A gap in the map?

mapping the Dutch energy saving policy instrument landscape for setting up a strategic niche management experiment to test direct current in the office environment

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Mapping the Dutch energy saving policy instrument landscape for setting up a strategic niche management experiment to test direct current in the office environment.

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Master Thesis

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Colofon

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Master thesis
Erik van Diest Bsc.
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Management Summary

Energy saving is a hot topic. One can do this saving at many different places, but one often overlooked is the electricity grid within buildings.

The current system for electricity transmission & distribution is based on Alternating Current. However, decentral electricity generators such as solar PV panels output Direct Current (DC) and also computers and LED lighting use this same DC. Currently it is however converted twice (DC to AC and back to DC), thereby losing energy and showing an opportunity for improving the efficiency of the grid (Vossos, Garbesi, & Shen, 2014).

However, as with most sustainability innovations, this one also has a hard time reaching the market all by itself. The Strategic Niche Management (SNM) model helps by describing how sustainability innovations should be shielded, nurtured and empowered so they have the time to become competitive within the existing market (Smith & Raven, 2012). Within this research SNM is used to design an experiment which uses applicable policy instruments to help DC set the next step. The main research question is therefore: *How can a SNM experiment for direct current in the office environment make use of policy instruments?*

Methodology

The research is built up in three parts. First of all an assessment is made of the ABN AMRO regional office Utrecht to determine the costs of remodelling an average office to DC. With the information from the assessment a model is built for the basis of the financial business case.

The second step is mapping all the different policy instruments for sustainable energy and energy saving innovations. These come from the European Union, the Dutch government and the Dutch Provinces. The relevant documents are placed in a database and summarized on three main points: key goals, mechanism and (expected) outcome of the policy instrument. From this database the instruments are analysed by their type, whether they are generic or niche and if they are part of an encompassing instrument, making them sub-instruments. Also their current fit with DC is determined. Using this analysis the applicable policy instruments for this experiment are found. This is checked using interviews with experts.

The third part is integrating the first two parts into a SNM experiment in which DC can be tested. For this experiment the basis of the financial case is combined with the options offered by the policy instruments to improve the business case. Also narrative of the experiment including stakeholders is presented.

Basis of the business case

The assessment of the office has led to five different groups of apparatus:

- Building installations (23 machines)
- Office area (9 types of apparatus)
- Kitchen/restaurant area (11 types of apparatus)
- Server area (5 types of apparatus)
- Café in the basement (5 machines)

From these groups the office area and the server area are the most simple to convert since in there most apparatus are already using DC. The other three groups are harder to convert since these use AC electro motors which need to be replaced with either a DC electromotor or which need the addition of a frequency

converter so they can run on DC.

In order to calculate the expected costs for the remodelling four different scenarios are designed ranging from total renovation (scenario 1) to renovating what is needed (scenarios 2a & 2b) to only the office area (scenario 3).

The expected energy reduction ranges from 10-14%, with costs ranging between €57.500 and €455.000. The payback times range from 12 to 31 years with negative NPVs for time periods up to ten years. This shows that the innovation needs sheltering from policy instruments in order to become competitive in the current market.

For the further development relatively little barriers in rules and legislation are encountered. The building code uses the NEN1010 standard for electrical systems in buildings which is already DC-proof.

Policy map

In total 84 different policy instruments have been found, of which 55 are generic and 29 are niche instruments. From these instruments 15 are considered to be generic sub-instruments and 13 are considered niche sub-instruments since they are mostly specific versions of one generic encompassing instrument.

The analysis shows that of the six types of instruments, the Dutch government has fitting instruments for DC in four of the six categories, not having investment subsidies and public procurement. The EU offers three types of instruments that are directly applicable; statutory obligations, subsidy tenders and low-interest loans. The provinces offer only two types of applicable instruments; investment subsidies and low-interest loans.

Looking more specifically at the applicability to DC, we see that there are 36 currently applicable instruments in five of the six categories. Only in the public procurement category there is currently no fitting instrument. Next to that 32 of the instruments are currently not fitting, but these might undergo a stretch-and-transform process to make DC fit into them. This process is usually enlarging the scope of the instrument to include DC. It is likely that this happens when the technique and the efficiency improvement have been proven. Only 16 instruments are deemed impossible to be stretched to fit DC.

Most of the to DC applicable instruments are generic instruments that focus on either general energy investments or on general innovation. The only notable exception comes from the subsidy tenders offered by the Dutch Government which are all niche instruments.

Design of the SNM experiment

For the design of the SNM experiment it is chosen to continue with scenario 3 (remodelling the office area) since it has relatively the highest improvement in efficiency and relatively lowest costs.

From the currently applicable instruments to DC the ones applicable to this specific experiment were found, which are per category:

- Statutory obligations: **'The Building Code'**
- Investment subsidy: **'Kansen voor West II'**
- Subsidy tender: **'SDE+'** (when solar PV panels are added to the experiment, otherwise this one is non-applicable)
- Fiscal incentives: **'WBSO', 'RDA'** and **'EIA'** for the investments in both time and machinery for the experiment
- Low interest loans: **'Energiefonds Utrecht'**

The other instruments are not applicable since they are either aimed at specific technical solutions that are not used, are not in the right region or are applicable to projects with a very large budget.

The impact of these policy instruments on the business case has been calculated. The statutory obligations do not influence the business case, these are merely an obligation for the design of the electrical system. The impact of the investment subsidy is unclear, but the needed investment subsidies show a range between €35.000 and €0, depending on the time scale, type of the experiment and the energy prices. These costs can also be seen as learning costs, a form of shielding and nurturing in the SNM framework.

A more certain impact comes from the fiscal incentives, that show that a modest €2.500

can be saved using these instruments, lowering the payback time to 13 years. When solar PV panels are attached to the buildings DC grid the payback period is reduced to just over 10 years, partly due to the higher efficiency of the system and partly due to the SDE+ subsidy for the PV panels. This still however higher than the wanted payback period of six years. To reach this higher subsidies need to be attracted or the learning costs need to be accepted.

It is also likely that the energy prices will fluctuate over the coming years due to statutory obligations and due to the growth in sustainable energy generators. The impact of these on the business case shows that when the energy price declines 2% the business case worsens with between 7,5% (with solar PV) and 10% (without solar PV). With a 2% rise in energy price the opposite happens, with improvements in the business case ranging between 7,5% (with PV) and 10% (without PV). It is however very uncertain how the energy prices will develop so it is unclear what the actual impact on the business case is.

The set-up of an actual SNM experiment requires that a larger group of stakeholders is integrated in the design phase of the experiment. These include the user, the designer and the builder of the DC system, but also hardware suppliers that need to change their machines and knowledge institutes.

The entire project will go through six different steps: *1. Project and Scope Definition, 2. Team Set-up, 3. Team Formation, 4. Experiment Design, 5. Running the Experiment* and *6. Finish and Reflection*. The first two steps are first of all done by one or two parties to determine the direction for the experiment and the initital stakeholders. In the third step the team will be formed. After that it is likely that the team will go one or several times back to step one to rethink the project. When the team is complete it will move on to the fourth step, designing the experiment, and running and reflecting on the actual experiment in steps five and six.

When running the actual experiment the SNM focus will mostly be on shielding and nurturing of the innovation, and not yet much on empowering.

The experiment of refitting an office with DC can be placed into a wider field of experiments taking place around the world, where all experiments can learn from each other. When multiple of these experiments are finished successfully and the technique has proven itself it is time to set the next step towards creating an actual protected market niche.

Discussion

For the next step there are however some gaps in the map that can help the creation of a protected niche. These are statutory obligations, public procurement and fitting fiscal incentives. The public procurement instrument can come from the existing instrument 'Energiegebruik Vastgoed Verminderen' extending that instrument to include DC. The fiscal incentives can come from creating a specific sub-instrument of the existing tax deduction instruments EIA & MIA/Vamil for investments in DC. The statutory obligations gap is however much harder to fill, and it is highly unlikely that such an instrument will be introduced in the coming years for DC.

Some limitations in the research come from the fact that the theoretical efficiency improvements have shown to be higher than in practice. It is also likely that certain policy instruments are missed due to the rigorous cut-off of only energy (innovation) related policy instruments.

Conclusion

As with most sustainability related innovations this one has a hard time reaching the market by itself. It is therefore that the options offered by the different policy instruments should be used for first of all shielding and nurturing the innovation, and later for empowering the innovation so it can survive in the existing market.

Finally, I recommended that a small scale SNM experiment is held with DC in the office environment so that the stakeholders can learn and that the innovation has the room to grow in a protected environment into a protected niche in the long term.

Preface

It all started over a year ago when I received an e-mail from the company mentor of my bachelor thesis. Someone from ABN AMRO visited him to talk about DC and had mentioned that they were opening up an intern position for it. And he had been so kind to drop my name.

Half a year later. I didn't hear anything from ABN AMRO, but while looking for internships I came across an opening at Grontmij where they were looking for someone to do research on direct current in office buildings, in co-operation with ABN AMRO. After applying for it I was chosen as the one, and the rest is history as told in this thesis.

I am very happy that I got the opportunity to continue my bachelor thesis work on direct current since it is an opportunity to make the world a bit better, a bit more sustainable and maybe even a bit more beautiful. And I'm glad that both ABN AMRO and Grontmij gave me the opportunity and the space to once again dive into the subject, find out more about it and spread the story even further.

Now, I can't say that it has always been an easy ride, but when going gets though, the though get going as they saying goes. So I'd like to dedicate this thesis to two people that I lost past March, along the way of working on this project. Opa and Oma, I'm glad you're both reunited with your big loves, somewhere high on a cloud, but I still miss you. This thesis is also in honour of you two.

However, most of time was a lot of fun and I also had the chance to do amazing things and do them my way. And so I have to thank many people, and I hope that I don't forget anybody, but if I do, I'm sorry. In no particular order, I'd like thank the following people:

- Tim Zijderveld, for introducing me to the wonderful world of DC and for introducing me to ABN AMRO;
- Dominique Pankow, Hendrie Scheer and all other employees of Grontmij for supporting me throughout the project;
- Het "Duurzame Duo" – Roelof and Rob Kuipers (no, they are not family) for opening up ABN AMRO for the story of direct current and for providing all the help needed;
- The Dutch DC foundation, for organising the day with many of the DC researchers in the Netherlands and for their other support;
- All interviewed people for giving me some of their time and lots of their knowledge;
- My family and friends, and especially my parents for the everlasting support, in finance, wisdom and love during the past 24 years;
- And finally, my girlfriend Janneke, for being there when I need it.

As a final word, I can only say that I hope you enjoy this thesis, and that in a few years we will all say that this was another step in the right direction; the **sustainable** direction.

Erik van Diest
Amsterdam – 13 September 2015

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1. Introduction

The need to reduce greenhouse gas (GHG) emissions is very clear. 2014 was worldwide the warmest year since the measurements started in 1880 (Cole, 2015) and the effects on the world are becoming more clear every year: the weather becomes more extreme with heavier rainfall, heat waves and longer periods of drought (Melillo, Richmond, & Yohe, 2014). The reduction of GHGs can take place at many different places, including the industry, the transportation sector and in the built environment.

In the built environment there are many options to help reduce these GHGs[1]; for example isolating the building to reduce heat losses. In this research, however, we will focus on the electricity grid in the building to reduce emissions. Making the electricity supply chain more sustainable can help in reducing GHG emissions. Within the electricity supply chain this can happen at three logical places: during generation, during the transmission & distribution and during consumption at the final user. The first can be achieved by building more generation units for sustainable energy, for example; wind energy, solar photovoltaic (PV) energy or by using tidal wave energy. Reduction during consumption can be achieved by designing and creating a market for more energy efficient appliances. This is for example achieved by the obligatory energy label which categorizes appliances on their level of energy use (European Commission, 2008).

For the transmission and distribution part, however, the reduction is a bit harder to achieve and has therefore largely been overlooked until recently. The entire electricity infrastructure in the western world is based on the use of Alternating Current (AC). At the end of the 19th century this method won the War of the Currents due to its ability to transform power easily between low and high voltage levels. This is important since low voltage levels are needed to safely run appliances in a home, whereas higher voltage levels are needed to efficiently transport the electricity over longer distances.

However, the loser of this war, Direct Current (DC), is working hard on a comeback since it offers a series of advantages compared to AC, especially when combined with sustainable energy generators. First of all, the overall losses using DC as transportation method are lower compared to AC (at the same voltage) due the lack of induction effects (AlLee & Tschudi, 2012). Next to that, almost all sustainable energy generating systems output DC which is later transformed to AC in order to feed it into the grid. At the consumption side (e.g. laptops) this AC is once again converted back into DC so power electronics can use it. This double conversion leads to an added power loss of over 10% for optimal converters, though higher losses are not uncommon (for example, the average of an AC/DC converter in a laptop is 79% (Garbesi, Vossos, & Shen, 2011)). Garbesi, Vossos, & Shen (2011) have modelled these savings for a home, where the outcome

1. Green House Gases (GHGs) are gases that speed up the global warming of the earth. They include (among others) Carbon Dioxide, Nitrogen Oxide and Methane.

showed that a reduction of 5 to 14% in energy use is possible. Even higher savings are expected in offices due to the more simultaneous generation and use of electricity throughout the day (Vossos, Garbesi, & Shen, 2014).

However, as with most sustainability innovations, this one also has a hard time crossing the chasm by itself. Some projects have already been set up testing the idea in small scale, but the step towards becoming a supported market niche is still not made. Luckily, the Dutch government has set the reduction of the energy use as a priority in the 'Energie akkoord'[2] (Sociaal-Economische Raad, 2013). This means that they agreed to co-operate with businesses to allow innovations aimed at reducing GHGs to grow by designing policy instruments aimed at doing so. These instruments can be aimed at providing subsidies to help gain market share, but also at stretching current rules and regulations to allow an innovation to grow.

Currently both the Netherlands and the European Union have a wide range of policy instruments to help sustainable energy generation as well as energy savings. Due to the large amount of options, most companies working on these innovations cannot see the wood for the trees. This might lead them to not applying for subsidies or tapping into other policy instruments that can help an innovation reach a protected niche since they either do not know about these instruments or because they believe it is too much hassle to tap into them.

Luckily it is not just bad news for DC. ABN AMRO is working hard on making its business more sustainable. In 2014 they reduced their energy use by 31% compared to 2012 (ABN AMRO Group N.V., 2015), but they want to improve it even further. One of the options they are considering is implementing direct current in their office environment, but not at any cost.

In the literature the problems of sustainable innovations trying to reach the market has been recognized as well, which has led to the development of the Strategic Niche Management (SNM) framework. The aim of the SNM framework is to design policy instruments that can aid the creation of protected niches in which the innovation can be nurtured and can grow, without prematurely being rejected by the current regime (Kemp, Schot, & Hoogma, 1998). This can happen when policy instruments provide nurturing, shielding and empowering to the innovation (Smith & Raven, 2012). Within this research the SNM model is used to design an experiment which uses applicable policy instruments to help the innovation set the next step towards becoming a protected niche. We will also see if a gap exists in the available policy instruments and discuss how this could be filled. When multiple successful experiments are finished a protected niche for DC might emerge.

1.1 Research Questions

Taken the above, numerous questions arise about the use of direct current in the office environment and how this can be optimally brought to flourish using the help of available policy instruments. This leads to the following main research question for this research:

> *How can a SNM experiment for Direct Current in the office environment make use of policy instruments?*

In order to be able to answer this main research question, a series of sub questions have been formulated. To get an idea about the opportunity for DC first of all some background research is performed on the working of a direct current system in an office to get an idea about the barriers that have to be overcome during implementation. These barriers could be technical issues, but also rules and regulations and financials might be barriers for the innovation. With these barriers in mind

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2. The 'Energie Akkoord' (Energy Agreement) is an agreement between the Government, NGOs and Corporations that aims at reducing the amount of energy used in the Netherlands. All groups participated equally in the design of this agreement and have their own targets they have to meet.

the policy instruments can be identified to help overcome these. These instruments can also help to set-up a SNM experiment and potentially a protected niche.

To help identify the applicable policy instruments an overview of the available instruments within the European Union and especially within the Netherlands is made in a policy instrument map. The possible applicable policy instruments under consideration will focus on sustainable energy and energy savings. These might be: “support for R&D; market development policies, such as niche market support and long-range targets and obligations; and financial incentives, such as capital subsidies, tax credits and hypothecation of revenues” (Foxon, et al., 2005). With the help of the policy instrument map the instruments applicable to DC in general and specifically to this experiment are found.

