nog tonen is om gebruikers tegemoet te komen die voor 20 november 2018 met deze getallen hebben gerekend en het resultaat willen inzien.

BENG indicatoren	
energiebehoefte	41,9 kWh/m²
primair energiegebruik	53,3 kWh/m²
aandeel hernieuwbare energie	32 %

Alle bovenstaande energiegebruiken zijn genormeerde energiegebruiken gebaseerd op een standaard klimaatjaar en een standaard gebruikersgedrag. Het werkelijke energiegebruik zal afwijken van het genormeerde energiegebruik. Aan de berekende energiegebruiken kunnen geen rechten ontleend worden.

Summarie calculation non compact

Uniec 2.2

STUDIEBEREKENING

[redacted] **0,45**

Jaarlijkse hoeveelheid primaire energie voor de energiefunctie		
verwarming (excl. hulpenergie)	$E_{H;P}$	53.489 MJ
hulpenergie		15.945 MJ
warmtapwater (excl. hulpenergie)	$E_{W;P}$	13.71[illegible] MJ
hulpenergie		0 MJ
koeling (excl. hulpenergie)	$E_{C;P}$	23.[illegible]4 MJ
hulpenergie		0 MJ
zomercomfort	$E_{SC;P}$	[illegible] MJ
bevochtiging	$E_{hum;P}$	0 MJ
ventilatoren	$E_{V;P}$	88.[illegible]7 MJ
verlichting	$E_{L;P}$	366.612 MJ
geëxporteerde elektriciteit	$E_{P;exp;el}$	0 MJ
op eigen perceel opgewekte & verbruikte elektriciteit	$E_{P;pr;us;el}$	264.627 MJ
in het gebied opgewekte elektriciteit	$E_{P;pr;del;el}$	0 MJ

Oppervlakten		
totale gebruiksoppervlakte	$A_{g;tot}$	1.500,00 m²
totale verliesoppervlakte	A_{ls}	3.510,00 m²

Elektriciteitsgebruik	
gebouwgebonden installaties	60.986 kWh
niet-gebouwgebonden apparatuur (stelpost)	52.560 kWh
op eigen perceel opgewekte & verbruikte elektriciteit	28.714 kWh
geëxporteerde electriciteit	0 kWh
TOTAAL	84.832 kWh

CO_2-emissie		
CO_2-emissie	m_{co2}	18.229 kg

Energieprestatie		
specifieke energieprestatie	EP	198 MJ/m²
karakteristiek energiegebruik	E_{Ptot}	297.423 MJ
toelaatbaar karakteristiek energiegebruik	$E_{P;adm;tot;nb}$	533.400 MJ
energieprestatiecoëfficiënt	EPC	0,447 -
energieprestatiecoëfficiënt	EPC	0,45 -
E_{ptot} / $E_{P;adm;tot;nb}$ (Bouwbesluit)		0,56 -
E_{ptot} / $E_{P;adm;tot;nb}$ (energielabel)		0,41 -
energielabel nieuwbouw utiliteit		A+++

Onderstaande BENG Indicatoren zijn berekend conform de Handreiking BENG gebaseerd op de NEN 7120. Vanaf 20 november 2018

BENG indicatoren	
energiebehoefte	44,1 kWh/m²
primair energiegebruik	57,2 kWh/m²
aandeel hernieuwbare energie	33 %

Alle bovenstaande energiegebruiken zijn genormeerde energiegebruiken gebaseerd op een standaard klimaatjaar en een standaard gebruikersgedrag. Het werkelijke energiegebruik zal afwijken van het genormeerde energiegebruik. Aan de berekende energiegebruiken kunnen geen rechten ontleend worden.

Discussion of the Uniec 2 results

To calculate if the renovation techniques are sufficient to achieve the new NZEB norms, Uniec 2 software is used. This software shows the NZEB results, like below.

