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Master's Thesis
Energy Science
GEO4-2510

A case study of the KNAW real estate

Implications of emission reduction target interaction on the conversion strategies of existing buildings to NZEB

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Abstract

Of all existing buildings that are currently in use, about 90% is estimated to still be in use by 2050. This creates urgency to convert existing buildings to NZEB in order to achieve international, national and regional energy reduction targets. For buildings there are short-term and long-term reduction targets set by governments which aim to reduce the energy consumption of existing buildings by a given year. This paper investigated how these targets can be met and if and how they interact when scenarios are drawn up to reach them. This was done by conducting a case study of the real estate portfolio of the KNAW (Royal Dutch Academy of Arts & Science), consisting of six different identifiably buildings, spread over five research institutes, in four different cities in the Netherlands. The research constructed two scenarios for these six buildings, setting up short-term scenario and a long-term scenario. Focusing respectively on short-term targets by implementing short-term scenario measures and long-term targets by implementing long-term scenario measures and focusing on regional policy such as the WTV (Transition Vision for Heat). The scenarios were constructed using building energy performance data, energy price predictions and energy conservation measure lists. With sensitivity analysis conducted on both energy prices and saving and cost parameters, the results from the study found negative interaction between the short-term and long-term targets for two of the six buildings under certain input parameters. These negative interactions resulted from the need for early depreciation of short-term measures when the implementation of long-term scenario measures needed to be executed.

Preface

Before you lies the Master's Thesis 'Implications of emission reduction target interaction on the conversion strategies of existing buildings to NZEB: A case study of the KNAW real estate'. It was written as a requirement for my Master program Energy Science at the University of Utrecht.

The topic was derived from KNAWs request to create an energy transition roadmap for its real estate, with both a short-term and long-term focused scenario. By drawing this request more broadly and also looking at the interaction between these scenarios an interesting research topic was developed.

After finalizing my research, I am proud of completing this study due to stamina and persistence together with excellent supervision and guidance by Robert Harmsen.

I hope you enjoy reading my thesis.

Sam Bernsen

Amsterdam, June 30th 2022

Contents

Acronyms and Abbreviations

BEI	Building Energy Index
BMS	Building Management System
EC	European Commission
EU	European Union
EES	Energy Efficiency Strategies
EEM	Recognized Energy Efficiency Measures
EML	Recognized Energy Efficiency Measures List
EPBD	European Energy Performance of Buildings Directive
LFA	Liveable Floor Area / Usage Area Building
GHG	Greenhouse gases
KNAW	Royal Dutch Academy of Arts & Science
NZEB	Near-Zero-Emission-Buildings (BENG in Dutch)
PBL	Netherlands Environmental Assessment Agency (Planbureau voor de Leefomgeving)
PBP	Pay-Back Period
RET	Renewable Energy Technologies
RES	Regional Energy Strategies
RSW	Regional Structure for Heat
WTV	Transition Vision for Heat

Chapter 1 | Introduction

In the first chapter the context of the research is given, from which we start to define the problem definition and gradually work to the objective and research question.

1.1 Context

There has been a broad consensus for a while now amongst scholars that the global climate is changing due to human activity, with one of the largest contributors being the exponential increase in energy consumption (UNIPCC, 2007). The urgency of this is now also broadly recognized amongst the European Union (EU) and most of its member states (EASAC, 2021). Being compliant with the Paris Agreement (UNFCCC, 2015) and decarbonizing the economies of all member states is crucial for staying on track with keeping the global temperature increase below the 1.5 °C (or at least 2 °C) target (UNIPCC, 2018).

Not always recognized as such a large contributor, buildings are responsible for around 25% of emitted greenhouse gasses (GHG) in the EU (EASAC, 2021). This percentage is even larger in the Netherlands, where it is about a third of the national annual GHG emissions (Rijksvastgoedbedrijf, 2019). The European Commission (EC) estimates that roughly 90% of all current buildings will still be in use by 2050, this results in existing buildings having to contribute the largest share of the total energy savings that have to be made within the built environment (EC, 2020).

For mitigating the climate impact of existing buildings in the Netherlands there are short- and long-term ambitions set on several levels and (mandatory) targets are being put in place. This is done for both existing residential real estate (the majority), as well as commercial real estate (Rijksoverheid, 2019a; European Parliament, Council of the European Union, 2018). To reach for these ambitions and to achieve these targets, organizations holding real estate have to set up energy efficiency strategies (EESs) for converting existing buildings to near-zero-emission-buildings (NZEB) (Arnoldussen, King, & Meuwese, 2020). For the Netherlands these EESs are (partly) dependent on the final energy performance standard for existing utility buildings (BENG-requirements), expressed in kWh/m²/year per building use category for the period until 2050 (Rijksoverheid, 2019a). These resulted from the European Energy Performance of Buildings Directive (EPBD-III) (European Parliament, Council of the European Union, 2018). In chapter 2 we will go more in-depth and analyze the requirements.

With the requirement to reduce greenhouse gas emissions rapidly and with buildings being responsible for such a significant part of the total emissions, more and more focus of researchers, policymakers and people active in the construction industry have been drawn to this topic. Making it crucial that all efforts are aligned in the right direction and that they do not negatively impact each other.

1.2 Scientific Relevance and Problem Definition

While various research analyzes buildings' life cycle costs or looks at energy efficiency in residential buildings over the years, there was a lack of research focusing on converting existing office-/commercial-/governmental-buildings to NZEB (Alajmi, Short, Ferguson, Vander Poel, & Griffin, 2020). Of the research looking into non-residential buildings, many of the papers focusing on the EU conducted case studies in Southern Europe (Dalla Mora, Righi, Peron, & Romagnoni, 2017) (Dimitriou, Kyprianou, Papanicolas, & Serghides, 2020) (Ascione, Francesca de Masi, De Rossi, Ruggiero, & Vanoli, 2017).

Some research already investigated the tension between short- and long-term ambitions and targets. Ranging from research looking into the implications of near-term policies for the costs and attainability of long-term climate objectives following the national pledges from the Copenhagen Accord (Riahi, et al., 2015); Research focusing on interactions between the sustainable development goals (SDGs), looking at both negative interactions (trade-offs) and positive interactions (co-benefits) (Nilsson, et al., 2018). To research looking into the influence of the EUs' sub-targets on their long-term ambitions, talking about the importance of linking these to prevent them from potentially leading to inefficiencies (Hekkenberg, Daniels, Gerdes, & Boonekamp, 2016).

This paper focused on looking into this tension when considering targets, short- and long-term, in the case of increasing an existing buildings' energy performance. In a cost-optimal strategy, the short-term targets must serve the long-term target. Meaning that any sub-targets for the short-term should follow from the measures that are required by the time a particular sub-target is due to achieve the final (long-term) target (see Figure 1-1 below, inspired by Hekkenberg et al., 2016).

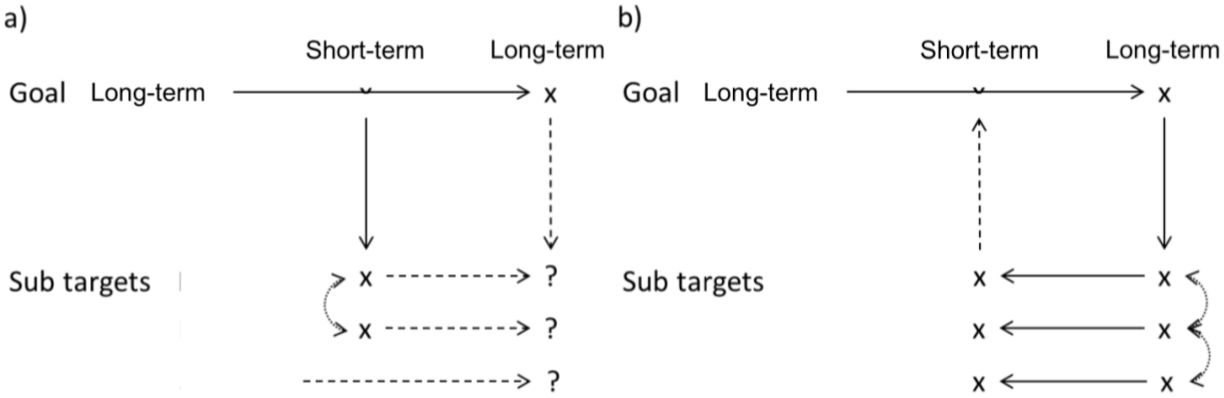

Figure 1-1 | ***a)*** *The current approach to target setting derives the intermediate sub-targets from the intermediate energy reduction target without connecting to longer-term energy reduction needs.* ***b)*** *A more cost-optimal approach first derives the long-term energy reduction needs and from there derives an intermediate sub-target. (Hekkenberg, Daniels, Gerdes, & Boonekamp, 2016)*

Applying this to existing (unique) buildings in the Netherlands and related international, national and regional energy reduction targets has not been investigated before this study.

For newly build buildings, from a target setting perspective, there are already numerous ambitions and goals in place. The EUs EPBD already specifies that since 2020 all new buildings should be NZEB (European Parliament, Council of the European Union, 2018). However, as mentioned, with the vast amount of the buildings in 2050 having been built pre-2020, converting these existing buildings to NZEB is of utmost importance. This research focused on the tension that arises between long-term targets and their short-term intermediate targets for converting existing to NZEB, looking into the tension between the ultimate 'Paris-Proof' goal (70 kWh/m2/year) and short-term targets such as the 2023 Label-C requirement for office buildings, as set by the Dutch government (RVO, 2021). Next to this, internal target interaction between regional policy and targets was researched, looking at how regional policies impact pathways to reaching (intermediate) targets.

1.3 Objective and Research Question

The research question was formulated as follows:

How do short-term and long-term targets interact* and how will this impact the conversion *of existing buildings to NZEB?

This research looked at scenarios for converting unique utility buildings to NZEB from a time scale perspective (long-term targets vs intermediate, short-term, targets) and a regional perspective (different regional policies). It looks at how tensions between these affect each other, on feasibility and cost. In addition, for a structured approach, the following sub-question was formulated:

Which short-term measures and long-term measures are needed for the conversion of existing buildings to NZEB?

Furthermore, this research aimed to clarify the feasibility of converting a variety of buildings into NZEBs. Identifying barriers and providing a short-term and long-term roadmap for potentially achieving this. To conduct this research a case study was done of several buildings from the real estate portfolio of the Royal Dutch Academy of Arts & Science (KNAW). The buildings that were analyzed in the case study are all unique and have different (user) functions. The KNAW functions also as the host institution for the internship of which this research is part. The KNAW is looking for an energy transition roadmap for its real estate. The roadmap follows a path of intermediate mandatory and voluntary targets to reach the 2050 goal of establishing a building supply that is completely climate-neutral.

Chapter 2 describes the underlying theoretical concepts. Chapter 3 describes the research design, the data collection and methods used for data analysis. In chapter 4 the results are provided, and recommendations are made. The research is concluded by chapters 5 and 6, providing the discussion and conclusions of the research.

Chapter 2 | Theory

In the second chapter of this research the theory and the research framework are presented. First, the relevant policy context is described, explaining the baseline situation, and the path that lies ahead from a policy perspective in the form of short- and long-term targets, respectively voluntary and mandatory. Section 2.2 introduces the buildings' energy performance, what variables are considered in this research, and which are not, explaining along the way why these decisions were made. Next to these definitions are provided, outlining a part of the research framework. Afterward, in section 2.3, we dive deeper into the interactions that occur between the policy targets and separate regional policies. In section 2.4 the case study at the KNAW is introduced, briefly describing the organization and presenting the buildings (and with them the separate institutions) that are part of the case study. Section 2.5 presents the input variables needed in addition to case study specific data. The chapter concludes with a synthesis, presenting the research flowchart.

2.1 Relevant Policy Context

Relevant policies are set on many different levels, this funnels from international agreements (think Paris Climate Accord) through European policy into national regulations which are partly translated from EU-level policies and partly based on national targets (think national climate accord). These are then again translated into regional and institutional policy instruments. In Figure 2-1 below an overview is presented of the different levels from which policies are set.

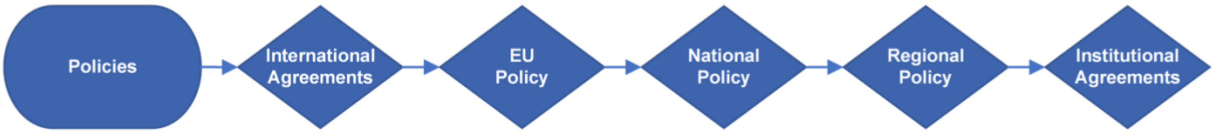

Figure 2-1 | Overview of the different levels on which policy is set

With most climate targets focusing on CO2 reduction and with a climate-neutral energy supply as the end goal, there are often also intermediate targets. For the built environment there are several and for this research, all mandatory and some voluntary targets are followed. For all voluntary targets, it is important to note that these can be brought forward in time. The year 2021 is used as the base year upon which the targets follow in the period from now until 2050. The relevant (mandatory) targets between now and 2050 that are followed in this research are illustrated in Figure 2-2 below and are elaborated upon afterward.

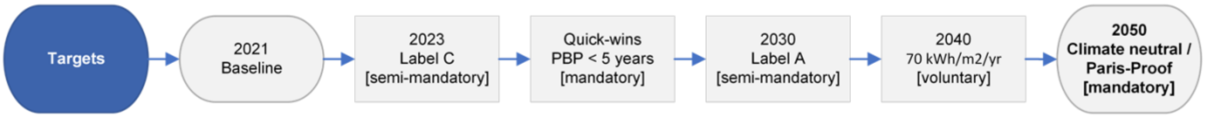

Figure 2-2 | Targets from 2021 to 2050 (with 2021 as the baseline year)

2023 Label C obligation

Label C is the most urgent target from a regulatory perspective. By 2023 all office buildings in the Netherlands are required to have a so-called label C, which corresponds with a fossil energy consumption that is lower than ±250 kWh/m²/year (RVO, 2021).

The unit kWh/m²/year, which was briefly mentioned in the introduction, is used in this research, all targets are per definition based on this unit. The reason for this is the (mandatory) energy label for (utility) buildings in the Netherlands. As of 2021, the energy label and the method of how the label is determined were put in line with the revision of the European Energy Performance of Buildings Directive. This new determination method (NTA 8800) has as an indicator for energy performance the unit kWh/m2 per year (Government of the Netherlands, 2020). Using this unit offers a way in which buildings can be compared on a relative energy consumption level, instead of solely on an absolute, total final energy, level. The unit represents the amount of annual final energy used by a building per m2.

Quick-wins and EML Measures obligation

This is a fluid target that ensures the execution of all applicable measures on the Recognized Energy Efficiency Measures List (EML). These Recognized Energy Efficiency Measures (EEMs; 'Erkende Maatregelen' in Dutch) are measures that are mandatory (under certain boundary conditions) to implement within a reasonable time frame. An integral property and precondition of EEMs is that they must have a pay-back-period (PBP) of 5 years or less, a requirement included in the environmental legislation (RVO, 2019). It is important to note that this is the only target that is not tied to a certain year and compared to the other targets, does not make use of the kWh/m2 per year unit.

2030 Label A

By 2030, the Dutch Climate Accord states that all existing office/utility buildings should aim for at least a label A. However, it does not make it mandatory as is the case for the 2023 Label C obligation (RVO, 2021). For utility buildings label A comes down to ± 200 kWh/m²/year (Energielabel.com, 2022).

2040 Paris Proof on average

Currently, the Dutch government has no active targets, mandatory or voluntary for the built environment for the year 2040. However, many organizations that want to have an exemplary and leading role bring forward the Paris Proof target of 70 kWh/m²/year in their internal sustainability plans with 10 years (Kamp & Boeters, 2020). Therefore the intermediate target of 70 kWh/m²/year on average by 2040 is used for this research. In addition, it is important to note that the European Commission stated in December 2021 that Member States should plan policies and measures with a complete phase-out in mind of the use of fossil fuels in buildings by 2040 (European Commission, 2021). With this in mind, it helps to comply with future national or regional regulations which can be expected in the future.

2050 Paris-Proof / Climate-neutral

For 2050 the Dutch Climate Accord states that utility buildings have to be low carbon with a target based on the NTA8800 expressed in kWh/m²/year (Rijksoverheid, 2019a). For most utility buildings this comes down to the earlier mentioned target of 70 kWh/m²/year, also called Paris-Proof with a CO2 balance that is at least equal to zero.

Regional and local policy influence

International climate agreements (Paris Accord) are translated into national climate agreements (Dutch National Accord), which in turn are translated to both regional and local levels. This is done in the Netherlands through the National Program Regional Energy Strategies (RES), the municipal heating visons and the district implementation plans (Buist, 2022), and the Regional Structure for Heat (RSW). The RSW provides insight into the heat demand and the heat supply of 1 of the 30 regions (Unie van Waterschappen, 2021). Furthermore, in the Transition Vision for Heat (WTV) municipalities establish a timeframe within which to transition away from heating by burning natural gas. They define per district which potential alternative energy infrastructures are most suitable (all-electric, heating grid, heating grid type, etc.). (Rijksoverheid, 2019a)

2.2 Building Energy Performance

The energy performance of a building is calculated based on several data sources, looking at the entire site of a building within predetermined boundaries. Here we also looked at the (full) building envelope, including the roof and possibilities for integrating renewable energy technologies (RETs). Other data sources are the buildings' energy supply, utility bills, next to smart metering data through the energy provider (or metering company). In addition, climate data, in the form of the settings of the building-management system (BMS).

As mentioned in the introduction, the final goal is to convert all existing buildings to NZEB by 2050. It is key to explain NZEB and how it is defined in this research. Several publications have defined this term in different ways over the years, e.g., net-zero site energy, net-zero source energy, net-zero energy costs, and net-zero energy emissions (Crawley, Pless, & Torcellini, 2009). In more recent research NZEB was defined more uniformly from a European perspective as a building with very high energy performance, with nearly zero or very low energy demand that should be covered to a very significant extent by energy from renewable sources produced on-site or nearby (D'Agostino & Mazzarella, 2019). Using this definition, NZEB, for this paper, means buildings with 'near net-zero energy emissions' that are climate-neutral, focusing on mandatory and voluntary targets set by national and internal policy.

2.3 Policy Interaction

To reach a target that is far on the horizon (such as the Paris-Proof target for the KNAWs real estate), it often helps to set intermediate goals in order to make the final goal more manageable. It is important to note that when setting multiple sub-targets, that support reaching a final long-term target, there will often be interactions between these. These can be positive interactions, but the sub-targets can also negatively impact the feasibility of the long-term goal. Negative interactions occur when early depreciation is required on sub-target related measures in order to complete a long-term target. Therefore, it is vital to research the optimal reduction pathway when setting (intermediate) targets (Hekkenberg, Daniels, Gerdes, & Boonekamp, 2016). As mentioned by Hekkenberg et al. (2016): 'Pursuing intermediate targets independently from long-term needs may lead to deviations from a cost-optimal pathway.' As introduced in section 1.2, in a cost-optimal strategy, the short-term targets should follow from the measures needed to achieve the final (long-term) target.