To help gather the information needed and to support the process of creating the policy instrument map and finding of the applicable policy instruments the following sub questions are formulated:

- How would a direct current system in the office environment look?
- What is the status of rules and regulations concerning direct current, and what other rules and regulations that are currently applicable to generation and consumption of electricity are too narrowly defined and will need adjustment so direct current will fit into these?
- What policy instruments are available to help set up an SNM experiment for a direct current system in the office environment?
- How does the implementation design look for optimal use of policy instruments in the experiment?
- How can this experiment be placed in the wider field of direct current experiments currently taking place?

With the help of these sub questions the development of direct current in the office environment should be helped forward by showing the options offered by policy instruments for the set-up of a SNM experiment and potential creation of a protected niche. Next to that also the literature on Strategic Niche Management is advanced by investigating the options of using current policy instruments in an experiment and the possibilities of fitting these for the creation of a protected niche for DC.

1.2 Reading Guide

The rest of the report starts with a short discussion of the relevant literature in chapter two. In chapter three the chosen method for the research is discussed, after which in chapter four the basis of the business case is discussed. In chapter five the policy instrument maps is discussed after which in chapter six the design of an SNM experiment for DC in the office environment is discussed, in both the business case form as well as a narrative form. The results and the next step in the creation of a protected are discussed in chapter seven after which the conclusions are drawn in chapter eight.

2. Literature Review

In this chapter a short review is given on the literature on transition studies, policy and direct current. This literature is used as building blocks for designing and doing the research.

2.1 Transition studies

Transition studies aim at sustainability innovations that span from several years up to several decades. Two often-used transition studies are Transition Management and Strategic Niche Management. In the coming paragraphs first Transition Management is discussed. From there the place of Strategic Niche Management in relation to Transition management becomes clear. Thereafter Strategic Niche Management is discussed in some more detail.

2.1.1 Transition management

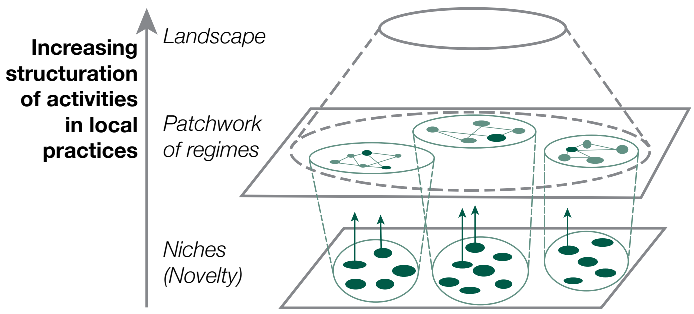
The main model used in transition studies is Transition Management (TM) which looks at the transition from one regime to the other using the Multi-Level Perspective (MLP, see figure 2.1) (Geels, 2002). Regimes are thereby defined as the following:

> "A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures" (Rip & Kemp, 1998).

The transition is enabled by a diverse group of stakeholders that come together in varying compositions during the different stages of the transition management cycle. The TM cycle starts by looking at the landscape level to come up with a strategy, then going to the regime level to design the tactics, then going to the niche level to come up with operational experiments and finally reflecting on all steps to close the cycle after which the cycle will start again (see figure 2.2).

The MLP (figure 2.1) divides the working of the world into three different levels. The top level is the current landscape consisting of a patchwork of regimes that are found one layer below. Within these regimes the focus mainly lies on incremental innovations

Figure 2.1. The multi-level perspective, adapted from Geels (2002).



to improve and reinforce the current regime. Below the regimes a series of niches are found in which more radical innovations are born and nurtured. From these niches disrupting innovations can come which can overthrow (part of) the current regime. For this to happen it is likely that the landscape will put pressure on the regime to change, for example by changed beliefs and values within society. Any changes in the regimes will have impact on the landscape but only on the longer term (Geels, 2002).

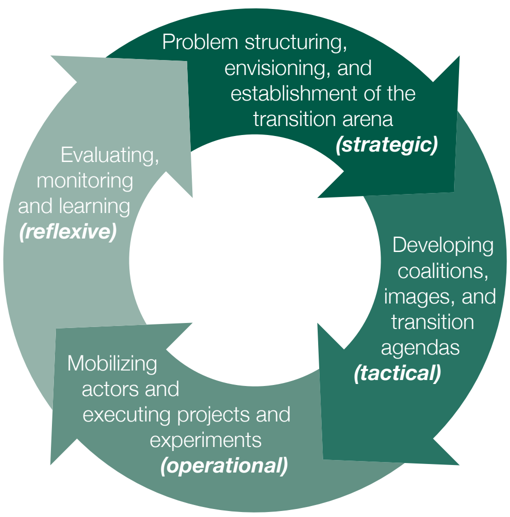
2.1.2 Strategic Niche Management

The creation of niches (as in the TM model) for sustainability innovations is described in the Strategic Niche Management (SNM) model. The aim of SNM is the following:

> "Strategic Niche Management is the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation" (Kemp, Schot, & Hoogma, 1998).

The main method to do this is designing policy instruments using a series of experiments that allow for Shielding, Nurturing and Empowering of the SNM niche (Smith & Raven, 2012) in order to help start a niche market.

Figure 2.2. The transition management cycle, adapted from Loorbach (2010).



Shielding is therein defined as: "those processes that hold at bay certain selection pressures from mainstream selection environments" (Smith & Raven, 2012), thereby providing the protection to the niche so the innovation can grow without immediately being fully exposed to the regular environment.

Nurturing is defined as: "processes that support the development of the path-breaking innovation" (Smith & Raven, 2012), thereby focusing on three points: *Expectations, Learning* and *Network building*.

Expectations

The first and most important focus point of nurturing is the setting of clear expectations by all actors that are involved in the experiment at the earliest moment possible. The setting of expectations and visions by every actor can guide the learning process further down in the experiment, as well as attract attention and legitimate protecting and nurturing within the niche. For the success of this it is important that the expectations are shared by many actors to make them more robust, that they are specific so they can give clear guidance and that they are of high quality, meaning that they are substantiated by ongoing projects and experiments (Schot & Geels, 2008).

Learning

The second focus point of nurturing is learning during the process. This can take place on two levels; First order learning focuses mainly on accumulating facts and data and learning how the innovation works. Second order learning takes one step deeper and focuses on the changing of behaviour, cognitive frames and assumptions (Schot & Geels, 2008).

Learning can happen in four different ways: Learning by Searching, *Learning by Doing, Learning by Using* and *Learning by Interacting. Learning by Searching* is usually the first step during innovation projects and is also known as R&D. It focuses on acquiring know-how in a systematic and organized way.

Learning by Doing focuses more on acquiring tacit knowledge during the production phase of a product in order to improve the current production skills and improve the production process.

Learning by Using is one step further further in the process since it focuses on the learning by users of the product. This process takes place when several complex and interdependent components are brought together within the system and focuses on finding the most durable way of using a new product.

Learning by Interacting focuses on learning in all the three other ways (Searching, Doing and Using) by learning from the interaction between users and designers/manufacturers of the product. Interaction between the different actors will lead to the most transfer of tacit knowledge, as well as other difficult to formalize knowledge (Kamp, Smits, & Andriesse, 2004).

Network building

The third focus point of nurturing within the experiment is the building of networks. This is important since it allows for interaction between users and relevant stakeholders, i.e. learning by interacting. It helps create a constituency behind the innovation and helps provide the necessary resources including money, people and expertise to the niche. The success of the network depends on both the size and depth of the network. By using a wide network many voices & ideas are heard and used during the development process, improving the overall end procuct. The depth of the network is shown by the influence that the stakeholders have within their own companies, where they preferably are able to mobilize commitment and resources (Schot & Geels, 2008).

Niche empowerment

The third goal of the policy instruments should be focussed at niche empowerment. Smith and Raven (2012) define niche empowerment as the following:

> "… either niche-innovations becoming competitive within *unchanged* selection environments" or "*niche-influenced changes in regime selection environments* in ways favorable to the niche-innovation" *(emphasis added)*.

These are also known as *Fit and Conform* and *Stretch and Transform* processes. Both options are used relatively often when it comes to sustainable energy innovations. The fit and conform process can for example be found in the solar PV sector, where the rapid decline in system prices over the past few years has made it possible to compete with conventional electricity generators (Smith, Kern, Raven, & Verhees, 2014). Stretch and transform on the other hand can mainly be found in less mature innovations. The reform of the British electricity market that included the introduction of long-term feed-in tariffs for sustainable electricity generators can be seen as an example of this since it changed the existing policy to fit these in. (Kern, Kuzemko, & Mitchell, 2014).

2.1.3 DC as a niche?

Niches are used in a special manner within the TM and SNM literature. The normal and most often used definition comes from the marketing literature, which defines niche markets as a small segment of the total market that is currently underserviced. However, for this niche to exist a working product should be available and some clear market should exist for this type of product (Baines, Fill, & Page, 2011).

Within the transitions literature, both TM and SNM, a different definition is used for niches. "These innovations, which present sustainable alternatives (…) but are not (yet) technologically and/or economically competitive, are conceptualized as 'niches'" (Verhees, Raven, Kern, & Smith, 2015). In this definition it is accepted that the product is still in its prototype phase. However, it does not have to be a technological niche and it does not need any clear market segment that will be used to enter a market. In this study this latter definition of a niche is used.

Next to that it is also important to note the difference between an experiment and a niche. This difference is exemplified within the research of Verhees et al. (2015) where the focus lies on the 'infant' sustainable technology of offshore wind. Within this offshore wind niche a large series of experiments have taken place. From this we can also see the difference between the niches and experiments. The niche exists around an immature technology that needs a series of experiments to reach maturity.

2.2 Policy

The main method that is being used in SNM is the creation and adaption of (public) policy (instruments) to create a protected niche. Public policy is aimed at supporting public goods, where public goods are defined as goods that are collectively consumed by large groups of people (Samuelson, 1954). These public goods are characterized by their indivisibility. This means that if one can enjoy the good, other people who refuse to contribute to the provision cannot be excluded from the benefits of that good. This leads to the state financing the good, relying on the use of sanctions or attractions to pay for these goods (Champney, 1988). The creation of a more sustainable energy supply is a good example of such a good, where one person (or company) builds a wind turbine of which everybody will benefit due to the reduction in GHG emissions while generating electricity.

Considering specifically sustainable energy policy instruments, several types of instruments are available. The most used include: "support for R&D; market development policies, such as niche market support and long-range targets and obligations; and financial incentives, such as capital subsidies, tax credits and hypothecation of revenues" (Foxon, et al., 2005). These have been divided into four different categories by Haas et al. (2008), dividing them into instruments aimed at Price or Quantity and at Investment or Generation of electricity (see table 2.1).

Most research has focused on finding the policy instruments with high success rates around the world that can provide protection to sustainable energy generation innovations. Depending on the current place in the innovation S-curve different policy instruments show success (see figure 2.3). Most countries give some support during the R&D and demonstration phase by providing subsidies or by alleviating rules (Rijksdienst voor Ondernemend Nederland, N.D.). During the later stages (pre-commercial and supported commercial) most countries move more to the options as described in the Haas et al. (2008) table (table 2.1).

The most commonly used option lies in the price/generation quadrant, where feed-in tariffs are used as support mechanism (Cherrington, Goodship, Longfield, & Kirwan,

Table 2.1. Renewable energy support policy types, adapted from Haas et al. (2008).

	Price	Quantity
Investment	• Investment subsidies • Tax credits • Low interest/soft loans	• Tendering systems for investment grants
Generation	• Fixed price feed-in tariffs • Premium feed-in tariffs • Tendering systems for long term contracts	• Renewable energy portfolio standards

2013) (Grieser, Sunak, & Madlener, 2015) (Haas, et al., 2011). These are used in many countries in Europe and have proven to be a successful method for significantly growing the amount of sustainable generated electricity.

However, the other options are also used throughout the S-curve of Foxon et al. (2005) to provide protection. For example, the options in the price/investment quadrant can also be placed in the demonstration phase, focussing on tax exemptions and R&D grants (a form of investment subsidies). It is usually in the pre-commercial phase that part of the instruments shift towards the investment/quantity phase to focus more on enlarging the current market by offering subsidies via a tendering system to innovations that need the least amount of support. When the supply quantity is large enough to create an actual market the focus shifts towards a combination of price/generation and quantity/generation instruments. These can be placed in the supported commercial phase of the S-curve of Foxon et al. (2005) focussing on ROCs/Renewable energy portfolio standards and on the statutory grants such as feed in tariffs.

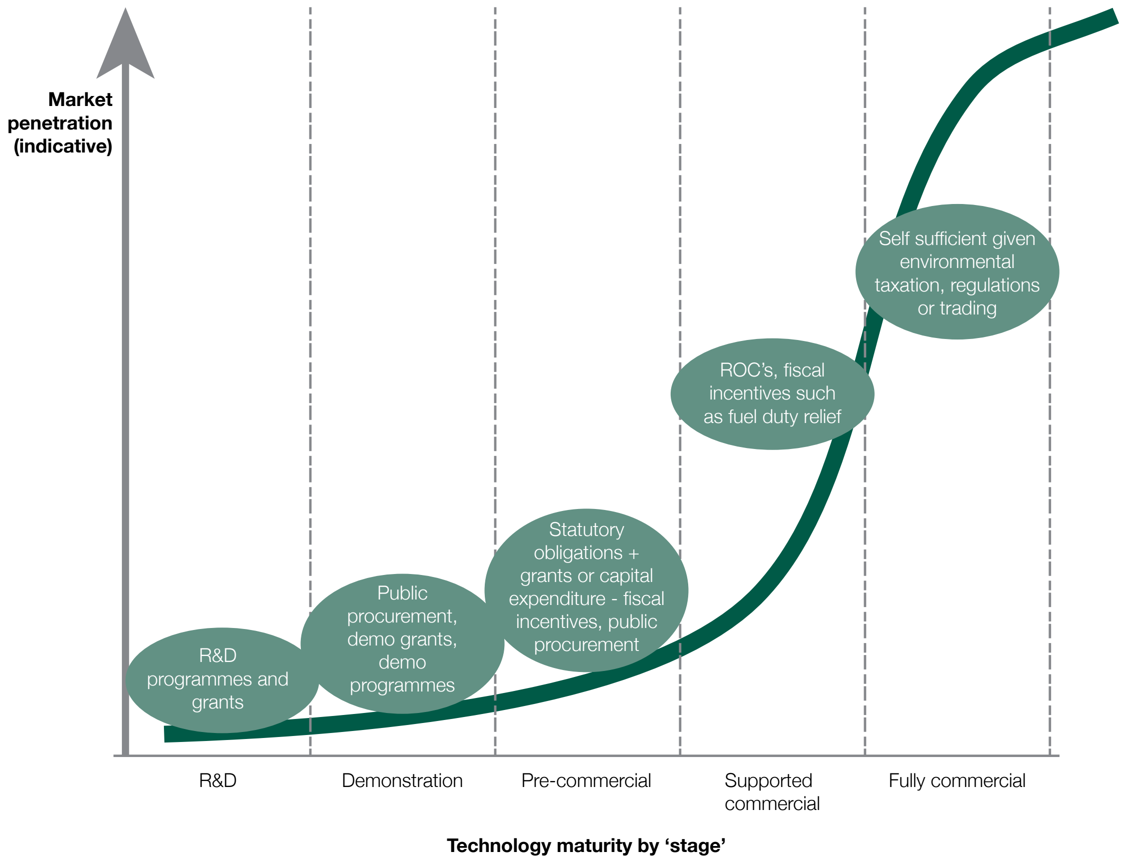
The main problem currently however is that the policy instruments are exclusively aimed at the generation of sustainable energy and not at the transmission and distribution of it. This means a challenge for innovations working on that and a gap to be filled so that these types of innovations can also grow in a protected niche.

2.3 Alternating Current & Direct Current

One of the innovations in the transmission and distribution of electricity that can use protection using the SNM framework is Direct Current (DC), a way of transmitting electricity from A to B and the opposite of the current method, Alternating Current (AC).

Although direct current is a promising option these days, it has not always been

Figure 2.3. S-curve of technological development and related policy instruments, adapted from Foxon et al. (2005).



like that. To understand the current rise we first need to go back to the end of the 19th century. During those years a war was fought between Thomas Edison on the DC side and Nikola Tesla & George Westinghouse on the AC side. Thomas Edison saw the future in creating a decentralized power system where many small-scale power plants across the city would power the electricity grid using low voltage DC (Hirsh, 1999). On the other side, the Tesla and Westinghouse saw the future in developing a mixed high and low voltage AC grid with centralized generation on the borders of the city to keep the air clear (Carley, 2011).

The war was won by AC due to the advantages that it can be easily transformed between high-voltage (for low-loss transmission) and low-voltage (for distribution) levels and since the system allows for more cost-effective large generators outside the city. Westinghouse demonstrated this concept when he built a 36 km long high voltage power line from the Niagara Falls to Buffalo NY to prove the higher potential of the AC system. This was the final blow for DC at that time, which led to the lock-in of AC for the century to come (Hirsh, 1999) (Reed, 2012).