BENG indicatoren		
energiebehoefte	40,3 kWh/m²	✓
primair energiegebruik	74,5 kWh/m²	✗
aandeel hernieuwbare energie	17 %	✗

However, these values are based on the preliminary norms from 2015. These norms were calculated according to NEN 7120. While the new (not definitive) norms are based on the new determination method, the NTA 8800. The reasons for the change of the norms are due to the new determination method, the cost optimization research and the change of NZEB definitions (Weijer, 2019).

	NZEB 1	NZEB 2	NZEB 3
2015 NEN 7210	25	25	50
2018 NTA 8800	Als/Ag <= 2,2--> 90 Als/Ag => 2,2--> 90 + 50 (Als/Ag – 2,2)	50	30

The first indicator is changed from 25 to 90. This big difference can be explained by the change of the definition of NZEB 1. In the new determination method, a fixed norm for ventilation is used. This results in a higher demand, since heat recovery is not taken into account.
For the second indicator, a more beneficial factor is used for electricity, than was used in the NEN 7210. This means that all-electric concepts are more favorable, than for example heating districts or highly efficient cv boilers. According to the new determination method, also the ‘cold’ is taken in account as renewable energy. For example, when using a WKO. Due to all these differences, it is difficult to compare the former NZEB norms with the new ones (Van der Loos & Kuijpers- van Gaalen, 2019).
It could be assumed that the third indicator will be higher, since for the renovations a WKO is used. The second indicator is expected to be lower, because of the use of the all-electric concept. The first indicator is expected to be higher, because the heat recovery is not taken in account anymore.
Since the calculations of the renovations comply with the new norms, but calculated with the old method. It could be assumed that the adaptation will achieve the new norms, also with the new determination method. This can be assumed because the second and third indicator are probably more favorable when calculating with the new determination method. For the first indicator, this is less easy to conclude, since the outcomes will probably be higher and the scale of this difference cannot be explained.

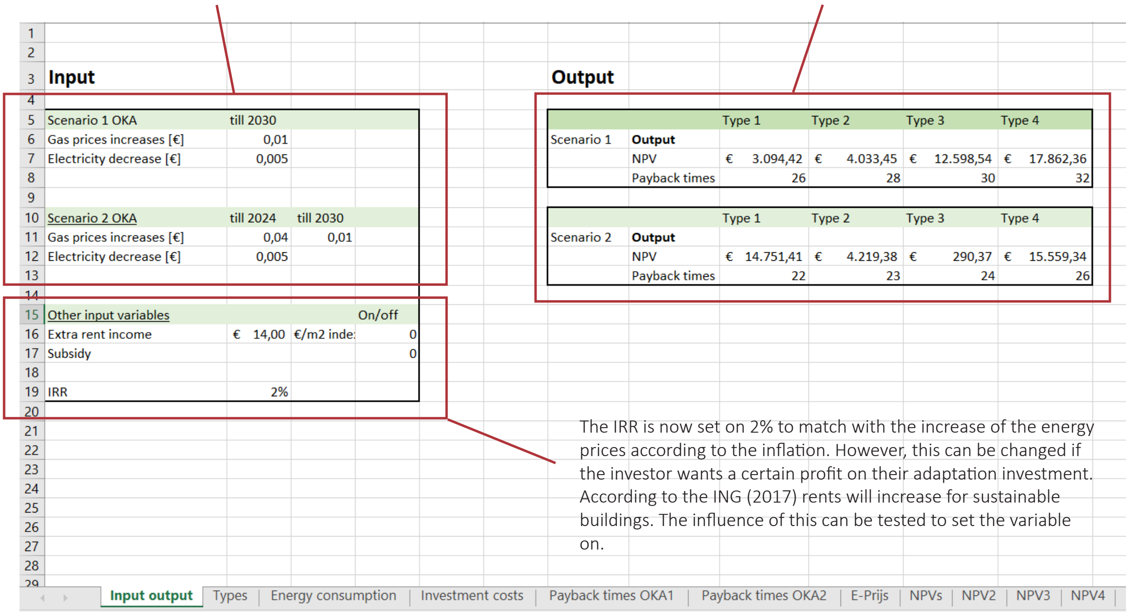
However, when using the new determination method, less solar panels are probably needed, since the use of the all-electric concept will result in a lower NZEB 2 indicator (so this doesn’t need to be compensated by solar panels) and the cold of the WKO is also taken in account for the third indicator.