In reaching the Paris-Proof target of 70 kWh/m²/year it is needed to have a cost-optimal approach. This translates to making maximum use of so-called natural moments for replacement or investment (Hekkenberg, Daniels, Gerdes, & Boonekamp, 2016). Buildings often have a (sustainable) multi-annual maintenance plan and thus it is critical to study these plans and optimize them for achieving intermediate and final NZEB targets. This financial aspect of energy conservation measures is what this research focused on when looking into target interactions, taking into account the energy savings from which the financial savings and PBPs result (this will be further elaborated upon in section 2.5).

Another factor that plays a role in target interaction, in both the short- and long-term, are regional policies. When these are drafted, they often stem from national policies, such as the National Climate Accord, interacting with targets on either a national or institutional level (Rijksoverheid, 2019a). This is a similar phenomenon as the target interaction that takes place between international/national targets on a time-scale level, as mentioned by Hekkenberg et al. (2016). An important difference is that these have varying influences based on the region of a certain building.

2.4 Case Study

A case study was conducted at the KNAW, or Royal Dutch Academy of Arts & Science. The KNAW was founded in 1808 as an advisory body to the Dutch Government. The Academy is responsible for thirteen institutes whose research and collections put them in the vanguard of Dutch science and scholarship. As a research organization, the Academy is responsible for a group of outstanding national research institutes. It promotes innovation and knowledge valorization within these institutes and encourages them to cooperate with one another and with university research groups (KNAW, 2022e).

The KNAW has a wide-ranging real estate portfolio, which is partly owned and partly leased. This case study will be part of the larger KNAWs sustainability plan, which is being developed in 2021/2022. For converting their real estate to NZEBs by 2050 a roadmap is set up with three initial phases: short-term strategies 2025, mid-term strategies 2030 & long-term strategies 2050. For the case, study five institutes that are part of the KNAW were selected, these are all the buildings that are self-owned by the KNAW. All buildings were analyzed generally, e.g., the overall energy consumption (electricity, natural gas, district heating), the main activities and building functions (offices, archives, research laboratories, greenhouses, etc.) and related technologies (HVAC systems, Ground-coupled heat exchanger, solar PV, etc.). In addition, regional policies are analyzed covering the buildings' locations throughout the Netherlands. The five institutes that were selected to be part of the case study are located in four different Municipalities and RES-regions and thus are impacted by different RESs and the WTVs. The KNAW HQ and IISG (both located in Amsterdam) are part of the Region North-Holland-South. The Hubrecht Institute (Utrecht) is part of the Region U16. The NIDI (The Hague) is part of the Region Rotterdam-The Hague. The NIOO (Wageningen) is part of the Region Foodvalley.

Sustainability at the KNAW

The KNAW is, as a (semi-)public institution obliged to follow national and sectoral agreements that followed from the international Paris climate agreement. This means a 49% reduction in CO2 by 2030 and a 95% reduction by 2050 compared to 2005 (Rijksoverheid, 2019c). With the final energy performance standard for existing utility buildings, mentioned in chapter 1, the 'Paris Proof' consumption for offices is set at 50 kWh/m²/year GFA and for educational buildings the limit is 70 kWh/m²/year GFA (Leenders & Stam, 2019). Since the KNAW does not fit perfectly in either of these categories it was decided to use the 70 kWh/m²/year GFA but move the deadline forward to 2040 (see also section 2.1, 2040 Paris Proof on average).

As was mentioned in the introduction, the KNAW is looking for an energy transition roadmap for the real estate that it owns. With this roadmap, the KNAW will be able to follow a path to a climate-neutral real estate portfolio by 2050. The intermediate mandatory and voluntary targets along the way will determine how it will arrive at this goal.

Het Trippenhuis (KNAW) – Amsterdam, North-Holland

The Trippenhuis is located in the historic city center of Amsterdam. Built in 1660-1662 by wealthy Amsterdam merchants, it became the seat of the KNAW in 1812 and has been so ever since (KNAW, 2022a). The Trippenhuis encompasses several different cadastral sites, of which Kloveniersburgwal number 23 and number 25 are owned by the KNAW and the others are rented from the national government.

To better analyze this building the numbers 23 and 25 are seen as separate buildings, KL23 and KL25. This is done to provide the most optimal scenarios for these buildings, among other things since they have different monumental statuses. It is important to note that the electricity consumption data for KL25 for the years 2020 and 2021 is an estimation based on the combined electricity consumption of KL25 and KL27. This is due to the fact that these connections have been merged since 2020. This estimate was based on the difference in LFA and the number of workspaces between KL27 and KL 25 (the ratios are roughly 5:1 and 2:1).

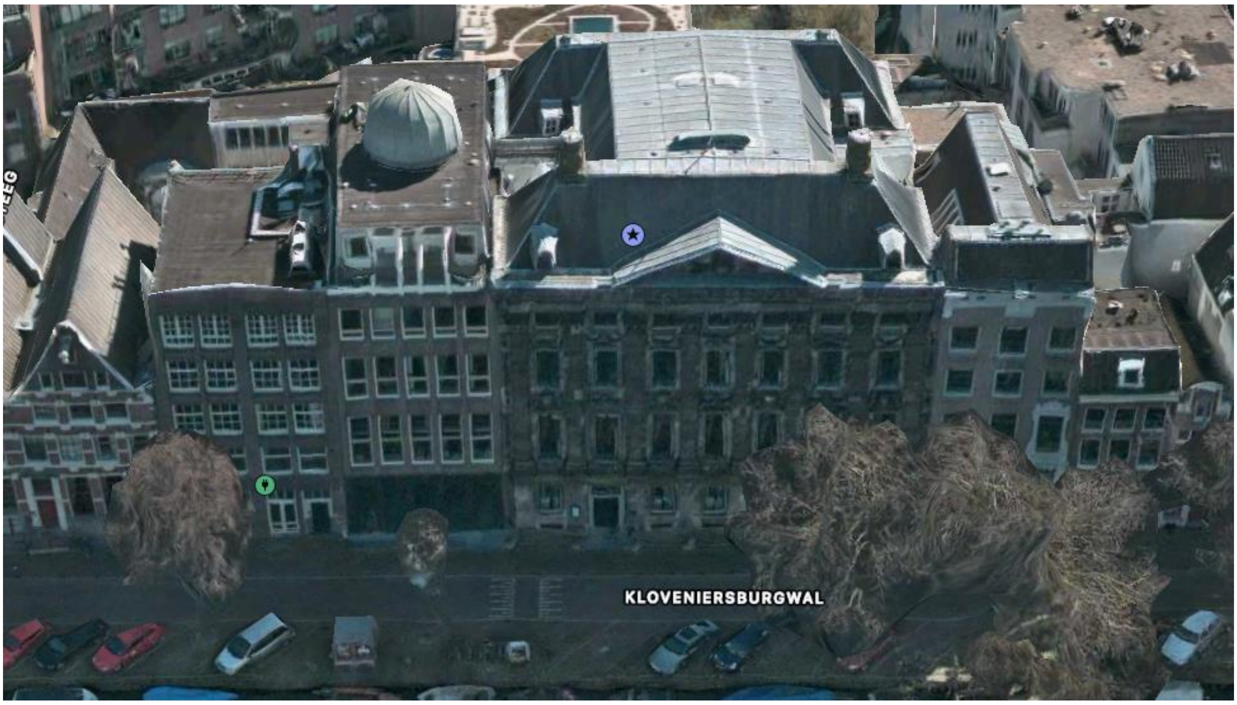

Figure 2-3 | Aerial view of Het Trippenhuis (image retrieved from Apple Maps)

KL23

Location:	Kloveniersburgwal 23, Amsterdam
Construction year:	1625
Latest renovation year:	1980
Usage area building (LFA)	1,041 m2
Electricity consumption 2019	14,306 kWh
Electricity consumption 2020	59,439 kWh
Electricity consumption 2021	26,324 kWh
Natural Gas consumption 2019	21,514 m3
Natural Gas consumption 2020	6,949 m3
Natural Gas consumption 2021	23,629 m3

For KL23, a monumental part of the building that houses apartments, the collected data are the following: A list of all installations, heating settings, monthly usage data of the electricity and gas consumption and a measurement report in accordance with NEN 2580. A site visit of this part of the building was not possible since the apartments were occupied by the visiting researchers who live there. The large fluctuation in both electricity and gas consumption is explained by varying apartment occupancy and a temporary shift to electronic heating in 2020 due to renovations.

KL25

Location:	Kloveniersburgwal 25, Amsterdam
Construction year:	1625
Latest renovation year:	1980
Usage area building (LFA)	1,172 m2
Electricity consumption 2019	44,716 kWh
Electricity consumption 2020	38,140 kWh
Electricity consumption 2021	38,140 kWh
Natural Gas consumption 2019	9,502 m3
Natural Gas consumption 2020	8,160 m3
Natural Gas consumption 2021	14,340 m3

For KL25, a non-monumental part of the building which houses mostly offices, the collected data are the following: A list of all installations, heating settings, monthly usage data of the electricity and gas consumption and a measurement report in accordance with NEN 2580.

International Institute of Social History (IISG) – Amsterdam, North-Holland

The International Institute of Social History (IISG) examines how work and labor relations have developed globally over time. To support its research, IISG collects archives and data from all over the world. The IISG is housed in an old cocoa warehouse that was built in 1962-1963, located in the eastern borough of Amsterdam-Oost. In 1989 the IISG moved into the building after a renovation of the whole building to make it suitable for housing archives. (KNAW, 2022b)

Figure 2-4 | Aerial view of the IISG (image retrieved from Apple Maps)

Location:	Cruquiusweg 31, Amsterdam
Construction year:	1905
Latest renovation year:	2010
Usage area building (LFA)	12,338 m2
Electricity consumption 2019	1,163,266 kWh
Electricity consumption 2020	1,052,778 kWh
Electricity consumption 2021	1,192,977 kWh
Natural Gas consumption 2019	20,902 m3
Natural Gas consumption 2020	20,919 m3
Natural Gas consumption 2021	24,389 m3

For the IISG the collected data are the following: A list of all installations, available Rc-values of the cavity walls and the windows, heating settings, monthly usage data of the electricity and gas consumption and a measurement report in accordance with NEN 2580. In addition to these, the building has a certified energy label (Label A+). However, this certification is only for the non-archive parts of the building, meaning that only the offices and the communal areas are graded.

Netherlands Interdisciplinary Demographic Institute (NIDI) – The Hague, South-Holland

The Netherlands Interdisciplinary Demographic Institute (NIDI) conducts research on population issues and makes demographic expertise available to researchers, policymakers and the public. The NIDI is housed in a state monument building that was built in the second half of the 19th century. In 1970 the NIDI moved into the building when it was founded. (KNAW, 2022c)

Figure 2-5 | Aerial view of the NIDI (image retrieved from Google Maps)

Location:	Lange Houtstraat 19, The Hague
Construction year:	1850
Usage area building (LFA)	1,445 m2
Electricity consumption 2019	63,921 kWh
Electricity consumption 2020	64,747 kWh
Electricity consumption 2021	64,283 kWh
Natural Gas consumption 2019	18,696 m3
Natural Gas consumption 2020	13,960 m3
Natural Gas consumption 2021	18,273 m3

For the NIDI the collected data are the following: A list of all installations, heating settings, monthly usage data of the electricity and gas consumption and a measurement report in accordance with NEN 2580.

Netherlands Institute of Ecology (NIOO) – Wageningen, Gelderland

The Netherlands Institute of Ecology (NIOO) was established in 1992 and conducts basic and strategic research on organisms, populations, ecological communities and ecosystems on land and in water. In 2011 the NIOO moved into its new building that was built according to the Cradle-to-Cradle principle. (KNAW, 2022d)

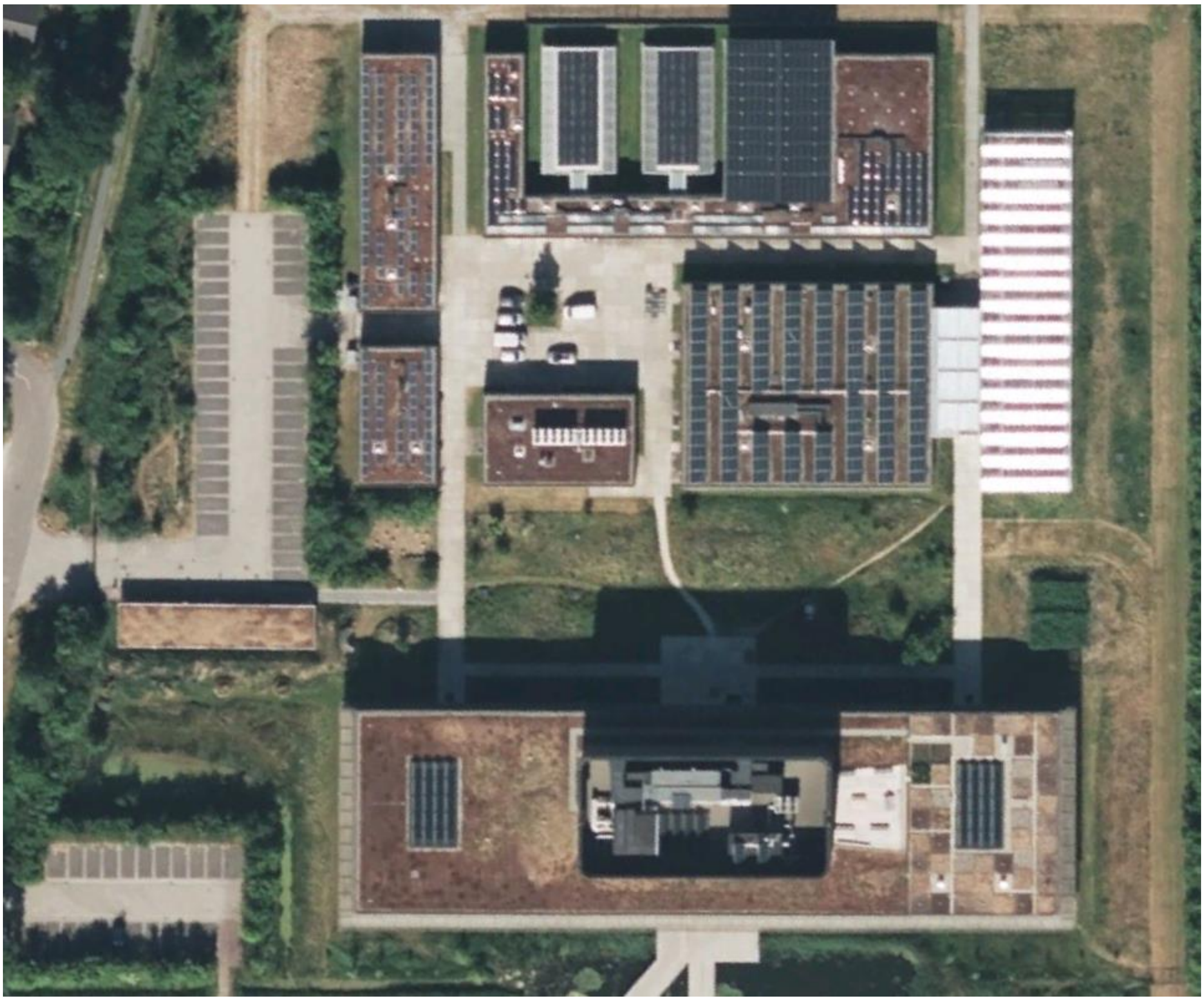

Figure 2-6 | Aerial view of the NIOO (image retrieved from Apple Maps)

Location:	Droevendaalsesteeg 10, Wageningen
Construction year:	2012
Usage area building (LFA)	5,998 m2
Electricity consumption 2019	2,166,096 kWh
Electricity consumption 2020	1,940,585 kWh
Electricity consumption 2021	2,002,677 kWh
Natural Gas consumption 2020	945 m3
Natural Gas consumption 2021	874 m3

For the NIOO the collected data are the following: A list of all installations, available Rc-values, heating settings, monthly usage data of the electricity and gas consumption and a measurement report in accordance with NEN 2580. In addition to these the building has a certified energy label (Label A+++), however, this certification is only for the non-laboratory parts of the building. Meaning that only the offices and the communal areas are graded, just like the IISGs energy label.

Hubrecht Institute – Utrecht, Utrecht

The Hubrecht Institute for Developmental Biology and Stem Cell Research focuses on developmental and stem cell biology. The institute has twenty-four interdisciplinary research groups that conduct basic research using healthy and sick cells, tissue and organisms. The institute ranks as one of the top institutes worldwide in the field of developmental and stem cell biology. The Hubrecht Institute is located in Utrecht at the Utrecht Science Park, the initial building envelope was constructed in 1963. However, several additions and partial renovations were made to the building over the years. (KNAW, 2022f)

Figure 2-7 | Aerial view of the Hubrecht Institute (image retrieved from Apple Maps)

Location:	Upsalalaan 6-8, Utrecht
Construction year:	1963
Latest renovation year:	2015
Usage area building (LFA)	18,786 m2
Electricity consumption 2019	5,860,491 kWh
Electricity consumption 2020	5,609,218 kWh
Electricity consumption 2021	5,645,612 kWh
Natural Gas consumption 2019	377,903 m3
Natural Gas consumption 2020	354,027 m3
Natural Gas consumption 2021	389,379 m3

For the Hubrecht the collected data are the following: A list of installations, available Rc-values of cavity walls, heating settings, monthly usage data of the electricity and gas consumption and a measurement report in accordance with NEN 2580. An extensive site visit was conducted through all the five different building parts (Building A to E).

2.5 Input variables

Next to the input data from the buildings in the case study, additional input data is needed to build the scenarios for converting these buildings to NZEB. These inputs are the energy conservation measures with energy saving and costs estimations per measures, predictions of future energy prices and lastly the predicted share of renewables in the electricity mix to estimate future CO2 emissions. Moreover, using this data the measures' Pay-Back-Periods (PBP) were calculated, this was essential for analyzing potential target interaction (see section 2.3). The PBP, also called the economic payback time, is the time it takes to financially recover the investment cost of a measure (Blok & Nieuwlaar, 2017). The PBP is calculated as follows:

$$PBP = \frac{I}{B - C} \qquad [Equation\ 2.1]$$

Where I is the investment costs of a measure, B the annual economic benefits from implementing a measure and C the potential annual economic costs an implemented measure might bring.

Measures

Table 2-1 shows the list of energy conservation measures including costs and saving assumptions. This list was prepared taking into account the building data from section 2.4. Assumptions were made using data from the InfoMil Knowledge Centre (Ministry of Infrastructure and Water Management, 2022) and the independent public information organization Milieu Centraal, which is funded by the Dutch Government (Milieu Centraal, 2022). For the EML measures the InfoMil Knowledge Centre most current list was used, this version of the EML measures list from April 9th 2020 can be found in the appendix.