In the 1970s DC started its comeback when the development of power electronics started. These power electronics allow for easy transformation between different DC voltages thereby overcoming the main problem that caused the earlier loss of the war.

Added to that the advantages such as the lower losses in cables compared to AC at the same voltage level, the fact that nowadays every electronic device runs on DC and the fact that sustainable energy producers such as solar PV panels and miniature wind turbines have a DC output, the time to overthrow the AC regime is here (Reed, 2012).

2.3.1 Current applications of DC

This renewed attention for DC is also reflected in the literature on the applications of DC. Right now a lot of research has been done on the use of ultra-high voltage power lines to connect electricity grids over long distances. This has led to several applications around the world (Reed, 2012) (Adapa, 2012). Also in the field of datacentres a lot of research has been conducted, mainly since these can profit from lower heat emissions due to centralized conversion and easier addition of uninterrupted power supplies (AlLee & Tschudi, 2012). Another improvement was shown in an experiment in a green house where part of the lighting has been replaced with a DC grid. Here the overall electricity costs were not only lower, but also the lamps last longer compared to the AC version leading to a lower total cost of ownership (TCO) for the DC system (Stokman, Van Willigenburg, & Backes, 2014).

For the rest, however, relatively little research has been conducted in the built environment. The potential is clear; studies show theoretical improved performance for DC and LED lighting (Thomas, Azevedo, & Morgan, 2012) and theoretical improved efficiency in a university office (Sannino, Postiglione, & Bollen, 2003). Also one practical test is known in the Netherlands. Joulz has remodelled two rooms in their Rotterdam Office to use direct current (Joulz, 2012). However, no official reports are given out on the performance of this test but one of stakeholders has confirmed that a small saving in the electricity use was made (Zijderveld, 2015).

3. Methodology

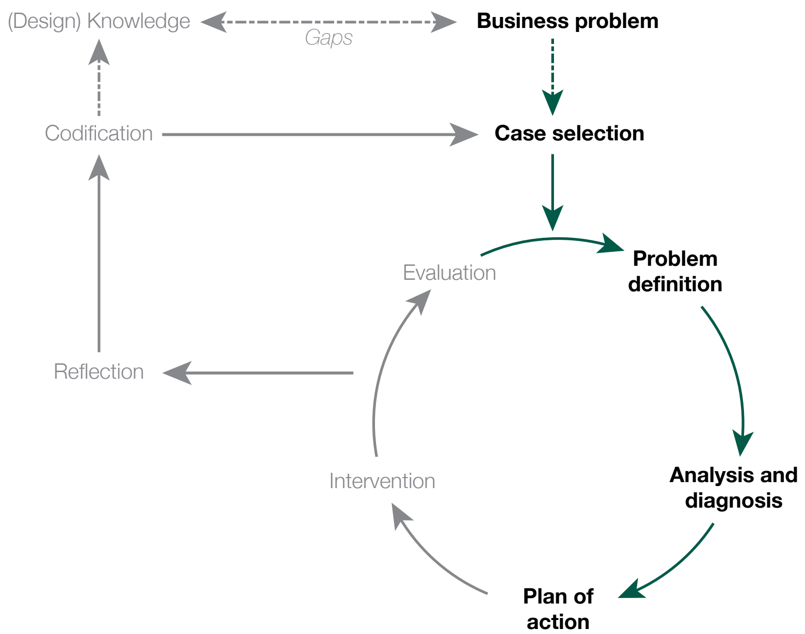
Within this research project the options for direct current in the office environment are researched. To do this the reflective cycle of Van Aken, Berends & Van der Bij (2007) (see figure 3.1) is used. This cycle combines the regulative cycle used for solving business problems of Van Strien (1997) with the reflective cycle of Van Aken (1994) to reflect on science based designs. This cycle aims at bridging the gap between design knowledge and business problems. This is useful in this case since numerous examples can be found in the literature describing strategies for developing protected niches for sustainable energy generators, but no literature is written yet on this for energy saving in the transmission and distribution part using direct current.

During the research it can become clear that some policy instruments need adjustment so DC will fit into these. Due to the relatively short period of time for the research and the long period of time for adjusting and making policy instruments no full regulative cycle is completed. This means that the research will finish at the Plan of Action part, in this case in the form of an SNM experiment.

3.1 Study design

This research is conducted using a case study. A case study is defined by Yin (1994) as: "an empirical enquiry that investigates a

Figure 3.1. The reflective cycle after Van Aken et al. (2007).
The grey parts of the model are not covered within this research project.



contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". The case study is especially relevant for exploratory research where the researcher has no control over behavioural events. Research on a new phenomenon in a real world business setting is an example of this.

3.2 Build-up of the research

This research is built up in three parts. First, an assessment is made of the current situation of an average ABN AMRO office using an AC grid. From this assessment the needed changes to run the office on DC are taken to design the basis of a financial case. Also, any non-technical barriers that need to be solved by policy instruments will follow from this. From this it will also become clear what protection has to be provided by the policy instruments.

The second part then focusses on mapping the current policy instruments related to sustainable energy and energy savings and finding the applicable policy instruments that can provide protection to DC in general.

In the third and final part the outcome of the first two parts is combined to create scenarios in which the different policy instruments are taken into account. This is done by designing a SNM experiment to test the business case and to show any gaps in the applicable policy instruments. This experiment is the intervention as described in the model of Van Aken et al. (2007).

The case study will make use of multiple sources of information to triangulate and validate the outcome. These sources include documents in which the policy is written down as well as interviews with experts and an online subsidy database.

The start of the research is a literature review in which the literature on transition studies, policy and direct current is discussed. Within this review the focus lies on the transition studies Transition Management and Strategic Niche Management; Policy in general and especially policy instruments for sustainable energy within the Netherlands and on the historical lock-in of alternating current and the current state of direct current. This review is used as a starting point for the further investigation. A summary of this can be found in chapter two.

3.2.1 Basis of the financial case

To assess the financial impact of the policy instruments first a basis for the financial case is made for the renovation of an average ABN AMRO office. On appointment of ABN AMRO the ABN AMRO office Utrecht Daalsesingel is used in this research as average office. This will show the expected costs and savings that can be achieved by implementing DC in the office environment. In this case no subsidies or tax exemptions are included since these are policy instruments providing a form of protection and thus influence the business case.

In order to design a model in which the costs and benefits of remodelling an office to DC can be calculated an assessment is made of the average office. This model is designed to determine the overall costs that are needed in the building and operation of the new system, as well as to determine the yearly energy savings. ABN AMRO supplies the data on the current electricity use of the chosen building. The efficiency data about the changed parts of the system are looked up in the Catalog of DC Appliances and Power Systems (Garbesi, Vossos, & Shen, 2011) to model the new system. Price information is requested at the regular suppliers. When no data are available or provided internal sources of Grontmij are used.

3.2.2 Policy instrument map

The second part of the research focusses on finding the applicable policy instruments that can provide protection to the innovation and aid the business case. Within this research, the following definition is used for policy:

> "(L)aws, plans, and actions that have been made and implemented by government to achieve societal goals.

> The policy is made in the "public's" name, and implemented by public and private actors" (Lloyd-Williams et al., 2014).

For the purpose of this study, the chosen policy instruments are those relating to Sustainable Energy and Energy Efficiency. Policy, policy instruments and policy documents are defined as written documents that contain strategies and priorities, with defined goals and objectives and are issued by a public administration. This is an adapted version of the Lloyd-Williams et al. (2014) definition. More specifically the focus lies on policy instruments that aim at: "support for R&D; market development policies, such as niche market support and long-range targets and obligations; and financial incentives, such as capital subsidies, tax credits and hypothecation of revenues," (Foxon, et al., 2005) since these are named as most often used types of policy instruments used for the development of sustainable energy.

Collection of documents

First of all relevant documents are sought in which policy for sustainable energy innovations and energy reduction innovations is written down. These documents may come from the field of innovation, economy, sustainability or energy savings. For this, an online search is conducted.

The online search will start at the websites of the Rijksdienst voor Ondernemend Nederland (RvO); the Ministry of Economic Affairs, Agriculture and Innovation (ELI) in the Netherlands; the website of the Dutch Government and the website of the European Commission. These are supplemented by a Google search for a combination of the terms; policy, sustainable energy, energy reduction, European union, European Commission and Nederland. As a final online tool the website Vindsubsidies.nl is used, to include any provincial subsidies using the same keywords as for the google search. The outcome of this search is complemented with any internal documentation that is available within Grontmij and ABN AMRO.

The relevant documents are placed in a database from which further analysis will take place. The documents are summarized on three main points: key goals, mechanism, and (expected) outcome of the policy instrument.

Inclusion criteria

Any document is deemed relevant for this research when the document describes policy (instruments) related to either sustainable energy or energy saving. Policy documents will include: Dutch and/or European Acts; Laws; other Legislation; Ministerial Decrees (or equivalent); policy; strategies or plans (in preparation) and documents about taxation and/or subsidies. The document should be either in English or in Dutch to be included in the analysis. Other languages will not be used in the analysis. When multiple versions of the same document are available the most recent version of the available document is being used. Policy instruments that are either in preparation or have not been implemented are excluded.

Analysis

For the analysis of the map the policy instruments will be divided based upon the types of instruments that have been found. Also the instruments will be divided into generic and niche instruments and when needed specific sub-versions of the instruments will be noted. Also they will be sorted on the geographical level from local to European level.

Next to that the instruments will be classified on a three point scale to assess in how far they fit DC at this moment, where 1 is described as absolutely not fitting, 2 is described as currently not fitting but with the potential of fitting using a stretch-and-transform process and 3 is currently fitting with DC.

Using the map an analysis is made to find out which instruments are currently applicable to DC and to see if there are any gaps in the map considering the availability of instruments to help the development of DC in general. Using the analysis of the applicable instruments to DC a further classification will be made to assess which instruments can be applied to the experiment as described in this research.

Interviews

To validate the outcome of the policy instrument search and the applicability of the policy instruments to DC experts are interviewed. One week before the interview the interviewees will receive the policy instrument map. They are asked to first of all see if they think that some policy instrument might be missing and are asked to fill this in then.

Second they are asked to discuss which policy instruments they think can provide some form of protection to the innovation and why. Also, they are asked to assess the impact of the policy instrument on the business case for the experiment.

The outcome of these interviews is used during the optimization of the business case for the experiment.

3.2.3 SNM experiment design

At the end of the analysis the applicable instruments to this experiment are found. The applicable instruments are added to the business case, after which the business case will go several times through the reflective cycle to adjust it and to make sure that all applicable policy instruments that are non-obligatory but useful (e.g. subsidies) are included. After the first run of the reflective cycle the outcome of the interviews will also be used to improve the business case.

The outcome of the process is presented as a set of policy instruments that are applicable to this specific experiment and can provide further protection to the niche when other experiments take place in there. This can include applying for subsidies but will also include instruments that can be help- or harmful during the further development of the niche. This might also include currently existing policy instruments that need to undergo a stretch and transform process to include DC. All together they are used during the design of the experiment.

For the nurturing part of the experiment first a stakeholder map is created, mapping the different stakeholders that are involved in the experiment. From this the narrative for the experiment will be given. An overview of the interviewed stakeholders is presented in appendix A.

The final experiment is checked internal at both Grontmij and ABN AMRO.

4. Basis of the business case

In this chapter the basis of the business case is discussed. First of all the office that is used as a model is discussed after which the different electrical components are discussed and the possibilities to convert these so they can operate on DC. Following from this the financial details are presented using four scenarios and a choice is made for the further development of an experiment.

4.1 Overview of the office

For the design of the financial business case the regional office ABN AMRO Daalsesingel Utrecht has been appointed by ABN AMRO. This office has a floor space of 8026m2, 526 workplaces laid out over four floors, a restaurant and six large meeting rooms at the top floor, 9 small rooms at the reception for receiving clients and a café in the basement. Currently no solar PV panels are installed on the roof. However, the impact of installing these panels on the roof and connecting these directly to the DC grid is included in the final experiment.

To get an overview of the electrical components in the office an inspection round was made followed up by a second round to collect any missing information from the first round. All components have been noted and can be found in appendix B, together with an in-depth explanation of the design of the model.

From this inspection five different groups of apparatus have been defined:

1. Building installations (23 machines)
2. Office area (9 types of apparatus)
3. Kitchen/restaurant area (11 types of apparatus)
4. Server area (5 types of apparatus)
5. Café in the basement (5 machines)

The yearly energy use per group is visualized in figure 4.1.

The group building installations is both in amount of different apparatus and yearly energy usage (61% of the total) the biggest group of the five. This is because it includes all machines that regulate the indoor climate, as well as the lift machinery and many different pumps which all use a lot of power.

The second group with the highest energy usage comes from the office area itself, where nine different types of apparatus can be found which account for around 25% of the total energy use. The bulk of the energy use here comes from the computers and the fluorescent lighting in the office areas.

Next comes the server area with 12% of the total, the kitchen with just 2,2% of the total energy use and the café accounts for just a minor 0,45% of the total electricity use. The low value for the server area comes from the fact that only a few computers are left there since they use off-site servers. The relative low energy use of the kitchen comes from high-efficiency appliances that are only used around lunchtime (except for the two large cooling units which run 24/7). The extremely small energy use of the café comes from the fact that it only operates on Friday afternoons.

4.2 Types of machines

To assess the changes that are needed to renovate the office to run it on DC some technical background is needed on the workings of these systems.

4.2.1 Electrical motors

Almost all apparatus in the building installations make use of electric motors to run pumps and fans for the transportation of water and air through the building. Also the cooling in the kitchen makes use of these electro motors. Even the coffee machines use them for grinding the beans and the printers for outputting papers. All of these motors make use of 1- or 3-phase AC to run the motor, which means that they cannot run directly on DC.

4.2.2 Microelectronics

Also, almost all components make use of some sort of microelectronics. In a small form these are the speed controllers for the pumps and in the larger forms these are the PCs on which the people are working. The advantage of all these microelectronics is that they are all designed to work with DC which means that they can all operate on DC without modifications. The workings of these apparatus have already been proven by the practical test of Joulz (2012) and the university of Bath (Williamson, 2011).

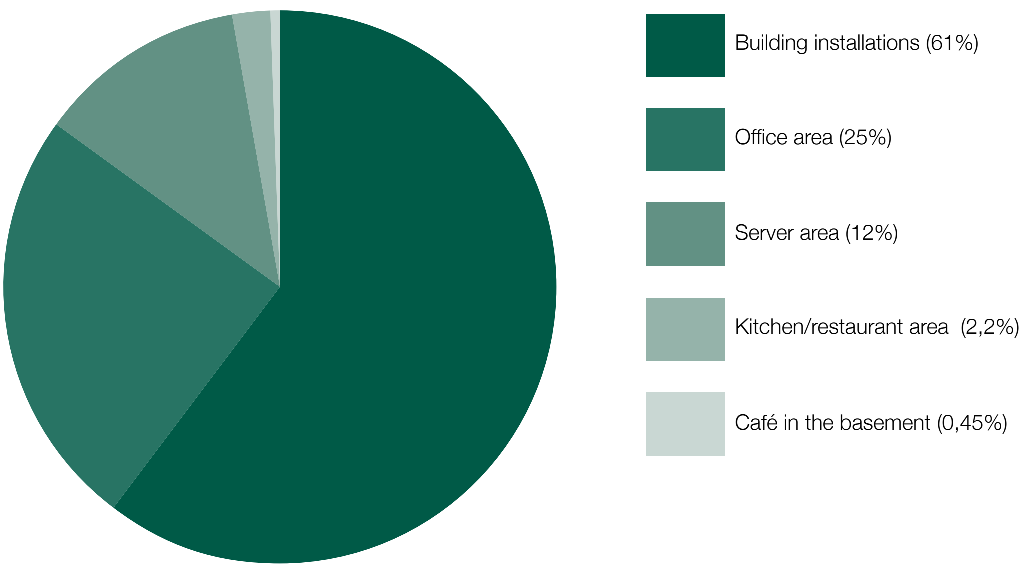
4.2.3 Lighting

Throughout the building fluorescent lighting is used. This means that every armature uses an electronic ballast to limit the current flowing through the bulb to make sure the tube does not burn itself out. These ballasts are usually designed for AC sources, but there are also versions available to connect the lamp directly to DC. In this office the AC version is found, which means that all lamps need replacement.

4.2.4 Electrical heating

Also, several electric heating elements can be found in the building. As a separate module these can be found in the area where the fresh water enters the building. As part of a larger system these can be found in the boilers of the coffee machines, but also in the contact grill in the kitchen and in the post heaters of the climate system. The issue with these other machines is that their thermostat uses a physical switch to stop the heating element when the desired temperature has been reached. The AC switch will cause electrical arcs when powered by DC, causing the machine to fail. This means that they will have to be adapted in order to run safely on DC (Van Willigenburg, 2015).