B.5 Excel calculations

To make the calculations, excel is used. Below a explanation on how the excel sheet is used is presented.

In the input form, the two scenario's of the Dutch climate Agreement is presented.

These are the outcomes for the different scenario's of the Dutch Climate Agreement. The Net Present Values are the first values below 0.



Description tabs

Input output: The first tab present the input variables and the output results. This functions as an overview of the total excel file.

Types:In the second tab the different types and their square meters are presented.

Energy consumption: The third tab shows the energy consumption and energy savings of the adaptation.

Investment costs: This tab shows the investments costs for the different measures and types.

Payback times OKA1: To calculated the payback times, return analysis are made. This tab is made based on the first scenario of the climate agreement. Different return analysis are made for each type.

Payback times OKA2: ''

E-Prijs: In this tab the energy prices are presented. These are indexed with 2% and the price evolvement for the different scenario's are shown.

NPV's 1-4: The last for tabs are needed to calculated the payback times, whereas the NPV is for the first time larger than zero.

B.6 Interview protocol

Interviewees:

Soort eigenaar	Pand locatie	Datum
Private eigenaar	Dordrecht	26 April 2019
Eigenaar gebruiker	Molenaarsgraaf	29 April 2019
Eigenaar gebruiker	Rotterdam	14 May 2019
Gebruiker ontwikkelaar	Amersfoort	6 May 2019
Eigenaar ontwikkelaar	Emmen	10 May 2019
Private eigenaar	Huis ter Heide	15 May 2019

Semi-structurered interview
The interview guide has a certain order, but is flexible to alter if it is necessary. The questions below the topics are used as examples and will differ for each interview.

1. Introductie

Voorstellen Saskia: Uitleg onderzoek, verwerken, opnemen.
Voorstellen geïnterviewde: Wie bent u, wat doet u en wat is uw relatie tot het pand?

2. Het pand (Technisch)

- Wanneer heeft u dit pand gekocht? Heeft u dit alleen gedaan? Aankoopdatum/bouw
- Wat was de reden dat u voor dit pand/ deze locatie koos?
- Huidige staat van het pand? Tussentijdse renovaties?
- Mogelijkheden tot renoveren?
- Kansen renovatie?

3. Organisatie (achtergrond informatie)

- Wie doet het beheer? Hoe gaat u hier mee om?
- Heeft u gebruik gemaakt van financieringsadviseurs?
- Andere adviseurs in dienst genomen? Advies van bank?
- Meerdere panden in eigendom?

4. Beleid (achtergrond informatie)

- Label C verplichting vanuit overheid.
- Bent u bewust van deze regelgeving?
- Heeft u al acties ondernomen?

5. Financieel

- Scenario’s: Naar energieneutraal en naar label C (384€ per m2 / naar C 57 € per m2)
- Mogelijkheden voor investeringen
- Rendement? Risico?
- Wie betaald(e) de energierekening?
- Huurprijs? Toekomst van locatie?
- Mogelijkheden voor herontwikkeling/ bestemmingsplanwijziging? (Legal)

6. Sociaal

- Overlast tijdens renovatie?
- Tijdelijke huisvesting?
- Comfort huidige/voorgaande gebruikers?
- Overlast voor de buurt?

7. Duurzaamheid

- Belang van verduurzaming?
- Belang van een voorlopersrol?
- Interne duurzaamheidsambities organisatie?

8. Afsluiting

- Laatste op of aanmerkingen?
- Bedankt