Table 2-1 | List of energy conservation measures with cost and saving assumptions

Measure name	Unit	Saving/unit	Cost/unit
All lighting to LED	pcs	0.03 kWh	€ 300.00
Application of radiator foil	m2	7.50 m3	€ 10.00
Apply a pump switch to the heating circulation pump		5%	€ 100.00
Apply hybride heatpumps		50% / 3.5 COP	€ 1,250
Apply timer to electric water heater	pcs	1,500 kWh	€ 100.00
Cap all thermostatic valves on position 3	pcs	60.00 m3	€ 10.00
Extra wall insulation	m2	12.50 m3	€ 100.00
Install water-saving showerheads	pcs	50.00 m3	€ 95.00
Insulate glass of greenhouses	m2	180 kWh	€ 415.00
Insulate glass of wamwater tanks	m2	60.00 m3	€ 416.67
Insulate the cavity wall (Building part C)	m2	22.50 m3	€ 30.00
Insulation of CV components	m2	15.00 m3	€ 20.00
Link an EMS (EBS) to the BMS (GBS)		2%	€ 25,000
Optimize the boiler settings		2%	€ -
Reduce room temperature by 1 degree		1%	€ -
Replace conventional emergency lighting	pcs	53.00 kWh	€ 50.00
Replace increased efficiency heating boiler with HR107 boiler		7%	€ 15,000
Set heating limit, weather dependent control and night reduction		5%	€ -
Solar panels (650pc extra ground-mounted)	kWp		€ 1,324
Use of weather stripping and gap sealing	pcs	8.00 m3	€ 25.00
Use the two installed AC units for heating	pcs		€ -
Apply insulated HR+++ greenhouses	m2		€ 3,125.00
Apply insulated HR+++ warmwater tanks	m2		€ 1,800
Install new AHU incl. heat wheel on roof		15%	€ 25,000
Replace central gas-fired water heaters with local close-in water heaters	pcs		€ 200.00
Replace single-glazing with HR++ insulated glass	m2	20.00 m3	€ 736.11
Solar Panels (200pc)	kWp		€ 1,324
Solar Panels (40pc)	kWp		€ 1,544
Solar Panels (600pc)	kWp		€ 1,103
Switch to electric (water) heating		100%	€ 70,000
Transition from natural gas-fired heating to district heating (regional plan gas-free)		95%	unkown
Use daylight-dependent control sensors	pcs	550 kWh	€ 390

Energy prices

For these parameters projections from the PBL are available (PBL, 2021). In Table 2-2 below, the current and predicted wholesale prices for electricity and natural gas (low and high estimates) are shown as predicted by the PBL, based on 2020 data incl. energy taxes. In this research all energy prices are shown including energy taxes, for the electricity prices this means that the prices are only valid for connections until 500 MWh (Belastingdienst, 2022).

Table 2-2 | Time-dependent prices (PBL, 2021) (Belastingdienst, 2022)

	Realized		**Projection**	
	2015	**2020**	**2030**	
			Low	High
Electricity price [EUR/kWh] incl. tax [max 500 MWh]	0.067	0.072	0.081	0.117
Natural Gas price [EUR/m3] incl. tax	0.411	0.463	0.523	0.683

However, energy price prediction can no longer fully rely on this data, because of the uncertainty in the energy market since the tensions between Ukraine and Russia that started in 2021 and resulted in the Russian invasion of Ukraine in early 2022 (Bilefsky, Pérez-Peña, & Nagou, 2022). To counter this a Monte Carlo analysis was executed to get a better view of the uncertainties in energy prices and to strengthen these parameters. The analysis was based on historic quarterly electricity and natural gas prices in the Netherlands from Q1 2018 to Q4 2021 (CBS, 2022). With an average electricity price of about 0.130 EUR/kWh (incl. tax) and an average natural gas price of about 0.709 EUR/m3 (incl. tax). The standard deviations were respectively 0.023 EUR/kWh and 0.069 EUR/m3. With these values the annual price development was calculated until 2040, by using the NORM.INV function. For both the years 2030 and 2040 a thousand price predictions were done which presented a spread in energy price predictions, for 2030 see Figure 2-8 and 2-9 and for 2040 see Figure 2-10 and 2-11. From these outcomes energy prices were selected, based on the 25th percentile (low) and the 75th percentile (high). These prices are shown in Table 2-3 (2030) and Table 2-4 (2040).

Most noticeable is the large spread in the natural gas price predictions, this heavily impacts the different outcomes in PBP when implementing insolation measures or when implementing measures that shift away from natural gas use altogether.

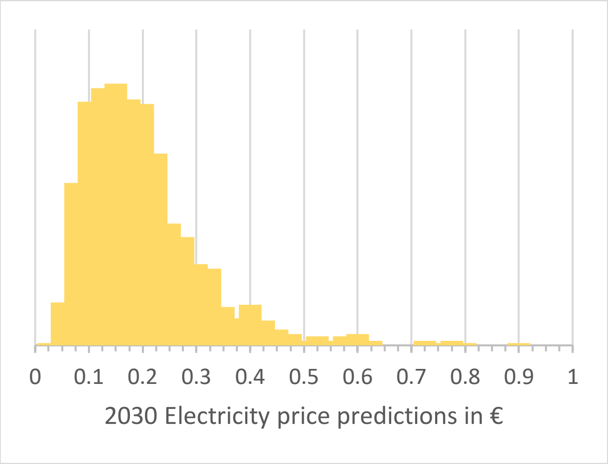

Figure 2-8 | Histogram of 2030 elec. price predictions

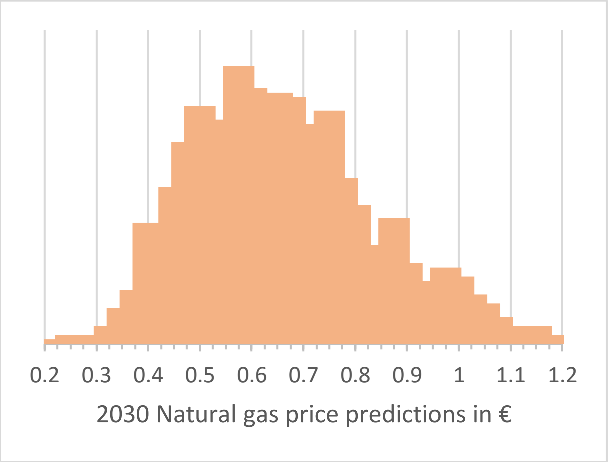

Figure 2-9 | Histogram of 2030 gas price predictions

Table 2-3 Energy price projections 2030

Energy price projections 2030	Low	Mean	High
Electricity price [EUR/kWh] incl. tax [max 500 MWh]	0.111	0.190	0.240
Natural Gas price [EUR/m3] incl. tax	0.251	0.668	1.693

For 2040 this spread is again most noticeable when looking at the natural gas prices predictions and moreover, this spread is even greater than for 2030.

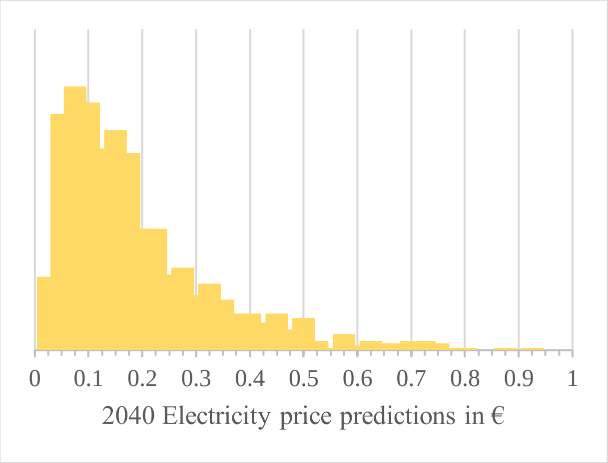

Figure 2-10 | Histogram of 2040 elec. price predictions

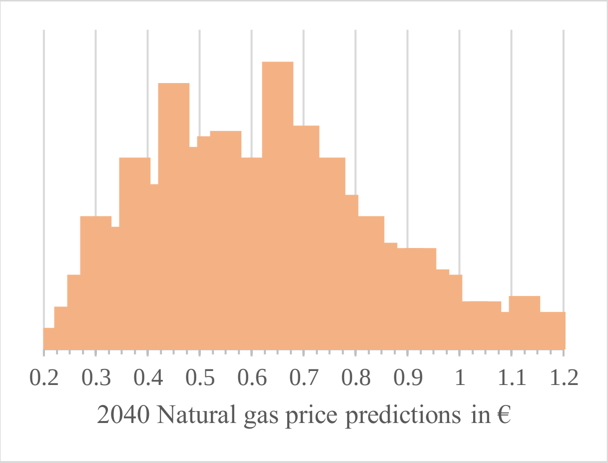

Figure 2-11 | Histogram of 2040 gas price predictions

Table 2-4 Energy price projections 2040

Energy price projections 2040	Low	Mean	High
Electricity price [EUR/kWh] incl. tax [max 500 MWh]	0.081	0.191	0.243
Natural Gas price [EUR/m3] incl. tax	0.165	0.667	2.566

Renewables in Electricity Mix

In Table 2-5 below, the development projections from the PBL on the percentage of renewables (RES) in the Dutch electricity mix are shown. These projections currently run until 2030, however for 2050 the transition toward a carbon-free electricity system needs to be completed (Rijksoverheid, 2019b).

Table 2-5 Share of Renewables in the Dutch Electricity Mix (PBL, 2021)

	Realized		**Projection**			
	2019	**2020**	**2023**	**2025**	**2027**	**2030**
Share of renewables in gross electricity consumption	*18.2%*	*26.0%*	*48.0%*	*58.3%*	*67.6%*	*74.4%*
in kgCO2-eq/kWh	0.455	0.411	0.289	0.232	0.180	0.142

2.6 Synthesis

This research consists of building blocks that together display a pathway for utility buildings to become NZEB and comply with the Paris-Proof target. These building blocks are the input data, the energy conservation measures, the scenarios and the interactions.

First, we looked at the scenarios separately to reach every target in isolation, without looking at the interactions that targets can have between them. One scenario focused on the short-term and one focused on the long-term. Targets are often set up, executed, and looked at from a linear perspective (Gasser, et al., 2018). On a national scale, policy is established that set the framework with mandatory (intermediate) targets. Respectively, organizational factors, like the baseline (current state of a building) and a (sustainable) multi-annual maintenance plan set the framework for voluntary intermediate targets.

Second, we look at the interactions between targets, between the scenarios and how these (negatively) impact each other. From these outcomes, the research question can be answered, and recommendations can be made for the optimal roadmap to NZEB.

In Figure 2-12 below a flowchart of the research design is presented. Showing from left to right the required data and the energy conservation measures which together are the bases for the scenarios that are developed. The two scenarios that are developed show how targets and (regional) policies interact with each other.

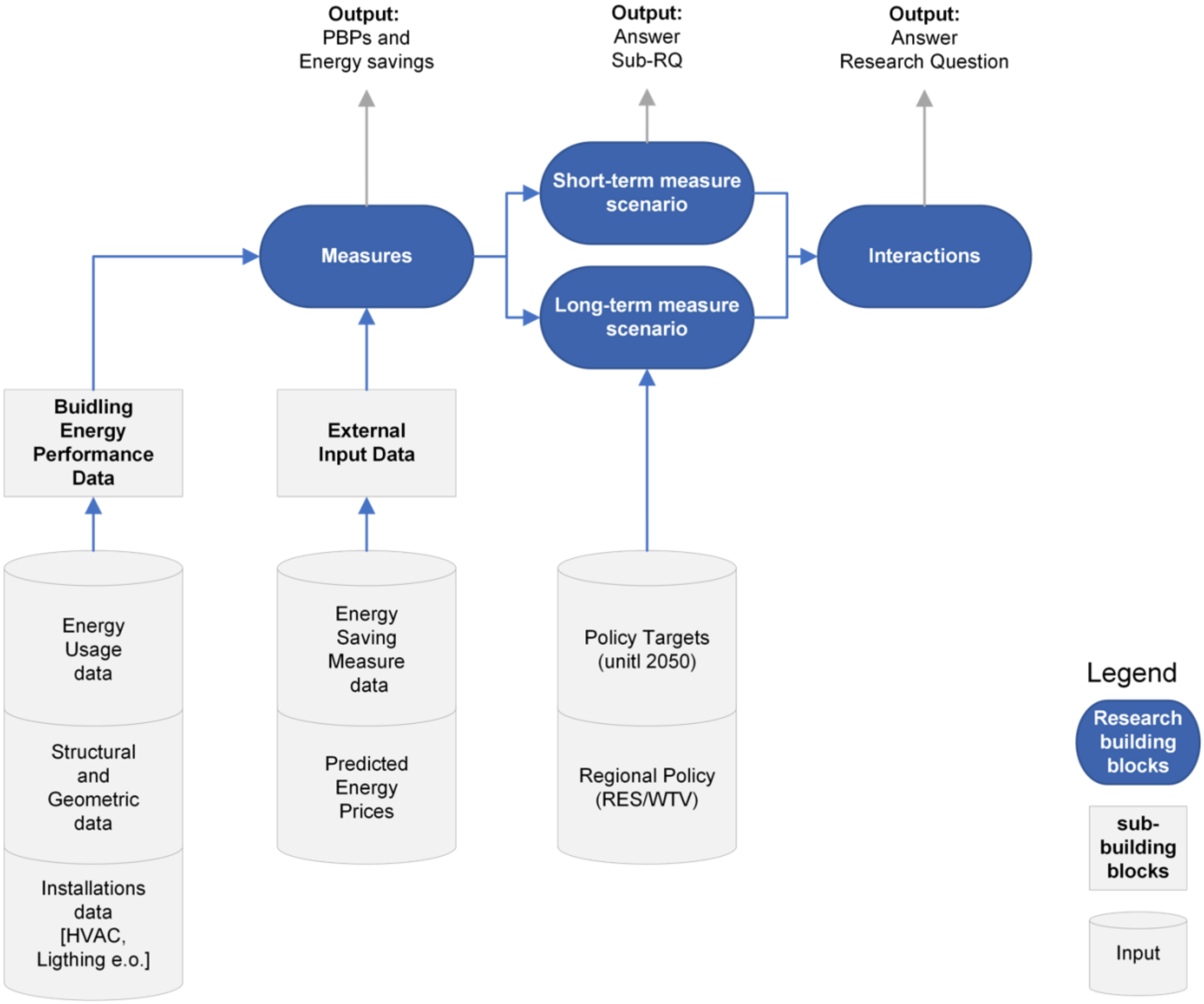

Figure 2-12 | Research flowchart; illustrating data, measures, scenarios and interactions

Chapter 3 | Method

The third chapter covers the methodology. It builds upon Figure 2-12 and was composed of the following parts: Input data (sub-building blocks) and the energy conservation measures, scenarios and interaction (research building blocks). Using these elements the outputs could be obtained; PBPs, savings and the answers to both the sub-research question and the main research question.

3.1 Input Data

Before setting up the scenarios and looking into the interactions, two preliminary steps had to be taken: Collecting all the required input data and setting up a list of energy conservation measures upon which the scenarios could be built.

Buildings Energy Performance

To improve the energy performance of existing buildings, it is needed to analyze the current baseline situation. To get credible and valuable results all available building data were acquired and used. The overall look of the building's site and energy consumption was analyzed (macro-scale) as well as the inside of the buildings and its internal components (micro-scale) (Alajmi, Short, Ferguson, Vander Poel, & Griffin, 2020).

The energy performance data, such as U-values and HVAC data and as-built drawings (geometrical and structural information) of buildings were acquired internally from the KNAW and from additional site visits. Furthermore, data were collected from the building's energy supply, acquiring utility bills next to smart metering data through the energy provider (or metering company). In addition, climate data, in the form of the settings of the building-management system (BMS) were acquired.

With this collected data the energy performance baseline measurement was done on which the next phase of the research was built. To ensure efficient collection of all relevant (and available) data at once, site visits were conducted in parallel with a meeting of the buildings' energy manager, during which all additional data files were requested. For the six buildings that are part of the case study, both the available and relevant data varied, as well as the (file) types. In consultation with the real estate team of the KNAW the data was gathered and rated. This was done through two intermediate presentations of the progress of the data collection and the research in general.

External Input Data

The external input parameters were the energy-saving measure data assumptions; the energy price predictions for electricity and gas in the coming decades; and the development of the share of renewables in the Dutch electricity mix. These last parameters were needed to calculate the CO2 reduction throughout the years more accurately (see section 2.5). The building energy performance data and the external input data, together with the energy conservation measures (see the next section 3.2), were required to build the scenarios which are elaborated upon in section 3.3.

3.2 Energy Conservation Measures

The second preparatory part of the research was the setup of the energy conservation measures. For each of the buildings from the case study a list of measures was prepared using the input data, estimating the energy, emission and monetary savings per measure. All measures were based on the data files from the following sources: The InfoMil Knowledge Centre from the Ministry of Infrastructure and Water Management (Ministry of Infrastructure and Water Management, 2022); and the independent public information organization Milieu Centraal, which is funded by the Dutch Government (Milieu Centraal, 2022). For the EML measures the InfoMil Knowledge Centre most current list was used, this version of the EML measures list from April 9th 2020 can be found in the appendix.

Savings were calculated by analyzing the data that was collected in the first step of the methodology and by examining the EML-list and the associated preconditions. After this initial stage, preliminary results were presented to the real estate team of the KNAW after which feedback was gathered and additional measures were included.

3.3 Scenarios

For the first main results of the study, a set of measures was selected to build the short-term scenario for each building. Followed by the second step of selecting a unique set of measures to build the long-term scenario for each building. Concrete and viable energy efficiency strategies were set up for converting existing buildings to NZEB. The scenarios were built by combining energy conservation measures (section 3.2) that were set up using the collected building data (section 3.1). Both scenarios were constructed by the influence of policy targets and regional policy plans (section 2.1). Measures were selected and assigned to a building by putting the buildings from the case study next to the energy conservation measures list from Table 2-1.

In addition, a roadmap has been developed that places both scenarios on a timeline between 2022 and 2050. All data were processed and added to an excel tool which was built in order to develop the scenarios and the roadmap for converting the buildings to NZEB.

Short-term Scenario

The short-term focused scenario was developed by focusing on reaching the nearest targets as quickly and efficiently as possible in chronological order. Different short-term groups of measures are part of this scenario: the Quick-wins and EML Measures; and potential extra measures to reach the Label C obligation (see section 2.1).

For the most drastic short-term scenario measures that were proposed for those buildings where reaching the targets is the most difficult an additional Monte Carlo analysis was done to account for the sensitivity in the cost and saving parameters (see input variables in section 2.5). This offered a view into the uncertainty of the PBP from an economical perspective.

Long-term Scenario

The second scenario, the long-term focused scenario, was developed by focusing on long-term (sometimes final) targets for reaching the goal of becoming climate-neutral (NZEB). For this scenario the region-specific RESs and the WTVs were included, as these outline a vision with an end goal for buildings to become NZEB. The groups of measures for this scenario differ per building but are all focused on reaching this goal of converting them to NZEB.