Figure 4.1. Percentage of the power used per group per year.



4.2.5 Uninterruptible Power Supplies

One special type of machine is the Uninterruptible Power Supply (UPS) found in the server area. In this building it consists of two separate units (one 60 kVa and one 80 kVa unit). These large units make use of a battery to supply power to the critical computers and cooling in the server area in case of a power failure. Internally these are based on DC, but they currently have AC as in- and output, meaning that they have to be adjusted.

4.3 Electrical Vehicle charger

The final special type of machine is the EV charger in the parking garage. The current charger outputs AC that is converted to DC in the car. However, more expensive DC fast chargers are available which output DC directly to the car. These are for example used in the Vehicle-to-Grid experiment of Stedin in Utrecht where they are testing the option of using EVs as battery storage system when there is a power surplus or shortage (Verheggen, 2015).

4.4 DC replacement

Now that it has been determined what needs to be replaced, the expected costs of transforming the entire office to DC can be calculated. To do so, prices were looked up or requested for each component that has to be changed.

4.4.1 Electrical motors

The biggest difference in costs between regular AC components and DC components comes from electrical motors and pumps. Electrical DC motors are currently only mass-produced for small sized motors with a power less than 1kW and a low-voltage input of 12 or 24 volts. For electrical motors with larger power outputs than that or with a higher voltage input custom made motors are needed which carry costs that are about 5-7 times higher than the AC version (Rotor B.V., 2015).

This problem has led us to come up with another solution for replacing the pumps and motors. Variable Frequency Drives (VFD) are already commonly used in the manufacturing industry to control the speed of a motor. It does so by converting the AC from input to DC after which this DC is converted into a square wave AC to run the three phase AC motor. The advantage of this is that by using a VFD one can run an AC motor on DC by feeding in the VFD with DC, thereby not using the first AC to DC step in the VFD (Novak, 2009). This means that most of the existing electrical motors in the building can run on DC, thereby lowering the costs of remodelling the office.

4.4.2 Office area

In the office area all computer equipment can run on DC without problems. At the moment a computer receives it DC power from the charger that you plug into the wall socket. The expectation is that in the coming years all small electrical equipment will shift to USB 3.1 type C plugs for their DC power and information exchange and that the normal wall sockets will be partly replaced with matching USB ports (Van Willigenburg, 2015) (Stokman, 2015) (Zijderveld, 2015). ABN AMRO is already installing the older USB 3.0 type A ports in their offices but these do not suffice for powering laptops. It is therefore that in the business case extra costs are added for putting USB 3.1 type C ports on every desk of the office, though it may be that ABN AMRO might cancel the current installation scheme and change it to the new type before these are installed at the office in which the experiment will take place. This will lead to lower investment costs and therefore an improved business case.

Next to the computers it is also very likely that the multifunctional printers can run on DC though this has not been tested in practice yet (Van Willigenburg, 2015).

The only two apparatus that have to be remodelled for sure in the office are the coffee machines and all lighting fixtures (Van Willigenburg, 2015). Currently there are fluorescent lighting bulbs hanging on the ceiling throughout the building. In order to be able to run these on DC the ballast of each light has to be changed to a DC version, or all lights will have to be replaced with LED lighting. ABN AMRO has no fixed scheme for replacing their lightbulbs in their offices, so it is unclear when the current light bulbs will be replaced and if they will be replaced by LED lighting at that moment. Also, changing lighting fixtures brings other problems with it related to the amount of light that should be put out in relation to the ARBO legislation. With this in mind we have chosen in the business case to adapt the old lighting to be able to run it on DC. The argument of reduced energy consumption for LED lighting is true for both AC and DC systems, so it has no added value for this business case. The removal of the AC/DC converter at the light bulb is however taken into account, but then for the fluorescent light. It is however expected that replacements with LED will lead to roughly the same costs.

4.4.3 Additions to the existing situation

Compared to the current situation one piece of equipment has to be added to the system; a central AC to DC converter including safety measures at the point where the electricity enters the building. Currently the entire supply chain is based on AC but for the experiment DC is needed in the building which means that a converter has to be added, preferably just behind the electricity meter.

4.5 Scenarios

In order to calculate the costs associated with remodelling of the building four different scenarios have been designed:

1. Total remodelling of the entire building using brushless DC motors
2a. Total remodelling using VFDs and new AC motors
2b. Total remodelling, using current electro motors refit with VFDs.
3. Remodelling of only the office area (Groups office and server area)

Scenario 2 has been divided into 2a and 2b for the following reason: part of the electromotors in the building are fairly new and can probably get away with the addition of a VFD. However, there are also some older engines which are nearing the end of their lifecycle. For these motors it would be better to replace them with newer models, which will have the added benefit of running more efficiently. In reality a combination of 2a and 2b is needed when remodelling the system.

Assumptions

For the calculation of the scenarios the following assumptions are made:

1. If a part has to be replaced to make it DC-compatible, the costs for replacing the entire part (e.g. motor + VFD) are taken (except scenario 2b, there only VFDs are added to the existing motors).
2. The efficiency of the central AC/DC converter, de-central DC/DC converters and VFDs is 97% for each individual converter.
3. A 2.8% efficiency gain is made by using 350Vdc instead of 230Vac throughout the building (Photovoltaic-software.com, 2015).
4. Efficiency gains from losing the AC to DC conversion at the appliances are taken from the Catalog of DC Appliances and Power Systems (Garbesi, Vossos, & Shen, 2011).
5. The price paid per kWh is € 0,138 (Gerdes, Marbus, & Boelhouwer, 2014).
6. The yearly energy use for this building is 900.000 kWh (calculated upon electricity consumption during the months July and August 2014 provided by ABN AMRO).
7. ABN AMRO accepts a payback time of 6 years maximum for innovative projects.
8. NPV will be calculated at 5% WACC for both 6 (ABN AMRO innovations standard) and 10 years (industry standard).
9. The costs for remodelling the air-conditioning unit are not taken into account since this is a custom made system with a very large peak usage (255 kW), therefore making it nearly impossible to make a decent guess of the

costs for remodelling it to make it work on DC.

4.5.1 Outcome of the scenarios

The outcome of the different scenarios is presented in table 4.1. From this it can be seen that none of the scenarios reaches the financial performance that is required by ABN AMRO since all scenarios show payback times of 12 years or longer. For designing an experiment it is however needed to choose at least one of the scenarios to for the financial business case and to predict the impact of policy instruments on it.

Considering the expected costs and impact during remodelling it is suggested to use scenario 3 for the design of the SNM experiment. This scenario has overall the lowest investment costs and the least impact during remodelling. Also it has the highest expected energy reduction in percentages looking only at the groups that are impacted. Together that makes this the most interesting scenario to design the experiment. The experiment can be extended in a later stage to include the rest of the office as in scenario 2a or 2b.

4.5.2 Non quantified advantages

One of the biggest advantages of DC can be achieved when the generation of DC power can be combined with the consumption of DC power. This can most easily be achieved by putting solar PV panels on the roof. Since these panels output DC power directly there are no extra losses from converting the DC power from the panels to AC power to feed into the grid. The avoided losses account to an extra output of 6-10% electrical energy compared to a regular AC system (Van Diest, 2013). These will be quantified in chapter six to show the impact if it is decided to add some solar PV panels to the building grid.

Another typical DC component that is currently not used very often but is up and coming is battery storage. With the current Dutch policy on renewable energy generation small systems can feed any electricity that they produce but don't use at that moment back into the grid. For this they are paid the same price as they pay for any electricity they buy, as long as they don't sell more electricity than they buy in a year. It is however expected that this policy instrument will be revised in 2017 or 2018 and that it will become more interesting to store the electricity to use it later instead of selling it to the grid for a low price (Stokman, 2015) (Markesteijn, 2015).

Other, non-financial benefits of adding a battery system is the ability to continue working when there is an external power failure since you have your own power source in the building. This is also applied at the office of Joulz in Rotterdam where they equipped their 'emergency room' with a battery pack allowing them to work on for four hours in case of a power failure (which is needed since they need to co-ordinate their technicians from that location to fix the power failure).

Table 4.1. Overview of outcome of the different scenarios

Scenario	1	2a	2b	3
Investment cost (€)	455.000	210.000	150.000	57.500
Expected energy reduction (%)	12	10	10	4,7 *(14*)*
Expected energy reduction (kWh)	106.000	90.500	90.500	30.500
Expected energy reduction (€)	14.700	12.500	12.500	4.250
Payback time (y)	31	17	12	14
NPV after 6 years (€)	- 380.000	- 146.000	- 86.000	- 36.000
NPV after 10 years (€)	- 342.000	- 113.000	- 53.000	- 25.000
Impact during remodelling	Very high	Very high	High	Little

**Comparing only the remodelled groups.*

The final advantage of DC comes from the fact that many products that use DC internal but have AC as input will last longer. For example, in a modern light fixture it is usually not the actual lamp that breaks but most often it is some part of the circuit in the lamp needed to convert the AC to DC (the capacitor to be exact). However, when using DC as input this component can be left out leading to a lower TCO for the lamp. Laptop chargers have the same problem so these can benefit from this too.

4.6 Legislation, rules and regulations concerning DC

In the Netherlands the 'Bouwbesluit' (building code) orders that all electrical systems must have proof that they are designed and can be operated in a safe way. This can be achieved in several ways, but the most common is by complying to two Dutch standards: the NEN1010 and the NEN3140. These two are however not obliged but merely suggested as preferred options. One can also choose to show that their design is safe in other ways without adhering directly to these standards, according to the Dutch High Council (ECLI:NL:HR:2012:BW0393, 2012). For this experiment, however, we will use these two standards.

The NEN 1010 'Veiligheidsbepalingen voor laagspanningsinstallaties' (Safety regulations for low voltage installations) is the first standard. This standardization document describes all safety regulations for designing low voltage AC (LVAC) and DC (LVDC) systems[3] described. When reading the document literally one can see that this standard has everything in it to design a safe low-voltage DC system. However, for the sake of clarity an extra paragraph will be added in the fall of 2015 stating that every AC term can also be read as the equivalent DC term. In this way the NEN1010 is made DC-proof (Stokman, 2015).

When the system has been built one should also be able to operate it in a safe way. This means that the system should be shut down when maintenance has to be done, that all cables are safe and that all apparatus attached to it are also safe. The preferred way to prove this is by following the standard NEN 3140 'Bedrijfsvoering van elektrische installaties – Laagspanning' (Operation of electrical installations – Low voltage). This standard is the operational equivalent of the NEN 1010 which means that it has the guidelines in it for safe operation of any LVAC and LVDC system and that it should be DC-proof.

Applicances

Appliances have their own rules. Any appliance that is imported by a company into the EU should have a CE marking on it that guarantees that the apparatus can be used safely. For any low-voltage apparatus this means that it should apply to the Low-Voltage Directive of the EU (2006/95/EC, from 20 april 2016: 2014/35/EU) in which guidelines and rules are stated that guarantee the safety of low-voltage apparatus. Only by guaranteeing that the apparatus applies to this a CE marking is given allowing it to be sold on the European market. This means that when an AC apparatus can run on DC without modifications one can sell it without problems. If however modifications have to be made in order to make it DC compatible it cannot be sold without first receiving a renewed CE mark.

This alteration of the apparatus also has other consequences, especially for the warranty that is given on products. Warranty voids on products when they are altered (with some exceptions), meaning that any alterations made to machines so they can run on DC should be done by the manufacturer itself to keep the warranty. Any homemade improvements will void the warranty.

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3. A system classifies as low-voltage AC (LVAC) system when the voltage is between 50V and 1000V AC. A system classifies as low-voltage DC (LVDC) system when the voltage ranges in 75V and 1500V DC. (NNI, 2008)

The running of DC apparatus (especially laptops) directly from DC sources without any adapter in between is not described in any warranty so it is not clear how this plays out when the computer breaks down when attached directly to DC. It can be seen as using an adapter not provided by the manufacturer which is sometimes given as reason for voiding the warranty when the computer fails. However, this is also not spelled out in the warranty of the manufacturers and will only become clear when the problem actually occurs.

4.7 Safety

Safety is one of the most recurring issues when it comes to the application of direct current. Two different types of safety should be looked at in this case; the dangers of touching a live wire and the dangers of arcing between two not directly connected items (either two wires or a live wire and a conductor).

Touching wires

Let's start by stating that it is never a good idea to touch a live wire, neither for AC nor for DC. However, when it might happen to you, you may praise yourself lucky if it is a DC wire. This has two reasons; First of all the let-go voltage (the highest voltage at which one can let loose of a live wire) for DC is higher than for AC. Also, more energy is needed to get your heart to fibrillate[4]. When touching an AC-wire your heart will start fibrillation at 13,5 watt-seconds, whereas with DC it takes 27 watt-seconds. DC can also help overcome fibrillation by setting a small and very short DC current over the heart to reset it, which is what a defibrillator does.

Arcing

The dangers of arcing are however bigger with DC systems compared to AC systems. An arc happens when the electrical energy flows through the air from one point to the other, where the start usually is a live wire with inadequate protection and the other part can be any conductor. The most simple example of this is (un)plugging an electrical device. The power wants to flow from the power outlet to the plug and will continue to do so as long as it has enough energy.

This leads to some issues with DC that are not there with AC. With AC the voltage reaches zero 100 times per second (for a 50hz system) meaning that the power flow is zero watts 100 times per second and the arc is broken. With a DC system however the voltage is at a constant high level, meaning that there is always power flowing. This leads to arcs remaining alive for a while when the plug is pulled out of the socket. The chances of getting wounded by this are fairly small as long as the system is designed safe, but the dangers for equipment are higher. Every time an arc is created when you (un)plug something you damage the plug itself. When this happens often enough it will break down.

There are also multiple solutions for this problem. By keeping the power transfer low the risk of arcing is minimized which is exactly what is done using the USB 3.1 standard. Another option is remodelling the current plugs. In electrical laboratories some prototypes have been developed. One of these uses one shorter pin for the information flow that cuts off the energy when unplugging the plug, but these are all just prototypes (Van Willigenburg, 2015).

4.8 Conclusion

Technically it is very well doable to convert an office to run on DC, though some appliances need adjustments to work on DC. Also on the rules and regulations side it looks as if it there are few barriers. However, on the financial side the case doesn't look very good.

In the next chapters the options to improve the business case by using policy instruments are investigated and an experiment is designed to test this business case in practice.

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4. Fibrillation of the heart are uncontrolled contractions of the heart muscle leading to failure of the heart to pump blood around the body, usually leading to dead after a few minutes (Jeroen Bosch Ziekenhuis, 2015).

5. Policy map

To find the policy instruments that are applicable to DC and to find which instruments can be used during the further development of DC a policy map has been created. In this policy map the different instruments that are available for energy saving and sustainable energy have been placed.

The geographical scope is the Netherlands, which means that instruments coming from the Dutch Provinces, the Dutch government and the European Union are included. The full map can be found in appendix C. In this chapter the different instruments will be classified and it is discussed which instruments apply directly to DC. The outcome is this is used in the next chapter to design an SNM experiment using the applicable policy instruments.

5.1 Division of the instruments

A first step in creating the map is dividing the instruments based upon their type. To do so the instruments are classified on their respective type of instrument dividing them into the following six categories:

1. Statutory obligations/ (alleviated) legislation
2. Investment subsidies
3. Subsidy tenders
4. Fiscal incentives
5. Public procurement & capital expenditure
6. Low interest loans

Under the first category all instruments related to statutory obligations, legislation and alleviation of legislation are put. The second category has all instruments where subsidy is granted without competition with other appliers for the subsidy. The third category has all the instruments in it where the appliers for the subsidy need to go through a tender where they compete with other appliers. The fourth category has all fiscal incentives in it that return part of the investment in the form of tax deductions. The fifth category has all instruments in it that focus on public procurement by the government. The sixth and final category features all instruments that provide low interest loans.

The instruments are furthermore divided into generic and niche instruments. An instrument is defined as generic in this analysis when the focus of the instrument is on sustainable energy or energy savings in general without setting any other specific boundary conditions. These are for example the statutory obligation 'Bouwbesluit' (instrument 6)[5] which aims at all buildings in the Netherlands and which partly focusses the safety and on lowering the energy use of buildings. Niche instruments, on the other hand, have a focus on a specific part of sustainable energy and energy savings, usually in the form of a special technique. These include the instrument 'Stimulering Duurzame Energieproductie' (SDE+, instrument 24) which focusses specifically on several sustainable energy generation techniques.

Finally some instruments are very broad in scope, leading them to be broken up into a large amount of specific versions of that

5. The number of the instrument corresponds with the number of instrument in the policy map.

instrument. These are called sub-instruments in this analysis. These sub-instruments can either be a generic instrument, such as the 'EIA Code 310000: Technische voorzieningen voor energiebesparing in of bij bestaande bedrijfsgebouwen' (instrument 26b) which only specifies a ratio between investment and achieved energy savings without naming specifically how this should be achieved, or a specific instrument such as the 'EIA code 210506: LED-verlichtingssysteem' (instrument 26d) which can only be applied for when using specific high efficiency LED lighting. In the policy map the encompassing instrument is included, as well as the sub-instruments. These sub-instruments can be recognized in the map by the letter that is put after the number that is given to the encompassing instrument.

Classifying the instruments according to these guidelines leads to the overview of table 5.1 and the full map in table C.1. in appendix C.

5.1.1 Generic vs. niche

In total 84 different (sub-)instruments have been found. These are divided into 56 different instruments, and 28 sub-instruments. The largest amount of instruments found are the generic instruments (55 generic vs. 29 niche). Of these 55 generic instruments 15 are sub-instruments, and of the 29 niche instruments 13 are sub-instruments.

Of the generic sub-instruments six are specific codes of the 'Energie Investerings Aftrek' (Energy Investment Deduction/EIA, instrument 26a-b) and the ' Milieu Investerings Aftrek' (MIA)/'Willekeurige Afschrijving Milieu Investeringen' (Vamil) (Environment Investment Deduction/Arbitrary Deduction Environmental Investments, instrument 27a-d) that aim at reducing the energy usage in buildings in general. Of the other nine generic sub-instruments, five come from the European Union. These include the specific sub-instruments in the Horizon 2020 research program (instruments 44a-c) and the sub-instruments for the co-operation between neighbouring countries in the Interreg program (instruments 45a-b). The other four generic sub-instruments are the regional versions of the EU instrument Regional

Table 5.1. Overview of the number of instruments per category, divided into (sub-)generic instruments and (sub-)niche instruments based on geography.

NL = Netherlands, EU = European Union. - *means no instruments are found in that cell. Instrument category number: see §5.1. In the columns with Sub the amount of sub-instruments for the specific generic or niche category are noted.*

Instrument category		NL	NL - Sub	EU	EU - Sub	Province	Province - Sub	Row total	Category total
1	*Generic*	12	-	3	-	0	-	*15*	20
	Niche	3	*2*	0	-	0	-	*5*	
2	*Generic*	2	-	2	-	2	*4*	*10*	15
	Niche	0	-	5	-	0	-	*5*	
3	*Generic*	0	-	2	*5*	0	-	*7*	15
	Niche	8	-	0	-	0	-	*8*	
4	*Generic*	4	*6*	0	-	0	-	*10*	21
	Niche	0	*11*	0	-	0	-	*11*	
5	*Generic*	1	-	0	-	0	-	*1*	1
	Niche	0	-	0	-	0	-	*0*	
6	*Generic*	4	-	3	-	5	-	*12*	12
	Niche	0	-	0	-	0	-	*0*	
	Column total	34	*19*	15	*5*	7	*4*	*84*	84

Development Fund, which in the Netherlands are the responsibility of the provinces (instruments 38a-d).

The niche sub-instruments show some resemblance with the generic sub-instruments. Also in there the largest share (11 out of 13) of the instruments comes from the specific EIA (instruments 26c-k) and MIA/Vamil (instrument 27e) codes for specific techniques. The other three are specific Green Deals (instruments 8a-c) that aim at either alleviating rules for DC, helping sustainable innovations reach low-cost financing and enlarging the share of sustainable distribution vehicles in the city.

5.1.2 Geographical

Considering the spread of the instruments on a geographical scale it is clear that over half of the instruments comes from the Dutch government (53 out of 84), with the EU following with 20 instruments and finally the provinces with only 11 instruments.

Also in the types of instruments offered a clear difference can be found between the three different policy makers. The Dutch government has the most different types of policy instruments available. From the six categories defined above the Dutch government provides all six.

The EU only provides four different types, missing the fiscal incentives and the public procurement. The missing of the fiscal incentives is explained by the fact that the EU does not collect taxes itself, making it impossible to use fiscal incentives. It is unclear why the EU does not do any public procurement for energy innovations.

The provinces are even more limited in the different types of instruments that they offer, offering only two types of instruments; the investment subsidies and the low-interest loans. The reason for not offering statutory obligations is that they do not have the power to create or relieve legislation. The reason for not offering fiscal incentives is that they do not receive any taxes based upon energy use, making it impossible to offer tax deductions on that. It is not clear why provinces do not offer subsidy tenders, though this is probably since they are only concerned with a small amount of projects, making it less interesting to go through large procedures used in tendering. It is also unclear why the provinces do not offer any public procurement instruments.

5.2 Types of instruments

It is also interesting to look at how the instruments are divided over the different categories of instruments. The statutory obligations (category 1) are the second instrument in amount, and especially in the Netherlands by far the largest group. This is because there is a large group of generic instruments in this category that have the main aim of reducing the energy use in general.

The second type of instrument (investment subsidies) is used far less, mainly because the EU and the Dutch government have shifted to subsidy tenders for almost all of their subsidy schemes. Only for the provinces it is far more common to use investment subsidies,. These instruments are generic and have a main aim of enlarging the investments in sustainable energy and energy saving in general. This has the main aim of creating a better investment climate for companies and improving the environment in their region.

The third type of instrument (subsidy tenders) is the preferred option for providing subsidy for both the Dutch government and the EU. In the Netherlands the government makes very specific subsidy tenders where they aim specifically at either demonstration projects of specific new techniques (e.g. the DEI (Demonstration Energy Innovation) instrument 19) or at enlarging the share of specific sustainable energy generators such as solar PV or wind turbines (e.g. the SDE+, instrument 24).

The EU, on the other hand, uses much more generic instruments. The two generic instruments that have a link with energy saving and sustainable energy are the Horizon 2020 program and the Interreg program.

The Horizon 2020 program is the overall program for all subsidy tenders of the EU aimed at research and innovation covering all subjects up to 2020, whereas the Interreg program aims at connecting neighbouring countries by helping them set up cross-border co-operation projects.

The fourth type of instrument (fiscal incentives) is the most widely available instrument. This is mainly due to two generic instruments that have a large variety of niche sub-instruments. These instruments are the EIA (instrument 26) and the MIA/Vamil (instrument 27). Both of these instruments allow for tax deductions based upon the investment made in energy saving measures. The percentage of the investment that can be deducted from the corporate tax differs per sub-instrument. The percentages that can be deducted per instrument are shown in figure 5.1.

The other two generic fiscal incentive instruments are focussed on investments of companies into Research & Development (R&D), either in time spend by people or by investing money into machines needed to do R&D. The impact of these instruments on the tax deductions is also presented in figure 5.1.

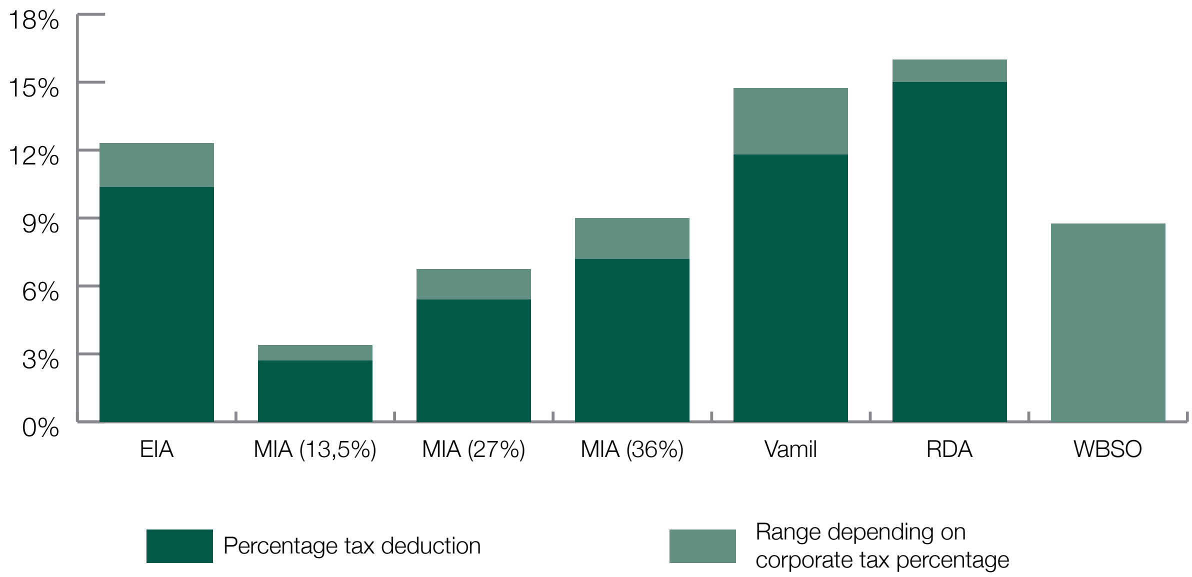
The public procurement is by far the least used option by all parties when it comes to policy instruments and energy. Only the Dutch government has one instrument focussed on this, named the 'Energiegebruik Vastgoed Verminderen' (Reduction energy use of buildings, instrument 31). With this instrument the Dutch government aims to be launching customer for any energy saving innovations in their buildings. The EU and the provinces do not offer any type of public procurement.

The sixth and final type of instrument that is widely available are the low-interest loans. All three (Dutch Government, EU and Provinces) offer these as generic instruments to help companies finance their R&D at lower rates or help both companies and people invest in energy saving measures using low interest rate loans.

5.3 Applicability to DC

Now that we know that a wide range of options is available for energy saving and sustainable energy, it is time to see how many and which instruments apply directly to DC. In order to do so the different instruments are classified on a 3-point scale, where 1 means that the instrument is not applicable to

Figure 5.1. The lowering of the corporate tax, shown as a percentage of the total investment.
The light green part of the bars shows the range which depends on the height of the corporate tax. The corporate tax in the Netherlands is 20% of any profits up to €200.000 and 25% for any profits over €200.000.



DC and that it cannot be made to fit using a stretch-and-transform process, 2 means that the instrument is not yet applicable but that it could be made applicable by using a stretch-and-transform process and 3 means that the instrument is currently already applicable to DC. The division of the instruments into this shown in table 5.2. For the reasoning per instrument, see the policy map in appendix C.

5.3.1 Non-applicable instruments

The amount of non-applicable and non-transformable instruments is fairly low. On the total of 84 instruments that are present in the map only 16 are not applicable and cannot be stretched and transformed so DC can fit into these.

The non-applicability has two reasons; either the instrument itself is not applicable since one can only apply for specific sub-instruments (e.g. Horizon 2020, instrument 44) or the instrument focusses on a very specific technique that is not related to DC, such as investments in research into more efficient and lower priced sustainable energy generators (e.g. Hernieuwbare Energie (TSE), instrument 20).

These non-applicable instruments are not just one specific type of instrument but come from instrument types 1, 2, 3 and 4 and can be found both in the Netherlands and in the EU.

5.3.2 Not yet applicable instruments

In total 32 of the instruments are not yet applicable, but can become applicable in the future by applying a stretch-and-transform process.

Small transformations

Most of these instruments encounter the same issue, focussing on energy saving in general, but not noting DC as an option for doing so thereby making the instrument not applicable.

Table 5.2. Numerical overview of the applicability of the exististing instruments to DC per category and geography.

NL = Netherlands, EU = European Union. **-** *means no instrument in that cell.*

The fit of the instrument with DC is given on a 3-point scale, where 1 means no fit, 2 means a stretch and transform process might lead to fit and 3 means that the instrument currently fit. The last three columns are the added totals of all three institutions, i.e. the Dutch government, the EU and the provinces.

Fit with DC/ Instrument category		NL			EU			Province			Total	Total	Total
		3	*2*	*1*	**3**	*2*	*1*	**3**	*2*	*1*	**3**	**2**	**1**
1	Generic	**2**	8	2	-	3	-	-	-	-	2	11	2
	Niche	**1**	2	2	-	-	-	-	-	-	1	2	2
2	Generic	-	1	1	-	-	2	**6**	-	-	6	1	3
	Niche	-	-	-	-	2	3	-	-	-	0	2	3
3	Generic	-	-	-	**5**	1	1	-	-	-	5	1	1
	Niche	**5**	1	2	-	-	-	-	-	-	5	1	2
4	Generic	**2**	6	2	-	-	-	-	-	-	2	6	2
	Niche	**7**	3	1	-	-	-	-	-	-	7	3	1
5	Generic	-	1	-	-	-	-	-	-	-	0	1	0
	Niche	-	-	-	-	-	-	-	-	-	0	0	0
6	Generic	**2**	2	-	**1**	2	-	**5**	-	-	8	4	0
	Niche	-	-	-	-	-	-	-	-	-	0	0	0
	Column totals	**19**	24	10	**6**	8	6	**11**	0	0	36	32	16

This can be explained by the fact that DC is currently in the demonstration phase and that the evidence that it can save energy is fairly small. When DC reaches the pre-commercial phase this evidence should however be there.

This information can then be used for stretching and transforming these generic instruments. This can be done in two ways:. either by making DC specifically a part of the applicable techniques for the instrument (e.g. 'Regeling Groenprojecten', instrument 28) or that it automatically becomes applicable when the instrument is an obligation to save energy in general without naming specific techniques (e.g. 'Energiebesparingsplicht', (Energy Saving Duty) instrument 2).

Larger transformations

This is however not true for all instruments. For some very specific instruments the transformation is much larger, meaning that the basic idea behind it can be stretched and transformed into a new instrument. This could be done with the ETS scheme (instrument 34) to create a market place for DC, though this is difficult and not needed at this moment.

All of the instruments that can undergo the stretch-and-transform process come out of all six categories and are offered by both the Dutch government and the EU.

5.3.3 Applicable instruments

The third and final set of instruments are the directly applicable instruments. In total 36 instruments have been found that fall under this category. Within these types of instruments two different types can be found, the very generic instruments that have a scope on energy or even wider on innovation in general, and some very specific (sub-)niche instruments that already have a focus on specific techniques that use DC.

Generic

The generic instruments can be found in the categories 1, 2, 3, 4 and 6 and are offered by the Dutch government, the EU and the Provinces. Per category they have the following focus:

- **Category 1:** Reduction of energy use in general by legislation and safety of electrical systems in buildings;
- **Category 2:** Regional development funds (via the EU) and specific regional funds with investment subsidies for investments to improve the region in general;
- **Category 3:** Subsidy tenders for the Horizon 2020 innovation program and cross-border co-operation projects;
- **Category 4:** Tax deductions for R&D investments and specific DC-using equiopment;
- **Category 6:** Diverse revolving funds with low-rate loans for investments in energy-related measures and innovation.

Niche

The niche instruments are all provided by the Dutch government and can be found in the categories 1, 3 and 4. These instruments focus on the following:

- **Category 1:** A Green Deal that aims at removing regulatory barriers concerning DC;
- **Category 3:** Five niche instruments that have a small scope and focus only on very specific energy projects;
- **Category 4:** Sub-instruments of the EIA and the MIA/Vamil that focus on techniques that use DC.

From this we can see that none of the instruments of the fifth category are currently applicable to DC. Considering that DC is currently in the demonstration phase this should not be seen as a problem since the technique will first of all have to be proven before it is interesting to start public procurement (category 5). When the potential is clear however public procurement can be started easily by stretching and transforming instrument 31 to include DC. The other five types of instruments are available, showing that in potential an experiment with DC is possible.

5.4 Niche protection

The instruments that are applicable to DC in general can also be seen as potential instruments for the formation of a protected niche. For this it is important to note which instruments are used most often in the first period of the development and which are used later. For this we can use the model of Foxon et al. (2005) in which the different types of policy instruments that are used during the development of sustainable energy generation innovations is described. For this it is important to know that DC can be placed on the start of the demonstration phase of this model.

5.4.1 Types of instruments needed

The model of Foxon et al. (2005) sees public procurement, demo programmes and demo projects as the types of instruments to use.

Looking at the applicable instruments that are currently available we can immediately note that the first (public procurement) is not available at this moment. The instrument is in another form available, but to make it applicable to DC it should first undergo a stretch and transform process, meaning a gap in the map.

On the other hand, demo programmes and projects are available in the Netherlands. The 'Demonstratie Energie Innovation' (Demonstration Energy Innovation, DEI instrument 19) offers a combination of these two types for energy innovations that are in the demonstration phase in the Netherlands. This instrument is placed in the third category as a niche instrument. From the EU no specific demo niche-instruments are available.

5.4.2 Extending the model

However, next to the instruments named by Foxon et al. (2005) there are also some generic instruments available from the Dutch Government, the EU and the provinces that are not named in their model. These include all the other instruments named in paragraph 5.3.3 and include instruments such as tax deductions for innovation costs, low-cost loans and investment subsidies.