An additional sensitivity analysis was not conducted on any long-term measures, as was done for some short-term term scenario measures due to their possible interactions with long-term scenario measures in case of longer PBPs. For the long-term measures, the length of the PBP does not affect the interactions between the two scenarios.

In the excel tool, the scenarios and their results show the impact when choosing a particular focus. Potentially resulting in different outcomes in the reduction of consumed energy, CO2 mitigation and financial outcomes. From an overall perspective (period 2021-2050) as well as on an intermediate timescale.

3.4 Interactions

After the two scenarios were developed the interactions were analyzed through a comparison of the outcomes and the different energy mitigation pathways that both scenarios follow. Looking at how short-term targets are reached and at what the difficulties are in reaching them. Long PBPs for short-term measures result in interaction with the long-term measures and long-term target(s), showing that limited flexibility in a target strategy may lead to substantial additional costs to achieve the final target (Hekkenberg, Daniels, Gerdes, & Boonekamp, 2016).

The interaction analysis was done by putting the outcome of the short-term scenario next to that of the long-term scenario. The first step was to identify the buildings for which interactions might occur. This was done by checking which buildings were already below the kWh/m2/year target value for the short-term targets which are set before the implementation of the long-term scenario. Secondly, by checking if the remaining buildings required the implementation of short-term scenario measures that have no interaction with the long-term scenario from an economical perspective. In case the PBPs of all short-term measures of a buildings’ short-term scenario were clearly shorter than the period between the implementation of both scenarios, it could be marked free of any interactions. Resulting in the remaining buildings having measures with PBPs that (tend) to overlap with the long-term scenario. For these measures the PBPs were put in a table for comparison. For these most significant measures the different PBPs were shown for interpretation purposes, showing the PBPs that were derived from the sensitivity analyses on the energy prices and the energy savings and investment costs.

Chapter 4 | Results

This chapter is divided into three sections, following the second part of the research flowchart in Figure 2-12. The first section presents the short-term scenario, the second section presents the long-term scenario, and the third section explains the interactions between them. Figure 4-1 and 4-2 show both the total final energy as well as the relative energy consumption of the six case study buildings in the baseline situation (2021). The left y-axis shows a buildings' total final energy consumption, with the solid green bar showing the total final energy and the patterned green bars showing respectively the electricity and the natural gas usage of a building (both expressed in MWh for easier comparison). On the right y-axis the relative energy consumption is displayed in kWh/m2, indicating the improvement in energy efficiency performance. The buildings are presented in the two different figures below for better readability because of the large difference in total final energy consumption, especially between the Trippenhuis and the Hubrecht Institute. Moreover, the NIOO and the Hubrecht are the only two out of the six buildings where interactions occur (see section 4.3).

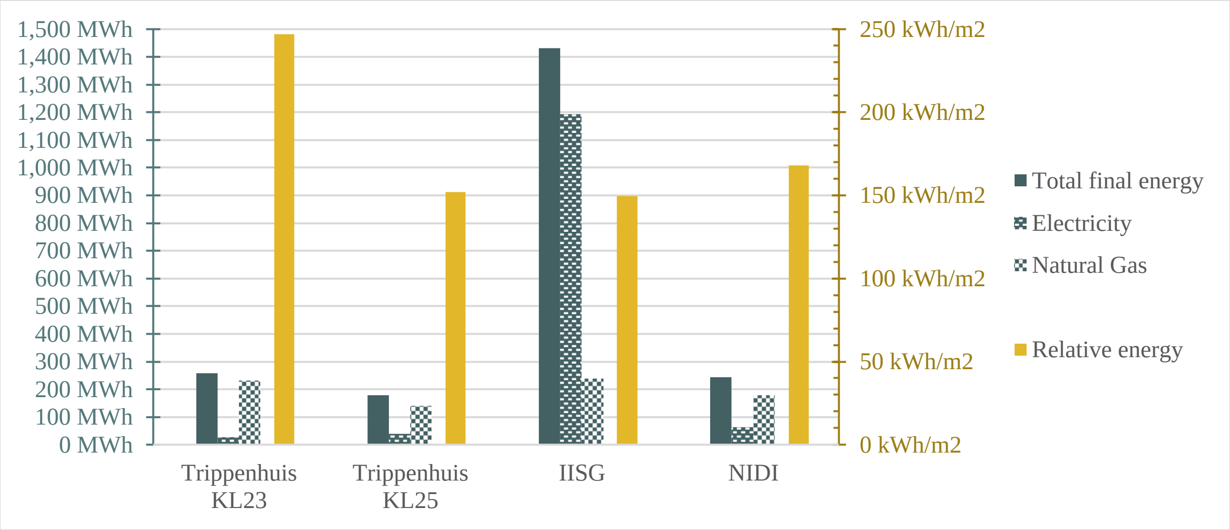

Figure 4-1 | Baseline situation of both the total final energy consumption (shown in green, see left axis) and the relative energy consumption (shown in yellow, see right axis) [KL23, KL25, IISG and NIDI]

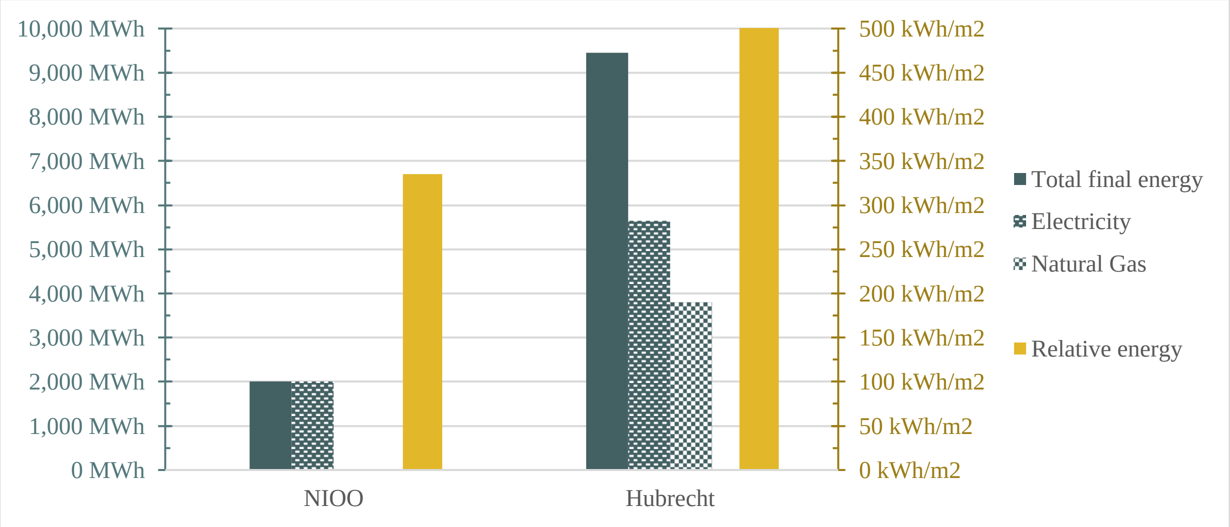

Figure 4-2 | Baseline situation of both the total final energy consumption (shown in green, see left axis) and the relative energy consumption (shown in yellow, see right axis) [NIOO and Hubrecht Institute]

4.1 Short-term Scenario

For all short-term scenarios, they are composed of quick-win measures, The Recognized Energy Efficiency Measures (EML) and potential additional measures for achieving Label C, as mentioned in section 2.1. In addition, extra measures were drawn up when higher energy reduction is needed in order to try and reach intermediate targets. These measures require larger investments and have relatively long depreciation periods but do not overhaul a certain system or require a large-scale renovation project.

For every building of the case study, a separate short-term scenario is composed. Table 4-1 below shows the list of short-term energy conservation measures in the first column and the case study buildings in the first row. Every time a measure applies to a building it is marked in green. These measures were taken from the long list of measures in Table 2-1.

Table 4-1 | List of short-term scenario measures per building

Measure name	KL23	KL25	IISG	NIDI	NIOO	Hubrecht
All lighting to LED	X	X	X		X	X
Application of radiator foil	X	X	X		X	X
Apply a pump switch to the heating circulation pump	X	X				
Apply timer to electric water heater			X			
Cap all thermostatic valves on position 3 (17pcs)	17x	29x				
Install water-saving showerheads	X					
Insulate the cavity wall (Building part C)						X
Insulation of CV components	X	X		X		X
Link an EMS (EBS) to the BMS (GBS)						X
Optimize the boiler settings	X					
Reduce room temperature by 1 degree	X	X	X	X	X	X
Replace conventional emergency lighting	X	X				
Replace increased efficiency heating boiler with HR107 boiler	X					
Set heating limit, weather dependent control and night reduction	X	X		X		
Use of weather stripping and gap sealing	X	X		X		
Use the two installed AC units for heating		X				
Solar panels (650pc extra ground-mounted)					X	
Insulate glass of wamwater tanks						X
Apply hybride heatpumps						X
Extra wall insulation						X
Insulate glass of greenhouses					X	

Using the data from Table 2-1, and applying these to the building specific cases, the PBPs for these measures were found by dividing the total costs by the annual savings. The annual savings were calculated using the predicted energy prices from the sensitivity analysis in Table 2-3. The expected PBPs for these short-term measures are shown in Table 4-2, together with the expected energy savings and corresponding CO2 reductions. Next to the mean expected PBP, a high PBP and a low PBP are given. These PBPs are the result from the sensitivity analysis which was conducted on the energy prices (see section 2.5). The low PBP corresponds with the 25th percentile and the high PBP with the 75th percentile. It is important to note that measures are only shown when there is an investment cost needed and thus a PBP can be calculated.

Looking at Table 4-2 we can see that most of the energy reductions have to be achieved with measures that have relatively longer PBPs (at least longer than 5 years). However, most gains in natural gas reduction can be achieved with measures that have an expected PBP of less than 5 years.

Table 4-2 | PBPs for the short-term scenario measures.

Building	Measure name	PBP low	PBP mean energy prices	PBP high	Saving Electricity	Saving Gas	CO2 reduction
Trippenhuis KL23	Replace increased efficiency heating boiler with HR107 boiler	35.8 yrs	13.5 yrs	6.1 yrs		1,654 m3	3.1 tCO2
Hubrecht	All lighting to LED	23.1 yrs	13.4 yrs	10.5 yrs	144,540 kWh		59.5 tCO2
NIOO	Insulate glass of greenhouses	21.4 yrs	12.4 yrs	9.7 yrs	43,200 kWh		17.8 tCO2
Hubrecht	Extra wall insulation	31.6 yrs	11.9 yrs	5.4 yrs		60,000 m3	113.0 tCO2
Hubrecht	Insulate glass of wamwater tanks	27.4 yrs	10.4 yrs	4.7 yrs		7,200 m3	13.6 tCO2
Hubrecht	Apply hybride heatpumps		9.0 yrs	1.7 yrs	-543,462 kWh	194,690 m3	143.2 tCO2
NIOO	Solar panels (650pc extra ground-mounted)	13.2 yrs	7.7 yrs	6.0 yrs	204,425 kWh		84.1 tCO2
IISG	All lighting to LED	10.5 yrs	6.1 yrs	4.8 yrs	78,840 kWh		32.4 tCO2
Trippenhuis KL23	Replace conventional emergency lighting	8.7 yrs	5.1 yrs	3.9 yrs	530 kWh		0.2 tCO2
Trippenhuis KL25	Replace conventional emergency lighting	8.7 yrs	5.1 yrs	3.9 yrs	2,120 kWh		0.9 tCO2
Trippenhuis KL25	Use of weather stripping and gap sealing	12.3 yrs	4.7 yrs	2.1 yrs		320 m3	0.6 tCO2
Trippenhuis KL23	Use of weather stripping and gap sealing	12.3 yrs	4.7 yrs	2.1 yrs		400 m3	0.8 tCO2
NIDI	Use of weather stripping and gap sealing	12.3 yrs	4.7 yrs	2.1 yrs		480 m3	0.9 tCO2
Trippenhuis KL23	All lighting to LED	7.0 yrs	4.1 yrs	3.2 yrs	1,971 kWh		0.8 tCO2
Trippenhuis KL25	All lighting to LED	5.9 yrs	3.4 yrs	2.7 yrs	2,365 kWh		1.0 tCO2
NIDI	All lighting to LED	5.5 yrs	3.2 yrs	2.5 yrs	4,993 kWh		2.1 tCO2
Trippenhuis KL23	Install water-saving showerheads	7.9 yrs	3.0 yrs	1.3 yrs		600 m3	1.1 tCO2
Trippenhuis KL23	Apply a pump switch to the heating circulation pump	4.2 yrs	2.4 yrs	1.9 yrs	1,316 kWh		0.5 tCO2
Hubrecht	Link an EMS (EBS) to the BMS (GBS)	5.0 yrs	2.4 yrs	1.4 yrs	28,228 kWh	7,788 m3	26.3 tCO2
IISG	Application of radiator foil	5.3 yrs	2.0 yrs	0.9 yrs		3,750 m3	7.1 tCO2
NIDI	Application of radiator foil	5.3 yrs	2.0 yrs	0.9 yrs		3,750 m3	7.1 tCO2
Hubrecht	Insulate the cavity wall (Building part C)	5.3 yrs	2.0 yrs	0.9 yrs		4,050 m3	7.6 tCO2
Hubrecht	Application of radiator foil	5.3 yrs	2.0 yrs	0.9 yrs		4,500 m3	8.5 tCO2
Trippenhuis KL25	Application of radiator foil	5.3 yrs	2.0 yrs	0.9 yrs		2,250 m3	4.2 tCO2
NIDI	Insulation of CV components	5.3 yrs	2.0 yrs	0.9 yrs		1,125 m3	2.1 tCO2
Trippenhuis KL25	Insulation of CV components	5.3 yrs	2.0 yrs	0.9 yrs		1,125 m3	2.1 tCO2
Trippenhuis KL23	Application of radiator foil	5.3 yrs	2.0 yrs	0.9 yrs		3,000 m3	5.7 tCO2
Hubrecht	Insulation of CV components	5.3 yrs	2.0 yrs	0.9 yrs		1,500 m3	2.8 tCO2
Trippenhuis KL23	Insulation of CV components	5.3 yrs	2.0 yrs	0.9 yrs		750 m3	1.4 tCO2
Trippenhuis KL25	Apply a pump switch to the heating circulation pump	2.9 yrs	1.7 yrs	1.3 yrs	1,907 kWh		0.8 tCO2
IISG	Apply timer to electric water heater	0.6 yrs	0.4 yrs	0.3 yrs	1,500 kWh		0.6 tCO2
Trippenhuis KL23	Cap all thermostatic valves on position 3	0.7 yrs	0.2 yrs	0.1 yrs		1,020 m3	1.9 tCO2
Trippenhuis KL25	Cap all thermostatic valves on position 3	0.4 yrs	0.1 yrs	0.1 yrs		1,740 m3	3.3 tCO2
Trippenhuis KL23	Optimize the boiler settings					473 m3	0.9 tCO2
Hubrecht	Reduce room temperature by 1 degree					3,504 m3	6.6 tCO2
IISG	Reduce room temperature by 1 degree					1,463 m3	2.8 tCO2
NIDI	Reduce room temperature by 1 degree					1,096 m3	2.1 tCO2
NIOO	Reduce room temperature by 1 degree					17 m3	0.0 tCO2
Trippenhuis KL23	Reduce room temperature by 1 degree					1,418 m3	2.7 tCO2
Trippenhuis KL25	Reduce room temperature by 1 degree					860 m3	1.6 tCO2
NIDI	Set heating limit, weather dependent control and night reduction					914 m3	1.7 tCO2
Trippenhuis KL23	Set heating limit, weather dependent control and night reduction					473 m3	0.9 tCO2
Trippenhuis KL25	Set heating limit, weather dependent control and night reduction					574 m3	1.1 tCO2
Trippenhuis KL25	Use the two installed AC units for heating				-2,555 kWh	800 m3	0.5 tCO2

The reduction in energy consumption can be achieved when implementing the short-term scenario measures shown per building in Figure 4-3 and Figure 4-4 below. The left y-axis shows a buildings' total final energy consumption, with the solid green bar showing the total final energy and the patterned green bars showing respectively the electricity and the natural gas usage of a building (both expressed in MWh for easier comparison). On the right y-axis the relative energy consumption is displayed in kWh/m2, indicating the improvement of energy efficiency performance. Again, the buildings are presented in two different figures to improve the readability.

In Figure 4-3 we can see the situation after the implementation of the short-term scenario measures for both parts of the Trippenhuis, the IISG and the NIDI.

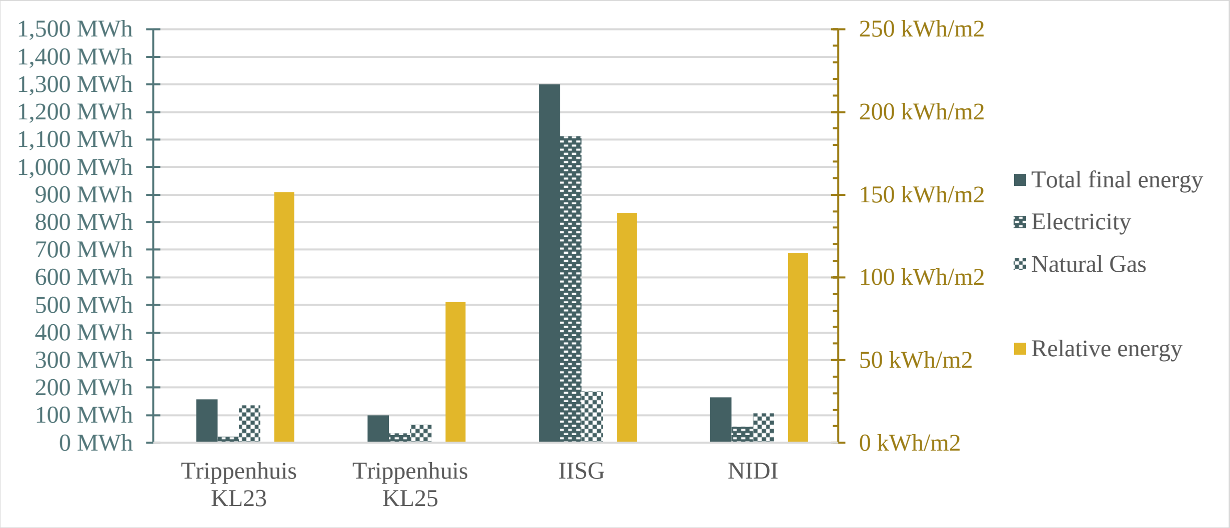

Figure 4-3 | Short-term scenario results, total final energy consumption shown in green (see left axis) and relative energy consumption shown in yellow (see right axis) [KL23, KL25, IISG and NIDI]

In Figure 4-3 and Figure 4-4 we can see the situation after the implementation of the short-term scenario measures for the NIOO and the Hubrecht Institute. For the NIOO the bar that represents the total final electricity usage is (almost) the same height as the total final energy since the NIOO barely uses natural gas. For the Hubrecht Institute, we see the biggest drop in the natural gas bar and a slight increase in electricity usage when compared to the baseline situation in Figure 4-2. This can be explained by the *apply hybrid heatpumps* measure (see tables Table 4-1 and Table 4-2), which decreases the natural gas usage severely, but this is partly replaced by an increase in electricity usage.