From this we can say that when considering the options for creating a protected niche in the demonstration phase for any energy-related innovation, the model of Foxon et al. (2005) should actually be extended to include all the options that are offered by the generic instruments as described before. More specifically for energy saving innovations this could even be extended to include the generic instruments in the first category (statutory obligations on energy saving).

When extending the model with the above mentioned generic instruments the options for creating a protected niche with policy instruments in the Netherlands is much more clear. Also the model will be of greater value since the innovation will receive more support than the current model says is possible.

5.5 Conclusion

In the map a large amount of instruments is found. Dividing them over the six different types of instruments we see that the Dutch government offers the largest amount of instruments and is the only one offering all six different types of instruments. The EU also offers a fairly large amount, but only 4 out of the 6 different types. The provinces are very focussed on only two types and also have the smallest amount available.

Considering the applicability we can see that a large amount is already applicable or can simply be stretched when the technique of DC has proven itself. Only a small amount is non-applicable or needs to undergo a large transformation.

Also, we saw that the instruments that are applicable to DC can also be used to start the creation of a protected niche. For this all the instruments applicable to DC can be used in this phase, which is an extension of the model as defined by Foxon et al. (2005).

Now that we have defined which instruments are applicable to DC we can see which are applicable to the experiment as described in chapter four. This will be done in the following chapter where after defining the applicable instruments the business case from chapter four will be extended.

6. Designing the SNM experiment

After describing the financial business case in chapter four and mapping the available policy instruments in chapter five it is time to integrate these two into a SNM experiment in which the case can be tested. First of all the policy map will be used to find the instruments that can be applied to this specific experiment. After finding the applicable instruments their respective impact on the business case is described, after which the narrative is presented for the experiment.

For the design of this SNM experiment we use scenario 3 as described in chapter four; the scenario in which only the office area is refitted to use DC. This one is chosen due to the relatively high improvement in efficiency and the relatively low impact on the office when doing the remodelling.

6.1 Applicable policy instruments to the experiment

Out of the policy instruments that have been found to be applicable to DC only a part is applicable to this experiment. This is due to some extra boundary conditions that apply specifically to this experiment, which are:

- **Geographical boundary:** The office is in the city of Utrecht, meaning that from the provincial instruments only the instruments from the province of Utrecht are applicable.
- **Costs:** The costs for the experiment are relatively low (€57k-€77k). The subsidy tenders from the EU all have a focus on projects of over €100k, meaning that the subsidy tenders from the EU are out of scope.

These extra boundary conditions are used to define which instruments are applicable to the experiment, considering the current available instruments for DC. The applicable instruments are discussed per category.

6.1.1 Category 1: Statutory obligations/ (alleviated) legislation

Under the first category one generic instrument is found that is applicable to this experiment:

- **Instrument 6: The building code**. This instrument regulates that all buildings in the Netherlands are both safe and energy efficient. When doing an experiment in an office building the electrical equipment has to apply to the guidelines as presented in the code.

No other policy instruments are currently applicable since the project first has to demonstrate the expected energy savings in order to make any of the regulations relying on that applicable.

6.1.2 Category 2: Investment subsidies

For the investment subsidies only one instrument is applicable:

- **Instrument 38a: Kansen voor West II** (operationeel programma west)

All the other instruments that are in the map are not applicable since they are outside the geographical boundaries of this experiment.

6.1.3 Category 3: Subsidy tenders

Out of the subsidy tenders the focus is only on the available tenders from the Dutch government. From this category 5 instruments are directly applicable to DC, however, none of these apply to this experiment. The reasons are the following:

- **Instrument 18: The Eureka label**. Not applicable since this requires cross-border co-operation.
- **Instrument 19: DEI**. Declared not applicable after consultation with the RvO (Dieleman, 2015).
- **Instrument 22: Innovatie Programma Intelligente Netten (IPIN)**. Program ends in September 2015 so no new projects can be added.
- **Instrument 23: Samenwerken Topsector Energie en Maatschappij STEM (TSE)**. The nstrument is only applicable when the focus of the research is on the impact of users and not on the technical side.
- **Instrument 24: Demonstratieprojecten, Haalbaarheidsstudies en Kenniswerving/ Investeringsvoorbereidingssubsidies**. Only applicable when the experiment is done in an upcoming economy.

Next to that one subsidy tender that is not applicable to DC can be used when it is decided to execute experiment with a large rooftop solar system. In that case one can apply for the SDE+ (instrument 24), leading to an improved business case.

6.1.4 Category 4: Fiscal incentives

Out of the fiscal incentives two generic instruments can be used for tax deduction for the costs incurred with doing the experiment. These are:

- **Instrument 29: RDA**, for deducting part of the material costs of doing the experiment
- **Instrument 30: WBSO**, for deducting part of the labour costs of doing the experiment.

Also one generic sub-instrument can be used for deducting the costs of replacing the existing plugs with USB ports:

- **Instrument 26b: 'Technische voorzieningen voor energiebesparing in of bij bestaande bedrijfsgebouwen'**

No other fiscal incentives can be applied for with this experiment.

6.1.5 Category 6: Low interest loans

For the financing of DC experiments there are also some instruments to receive low interest funding. However only one instrument can be used in this experiment:

- **Instrument 53: Energiefonds Utrecht**, the fund of the region Utrecht that offers low interest financing to energy projects

The other funds are either geographically out of scope or need larger investments, such as the EU investment funds. It is also not sure if this type of instrument is needed since the experiment takes place at the ABN AMRO bank, which can take care of their own low-interest financing.

6.2 Impact of financial instruments on the business case

To assess the impact of the financial instruments on the business case the basic financial case of scenario 3 is used. To keep things clear this scenario (scenario 3) is named scenario 3a from here. From this scenario first scenario 3b is built. In this scenario the fiscal incentives as described above are added. Next to that the expected interest rate on the project is lowered to 3,5% assuming the instrument from the sixth category brings down the interest rate to be paid upon a loan with 1,5% to 3,5% per annum. Any investment subsidies are not yet taken into account. All other factors remain the same as in scenario 3a.

Scenario 3c builds further upon scenario 3b. In this case 60 solar PV panels are added to the system with a maximum output of 15 kWp. This is the minimal size of the system to be able to apply for SDE+ subsidy and it can probably fit on the roof of the building. If there is more space available more panels could be placed, thereby improving the business case. The output of the system is assumed to be 8% over the normal Dutch output of 0,85 kWh per Wp (Van Diest, 2013). The SDE+ subsidy is assumed to have a base amount of €0,11 and a correction amount of €0,045 per kWh produced solar electricity (phase 5 of the SDE+ 2015). This phase is chosen since it is right in the middle and the chances are relatively high of being granted the subsidy. The output of scenarios 3a, 3b and 3c is shown in table 6.1.

To reach a payback period of 6 years maximum as specified by ABN AMRO an investment subsidy from category 2 needs to be won in order to overcome the difference between the current payback period of 13 or 10 years and the wanted payback period of 6 years.

Using the model it is determined that for scenario 3b an extra subsidy of €29.500 has to be won in order to reach the six years; 54% of the total investment. For scenario 3c a subsidy of €32.750 has to be won in order to reach the six years payback period; 44% of the total investment. To reach a neutral NPV another €2750 or €5500 has to be won. Both are quite high, but the chances are highest for scenario 3c since the relative attribution of the subsidy to the project is lowest of the two options and the expected NPV is closest to zero after ten years.

6.2.1 Impact of changing energy prices

Although not everything can be quantified in a simple matter we can expect some of the instruments in category 1 that are currently not applicable to DC to have a profound impact on the development of the energy prices because they aim at reducing the energy use in general.

Most of these policy instruments focus on the reduction of the amount of energy used. The most simple way to achieve this is by raising the price of electricity by adding an extra tax on electricity use. This is however highly speculative since no one knows if and when this will happen.

Another instrument which might lead to higher prices is the 'Ontwerpbesluit Rendementseisen Kolencentrales' (Draft decision for the efficiency of coal power plants, instrument 14). When this comes into effect five coal-fired power plants will be closed in the Netherlands. With less supply and equal staying demand the prices of electricity can be expected to rise.

As a final instrument of indirect influence the European Emissions Trading Scheme (ETS, instrument 34) can be considered to be

Table 6.1. Overview of the impact of the financial instruments on the business case.

Scenario	3a (base case)	3b (subsidies included)	3c (subsidies & solar PV)
Investment (€)	57.500	57.500	77.500
Energy savings due to DC (kWh/year)	30.500	30.500	30.500
Subsidy (RDA/WBSO/ELA) (€)	0	2.500	2.500
Output solar panels (kWh/year)	-	-	13.650
Expected SDE+ subsidy (€/year)	-	-	887
Total savings due to investment (€/year)	4200	4200	7000
Payback period (years)	13	13	10
NPV after 6 years (€)	-35.000	-31.000	-38.000
NPV after 10 years (€)	-24.000	-19.000	-17.000
Subsidy needed to reach 6 years payback period (€)	30.750	29.500	32.750
Subsidy needed to reach 10 years payback period (€)	14.000	12.500	4.750

of influence on the business case. Currently, the price paid for CO_2 emissions under the ETS is around €7,- per ton, which is far too low to have a significant impact on the behaviour of the industry. However, the prices of the certificates are expected to rise over the coming years due to a reduction in the number of certificates (Neslen, 2015). This will lead to higher energy prices.

On the other hand, lower energy prices can be expected at certain times due to the overcapacity of energy generation in Germany. On several days in 2014 the average energy price over a 24-hour period was negative. If this trend continues it might mean that the average prices in the Netherlands might also decline in the coming years, though a negative energy price is very uncommon in the Netherlands (Nierop, 2014).

Taking the above into account we can set a bandwidth in which we can expect the electricity prices to rise or decline over the coming years. A conservative estimate is a range between -2% and +2%, though higher and lower percentages can also happen. However, for calculations in this part we will use this range. To assess the impact of this on the business case, scenarios 3b and 3c are calculated once more, but this time with the range in energy price development. The results from these scenarios are shown in table 6.2 for scenario 3b and table 6.3 for scenario 3c.

As can be seen in tables 6.2 and 6.3 the energy price does have a profound impact on the business case. The range of the business case is around €10.000 for both scenarios, meaning a deviation ranging between -10% and +10% of the investment for scenario 3b, and a deviation ranging between -7,5% to +7,5% of the investment for scenario 3c.

6.2.2 Non-feasibility of the business case?

From the above we can conclude that this project is currently not financially feasible in the unprotected environment. Therefore it should be treated as a pilot project in which the focus should not be on earning back the investment as soon as possible, but merely on

Table 6.2. Overview of the impact of changing energy prices on scenario 3b.

Change in energy price	2% decline	1% decline	0% change	1% rise	2% rise
Payback period (years)	15	14	13	12	12
NPV after 6 years (€)	-34.000	-33.000	-32.000	-32.000	-31.000
NPV after 10 years (€)	-23.000	-22.000	-19.000	-18.000	-16.000
Subsidy needed to reach 6 years pay-back period (€)	31.250	30.250	29.500	28.500	27.750
Subsidy needed to reach 10 years pay-back period (€)	17.000	14.750	12.500	10.250	7.750

Table 6.3. Overview of the impact of changing energy prices on scenario 3c.

Change in energy price	2% decline	1% decline	0% change	1% rise	2% rise
Payback period (years)	11	11	11	10	10
NPV after 6 years (€)	-40.000	-39.000	-38.000	-37.000	-36.000
NPV after 10 years (€)	-21.000	-19.000	-17.000	-14.000	-12.000
Subsidy needed to reach 6 years pay-back period (€)	35.000	33.750	32.750	31.500	30.250
Subsidy needed to reach 10 years pay-back period (€)	10.500	7.750	4.750	1.500	0

learning as much as possible by each member of the team during the experiment, thereby enabling learning-by-doing.

When you look at the project in this light, the needed investment subsidy can also be seen as R&D costs to learn more about DC. For this it is however important to keep in mind that in the longer term DC projects should be able to pay back itself within the specified period of time. The believe is that this is likely to happen since some parts of the technique are still new, meaning that the prices are currently high but that they will drop over the coming years.

This is also in line with the basic idea behind the SNM framework, and so this R&D costs can be seen as shielding and nurturing for the innovation.

It can also happen that the outcome of the project is that the case is not feasible for renovation projects, but that new buildings are a much better opportunity for this. However, also for this most of the lessons learned during an experiment will apply, so it does make sense to at least set up one real experiment to continue the learning process.

6.3 Generalization of the results

In order to make it easier to compare the results from this case with other experiments we will also look at the generalized numbers. For this the investment, the energy savings per year in kWh and the investment subsidy are calculated per m² floor space and per workplace for scenarios 3a, 3b, and 3c and presented in table 6.4. Unfortunately no comparative numbers are found.

6.4 Narrative of the design of the experiment

The setting up of an experiment using the guidelines of SNM is done in six steps:

1. Project and Scope Definition;
2. Team Set-up;
3. Team Formation;
4. Experiment Design;
5. Running the Experiment;
6. Finish and Reflection.

A short narrative on setting up an experiment to test DC in the office environment is presented in the next paragraphs. This can be used to guide the setup of an actual SNM experiment.

6.4.1 Step 1: Project and scope definition

The first step in setting up a SNM experiment is defining exactly what the project will be about and what the scope of the project will be. This is used as a starting point for further discussion and can be adjusted in later steps by going through one or several reflective cycles.

In this experiment the project is about setting up a DC micro grid in an office to test the feasibility of this and to find out if the theoretical underpinnings are also applicable in real-life situations.

Within the scope of the project are all questions related to the technical side of the machines that will be used: Will or won't they work? And if they do not work, what should be modified to make them work? The designing and actual building of a DC grid will also be part of the learning process of the experiment.

Also, any legal barriers which one might encounter are in the scope of the project.

Table 6.4. Generalized results for scenarios 3a, 3b and 3c.

Scenario	3a	3b	3c
Investment per m² (€/m²)	7,17	6,84	9,33
Investment per workplace (€/workplace)	109	104	142
Energy savings due to DC per m² (kWh/year/m²)	3,82	3,82	3,82
Energy savings due to DC per workplace (kWh/year/workplace)	58	58	58

Although it is stressed by most experts that it should be possible to run the experiment within the current laws, it is advised to always check that with the legal department.

A final part that is inside the scope is if everything works as expected by constantly monitoring the technical side and by checking if the employees undergo any changes in how they work, either positive or negative.

Outside of the scope are all other factors, including any machines that are not used in the experiment.

6.4.2 Step 2: Team set-up

The second step in setting up the experiment is setting up a team. Within the team all disciplines should be available to be able to execute the experiment. The easiest way to identify the relevant team members is by mapping all involved stakeholders and how they are connected to each other. For this experiment this stakeholder map has been created (see appendix E) in which all relevant stakeholders are identified. For this experiment the team will at least consist of these parties, where the named companies are interchangeable:

- **The user of the system** - ABN AMRO.
- **The system designer** - Grontmij.
- **The system builder** - An electro technical installation company. Specifically for this exeperiment Leertouwer has expressed interest since they are also involved in the development of other DC projects.
- **Hardware suppliers** – Amstel/Hellas Rectifiers for the AC/DC converter, ABB for the USB type C sockets and Philips for the lighting. Some parts of the system are new for the industry partners, so they should be involved in testing their parts in a real-life setting.
- **Knowledge institutes** - The the Hague University of Applied Sciences is involved in a DC research project and has knowledge on how to modify machines to make them work on DC.
- *Extra possibility:* **a DC expert** – DC is new to some of the partners so it might be wise to involve someone with extensive knowledge on the subject to help tackle certain issues that will arise during the experiment.

Next to that there will be many other parties involved in the project, however more from the side. These can also be found in the stakeholder map in appendix E.

When the project team has been assembled it is important that one of the members is picked as the leader of the project. This will probably come from the user of the system since this stakeholder will always remain involved in the project. Also it can be good to pick an outsider (for example the DC expert) since this person is less influenced during decision making by other projects running in the final users company. Both can be fine, as long as this person has the power to lead the group throughout the entire project.

6.4.3 Step 3: Team formation

When the team members are picked a first meeting will be held in which the project is introduced according the ideas that have been formed in the first step by the initiators. This project definition should then be opened up for discussion amongst all members where each member should state for themselves the following points:

- What do I expect from this experiment?
- What do I want to learn from this experiment? And how do I want to learn that, by doing theoretical research or by learning by doing?
- What can I bring in to the experiment in 1. Knowledge, 2. Finance & Kind and 3. Other actors in my network?

Using the answers of all team members the initial project plan and scope of step one will be adjusted so that all members of the team agree with the plan and share the vision of it. By having this strong shared vision for the project the chances of success will be higher. However, the adjusting of the original vision might also lead to stepping back to the first step and going once again through the team cycle to redesign the scope and aim of the experiment.

When stepping back to the first step it can also be helpful to open up the experiment to other members that are initially not included in the experiment. This will build and strengthen the network.

6.4.4 Step 4: Experiment design

When the team has set out for themselves the direction of the experiment it is time to design the actual experiment. The team will have to design the experiment in such a way that it every member can learn what it wants to learn in the way that it can be learnt best, so by learning-by-doing, learning-by-interacting or by learning-by-using. At this point in time the experiment is still in the theoretical design phase.

The general design of the experiment itself will have to be done by the leader of the group, in co-operation with the other members. The other members of the group can then work on the details of the part in which they have specialized, so the System Designer will make the actual electrical design and the Hardware suppliers will have to theoretically determine if their hardware needs modifications and if so, what needs to be modified to make it work on DC.

At the end of this step the experiment should be worked out into details including how each member thinks he can learn from the experiment what they want to learn and how long the experiment should take, but only theoretical to keep the costs low at this point. This theoretical design will be checked by each member of the group and go through one or several reflective cycles to adjust it so everyone agrees with it.

With this theoretical design the team will have to decide whether or not they want to continue and run the actual test in a real life setting or if they do not believe in the experiment anymore.

6.4.5 Step 5: Running the experiment

During this fifth step the experiment as worked out in theory in the fourth step will take place in a real-life setting. Each participant will deliver what it agreed upon during the second step.

In this step it is of extra importance that each member monitors for itself that he or she learns from the experiment what he or she expects to learn from it and that all information is shared among the members of the group.

During the running of the experiment the team will meet every month or every three months (depending on the total runtime of the experiment) to evaluate and discuss the intermediate results of the experiment. This might lead to some small adjustments in the experiment, but the general vision of what the team wants to get out of the experiment should stay the same so that other team members can still learn what they want. It is the task of the leader to keep the focus on the vision that was agreed on in step three.

6.4.6 Step 6: Finish and reflection

At the end of the runtime of the experiment a final report will be made by the team. This report should at least include the 'hard' results of the experiment, so the amount of energy saved compared to the old situation, but also what each member of the group learned from the experiment on the soft side.

With this final report the team can have a final meeting in which they can all reflect on the final outcomes of the experiment. In this meeting they can also look forward to see if they want to learn more about specific points and if they want to do that with the same group or if they want to set up an entire new experiment and start again at step 1.

6.4.7 Experiment loop

Using this narrative a loop model has been created showing the different steps. This model is shown in figure 6.1.

6.5 Relation of the experiment with the transition frameworks

In chapter two the transition frameworks 'Transition Management' (TM) and 'Strategic Niche Management' (SNM) were introduced. We will now look at the relation between the proposed experiment and these two frameworks.

6.5.1 Relation with SNM

The SNM model focusses on three points: Shielding, Nurturing and Empowering. Within this experiment the first two are explicitly addressed, whereas the third is not. However, at later stages and during different experiments within the niche this can be adressed explicitly.

Shielding

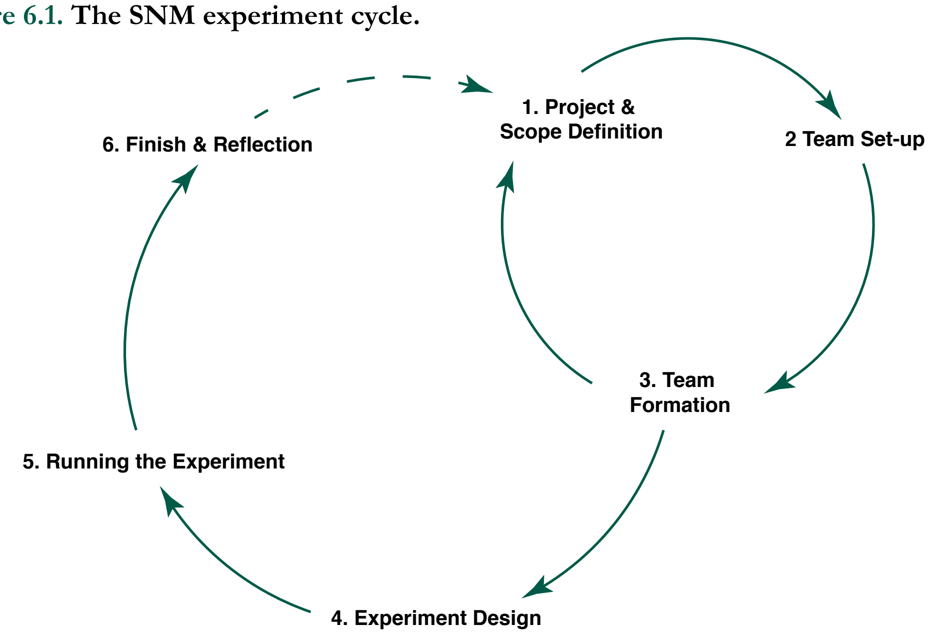
In somewhat more detail, the shielding in this experiment comes from the members of the team that are willing to invest in the research (that might include receiving a subsidy from the government), therefore paying a higher price than is economically acceptable by the user. The experiment will however be exposed to the actual rules and regulations that are currently prevailing since no exceptions will be made by the Dutch government for experiments involving DC. However, shielding is provided by policy instruments in the form of investment subsidies and tax incentives as named in paragraph 6.1.

Nurturing

The innovation is nurtured on three focus points throughout the entire experiment:

1. **Network building:** From the first step in the experiment the team will have to think about who to include in the experiment. The building of the network is therefore taken care of from the first step in the process and will continue throughout the experiment.
2. **Expectations:** During the second step of the experiment each team member is asked for their expectations and the team should try to set one general view of what they expect from the experiment. The expectations part is explicitly taken care of in this way.
3. **Learning:** From the first step the learning within the experiment is stressed by the leader of the experiment. The actual learning by each team member will depend on their own effort, but it is likely that both first and second order learning will happen.

Figure 6.1. The SNM experiment cycle.



Empowering
The empowering of the niche is only adressed implictly in this experiment, mainly since DC is currently at the most a technological niche, but no market niche. Therefore more focus on empowerment of the niche will be subject in an experiment that can follow from the outcome of this experiment.

6.5.2 Relation with TM
When looking at the experiment on a larger scale we can also place it in the different levels of the TM framework.

When looking at the literature the experiment can be placed on the operational level of the TM cycle, where the actual experiments take place. On this level many more experiments take place, which are further discussed paragraph 6.6. This can also be seen as the niche in the SNM framework since most of these experiments benefit from the same protection as this one and all focus on the same innovation.

The first step in the SNM experiment cycle can thereby be connected to the tactical level of the TM framework since in that phase it is decided in which direction the experiments should go. It is from this phase that the information comes for the project & scope definition.

The final step of finish and reflection in the SNM experiment cycle can be connected to the reflexive part of the TM cycle, since it has the same aim of reflecting on what has happened and trying to learn the lessons from that which can be applied to other projects.

6.6 Place in experimental field
Within the TM framework it is recognized that multiple experiments happen simultaneously within one transition arena to learn as much as possible about the innovation at hand. In the SNM framework it is also recognized that usually several experiments take place in a niche at the same time. It is therefore that we can also place this experiment in the wider field of DC micro grid experiments that are currently taking place around the world. The focus in here is solely on LVDC projects in distribution grids.

6.6.1 United Kingdom
One of the most interesting experiments related to DC and the office environment has taken place in the UK where in 2011 the university of Bath has remodelled 50 computers in their library to run on DC. The outcome of this experiment showed that the computers used 14% less energy compared to their equal AC counterparts. However, in total the entire energy consumption did go up since the scientists had to use products that were not designed specifically for this application. For example, they had to use a rectifier with a large output surplus and the entire system was designed on 24V since these were the only available products. Together this led to higher losses throughout the system compared to the computers using an AC system. They expected however that when more suitable products become available and more computers will be attached the system efficiency will go up.

Another nice outcome was that the students preferred the DC computers over the AC computers since they make less noise and have a lower heat output (Williamson, 2011).

The outcome of this project has also led to a bigger experiment in Bristol in England. In this new experiment the University of Bath has partnered with grid operator Western Power Distribution, Siemens, the Bristol City Council and Knowle West Media Centra to refit five schools, one office and 26 homes with solar PV panels, a battery storage system and a DC micro grid for the lighting and USB charging. The background of this research is more technical, with the grid operator wanting to learn more about the best way to add decentralised power generation to the grid (Western Power Distribution, 2015). This experiment is currently in progress and no intermediate results have been published.

6.6.2 USA
Another experiment with a bigger scope has just started in the USA. Bosch will start

refitting a distribution centre for Honda so it runs completely on DC. Within this building they will use a 380V DC grid to which a battery pack and a large solar PV array will be attached. This project is partly funded by the state of California under their energy program thereby providing some protection (Beckmeyer, 2015).

6.6.3 The Netherlands

Also in the Netherlands some new experiments are on the verge of beginning. After the first small steps for DC in homes were set in the project 'De Stroomversnelling' by Direct Current b.v. and BAM, a new project will start in the fall of 2015 when Alliander starts with testing homes completely refitted with a DC micro grid. Currently they are also investigating the options for running apparatus on DC to be ahead of any problems that might occur due to this. One of the things Alliander wants to learn from this is the impact of DC and smart grids on their grids. Also they want to find out the impact of a DC grid on the user of the home (Direct Current B.V., N.D.) (Tijsseling, 2015).

Another Dutch project that is also aimed at the built environment is an extension of the Greenhouse DC project that opened in 2013. In the first part of the experiment only a small group of light fixtures was converted to a DC micro grid (Stokman, Van Willigenburg, & Backes, 2014). In this second part the grid will be extended to the rest of the greenhouse and the neighbouring greenhouse and it will include a solar PV park with a size of one hectare. The planning permission for the solar park has already been granted (Walraven, 2015) and also the 'DEI' subsidy tender has been won (Dieleman, 2015) meaning that the actual construction is expected in 2016. The main learning goal of this experiment is to see if the advantages of the smart grid in combination with DC are in practice just as good as in theory (Stokman, 2015)

Other experiments are currently in their theoretical phase. For example, grid operator Stedin is currently setting up a research project to test the influence of DC on the degradation of their cables in the ground. This research is important when rolling out DC over larger areas (Eerhard, 2015). Also grid Operator Alliander is currently researching DC in larger areas, however with a wider scope. They are currently investigating the opportunities for creating a micro-DC grid for the OMALA industrial terrain in Lelystad (Van der Eerden, 2015). Their research ends at the meter of the user, whereas this research starts there.

6.6.4 Relation to this experiment

The experiment described in this thesis is an addition to all the above mentioned experiments. However, it can also learn a lot of those. The learning within niches is also seen as one of the important points of the SNM framework.

To start off with the British experiment; from this experiment most of all technicalities can be learnt. For example, the information on the efficiency of computers and that they work on DC can be learnt from that experiment. This is even more true for the Bosch experiment where they will find out all the technical details on both the design as well as the operation of a building running on DC. From both these experiments one can also learn more about the user behaviour in buildings using DC micro grids.

Looking at the application of rules and regulations, however, one cannot learn very much from these foreign experiments since each country still uses its own rules, even though they are quite alike among the countries since they are based on the same standard. Still, on this point a lot can be learnt from the Dutch experiments since these fall under the same rules as this new experiment will. If the experiment will take place in practice it is therefore advised to contact the other parties working on these experiments to exchange information about how they handled issues related to rules and regulations.

7. Discussion

At this moment DC, especially in the office environment, is only at the start of the demonstration phase when placed in the S-curve. With the outcome of this research we can however assume that it is likely that it will move further along the curve and that it will make the next step; creating a protected market niche. So far the focus has merely been on policy instruments that can help in the demonstration phase, but it is also interesting to look a bit ahead and see what policy instruments should be developed over the coming years to help the protected niche for DC in the office environment forward.

To define the policy instruments that are needed for this next step, the frameworks of Foxon et al. (2005) and Haas et al. (2008) will be used to define which types of instruments are needed to create a protected niche. These frameworks are based on sustainable energy generators, which means that not the exact instruments can be copied, but that we merely consider the instrument types that they suggest. We hereby place the protected niche at the start of the pre-commercial phase of the S-curve.

Keeping this place in the S-curve in mind, an assessment is made of the currently available instruments to see where the gaps exist for DC. From here a direction will be given for new instruments to be developed so a protected niche for DC can emerge, considering the already available instruments in the other parts of the electricity system.

7.1 Types of instruments needed for creation of a protected market niche

As said before, the creation of a protected market niche can be placed at the start of the pre-commercial phase of the S-curve as defined by Foxon et al. (2005), see figure 2.3. Within the S-curve of Foxon et al. (2005) the instruments that are named for this phase are: "Statutory obligations and grants or capital expenditure, fiscal incentives and public procurement" (Foxon et al., 2005). These can be placed under category 1 *(statutory obligations)*, categories 2 & 3 *(statutory grants)*, category 4 *(fiscal incentives)* and category 5 *(public procurement & capital expenditure)*.

All of these instruments are aimed at market creation by providing either incentives for companies to invest into these innovations in the form of tax incentives or subsidies, or by creating a law that obligates companies to start using the new technique. Also, it is common for governments to support public procurement of the innovation. This is usually done by investing in the innovation by the government itself as launching customer (capital expenditure) and by setting it in the spotlight at various events such as trade missions to other countries.

The other model from which the instruments can be derived that have an effect on the development of energy innovations is the model of Haas et al. (2008), see table 2.1. From the classification made by these researchers the focus should be on the instruments that can be found in the Price/Investment quadrant and in the Price/Generation quadrant. This is since the instruments named in the Price/Investment quadrant are all linked to the instruments named by Foxon et al. (2005) for the pre-commercial phase, whereas it is also common for investment subsidies to be given out through a tender where only the high performing innovations are given financial support, which can be found in the Price/Generation quadrant.

When combining these two models it becomes clear that all six types of instruments can be used in the formation of a protected niche in the pre-market phase. It is therefore that in the map the focus will now shift to find out if there are any specific instruments that apply to the pre-market phase and that can be used for that.

7.2 Link with existing instruments

Using the created policy map an overview is created of the applicable policy instruments for creating protection in the pre-market phase. These are summarized in table 7.1 and further discussed below per instrument type.

Category 1: Statutory obligations/(alleviated) legislation

First of all, the statutory obligations. Currently there are no statutory obligations for the use of DC in the office environment. This means that there is a gap for this type of instrument that might be filled in when the development continues to help create a protected niche.

Category 2: Investment subsidies

Second, the statutory grants (Foxon, et al., 2005) & investment subsidies (Haas, et al., 2008). The Dutch government does not provide any investment subsidies in a direct form, but only through subsidy tenders. The provincial governments do provide direct subsidies however through the generic sub-instruments 'Operational Programs' (Kansen voor West II & Operationeel Programma Noord, Oost & Zuid, instruments 38a, b, c & d). The statutory grants are therefore available.

Table 7.1. Overview of the existing policy instruments that are useable for the creation of a protected niche.

Between brackets is the number of the policy instrument in the map.

Instrument type	Dutch Government	European Union	Provincial/Local
Statutory obligations	None	None	None
Investment subsidies	None	Indirect from Cohesion Fund via Dutch provinces (#38)	Operational Programs of the Provinces (#38a, b, c & d)
Subsidy tenders	iDEEGO (#21)	Fast Track to Innovation 2020 (#44b)	None
Fiscal incentives / Tax credits	EIA (#26) & MIA/Vamil (#27) (not yet applicable)	None	None
Public procurement & capital expenditure	Energiegebruik Vastgoed Verminderen (#30) (not yet applicable	None	None
Low interest / Soft loans	FEIST N.V. (#31) & Regeling Groenprojecten (#33)	EEEF (#47) & PF4EE (#48)	Energiefonds Brabant (#51), Overijssel (#52), Utrecht (#53), Friesland (#54) & Limburg (#55)

Category 3: Subsidy tenders

Related to the investments subsidies are the tendering systems for investment subsidies. The only applicable niche-instrument offered by the Dutch government is the 'innovatie Duurzame Energie en Energiebesparing in de Gebouwde Omgeving' (innovation Sustainable Energy and Energy saving in the Built Environment, iDEEGO, instrument 21), part of the TKI EnerGo. This instrument provides subsidy tenders for innovative projects aimed at sustainable energy and energy savings.

The EU has a generic subsidy tender instrument for innovations called the 'Fast Track to Innovation in Horizon 2020' (instrument 44b), though this one has no specific focus on energy. It can however be used for this innovation since it has a general aim of accelerating innovations towards the market. We can therefore say that subsidy tenders are available.