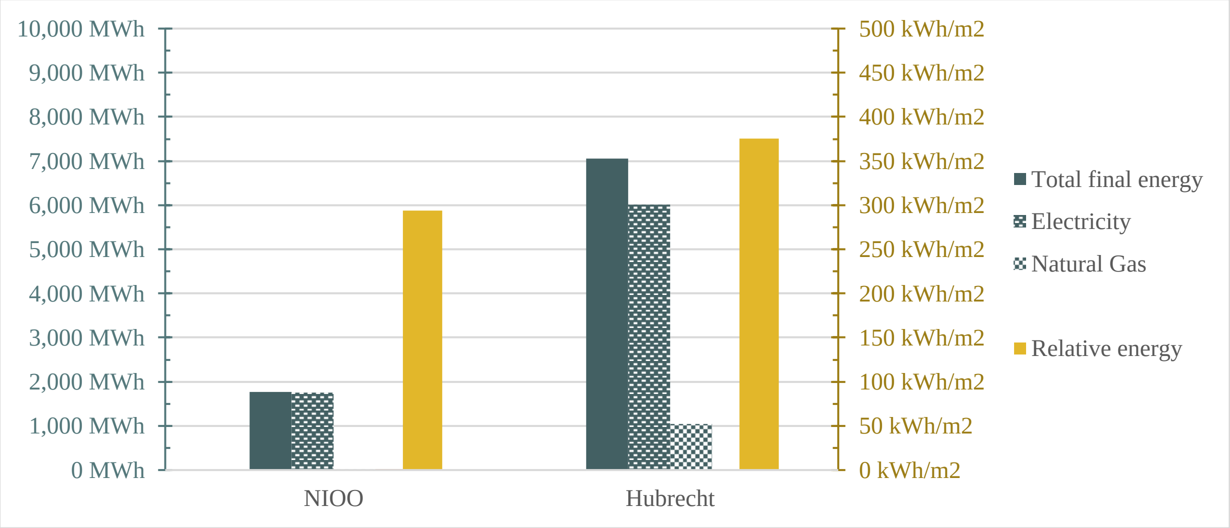

Figure 4-4 | Short-term scenario results, total final energy consumption shown in green (see left axis) and relative energy consumption shown in yellow (see right axis) [NIOO & Hubrecht Institute]

In Figure 4-5 the reduction in relative energy consumption is shown at the baseline situation in 2021 and after the implementation of the short-term scenario measures. The largest reduction can be seen at the Trippenhuis locations and the Hubrecht. With the Trippenhuis locations, the IISG and the NIDI all dropping below the 200 kWh/m2 mark, which corresponds with the energy label A.

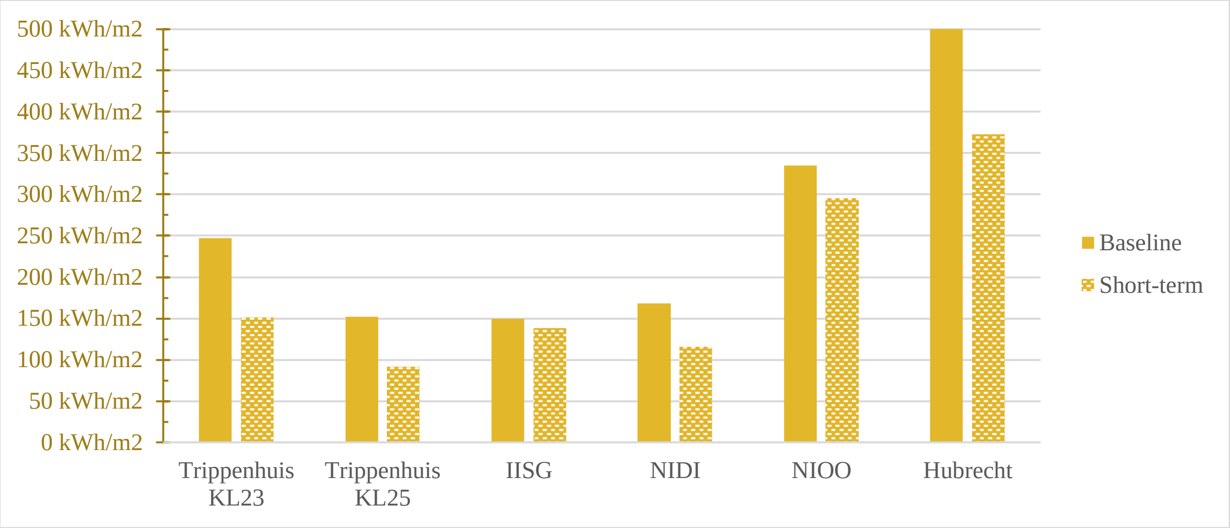

Figure 4-5 | Relative energy consumption when implementing the short-term scenario vs the baseline

Het Trippenhuis (KNAW)

For both sections of Het Trippenhuis, KL23 and KL25, the implementation of the short-term scenario is set for the period until 2030. Both are already within the 250 kWh/m2/year Label C target, with KL25 already being under the 200 kWh/m2/year 2030 Label A target. After the implementation of the short-term scenario KL23 also drops well below this 200 kWh/m2/year target.

With the KL23 being located in a monumental building it has some challenges when trying to reach short-term targets without getting in trouble with legislation concerning monumental buildings. For KL25 the implementation of measures is easier since this part of Het Trippenhuis does not have a monumental status, meaning that is less cumbersome to implement measures.

Implementation of the short-term scenario measures will, compared to the baseline year of 2021, reduce CO2 emissions by 36% for KL23 to 35.3 tCO2 and 38% for KL25 to 26.7 tCO2. When considering the increasing share of renewables in the Dutch electricity mix (see Table 2-5), the emissions of KL23 and KL25 will be respectively 29.3 tCO2 and 17.5 tCO2 by 2030.

International Institute of Social History (IISG)

Similar to both parts of Het Trippenhuis, the implementation phase for the short-term scenario for the IISG is also the period until 2030. With the IISG already being well underway in becoming a NZEB, already having an A+ Energy Label, as was mentioned in section 2.4, and having an energy intensity value of about 150 kWh/m2/year, the short-term scenario focuses mainly on quick-wins that are left on the table and some EML measures. These include replacing all lighting with LED in the short-term and smaller measures such as reducing room temperatures, applying radiator foil and installing timers on the electric water heaters. In the coming years, no major measures are needed to reach the short-term targets that are set by either the government or the KNAW itself.

Implementation of the short-term scenario measures will, compared to the baseline year of 2021, reduce CO2 emissions with 8% for KL23 by 493.9 tCO2. When considering the increasing share of renewables in the Dutch electricity mix (see Table 2-5), the emissions of the IISG will reduce to 194.5 tCO2 by 2030.

Netherlands Interdisciplinary Demographic Institute (NIDI)

For the NIDI the implementation phase of the short-term scenario is shorter due to the fact that the implementation phase of the long-term scenario runs until 2030 (see section 4.2 for more details regarding the long-term scenario implementation). This resulted in the short-term scenario implementation phase needing to be complete by 2025. Nonetheless, the NIDIs energy intensity value is already below both the Label C and Label A target of respectively 250 kWh/m2/year and 200 kWh/m2/year.

Similar to KL23, the NIDI is located in a monumental building and thus there are some challenges when trying to reach short-term targets without getting in trouble with legislation concerning monumental buildings.

Implementation of the short-term scenario measures will, compared to the baseline year of 2021, reduce CO2 emissions by 29% for KL23 to 43.4 tCO2. When considering the increasing share of renewables in the Dutch electricity mix (see Table 2-5), the emissions of the NIDI will reduce to 29.0 tCO2 by 2030.

Netherlands Institute of Ecology (NIOO)

The NIOO is located in the building that is the closest to becoming a NZEB of all buildings in the case study. However, since the NIOO operates energy intensive laboratory facilities the kWh/m2/year value is the second highest value of all 5 case study buildings. In order to reach the intermediate target very aggressive measures need to be implemented in the short term. Thus, the implementation phase for the short-term scenario is set to run in the coming 5 years, until 2026.

Implementation of the short-term scenario measures will, compared to the baseline year of 2021, reduce CO2 emissions by 12% for KL23 to 723.7 tCO2. When considering the increasing share of renewables in the Dutch electricity mix (see Table 2-5), the emissions of the NIOO will reduce to 251.4 tCO2 by 2030.

Hubrecht Institute

With the Hubrecht Institute being the biggest building of all and having, by some distance, the largest energy consumption it is the most challenging one to transform into a NZEB. It is also the trickiest when aiming to reach the short-term targets. Similar to the NIOO, the Hubrecht Institute operates energy intensive laboratory facilities, which results in it having an energy intensity value of over 500 kWh/m2/year. This results in the requirement of the implementation of very aggressive measures in the short-term scenario when trying to reach the intermediate targets. Thus, the implementation phase for the short-term scenario is also set to run in the coming 5 years, until 2026.

Implementation of the short-term scenario measures will, compared to the baseline year of 2021, reduce CO2 emissions by 12% for KL23 to 2675.3 tCO2. When considering the increasing share of renewables in the Dutch electricity mix (see Table 2-5), the emissions of the Hubrecht will reduce to 1056.3 tCO2 by 2030.

Sensitivity analysis on PBP

For several short-term measures that were proposed for the two buildings with the highest energy intensity (NIOO and Hubrecht) to try and reach the intermediate targets, a Monte Carlo analysis was conducted on the economic factors (the energy savings and investment costs). These are the last four measures from Table 4-1 (shown in grey), this Monte Carlo analysis was done to account for the sensitivity in the variables from which the PBP is derived. The analysis was done in a similar manner as was done for the energy prices (see section 2.5), only this time testing the uncertainty in measure related economic factors. The spread in PBPs that was found is shown below in Table 4-3, with the low PBP representing the 25th percentile and the high PBP representing the 75th percentile.

Table 4-3 | Spread in PBP for the four large short-term scenario measures.

Building	Measure	Low PBP	Mean PBP	High PBP
NIOO	Insulate glass of greenhouses	11.1 yrs	14.1 yrs	16.2 yrs
Hubrecht	Insulate glass of wamwater tanks	8.0 yrs	10.1 yrs	11.6 yrs
Hubrecht	Apply hybride heatpumps	7.5 yrs	9.4 yrs	10.8 yrs
Hubrecht	Extra wall insulation	10.0 yrs	12.3 yrs	14.2 yrs

From this analysis we can conclude that there is a relatively large uncertainty when it comes to the PBP, with a higher PBP being up to 2 years longer compared to the mean expected PBP. Combined with the uncertainty in energy prices, and the effect that this has on the PBP, interactions with the long-term scenario can quickly arise.

4.2 Long-term Scenario

All long-term scenarios are strongly influenced by (local) policies with on the forefront the Transition Vision for Heat (WTV), as mentioned in sections 2.1 and 3.3. The long-term measures have high sunk costs and long PBPs. These are measures that e.g., completely overhaul the heating system of a building when transitioning away from fossil fuels and are often impacted and steered by (regional) policy (see section 2.1).

For every building of the case study a separate long-term scenario is composed, however for several buildings the long-term scenario is fairly similar due to the fact that the WTVs are the same. For the IISG, the NIDI and the Hubrecht the WTV focuses on transitioning from gas-fired heating to district heating. However, for the NIDI this can shift to using heat pumps instead (Gemeente Den Haag, 2022). Also, this transition is already planned to be completed by 2030, instead of 2040 for respectively the IISG and the Hubrecht (Gemeente Amsterdam, 2020) (Gemeente Utrecht, 2021).

Table 4-4 below shows the list of long-term energy conservation measures in the first column and the case study buildings in the first row. Every time a measure applies to a building it is marked in green.

Table 4-4 | List of long-term scenario measures per building

Measure name	KL23	KL25	IISG	NIDI	NIOO	Hubrecht
Converting to electric (water) heating	X	X				
Install new AHU incl. heat wheel on roof				X		
Replace central gas-fired water heaters with local close-in water heaters						X
Replace single-glazing with HR++ insulated glass	X			X		X
Install Solar Panels			200x	40x		600x
Transition from natural gas-fired heating to district heating			X	X		X
Use daylight-dependent control sensors					X	X
Apply insulated HR+++ greenhouses					X	
Apply insulated HR+++ warmwater tanks						X

The reduction in energy consumption that can be achieved when implementing the long-term total final measures is shown per building in Figure 4-6 and Figure 4-7 below. The left y-axis shows a buildings' total final energy consumption, with the solid green bar showing the total final energy and the patterned green bars showing respectively the electricity and the natural gas usage of a building (both expressed in MWh for better comparison). On the right y-axis the relative energy consumption is displayed in kWh/m2, indicating the improvement in energy efficiency performance. Again, the buildings are presented in two different figures to improve the readability.

InFigure 4-6 we can see the situation after the implementation of the long-term scenario measures for both parts of the Trippenhuis, the IISG and the NIDI. For all four buildings, the bar that represents the total final electricity usage is the same height as the total final energy since they do not use natural gas anymore after implementation of the long-term scenario measures.

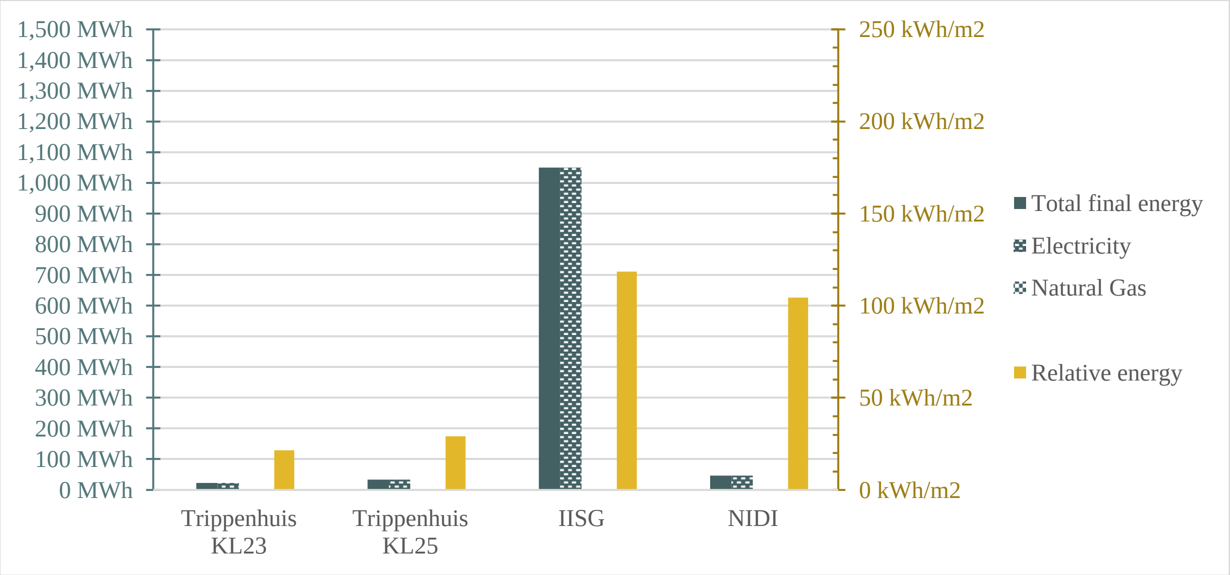

Figure 4-6 | Long-term scenario results, total final energy consumption shown in green (see left axis) and relative energy consumption shown in yellow (see right axis) [KL23, KL25, IISG and NIDI]

In Figure 4-7 we can see the situation after the implementation of the long-term scenario measures for the NIOO and the Hubrecht Institute. For both the NIOO and the Hubrecht the bar that represents the total final electricity usage is (almost) the same height as the total final energy since both barely use natural gas anymore after the implementation of the long-term scenario.

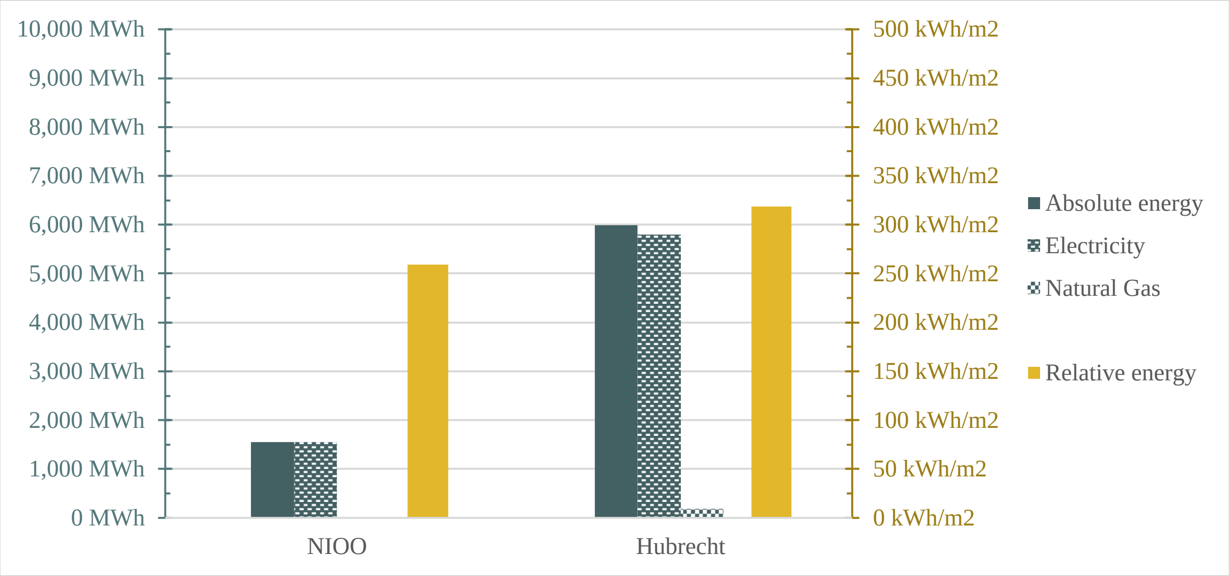

Figure 4-7 | Long-term scenario results, total final energy consumption shown in green (see left axis) and relative energy consumption shown in yellow (see right axis) [NIOO and Hubrecht Institute]

In Figure 4-8 the reduction in relative energy consumption is shown at the baseline situation in 2021, after the implementation of the short-term scenario measures and after the implementation of the long-term scenario measures. The largest reduction can, again, be seen at the Trippenhuis locations. With the Trippenhuis locations dropping below the 70 kWh/m2 mark which corresponds with the 'Paris-Proof' target and the IISG and the NIDI nearing still falling short with about 35 to 50 kWh/m2.

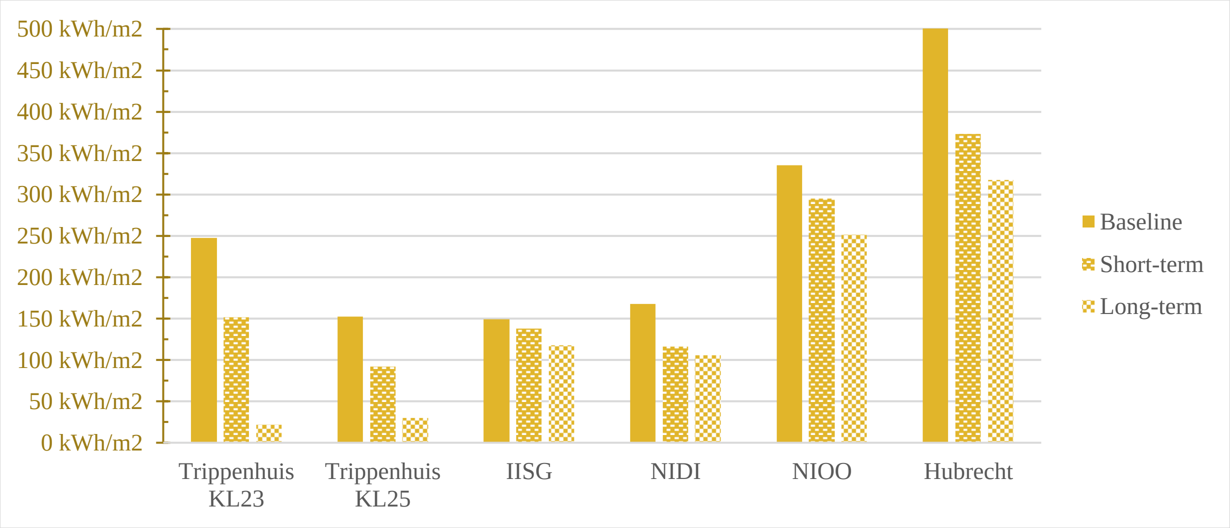

Figure 4-8 | Relative energy consumption comparison when implementing the two scenarios vs the baseline

Het Trippenhuis (KNAW)

For both sections of Het Trippenhuis, KL23 and KL25, the implementation of the long-term scenario is set for the decade between 2030 and 2040. With this, the long-term scenario overlaps with the WTV for this part of Amsterdam. For KL23 as well as for KL25 the long-term scenario focuses on increasing insolation and other large overhaul measures, which aim to reduce gas consumption by 70%. As the regional Transition Vision for Heat prescribes in their plan 'natural gas-free gas grid' (Gemeente Amsterdam, 2020). After the implementation of the long-term scenario measures that are listed in Table

4-4 above, both KL23 and KL25 should be ‘Paris-Proof’, with energy intensity values around and below 30 kWh/m2/year.

Implementation of the long-term scenario measures will, compared to the baseline year of 2021, reduce CO2 emissions by 83% for KL23 to 9.4 tCO2 and 67% for KL25 to 14.1 tCO2. When considering that the Dutch electricity mix will consist of 100% renewable electricity the emissions will be near zero for both the KL23 and KL25 by 2050.

One of the main measures to achieve this is by replacing all single-glazing with high-performance insulated glass (HR++). For KL23, with the current legislation on monumental buildings, this is relatively more difficult to achieve when comparing it to KL25 which does not have a monumental status.

International Institute of Social History (IISG)

For the IISG the long-term scenario focuses on the transition from natural gas-fired heating to district heating. As the regional Transition Vision for Heat prescribes in their plan for a ‘natural gas-free gas grid’ (Gemeente Amsterdam, 2020). This long-term scenario aims at being realized in alignment with the WTV for this part of Amsterdam, meaning that it will be finished by 2040.

Implementation of the long-term scenario measures will, compared to the baseline year of 2021, reduce CO2 emissions with 15% to 457.0 tCO2. When considering that the Dutch electricity mix will consist of 100% renewable electricity the emissions will be near zero for the IISG by 2050.

Netherlands Interdisciplinary Demographic Institute (NIDI)

For the NIDI the long-term scenario focuses on the transition from natural gas-fired heating to district heating or electric heat pumps. As the regional Transition Vision for Heat prescribes in their plan for a ‘natural gas-free gas grid’. This long-term scenario aims at being realized by 2030, due to the fact that the local WTV for this part of The Hague is planned to be executed before 2030 (Gemeente Den Haag, 2022).

Implementation of the long-term scenario measures will, compared to the baseline year of 2021, reduce CO2 emissions by 63% to 22.7 tCO2. When considering that the Dutch electricity mix will consist of 100% renewable electricity the emissions will be near zero for the NIDI by 2050.

Netherlands Institute of Ecology (NIOO)

The long-term scenario for the NIOO is an outlier, due to the fact that it is already well on the way to becoming a NZEB. This results in only minor incremental improvements for this institute. These can mostly be found in optimizing the heating and ventilation settings of the main building and the adjacent greenhouses. Also, the NIOO is already in line with the WTV, transitioning to district heating by using local Ground-coupled heat exchangers (WKOs) and connecting them by a loop, as published by the municipality of Wageningen (Gemeente Wageningen, 2022).

Implementation of the long-term scenario measures will, compared to the baseline year of 2021, reduce CO2 emissions by 23% to 637.3 tCO2. When considering that the Dutch electricity mix will consist of 100% renewable electricity the emissions will be near zero for the NIOO by 2050.

Hubrecht Institute

For the Hubrecht Institute, the long-term scenario focuses on the transition from natural gas-fired heating to district heating. As the regional Transition Vision for Heat prescribes in their plan for a 'natural gas-free gas grid'. This long-term scenario aims at being realized by 2040 in accordance with the local WTV for this part of Utrecht (Gemeente Utrecht, 2021).

Implementation of the long-term scenario measures will, compared to the baseline year of 2021, reduce CO2 emissions by 18% to 2498.6 tCO2. When considering that the Dutch electricity mix will consist of 100% renewable electricity the emissions will be near zero for the Hubrecht by 2050.

4.3 Interactions

There are both positive and negative interactions between the short-term and long-term scenarios. Negative interactions occur when early depreciation is required on a short-term scenario measure in order to complete a long-term scenario measure (see section 2.3). For the KL25 part of Het Trippenhuis, the IISG and the NIDI these interactions are not applicable, since they are already below the kWh/m2/year target value for the intermediate targets which are set before the implementation of the long-term scenario.

Regarding the three other buildings, negative interactions only occur at the NIOO and the Hubrecht Institute. The KL23 part of Het Trippenhuis only requires the implementation of short-term scenario measures that have no interaction with the long-term scenario from an economical perspective (see section 4.1). Table 4-5 shows for which buildings the short-term targets are reached without any complications and for which there may be interactions.

Table 4-5 | Short-term targets reached without interactions per building

Measure name	KL23	KL25	IISG	NIDI	NIOO	Hubrecht
Short-term targets reached without negative interactions	X	X	X	X		

Regarding the Hubrecht Institute, but also to a lesser extent for the NIOO, when extra measures are implemented in the short-term scenario, which aims to reach the intermediate targets, they result occasionally in a negative interaction between these and the long-term scenario (and targets). One of the main drivers of this negative interaction is the Transition Vision for Heat (WTV). Short-term scenario measures that are implemented must already be depreciated before the end of their PBP when the long-term scenario measures related to the WTV need to be implemented. This is dependent on the uncertainty in energy prices as well as on a measures' saving potential. For example, as shown in Table 4-3, when the saving potential of a measure is lower than the expected average saving, the PBP can increase significantly. When combining this with lower energy prices a measure that is implemented in the short-term scenario, in order to try and reach intermediate targets, can already be redundant when a long-term scenario measure needs to be implemented before it is paid back.

In the tables below, the PBPs for these measures are shown. Table 4-6 shows the different PBPs for the measure *insulate glass of greenhouses* that was assigned to the NIOO. The measure is proposed to reach short-term targets, however for the long-term target this measure needs to be replaced by the measure *apply insulated HR+++ greenhouses*. In case the PBP of the short-term measures ends up in the range of 10+ to 20+ years, it will negatively interact with the long-term scenario measure.

Table 4-6 | Different PBPs for insulate glass of greenhouses measure (NIOO)

Insulate glass of greenhouses	Low PBP	Mean PBP	High PBP
High energy prices	8.1 yrs	10.4 yrs	12.1 yrs
Mean energy prices	11.1 yrs	14.1 yrs	16.2 yrs
Low energy prices	16.4 yrs	21.1 yrs	24.3 yrs

Table 4-7 shows the different PBPs for the measure *insulate glass of warmwater tanks* which is assigned to the Hubrecht Institute. The measure is proposed to reach short-term targets, however for the long-term target this measure needs to be replaced by the measure *apply insulated HR+++ warmwater tanks*. In case the PBP of the short-term measures ends up in the range of 10+ to 20+ years, it will negatively interact with the long-term scenario measure.

Table 4-7 | Different PBPs for insulate glass of warmwater tanks measure (Hubrecht Institute)

Insulate glass of wamwater tanks	Low PBP	Mean PBP	High PBP
High energy prices	3.7 yrs	4.7 yrs	5.5 yrs
Mean energy prices	8.0 yrs	10.1 yrs	11.6 yrs
Low energy prices	23.0 yrs	29.1 yrs	34.1 yrs

Chapter 5 | Discussion

This study was conducted to provide a clear and comprehensive analysis of target interactions between short-term and long-term targets when it comes to the conversion of existing buildings to NZEB. The first section of this discussion examines what the implications of the results mean for the conversion of existing buildings to NZEB and for policy/target setting. These implications are however based on a construct of assumptions and concessions and therefore have their limitations. The second section subsequently discusses these limitations and to what extent they influenced the results. The final section advocates for additional research to further investigate energy reduction target interactions in the built environment.

Contribution to the literature

The results of this paper are meant to inform on how short-term and long-term targets interact and how this impacts the conversion of existing buildings to NZEB. This section further elaborates what the results mean for the conversion of building to NZEB and for future policy and target setting.

The tension between short- and long-term targets was previously investigated by Hekkenberg, et al., (2016); looking into the influence of the EUs' sub-targets on their long-term ambitions, talking about the importance of linking these to prevent them from potentially leading to inefficiencies. This paper researched a similar tension between short- and long-term energy reduction targets for existing buildings. It reaffirmed the message from Hekkenberg, et al, (2016), that when designing short-term targets, the significance of aligning them with the long-term target(s) should not be overlooked. In the case of the Netherlands, the location of the case study, there was no alignment during the setting of the short-term targets and the WTVs, which was defined as a long-term target. The WTVs were written after the short-term targets were already in place.

Moreover, new insight from the research is the need for closer cooperation between all stakeholders in the future. These stakeholders are the building owners (the KNAW in this papers' case study), regional governments (e.g. municipalities and RES-regions) and other stakeholder groups (e.g. Utrecht Science Park in this papers' case study).

In addition, this paper conducted a case study in the Netherlands, it looked into the conversion of Western European utility buildings, whereas most of the existing EU-focused research on this topic conducted case studies in Southern Europe (Dalla Mora, Righi, Peron, & Romagnoni, 2017) (Dimitriou, Kyprianou, Papanicolas, & Serghides, 2020) (Ascione, Francesca de Masi, De Rossi, Ruggiero, & Vanoli, 2017). This paper fills that gap in research on the conversion of utility buildings to NZEB in the Netherlands and Western Europe in general.

Limitations of the research

From the case study perspective there was a limitation, due to the fact that only two out of the six buildings truly tested the research question (the NIOO and the Hubrecht Institute), since the other buildings were already (practically) in line with the short-term targets that were set. Moreover, these two buildings that needed significant energy improvements in order to try and reach the short-term targets, had energy intensive research activities which made them difficult to fit in the energy intensity boundaries that were set in this research. However, the research question could still be investigated since there were short-term scenario measures that interacted with long-term scenario measures (under certain circumstances).

Other limitations were the uncertainty in the data collection, the COVID-19 pandemic impacted the data of a buildings' energy consumption differently. To ensure successful research it was important to look ahead if (complete) building energy performance data was available. Due to the pandemic employees were working from home for an x amount of the total annual office hours (Government of the Netherlands, 2021), this resulted in different annual energy consumption data, which may not be the most representative depending on the 'normal' user function of a building. This was addressed by comparing energy consumption data from the years 2019, 2020 and 2021. Cases of significant deviation in this annual consumption data were flagged and mentioned. However, 2021 was still chosen to be the baseline year for each building to ensure consistent research.

In more general terms, it can be argued that there is some degree of uncertainty in the input data and measures that resulted from these. A limitation of this research was a limited list of measures, that could have been more comprehensive when a more in-depth analysis of the building was made by experts in this field. A recommendation to the KNAW will therefore be of having a comprehensive analysis done of their buildings. Which could develop a list of measures not only for the buildings they own but also for the buildings they rent. This would counter the limitation that is argued here and build on the research started in this paper. When considering limitations of the external input data (prices, savings and investment costs), uncertainties were mostly countered by performing a sensitivity analysis on the variables. Moreover, the results (PBP calculations) are not affected in such a way that this changes the outcome of this research.

Future research

The previous paragraph already briefly addressed future research, here other improvements are discussed.

To improve upon this research there are two methods to tackle the issue of energy intensive research facilities. A breakdown of all energy functions of a building can be done, by differentiating the basic energy functions of a building from the other functions such as energy intensive research activities. This allows for wider comparisons between buildings and in terms of measuring the realization of the set reduction targets.

Alternatively, a benchmark for energy intensive research facilities could be implemented (in this case study the NIOO and the Hubrecht Institute). This enables for better comparison between similar buildings and creates more achievable and credible targets. This will result in less extreme measures that need to be taken to achieve short-term targets.

Chapter 6 | Conclusions

This study was set up to investigate the interactions between short-term and long-term targets and understand how they impact the conversions of existing buildings to near-zero-emission-buildings (NZEB). The main research question was therefore stated as follows:

How do short-term and long-term targets interact and how will this impact the conversion of existing buildings to NZEB?

To support in answering this main research question the following sub-question was formulated:

Which short-term measures and long-term measures are needed for the conversion of existing buildings to NZEB?

These questions were answered by setting up both a short-term scenario and a long-term scenario set of measures for the KNAWs six buildings from the case study. By conducting sensitivity analysis on input variables for these measures, a spread in PBPs was found for the short-term scenario measures. For two buildings (the NIOO and the Hubrecht Institute) this resulted in a realistic chance for interaction with the long-term scenario under certain outcomes of the sensitivity analysis. These interactions can result in early depreciation on measures that needed to be taken in order to reach short-term targets. Consequences are that the pathway to reach the final target, trying to convert a building to NZEB, becomes less efficient from a financial, but also technical perspective.

To summarize, short-term targets interact negatively with long-term targets when the investment of a measure, that needed to be taken in order to reach these short-term targets, was not recovered before new measures must be taken to achieve the long-term target. This results in a less efficient pathway when converting existing buildings to NZEB.

Recommendations to proactive organizations, municipalities and other governmental bodies

Other findings are in the form of recommendations on aligning the government with proactive organizations on policy and targets. This to diminish negative interaction between short-term and long-term targets for converting existing buildings to NZEB. One way to approach this is for local governments to set up an association of stakeholders at locations where utility buildings are clustered together. In such an association target, approaches in how to reach them and timelines can be aligned so that the most efficient reduction pathway is followed. Most efficient means in both economical as well as technical terms.

Recommendations to the KNAW

Below the roadmap is provided showing the measures that can be taken on a timeline with the corresponding CO2 reductions. As mentioned in section 2.1, as indicator for energy performance the unit kWh/m2 per year is used. The current value per building can be found in Table 6-1 to 6-3 below in the third column. Projected values are shown in the last column of tables Table 6-1 to 6-3. It is important to notice that a buildings' kWh/m2 value deviates significantly when it has a different usage function. For the NIOO, and especially the Hubrecht Institute, it is the case that a large fragment of its energy consumption arises from energy intensive research which is difficult to categories or find an appropriate benchmark for. Thus, for every building's (intermediate) target, governmental guidelines for office buildings are used which are mentioned in section 2.1. It is up to the KNAW itself to either stick with this approach or find an appropriate way to deviate from this for the energy intensive research institutes.

Overall recommendation for the long-term scenario implementation is to seek contact with local and regional governmental organization and work closely together on the transition away for (natural) gas-fired heating. This is necessary to reduce the risk of early depreciation on large investments in these long-term scenario-measures. Furthermore, one of the main takeaways is to focus on making optimal use of natural moments (moments where the technical lifetime is reached) when implementing replacement or maintenance measures that require high investment costs.

Shown in Table 6-1 below is the first period of the roadmap from 2022 to 2030. The implementation of the short-term scenario measures is concentrated in the first years of this period. For the NIDI during this period also the long-term scenario measures need to be (completely) implemented due to the fact that the municipality of The Hague is already planning to transition away from gas-fired heating for this part of the city by the end of 2030. For the other institutes a start can be made for implementing long-term scenario measures in at the end of this period.

Table 6-1 | Roadmap 2022-2030

KNAW Real Estate		**Base year**	**CO2 reduction in kgCO2-eq**								
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
				LABEL C							LABEL A
Trippenhuis KL23	56,387 kgCO2	55,348 kgCO2	*Quick-wins*	-1,107 kgCO2		Short-term scenario measures		-20,009 kgCO2			
Amsterdam				-2%				-36%			
	225,031 kWh	257,179 kWh						-99,436 kWh			
								-39%			
		247 kWh/m2		LABEL C				152 kWh/m2			LABEL A
Trippenhuis KL25	31,066 kgCO2	42,709 kgCO2	*Quick-wins*	-854 kgCO2		Short-term scenario measures		-16,027 kgCO2			
Amsterdam				-2%				-38%			
	117,864 kWh	178,242 kWh						-78,763 kWh			
								-44%			
		152 kWh/m2		LABEL C				85 kWh/m2			LABEL A
IISG	472,566 kgCO2	536,787 kgCO2	*Quick-wins*	-10,736 kgCO2				-42,877 kgCO2			
Amsterdam				-2%				-8%			
	242,519 kWh	1,431,258 kWh						-131,274 kWh			
								-9%			
		149 kWh/m2		LABEL C				139 kWh/m2			LABEL A
NIDI	52,940 kgCO2	60,875 kgCO2	Short-term scenario measures		-17,452 kgCO2		Long-term scenario measures			-20,703 kgCO2	
The Hague					-29%	Transition from gas-fired heating to district heating or HP				-63%	
	201,136 kWh	242,810 kWh			-76,950 kWh					-119,151 kWh	
					-32%					-81%	
		168 kWh/m2		LABEL C	115 kWh/m2					104 kWh/m2	LABEL A
NIOO	800,215 kgCO2	825,628 kgCO2	*Quick-wins*	-16,513 kgCO2	Short-term scenario measures		-101,915 kgCO2				
Wageningen				-2%			-12%				
	1,949,818 kWh	2,011,216 kWh					-247,794 kWh				
							-12%				
		335 kWh/m2	*needed for C*	-85 kWh/m2			294 kWh/m2			*needed for A:*	*-94 kWh/m2*
Hubrecht	2,974,844 kgCO2	3,056,421 kgCO2	*Quick-wins*	-63,381 kgCO2	Short-term scenario measures		-381,090 kgCO2				
Utrecht				-2%			-12%				
	9,068,062 kWh	9,449,845 kWh					-2,396,478 kWh				
							-25%				
		503 kWh/m2	*needed for C*	-253 kWh/m2			375 kWh/m2			*needed for A:*	*-175 kWh/m2*

Shown in Table 6-2 below is the second period of the roadmap from 2031 to 2040. During this period the full implementation of the long-term scenario measures happens, with a potential exception for on-site renewable electricity production (e.g., the application of rooftop solar panels). For all institutes (except the NIDI) the transition from (natural) gas-fired heating is planned to take place during this decade.

Table 6-2 | Roadmap 2031-2040

KNAW Real Estate		Base year	CO2 reduction in kgCO2-eq									
	2020	2021	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
												Paris-Proof
Trippenhuis KL23	56,387 kgCO2	55,348 kgCO2						Long-term scenario measures		-25,971 kgCO2		
Amsterdam			Increase insolation reduce gas comsumption by 70% (regional plan fossil-free gas grid)							-83%		
	225,031 kWh	257,179 kWh								-134,682 kWh		
										-91%		
		247 kWh/m2								22 kWh/m2		Paris-Proof
Trippenhuis KL25	31,066 kgCO2	42,709 kgCO2						Long-term scenario measures		-13,950 kgCO2		
Amsterdam			Increase insolation reduce gas comsumption by 70% (regional plan fossil-free gas grid)							-66%		
	117,864 kWh	178,242 kWh								-72,342 kWh		
										-80%		
		152 kWh/m2								30 kWh/m2		Paris-Proof
IISG	472,566 kgCO2	536,787 kgCO2						Long-term scenario measures		-36,888 kgCO2		
Amsterdam			Transition from gas-fired heating to district heating (regional plan gas-free)							-16%		
	242,519 kWh	1,431,258 kWh								-250,246 kWh		
										-27%		
		149 kWh/m2								118 kWh/m2	*needed for PP:*	*-48 kWh/m2*
NIDI	52,940 kgCO2	60,875 kgCO2										
The Hague												
	201,136 kWh	242,810 kWh										
		168 kWh/m2									*needed for PP:*	*-35 kWh/m2*
NIOO	800,215 kgCO2	825,628 kgCO2						Long-term scenario measures		-107,118 kgCO2		
Wageningen										-25%		
	1,949,818 kWh	2,011,216 kWh								-260,348 kWh		
										-25%		
		335 kWh/m2								251 kWh/m2	*needed for PP:*	*-181 kWh/m2*
Hubrecht	2,974,844 kgCO2	3,056,421 kgCO2						Long-term scenario measures		-173,624 kgCO2		
Utrecht				Transition from gas-fired heating to district heating (regional plan gas-free)						-19%		
	9,068,062 kWh	9,449,845 kWh								###############		
										-37%		
		503 kWh/m2								317 kWh/m2	*needed for PP:*	*-247 kWh/m2*

Shown in Table 6-3 below is the third and last period of the roadmap from 2041 to 2050. In this last period until 2050, measures need to be taken to reach a fully climate-neutral real-estate portfolio. This period is still too unpredictable for making any substantial predictions, there is a high uncertainty in technological developments, policy and energy prices.

Table 6-3 | Roadmap 2041-2050

KNAW Real Estate		Base year	CO2 reduction in kgCO2-eq									
	2020	2021	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
												Climate Neutral
Trippenhuis KL23	56,387 kgCO2	55,348 kgCO2										
Amsterdam			TBD >>									
	225,031 kWh	257,179 kWh										
		247 kWh/m2									*needed for 0*	*-247 kWh/m2*
Trippenhuis KL25	31,066 kgCO2	42,709 kgCO2										
Amsterdam			TBD >>									
	117,864 kWh	178,242 kWh										
		152 kWh/m2									*needed for 0*	*-152 kWh/m2*
IISG	472,566 kgCO2	536,787 kgCO2		Solar Panels	-25,118 kgCO2							
Amsterdam			TBD >>									
	242,519 kWh	1,431,258 kWh										
		149 kWh/m2									*needed for 0*	*-149 kWh/m2*
NIDI	52,940 kgCO2	60,875 kgCO2		Solar Panels	-5,024 kgCO2							
The Hague			TBD >>									
	201,136 kWh	242,810 kWh										
		168 kWh/m2									*needed for 0*	*-168 kWh/m2*
NIOO	800,215 kgCO2	825,628 kgCO2										
Wageningen			TBD >>									
	1,949,818 kWh	2,011,216 kWh										
		335 kWh/m2									*needed for 0*	*-335 kWh/m2*
Hubrecht	2,974,844 kgCO2	3,056,421 kgCO2		Solar Panels	-75,355 kgCO2							
Utrecht			TBD >>									
	9,068,062 kWh	9,449,845 kWh										
		503 kWh/m2									*needed for 0*	*-503 kWh/m2*

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Appendices

Recognized Energy Efficiency Measures List for Offices

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Inrichtingen voor het uitvoeren van administratieve werkzaamheden. De inrichting heeft een kantoor- functie zoals aangehaald in het Bouwbesluit 2012. Denk aan het openbaar bestuur, overheidsdiensten, verplichte sociale verzekeringen en zakelijke en financiële dienstverlening. Ter indicatie de SBI-codes die voor de indeling van deze diensten veelal worden gebruikt zijn SBI-code 64 t/m 74 en 84. In de bedrijfstak ‘kantoren’ zijn erkende maatregelen aangemerkt voor de in tabel 4 genoemde activiteiten.

Erkende maatregelen voor energiebesparing

Tabel 4. Erkende maatregelen voor energiebesparing in kantoren

Activiteiten	Nummers
Gebouw (G)	
A. Gebruiken van een energieregistratie- en bewakingssysteem	GA1
B. Isoleren van de gebouwschil	GB1
C. Ventileren van een ruimte	GC1 t/m GC5
D. Verwarmen van een ruimte	GD1 en GD2
E. In werking hebben van een ruimte- en buitenverlichtingsinstallatie	GE1 t/m GE7
Faciliteiten (F)	
A. In werking hebben van een stookinstallatie (emissies naar de lucht)	FA1 t/m FA5
B. In werking hebben van productkoeling	FB1 t/m FB4
C. Bereiden van voedingsmiddelen	FC1 t/m FC2
D. In werking hebben van een liftinstallatie	FD1 en FD2
E. In werking hebben van een roltrapsysteem	FE1
F. Gebruiken van informatie- en communicatietechnologie	FF1
G. In werking hebben van serverruimten	FG1 t/m FG9
H. In werking hebben van een noodstroomvoorziening	FH1
I. In werking hebben van elektromotoren	FI1

Activiteit	Gebruiken van een energieregistratie- en -bewakingssysteem		
Nummer maatregel	GA1		
Omschrijving maatregel	Borgen van de optimale energiezuinige in- en afstellingen van klimaatinstallaties door het automatisch laten registeren en analyseren van energieverbruiken met een energieregistratie- en bewakingssysteem (EBS).		
Mogelijke technieken ten opzichte van uitgangssituatie	a) Slimme meter met een energieverbruiksmanager toepassen voor elektriciteit, aardgas (a.e.) en/of warmte.	b) Een automatisch EBS met een rapportagefunctie (voor een overzicht van het energieverbruik per dag, week en jaar) toepassen.	c) Een automatisch EBS met een rapportagefunctie (voor een overzicht van het energieverbruik per dag, week en jaar) toepassen, in combinatie met een gebouwbeheersysteem (GBS).
Uitgangssituatie op basis van een referentietechniek	a) Elektriciteit- en gas- en/of warmtemeters die op afstand kunnen worden uitgelezen (de zogenaamde slimme meters) ontbreken.	b) EBS ontbreekt.	c) Gebouwbeheersysteem is aanwezig zonder een EBS.
Technische randvoorwaarden	Niet van toepassing.		
Economische randvoorwaarden	a) Voor het bedoelde gebouw geldt: Jaarlijkse warmteverbruik is meer dan 25.000 m^3(a.e.); of Jaarlijkse elektriciteitsverbruik is meer dan 88.000 kWh; of Een bruto vloeroppervlakte van meer dan 1.500 m^2.	b) Voor het bedoelde gebouw geldt: Jaarlijkse warmteverbruik is meer dan 75.000 m^3(a.e.); of- Jaarlijkse elektriciteitsverbruik meer dan 265.000 kWh; of Een bruto vloeroppervlakte van meer dan 4.400 m^2.	c) Voor het bedoelde gebouw geldt: Jaarlijkse warmteverbruik is meer dan 170.000 m^3 (a.e.); of Jaarlijkse elektriciteitsverbruik is meer dan 1.000.000 kWh; of Een bruto vloeroppervlakte van meer dan 10.000 m^2.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.		
Alternatieve erkende maatregelen	Niet van toepassing.		
Bijzondere omstandigheden	Niet van toepassing.		

Activiteit	Isoleren van de gebouwschil
Nummer maatregel	GB1
Omschrijving maatregel	Warmte- en koudeverlies via buitenmuur beperken.
Mogelijke technieken ten opzichte van uitgangssituatie	Spouwmuren isoleren. Gebouw wordt verwarmd en/of gekoeld.
Uitgangssituatie op basis van een referentietechniek	Isolatie in spouwmuren ontbreekt. Gebouw wordt verwarmd.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	In kantoorgebouwen met minimaal een energielabel C, of kantoorgebouwen met een bouwjaar vanaf 2003 of later wordt aangenomen dat de maatregel al is genomen. Het energielabel staat voor de energieprestatie op basis van getroffen maatregelen.

Activiteit	Ventileren van een ruimte
Nummer maatregel	GC1
Omschrijving maatregel	Aanstaan van ventilatie buiten bedrijfstijd voorkomen.
Mogelijke technieken ten opzichte van uitgangssituatie	Schakelklok toepassen.

Uitgangssituatie op basis van een referentietechniek	Automatische aan- en uitschakelingen ontbreken.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	Ventileren van een ruimte
Nummer maatregel	GC2
Omschrijving maatregel	Vollasturen ventilatoren beperken door afschakelen van ventilatoren bij lager ventilatiedebiet.
Mogelijke technieken ten opzichte van uitgangssituatie	Cascaderegeling toepassen.
Uitgangssituatie op basis van een referentietechniek	Cascaderegeling ontbreekt.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	In kantoorgebouwen met minimaal een energielabel C, of kantoorgebouwen met een bouwjaar vanaf 2003 of later wordt aangenomen dat de maatregel al is genomen. Het energielabel staat voor de energieprestatie op basis van getroffen maatregelen.

Activiteit	Ventileren van een ruimte
Nummer maatregel	GC3
Omschrijving maatregel	Warmte uit uitgaande ventilatielucht gebruiken voor voorverwarmen ingaande ventilatielucht bij gebalanceerd ventilatiesysteem.
Mogelijke technieken ten opzichte van uitgangssituatie	Warmtewiel, kruisstroomwarmtewisselaar of twincoilsysteem toepassen.
Uitgangssituatie op basis van een referentietechniek	Warmteterugwinsysteem ontbreekt in luchtbehandelingskast.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	In kantoorgebouwen met minimaal een energielabel C, of kantoorgebouwen met een bouwjaar vanaf 2003 of later wordt aangenomen dat de maatregel al is genomen. Het energielabel staat voor de energieprestatie op basis van getroffen maatregelen.

Activiteit	Ventileren van een ruimte
Nummer maatregel	GC4
Omschrijving maatregel	Energiezuinige ventilator toepassen.
Mogelijke technieken ten opzichte van uitgangssituatie	IE3-elektromotor of beter met toerenregeling toepassen.
Uitgangssituatie op basis van een referentietechniek	Elektromotor met rendementsklasse IE2 of lager is aanwezig zonder frequentieregelaar. Benodigd luchtdebiet varieert.

Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	Ventileren van een ruimte
Nummer maatregel	GC5
Omschrijving maatregel	Warmteverlies ventilatiekanalen beperken in ruimten waar geen warmteafgifte nodig is.
Mogelijke technieken ten opzichte van uitgangssituatie	Isolatie om ventilatiekanalen aanbrengen.
Uitgangssituatie op basis van een referentie-techniek	- Isolatie om ventilatiekanalen ontbreekt. - Luchttoevoerkanalen en/of afzuigkanalen zijn verbonden met een recirculatie- of warmteterugwinsystemen.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Temperatuur kanaal is minimaal 10°C hoger dan omgevingstemperatuur.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja, als de jaarlijkse bedrijfstijd minimaal 2.700 uur is. Natuurlijk moment: Ja, als de jaarlijkse bedrijfstijd minimaal 1.500 uur is.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	Verwarmen van een ruimte
Nummer maatregel	GD1
Omschrijving maatregel	Warmteverlies via warmwaterleidingen en -appendages beperken.
Mogelijke technieken ten opzichte van uitgangssituatie	Isolatie aanbrengen om leidingen en appendages.
Uitgangssituatie op basis van een referentie-techniek	Isolatie om leidingen en appendages ontbreekt.
Technische randvoorwaarden	In verwarmde ruimten alleen de ringleiding isoleren.
Economische randvoorwaarden	Aardgasverbruik is minder dan 170.000 m^3 per jaar. Bedrijfstijd van installatie behorende bij leidingen en appendages is minimaal 1.250 uur per jaar.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	Verwarmen van een ruimte
Nummer maatregel	GD2
Omschrijving maatregel	Temperatuur per ruimte naregelen.
Mogelijke technieken ten opzichte van uitgangssituatie	Klokthermostaten en overwerktimers toepassen.
Uitgangssituatie op basis van een referentie-techniek	Individuele naregeling in verblijfsruimten met radiatoren of verwarmingsgroepen ontbreekt.
Technische randvoorwaarden	Het regelelement van de radiator beschikt over een motorbediende afsluitklep.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van een ruimte- en buitenverlichtingsinstallatie	
Nummer maatregel	GE1	
Omschrijving maatregel	Onnodig branden van buitenverlichting voorkomen.	
Mogelijke technieken ten opzichte van uitgangssituatie	a) Bewegingssensors, schemer- en tijdschakelaars toepassen.	b) Schemer- en tijdschakelaars toepassen.
Uitgangssituatie op basis van een referentietechniek	Automatische aan- en uitschakeling ontbreekt. Buitenverlichting (niet zijnde reclame- of noodverlichting) is overdag, in de avond en/of 's nachts aan.	
Technische randvoorwaarden	Niet van toepassing.	
Economische randvoorwaarden	Minimaal 20 armaturen zijn aanwezig. Buitenverlichting is 's nachts minimaal 6 uur uit.	
Toepasbaar op een zelfstandig of natuurlijk moment?	a) Zelfstandig moment: Ja, als minimaal 50 armaturen aanwezig zijn. Natuurlijk moment: Ja.	b) Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.	

Activiteit	In werking hebben van een ruimte- en buitenverlichtingsinstallatie
Nummer maatregel	GE2
Omschrijving maatregel	Onnodig branden van reclameverlichting voorkomen.
Mogelijke technieken ten opzichte van uitgangssituatie	Schemer-, en/of tijdschakelaars toepassen.
Uitgangssituatie op basis van een referentietechniek	Automatische aan- en uitschakeling ontbreekt Reclameverlichting is overdag en/of 's nachts aan.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Reclameverlichting kan in de nacht minimaal 6 uur worden uitgeschakeld.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van een ruimte- of buitenverlichtingsinstallatie	
Nummer maatregel	GE3	
Omschrijving maatregel	Geïnstalleerd vermogen buitenverlichting beperken.	
Mogelijke technieken ten opzichte van uitgangssituatie	Ledlampen in bestaande en/of nieuwe armaturen toepassen.	
Uitgangssituatie op basis van een referentietechniek	a) Halogeenlampen en/of breedstralers zijn aanwezig.	b) Hogedrukkwiklampen zijn aanwezig.
Technische randvoorwaarden	Technische staat van de bestaande armaturen is volgens de installateur voldoende.	
Economische randvoorwaarden	a) Niet van toepassing.	b) Aantal branduren is minimaal 4.000 uur per jaar.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.	
Bijzondere omstandigheden	Niet van toepassing.	

Activiteit	In werking hebben van een ruimte- of buitenverlichtingsinstallatie
Nummer maatregel	GE4
Omschrijving maatregel	Geïnstalleerd vermogen reclameverlichting beperken.
Mogelijke technieken ten opzichte van uitgangssituatie	Ledlampen in bestaande armaturen toepassen.
Uitgangssituatie op basis van een referentie-techniek	Gloei- en/of halogeenlampen zijn aanwezig.
Technische randvoorwaarden	Technische staat van de bestaande armaturen is volgens de installateur voldoende.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van een ruimte- en buitenverlichtingsinstallatie
Nummer maatregel	GE5
Omschrijving maatregel	Geïnstalleerd vermogen verlichting vluchtwegaanduiding beperken.
Mogelijke technieken ten opzichte van uitgangssituatie	Nieuwe armaturen met ledlampen toepassen.
Uitgangssituatie op basis van een referentie-techniek	Conventionele armaturen met langwerpige fluorescentielampen (TL) zijn aanwezig.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van een ruimte- en buitenverlichtingsinstallatie	
Nummer maatregel	GE6	
Omschrijving maatregel	Geïnstalleerd vermogen accentverlichting beperken.	
Mogelijke technieken ten opzichte van uitgangssituatie	Ledlampen in bestaande armaturen toepassen.	
Uitgangssituatie op basis van een referentie-techniek	a) Gloei- of halogeenlampen zijn aanwezig.	b) Hogedrukkwiklampen zijn aanwezig.
Technische randvoorwaarden	Technische staat van de bestaande armaturen is volgens de installateur voldoende.	
Economische randvoorwaarden	a) Niet van toepassing.	b) Aantal branduren is minimaal 4.000 uur per jaar.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.	
Bijzondere omstandigheden	Niet van toepassing.	

Activiteit	In werking hebben van een ruimte- en buitenverlichtingsinstallatie	
Nummer maatregel	GE7	
Omschrijving maatregel	Geïnstalleerd vermogen basisbinnenverlichting beperken.	
Mogelijke technieken ten opzichte van uitgangssituatie	Langwerpige ledlampen toepassen in bestaande armaturen.	
Uitgangssituatie op basis van een referentie-techniek	a) Armaturen met conventionele TL zijn aanwezig.	b) Armaturen met PL-lampen (spaarlampen) zijn aanwezig.
Technische randvoorwaarden	De technische staat van de aanwezige moet voldoende zijn en de verlichtingssterkte in de nieuwe situatie moet voldoen aan de geldende norm.	

Economische randvoorwaarden	a) Aantal branduren is minimaal 1.200 uur per jaar.	b) Aantal branduren is minimaal 2.000 uur per jaar.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.	
Bijzondere omstandigheden	Niet van toepassing.	

Activiteit	In werking hebben van een stookinstallatie (emissies naar de lucht)
Nummer maatregel	FA1
Omschrijving maatregel	Opstarttijd cv-installatie regelen op basis van buitentemperatuur en interne warmtelast.
Mogelijke technieken ten opzichte van uitgangssituatie	Optimaliserende regeling toepassen.
Uitgangssituatie op basis van een referentie-techniek	Optimaliserende regeling ontbreekt.
Technische randvoorwaarden	Niet van toepassing.

Economische randvoorwaarden	Aardgasverbruik is minder dan 170.000 m^3 per jaar.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van een stookinstallatie (emissies naar de lucht)	
Nummer maatregel	FA2	
Omschrijving maatregel	Energiezuinige warmteopwekking toepassen.	
Mogelijke technieken ten opzichte van uitgangssituatie	Hoogrendementsketel 107 (HR 107-ketel) toepassen.	
Uitgangssituatie op basis van een referentie-techniek	a) Conventioneelrendementsketel (CR-ketel) of verbeterdrendementsketel (VR-ketel) is aanwezig voor basislast.	b) Hoogrendementsketel 100 (HR 100-ketel) is aanwezig voor basislast.
Technische randvoorwaarden	Niet van toepassing.	
Economische randvoorwaarden	Niet van toepassing.	
Toepasbaar op een zelfstandig of natuurlijk moment?	a) Zelfstandig moment: Ja. Natuurlijk moment: ja.	b) Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	In kantoorgebouwen met minimaal een energielabel C, of kantoorgebouwen met een bouwjaar vanaf 2003 of later wordt aangenomen dat de maatregel al is genomen. Het energielabel staat voor de energieprestatie op basis van getroffen maatregelen.	

Activiteit	In werking hebben van een stookinstallatie (emissies naar de lucht)
Nummer maatregel	FA3
Omschrijving maatregel	Energiezuinige warmteopwekking van tapwater toepassen.
Mogelijke technieken ten opzichte van uitgangssituatie	Gasgestookte hoogrendementsboiler (HR-boiler) toepassen.
Uitgangssituatie op basis van een referentie-techniek	Conventionele gasgestookte boiler is aanwezig.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	In kantoorgebouwen met minimaal een energielabel C, of kantoorgebouwen met een bouwjaar vanaf 2003 of later wordt aangenomen dat de maatregel al is genomen. Het energielabel staat voor de energieprestatie op basis van getroffen maatregelen.

Activiteit	In werking hebben van een stookinstallatie (emissies naar de lucht)	
Nummer maatregel	FA4	
Omschrijving maatregel	Aanstaan van ruimteverwarming buiten bedrijfstijd voorkomen.	
Mogelijke technieken ten opzichte van uitgangssituatie	a) Tijdschakelaar (met of zonder overwerktimer) toepassen.	b) Tijdschakelaar met weekschakeling (met of zonder overwerktimer) toepassen.
Uitgangssituatie op basis van een referentie-techniek	Automatische aan- en uitschakelingen ontbreken.	
Technische randvoorwaarden	Niet van toepassing.	
Economische randvoorwaarden	Niet van toepassing.	
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.	
Bijzondere omstandigheden	Niet van toepassing.	

Activiteit	In werking hebben van een stookinstallatie (emissies naar de lucht)
Nummer maatregel	FA5
Omschrijving maatregel	Aanvoertemperatuur cv-water automatisch regelen op basis van buitentemperatuur.
Mogelijke technieken ten opzichte van uitgangssituatie	Weersafhankelijke regelingen toepassen.
Uitgangssituatie op basis van een referentietechniek	Weersafhankelijke regeling ontbreekt op cv of op cv-groepen met hogetemperatuurverwarming.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing

Activiteit	In werking hebben van productkoeling
Nummer maatregel	FB1
Omschrijving maatregel	Branden van verlichting in koel- en vriescel beperken.
Mogelijke technieken ten opzichte van uitgangssituatie	Deurschakeling of bewegingsmelder toepassen.
Uitgangssituatie op basis van een referentietechniek	Deurschakeling en bewegingsmelder ontbreken.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van productkoeling
Nummer maatregel	FB2
Omschrijving maatregel	Beperken van ijsvorming op de verdamper(s).
Mogelijke technieken ten opzichte van uitgangssituatie	Automatische ontdooiing van de verdamper(s) toepassen.
Uitgangssituatie op basis van een referentietechniek	Regeling voor ontdooiing en/of ontdooibeëindigingsthermostaat ontbreekt.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van productkoeling
Nummer maatregel	FB3
Omschrijving maatregel	Energiezuinige lampen in koelcel toepassen.
Mogelijke technieken ten opzichte van uitgangssituatie	Ledlampen in armaturen toepassen.
Uitgangssituatie op basis van een referentietechniek	Conventionele armaturen met langwerpige fluorescentielampen (TL8) zijn aanwezig.

Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van productkoeling
Nummer maatregel	FB4
Omschrijving maatregel	Binnentreden van warme en/of vochtige lucht in koelcel beperken.
Mogelijke technieken ten opzichte van uitgangssituatie	Deurschakeling toepassen om verdampingsventilatoren te onderbreken.
Uitgangssituatie op basis van een referentietechniek	Deurschakeling ontbreekt.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	Bereiden van voedingsmiddelen
Nummer maatregel	FC1
Omschrijving maatregel	Het debiet van afzuigsystemen in grootkeukens beperken.
Mogelijke technieken ten opzichte van uitgangssituatie	Rook- en/of dampdetectieapparatuur in combinatie met meet- en regelapparatuur van de afzuiginstallatie toepassen.
Uitgangssituatie op basis van een referentietechniek	Meet- en regelapparatuur van de afzuiginstallatie ontbreekt.
Technische randvoorwaarden	Motoren zijn geschikt om frequentie te schakelen.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	Bereiden van voedingsmiddelen
Nummer maatregel	FC2
Omschrijving maatregel	Een infrarood salamander met aan/uit of tijd schakelaar wordt ingezet voor het verwarmen of grillen van producten.
Mogelijke technieken ten opzichte van uitgangssituatie	Automatische pan detectie, waardoor onnodig aanstaan van het grill element wordt voorkomen.
Uitgangssituatie op basis van een referen- tietechniek	Ongeregelde infrarood salamander worden ingezet voor het verwarmen of grillen van producten.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van een liftinstallatie
Nummer maatregel	FD1

Omschrijving maatregel	Energieverbruik voor verlichting en ventilatie voorkomen als lift niet in gebruik is.	
Mogelijke technieken ten opzichte van uitgangssituatie	a) Stand-by schakeling op liftbesturing toepassen.	b) Aanwezigheidsdetectie toepassen.
Uitgangssituatie op basis van een referentietechniek	Verlichting en ventilatie cabine zijn continu in gebruik.	
Technische randvoorwaarden	Niet van toepassing.	
Economische randvoorwaarden	Niet van toepassing.	
Toepasbaar op een zelfstandig moment of natuurlijk moment?	a) Zelfstandig moment: Ja. Natuurlijk moment: Ja.	b) Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.	

Activiteit	In werking hebben van een liftinstallatie
Nummer maatregel	FD2
Omschrijving maatregel	Geïnstalleerd vermogen verlichting liftcabine beperken.
Mogelijke technieken ten opzichte van uitgangssituatie	Ledlampen toepassen.
Uitgangssituatie op basis van een referentietechniek	Gloei- en halogeenlampen zijn aanwezig.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig moment of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van een roltrapsysteem
Nummer maatregel	FE1
Omschrijving maatregel	Energiezuinige roltrapbesturing toepassen.
Mogelijke technieken ten opzichte van uitgangssituatie	Aanbodafhankelijke onderbrekende besturing toepassen.
Uitgangssituatie op basis van een referentietechniek	Roltrap is zonder aanbodafhankelijke regeling uitgevoerd en draait continu tijdens gebruikstijden.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig moment of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	Gebruiken van informatie- en communicatietechnologie
Nummer maatregel	FF1
Omschrijving maatregel	Pas energiezuinig printen en/of kopiëren op de werkplek toe.
Mogelijke technieken ten opzichte van uitgangssituatie	Centraal printen en kopiëren.
Uitgangssituatie op basis van een referentietechniek	Minimaal 10 lokale printers en/of kopieermachines zijn aanwezig.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van een serverruimte
Nummer maatregel	FG1
Omschrijving maatregel	Inzet van fysieke servers in serverruimten beperken.
Mogelijke technieken ten opzichte van uitgangssituatie	Meerdere gevirtualiseerde servers werken op een minder aantal fysieke servers.
Uitgangssituatie op basis van een referentietechniek	Geen gevirtualiseerde omgeving aanwezig.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Serverruimte heeft opgesteld vermogen van minimaal 5 kW.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

<table>
<tr><th>Activiteit</th><th colspan="3">In werking hebben van een serverruimte</th></tr>
<tr><td>Nummer maatregel</td><td colspan="3">FG2</td></tr>
<tr><td>Omschrijving maatregel</td><td colspan="3">Vrije koeling in serverruimten toepassen om bedrijfstijd van koelinstallatie te beperken.</td></tr>
<tr><td>Mogelijke technieken ten opzichte van uitgangssituatie</td><td>a) Direct vrije luchtkoeling toepassen inclusief compartimenteren en back-up door koelinstallatie toepassen.</td><td>b) Verdampingskoeler(s), adiabatische of hybride koeler(s) via (vorstbestendige) bypass toepassen.</td><td>c) Verdampingskoeler(s), adiabatische of hybride koeler(s) via (vorstbestendige) bypass toepassen inclusief compartimenteren en plaatsen van zaalkoelers die werken op hogere temperaturen.</td></tr>
<tr><td rowspan="2">Uitgangssituatie op basis van een referentietechniek</td><td rowspan="2">a) Airconditioning of DX- (directe expansie) koeling met seizoensgemiddelde COP van maximaal 2,5 is aanwezig.
Temperatuur in koelsysteem en buitenklimaat maken minimaal 95% vrije koeling mogelijk.</td><td colspan="2">b en c) Compressiekoelinstallatie verzorgt de volledige koeling.</td></tr>
<tr><td>b) De koelinstallatie en de zaalkoelers zijn geschikt om met hogere temperaturen te werken.
Compressiekoelinstallatie met seizoensgemiddelde COP van maximaal 4 is aanwezig.
Temperatuur in koelsysteem en buitenklimaat maken minimaal 50% vrije koeling mogelijk.</td><td>c) Compressiekoelinstallatie met seizoensgemiddelde COP van maximaal 2,5 is aanwezig.
Temperatuur in koelsysteem en buitenklimaat maken minimaal 50% vrije koeling mogelijk.</td></tr>
<tr><td>Technische randvoorwaarden</td><td colspan="3">Bouwkundig moet het mogelijk zijn. Bv het dak moet het gewicht van het systeem voor vrije koeling kunnen dragen en er moet ruimte zijn voor luchtkanalen en overige installaties.</td></tr>
<tr><td>Economische randvoorwaarden</td><td colspan="3">Serverruimte heeft opgesteld vermogen van minimaal 5 kW.</td></tr>
<tr><td>Toepasbaar op een zelfstandig of natuurlijk moment?</td><td colspan="2">a en b) Zelfstandig moment: Ja.
Natuurlijk moment: Ja.</td><td>c) Zelfstandig moment: Nee.
Natuurlijk moment: Ja.</td></tr>
<tr><td>Bijzondere omstandigheden</td><td colspan="3">Niet van toepassing.</td></tr>
</table>

<table>
<tr><th>Activiteit</th><th colspan="2">In werking hebben van een serverruimte</th></tr>
<tr><td>Nummer maatregel</td><td colspan="2">FG3</td></tr>
<tr><td>Omschrijving maatregel</td><td colspan="2">Energiezuinige koelinstallatie voor koeling serverruimten toepassen.</td></tr>
<tr><td>Mogelijke technieken ten opzichte van uitgangssituatie</td><td>a) Computer Room Air Conditioner (CRAC) met seizoensgemiddelde COP van minimaal 5,5 toepassen.</td><td>b) Compressiekoelinstallatie met seizoensgemiddelde COP van minimaal 5,5 toepassen.</td></tr>
</table>

Uitgangssituatie op basis van een referentietechniek	a) CRAC met seizoensgemiddelde COP van maximaal 3 is aanwezig.	b) Compressiekoelinstallatie met seizoensgemiddelde COP van maximaal 3 is aanwezig.
Technische randvoorwaarden	Niet van toepassing.	
Economische randvoorwaarden	Serverruimte heeft opgesteld vermogen van minimaal 5 kW.	
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.	
Bijzondere omstandigheden	Niet van toepassing.	

Activiteit	In werking hebben van een serverruimte
Nummer maatregel	FG4
Omschrijving maatregel	Met hogere koeltemperatuur in serverruimten werken.
Mogelijke technieken ten opzichte van uitgangssituatie	Volledig gescheiden koude- en warme gangen (compartimenteren) en blindplaten op ongebruikte posities in racks toepassen.
Uitgangssituatie op basis van een referentietechniek	Warme en koude gangen en blindplaten ontbreken.
Technische randvoorwaarden	ICT-apparatuur in racks moet aan één zijde van apparatuur lucht aanzuigen.
Economische randvoorwaarden	Serverruimte heeft opgesteld vermogen van minimaal 5 kW.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van een serverruimte
Nummer maatregel	FG5
Omschrijving maatregel	Inzet van servers in serverruimte afstemmen op de vraag.
Mogelijke technieken ten opzichte van uitgangssituatie	Powermanagement op servers toepassen.
Uitgangssituatie op basis van een referentietechniek	De CPU (central processing unit) draait continu op maximale snelheid.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Serverruimte heeft opgesteld vermogen van minimaal 5 kW.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van een serverruimte			
Nummer maatregel	FG6			
Omschrijving maatregel	Vrije koeling in datacenter toepassen om bedrijfstijd van compressiekoelinstallatie te beperken.			
Mogelijke technieken ten opzichte van uitgangssituatie	a) Droge koeler(s) via bypass toepassen.	b) Verdampingskoeler(s) via bypass toepassen.	c) Kunststof kruisstroom-warmtewisselaar en verdampingskoeler aan buitenzijde toepassen (indirecte lucht/luchtkoeling).	d) Open koelsysteem (directe vrije luchtkoeling) met additionele indirecte adiabatische koeler toepassen.

Uitgangssituatie op basis van een referentietechniek	Compressiekoelinstallatie verzorgt de volledige koeling.		
	a) Klein datacenter met compressiekoelinstallatie met seizoensgemiddelde COP van maximaal 2,0. Temperatuur in koelsysteem en buitenklimaat moeten minimaal 40% vrije koeling mogelijk maken.	b) Compressiekoelinstallatie met seizoensgemiddelde COP van maximaal 2,5. Temperatuur in koelsysteem en buitenklimaat moeten minimaal 80% vrije koeling mogelijk maken. Bijvoorbeeld in	c en d) Compressiekoelinstallatie met seizoensgemiddelde COP van maximaal 3,0. Temperatuur in koude gang moet nagenoeg altijd vrije koeling mogelijk maken. Flexibele operatie van temperatuur en vochtigheid is mogelijk binnen de grenzen van ASHRAE recommended envelope en SLA's.
Technische randvoorwaarden	Niet van toepsasing.		
Economische randvoorwaarden	Serverruimte heeft opgesteld vermogen van minimaal 5 kW.		
Toepasbaar op een zelfstandig of natuurlijk moment?	a en b) Zelfstandig moment: Ja. Natuurlijk moment: Ja.		c en d) Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.		

Activiteit	In werking hebben van een serverruimte
Nummer maatregel	FG7
Omschrijving maatregel	Hogere koeltemperaturen in datacenter realiseren om efficiëntie van compressiekoelinstallatie te verhogen en om meer gebruik te maken van vrije koeling (beneden 12/13°C buitenluchttemperatuur).
Mogelijke technieken ten opzichte van uitgangssituatie	Zaalkoelers met hogetemperatuurkoeling toepassen (ter indicatie: koelwater is minimaal 18°C).
Uitgangssituatie op basis van een referentietechniek	Zaalkoelers met lagetemperatuurkoeling zijn aanwezig. Seizoensgemiddelde COP van bestaande compressiekoelinstallatie is maximaal 3,5 bij groot datacenter en maximaal 5,0 bij klein datacenter.
Technische randvoorwaarden	Gescheiden koude en warme gangen met vrije koeling zijn aanwezig.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van een serverruimte
Nummer maatregel	FG8
Omschrijving maatregel	Met hogere koeltemperatuur in datacenter werken door menging van warme en koude lucht bij ongebruikte posities in racks te voorkomen.
Mogelijke technieken ten opzichte van uitgangssituatie	Blindplaten toepassen.
Uitgangssituatie op basis van een referentietechniek	Blindplaten ontbreken.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Serverruimte heeft opgesteld vermogen van minimaal 5 kW.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Ja. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van een serverruimte	
Nummer maatregel	FG9	
Omschrijving maatregel	Toerental van ventilatoren in zaalkoelers (CRAH's) in datacenter beperken.	
Mogelijke technieken ten opzichte van uitgangssituatie	a) Toerenregeling (sensoren en actuatoren) toepassen op bestaande ventilatoren.	b) In nieuwe zaalkoelers (CRAH's) ventilatoren met toerenregeling toepassen.
Uitgangssituatie op basis van een referentietechniek	Toerentalgeregelde ventilatoren ontbreken.	
Technische randvoorwaarden	Niet van toepassing.	
Economische randvoorwaarden	Serverruimte heeft opgesteld vermogen van minimaal 5 kW.	
Toepasbaar op een zelfstandig of natuurlijk moment?	a) Zelfstandig moment: Ja. Natuurlijk moment: Ja.	b) Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.	

Activiteit	In werking hebben van een noodstroomvoorziening
Nummer maatregel	FH1
Omschrijving maatregel	Energiezuinige uninterrupted system (UPS) toepassen.
Mogelijke technieken ten opzichte van uitgangssituatie	Efficiënt UPS-systeem (bij dubbele conversie is 96% of hoger) toepassen.
Uitgangssituatie op basis van een referentietechniek	Inefficiënte UPS (efficiëntie in deellast is maximaal 91%) is aanwezig in datacenter of serverruimte.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	Niet van toepassing.
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.

Activiteit	In werking hebben van elektromotoren
Nummer maatregel	FI1
Omschrijving maatregel	Energiezuinige motoren toepassen.
Mogelijke technieken ten opzichte van uitgangssituatie	IE4-motoren toepassen of beter.
Uitgangssituatie op basis van een referentietechniek	Motoren met vermogen minder dan 375 kW en meer dan 4 kW en met rendementsklasse IE1, IE2 of lager zijn aanwezig.
Technische randvoorwaarden	Niet van toepassing.
Economische randvoorwaarden	De motor heeft minimaal 4.500 bedrijfsuren per jaar
Toepasbaar op een zelfstandig of natuurlijk moment?	Zelfstandig moment: Nee. Natuurlijk moment: Ja.
Bijzondere omstandigheden	Niet van toepassing.