Category 4: Fiscal incentives

The fourth type of instrument are the fiscal incentives/tax credits. For companies there are several instruments available. For general investments in energy saving equipment the generic instrument 'Energie Investerings Aftrek' (EIA, instrument 26) is available which has a large amount of sub-instruments that allow for a tax deduction when investing in energy efficient machines.

Currently, however, no specific sub-instrument of the EIA is available for DC. Also the other related instruments 'MIA'& 'Vamil' (instrument 27) do not have a specific sub-instrument for DC.

Fiscal incentives are also not offered by the EU and the provinces, showing a gap in the map for this type of instrument in the pre-market phase.

Category 5: Public procurement

The fifth type of instrument is the public procurement & capital expenditure that is done by the government. The Dutch government offers for this the generic instrument 'Energiegebruik Vastgoed Verminderen' (instrument 30) with which they intend to be a launching customer for innovations that help reduce the energy usage of buildings owned by the government. Currently this instrument is however not fitting for DC due to the lack of evidence that DC actually is more energy efficient than the existing system.

Category 6: Low interest/soft loans

The sixth and final type of instrument is the low interest/soft loans. This instrument is widely available for any type of energy related innovation. The Dutch government has the generic instrument called 'Fund for Energy, Innovation, Sustainability and Technology' – FEIST N.V. (instrument 31) which offers cheap funding for energy and innovation related projects.

The EU also offers two generic instrument funds for financing energy innovations; the European Energy Efficiency Fund (EEEF, instrument 47) and the 'Private Financing for Energy Efficiency' (PF4EE, instrument 48).

Even at a provincial level there are a series of generic instrument funds available for energy efficiency innovations, for example in the provinces of Brabant, Overijssel, Utrecht, Friesland and Limburg (instruments 51-55).

A special version of this type of instrument is also available in the Netherlands. In the above examples the government is the company lending the money to the companies. However, the bank to company financing market is much larger in size. To help lower the interest rates offered by banks for sustainable innovations the Dutch government has also created an instrument named the 'Regeling Groenprojecten' (instrument 30). This instrument gives out a label to energy efficient and sustainable innovations, thereby making these eligible for low-interest loans from banks.

Together this shows that this type of instrument is widely available in the Netherlands and applicable to the pre-market phase.

7.3 Missing instruments

From table 7.1 it is clear that a large share of the instruments deemed relevant for the creation of a protected niche in the pre-market phase is already available. They are offered by different institutions and most of these instruments have a generic focus on energy innovations. However, it is also clear that some instruments are still missing that are used very often in the pre-market phase according to Foxon et al. (2005) and Haas et al. (2008); especially the statutory obligations, the fiscal incentives and the public procurement. Although these instruments are not necessary for the creation of a protected niche it is still interesting to consider the options for filling in these gaps to aid the creation of a protected niche.

It is of interest to consider the options that are presented in other parts of the electricity system to fill in these gaps. As mentioned before, the system exists of three dependent parts; the generation, the transmission & distribution and the consumption of electricity. The energy efficiency related innovations in transmission and distribution (and the related policy instruments) are currently lagging behind the other two parts (generation and consumption) when considering the place in the S-curve. This is not only valid for the large scale grid in front of the electricity meter, but also for the grid in buildings behind the electricity meter. It is therefore that we will look into the options offered by instruments for generation and consumption to see if these can be made applicable to DC distribution systems in buildings in order to help the creation of a protected niche.

7.3.1 Statutory obligations

First of all we will start with the gap in the statutory obligations, considering first the options offered for generation and second for consumption.

Generation

The common goal of the statutory obligations aimed at the generation of electricity is reducing the amount of GHG emissions and generating more sustainable energy. The European Union has created the 'Emissions Trading Scheme' (ETS, instrument 34) as statutory obligation to achieve this. This law obligates companies to buy the appropriate number of certificates to compensate their CO_2-emissions throughout the year. Companies are allowed to buy and sell their certificates on the market to each other.

The challenge with copying this type of instrument is that a market has to be created on which yearly a smaller amount of certificates is available. By decreasing the market each year companies are forced to invest in equipment that will help them buy less certificates each year. Next to that it is also important that companies are willing to participate in the market (potentially by law). The creation of a such a market and the participation of companies can however take very long, making it very hard to convert this type of instrument to a viable version for DC.

Whereas the ETS focusses on making the existing system more sustainable by reducing emissions, one can also focus on enlarging the share of sustainable energy generators. Within the 'Energie Akkoord' agreements were made between the Dutch Government and the utilities companies to enlarge the amount of sustainable generated energy in 2020 to 14% of the total energy use in the Netherlands (Sociaal-Economische Raad, 2013). However, this agreement is on a voluntary basis which might lead to problems as power company Eneco showed this year when they threatened to step out of the agreement when they will be forced to split up into an energy trading company and a grid operator (Baas, 2015).

Within the UK the government has taken the same idea a step further to be ahead of these problems. They created the 'Renewables

Obligation' which obliges power companies to buy a certain amount of Renewable Obligation Certificates (ROCs) with which they can guarantee that they sell a certain amount of sustainable generated electricity. These certificates are linked to sustainable energy generators, where each MWh of produced energy delivers one ROC. These ROCs can be bought and sold on the market between power companies so they can buy extra from other companies when they have a shortage in their own production.

Just like the ETS, the RO uses a market system in order to function which means that it will encounter the same problems. However, the idea behind it, forcing companies to invest in sustainability, can be copied to DC distribution in offices. When the technology has proven to be successful and a significant improvement over the existing system the government can force the use of DC distribution in buildings by implementing it in the building code, thereby forcing companies to use it in their buildings. This will however only be on the long-term.

Consumption

In the consumption phase we can also find one instrument that is used to oblige companies to make more efficient machines. For machines in the consumption phase the 'Ecodesign for energy-using appliances' is in charge; a law that obliges a minimal efficiency for apparatus and classifies these using energy labels to show the efficiency of the machine.

The concept of a label as an instrument can also be used for the creation of a protected niche for DC in the office environment. Currently the energy label for buildings is an already existing instrument that classifies existing buildings on their energy use. This could be extended by also awarding points to DC distribution systems in buildings, thereby improving the label of the building.

7.3.2 Tax incentives

For the tax incentives it is also of interest to look at the instruments that are available at the generation and consumption phase.

Generation

The main tax incentive that is currently in use for the generation of sustainable energy is the instrument that allows one to pay less energy taxes on the energy that is generated sustainable by a co-operation when one is a member of this co-operation.

This instrument can simply be copied to DC systems by lowering the energy taxes that are paid for electricity that is distributed via DC systems in buildings. This will however cause other users without DC systems to pay for the difference, making it a less interesting option since it will encounter a lot of resistance from non-users.

Consumption

On the consumption side, on the other hand, three instruments are already in place for several years. The 'EIA, MIA & Vamil' allow a company to deduct part of the investment in sustainability from their EBIT to lower the corporate tax they have to pay. All three instruments are already available for a wide range of energy saving measures, but not yet for investments in machinery that enable the use of a DC distribution system in a building (e.g. rectifiers & solar panel optimizers). They can however be fairly simple extended to include energy saving measures using DC by creating a specific sub-version of these instruments for investments in DC.

7.3.3 Public procurement

Although that we name a gap in the map for public procurement for DC, it is actually a very small one. Currently there is no fitting instrument for DC but the Dutch government does already offer a generic instrument for public procurement of energy innovations: 'Energiegebruik Vastgoed Verminderen' (instrument 30). This instrument can be quite easily stretched and transformed to include DC once there is enough proof that it is more efficient, by including it in the types of innovations that they are willing to be launching customer for.

7.4 Conclusion

As we can see from this analysis, the step towards becoming a protected market niche is not as big as one might think. Already a lot of policy instruments are available and from the suggested instruments of Foxon et al. (2005) and Haas et al. (2008) three types are missing, two of which can easily be filled.

The fiscal incentive instrument EIA or MIA/Vamil can easily be extended to include DC systems. Also the public procurement can easily be filled by stretching and transforming the existing instrument of the Dutch government.

The statutory obligations, on the other hand, show a much bigger gap. This gap is the hardest to fill for two reasons. First of all, the time needed to create a law, have enough people support it and have it in charge can take a long time, especially with more controversial subjects as forcing companies to a more sustainable way of working. And second, and maybe of even greater influence, is that most companies are not very excited to say the least when they are forced to do something by law, making it hard to implement the new law. It is also fairly likely that lobbyists paid for by these companies will try to stop the implementation of this law as good as they can. The statutory obligations are however a very powerful instrument and it is therefore a wise idea to further investigate the possibilities that are offered by this instrument to start the creation of a protected niche for DC.

7.5 Limitations

Although a glorious future is expected for DC, this research also has some limitations to it that need to be considered when looking into the future. Both the limits for the business case, as well as for the policy research and the theory are discussed next.

7.5.1 Business case limitations

The business case shows promising results when looking at the expected energy savings and the reduced impact on the environment. There are however several limitation to this.

First of all, the numbers in the catalog of DC appliances (Garbesi, Vossos, & Shen, 2011) are all based on theoretical research on the efficiency of converters. No practical research was done however to verify these numbers which might mean that these efficiency numbers are on the low side, i.e., that the actual efficiency might be higher in practice than in theory. This is substantiated by the experiment at the University of Bath. They did practical tests and found lower efficiency improvements for the computers compared to the catalog of Garbesi, Vossos & Shen (2011) (Williamson, 2011) (see table 7.2).

With this in mind the overall business case is likely to be on the optimistic side since a larger improvement in efficiency is expected from the theory. This means that the payback periods and NPVs mentioned are too positive and that it is possible that the financial business case will be more negative.

Table 7.2. Comparison between theoretical and practical efficiencies.

Efficiency improvement by removing the AC/DC converter of the ... according to:	Garbesi, Vossos & Shen (2011) (theory)	Williamson et al. (2011) (practice)	Difference
Computer	18%	11%	-7%
LCD monitor	24%	24%	-0%
Combination	18%	14%	-4%

Another point of influence for the business case is that the energy use for the different machines is calculated and not measured. Although the calculations are done using partly factual information (the power rating) and partly well estimated guess (load hours per year), we know for sure that the calculations are incorrect (i.e. the total power consumption is too high). However, we do not know which parts of the system create the difference so it is possible that the distribution of the power use per group as shown in figure 4.1 is wrong. This might mean that the total efficiency gain of the system is also different because some high-efficiency apparatus has an actual power use lower than expected and a low-efficiency apparatus has a higher actual power use than expected, leading to a lower system efficiency.

Next to that not all efficiencies are known so for two machines an assumption of the efficiency is made. Rectifiers come in many different formats, all with different prices, power outputs and efficiencies. In order to make calculations a high efficiency rectifier is chosen with an efficiency of 97%. This can be reached by high efficiency rectifiers, but only under full load. It is likely that the practical efficiency of a rectifier is lower, as was also shown in the experiment of the University of Bath. Also for the USB plugs a theoretical efficiency of 97% has been chosen. This is simply because currently there is only a prototype available and no production unit of which the efficiency has been measured. The final production model should have an efficiency of 98%, but that is not reached yet (Stokman, 2015).

This also brings up another point about the powering of laptops and USB plugs. Currently there are only a few laptops that can be powered over USB, making it currently not feasible to change the office to a USB only system. It is expected that most brands will switch over in the coming years but until there is a large availability of laptops it is not possible to remove all standard power plugs from the office. This development is however of indirect influence on enabling the further roll out of DC distribution systems in new offices.

Finally, the case is based upon one office. Although this office is seen as a representative office for the Dutch office market, the business case should be made for multiple offices to be able to make more bold general statements.

7.5.2 Policy research limitations

Within the search for applicable policy instruments a wide search scope was used, but a rigorous cut-off is used to only include policy instruments related to the generation of sustainable energy or energy savings. The scope however was held wide enough to include policy instruments related to energy transmission and distribution, as long as they were related to sustainable energy or energy savings.

This rigorous cut-off might mean that specific policy instruments that are indirectly related are excluded. These might include any specific policy instruments aimed at farmers, since this research solely focusses on any policy instruments that are applicable for the office environment.

A final limitation is that policy is always evolving. For some policy instruments the changes are communicated long ahead (such as the reform of the Low Voltage Directive), whereas others change every year and are communicated within much shorter timeframes (such as the EIA).

7.5.3 Theoretical limitations

The theory on Strategic Niche Management has a focus on the empowering of technological niches and market niches to help them become a full market (or regime as they are called in the SNM model). However, the current status of DC in buildings is far from being a market niche, but more at the start of a small technological niche.

In this research the focus has most of all been on shielding and nurturing the innovation and a lot less on empowering the innovation.

This is mainly since in the first stages of the innovation the focus mainly lies on creating space for experiments, meaning that this place has to be shielded from external market influences and that it has to be nurtured by the stakeholders in the form of time and money to run the experiment. There is however no real focus on empowering yet since the technology has to prove itself first. However, the first steps in empowering do take place in that stage since it will become clear how far there is a fit with the existing regime and if any changes need to take place in it in order to fit DC distribution in buildings in it.

7.6 Theoretical implications

Following from the results, the research has several theoretical implications for both the SNM model, as well as for research on policy instruments.

7.6.1 Theoretical implications for SNM

Within this research part of the of the SNM model has been used for the design of an experiment from which a market niche might start. This differs from the original aim of designing policy (instruments) to help the development of sustainable innovations. This new application of the model shows that most of the model can be used for sustainable innovations that are one stage before creating a niche market.

The difference however between the original and this new application comes from the fact that in the new application the focus lies most of all on nurturing and shielding, whereas in the original application the focus also lies on empowering. This difference comes from the fact that the innovation has not reached a level of maturity for it to reach the market. The rest of the model, however, is still very relevant for the innovation since the problems related to sustainable innovations are also applicable in earlier stages and so the protected space is still needed for the innovation to grow. It is therefore suggested that the first two parts of the model are used as a guide in designing experiments for sustainable innovations so the step towards the market will be smaller later. One should however also keep an eye out to see how the innovation fits in the existing regime so it can be empowered for that in the later stages.

As a first step towards this model the narrative from chapter six is used as a starting point from which an SNM experiment cycle is designed. This leads to a model as shown in figure 6.1, in which the six steps of the narrative are shown in a loop. This model should be further refined and validated by applying it to real life examples.

7.6.2 Theoretical implications for research on policy instruments

This research also shows some gaps in the research on policy instruments, especially in relation to energy saving innovations. The literature on policy instruments aimed at energy reduction is very rich. A quick search for the keywords: "Energy saving policy" in the journal Energy Policy leads to a total of 7141 suggested results[6]. However, the vast majority of these articles are aimed at the general process of reducing energy and policy instruments related to that, but not on policy instruments that can help an energy saving innovation reach the market.

For sustainable energy generation this is different. The most comprehensive research on policy instruments for helping sustainable energy has been done in the UK by Foxon et al. (2005). In this research they have analysed all policy instruments aimed at sustainable energy within the UK in all stages of innovation. In the literature on energy saving, however, there is a gap for this kind of study. A potential new study could therefore focus on replicating the Foxon et al. (2005) but this time for energy saving policy instruments. Within this research the scope has merely been on the demonstration phase of innovation, but not on the other four phases treated in the Foxon et al. (2005) study so this study should be extended to include all phases from

6. Search conducted on 6 July 2015.

R&D to fully commercial. From there on it would be nice to compare that study to the currently available instruments for both energy reduction and sustainable energy generation and see if there is a fit or a total lack of fit between the study and the instruments that show the best performance. This could then lead to a discussion on the currently available instruments and maybe an adjustment of these on the longer term.

When discussing the instruments it would also be a good idea to keep the SNM approach in mind, thereby focussing on a certain level of protection that has to be reached for the innovation to reach maturity and also on when to break down this protection. Also on the exact timing of breaking down protection the literature can be advanced, since most of the times it is not clear at what point in time to do this.

7.7 Practical implications

Next to the theoretical implications also some practical implications follow from the results.

7.7.1 Policy

The outcome of this research shows that there are relatively few policy instruments aimed at energy saving innovations provided by the Dutch Government and that these are not very diverse. Almost all instruments are generic instruments aimed at energy reduction in general. A fair share of the instruments is aimed at providing low-interest loans & fiscal incentives for renovation projects that use products that are much further in their innovation curve than DC currently is.

There are also some general R&D instruments available, including the RDA and the WBSO that can be used in this case. Specifically for energy innovation demonstration projects however only one instrument is available, the DEI. The problem with this instrument is that it has very strict rules when applying and is only interesting for larger sums of money. Also, another DC demo project has won the DEI subsidy tender, making the chances for another DC demo project nearly null (Dieleman, 2015).

Considering the practical implications of remodelling an office to run on DC, the output shows that it should be possible to run an office on DC in theory. The financial case shows that the payback times are currently longer than acceptable for the client in this case, but since the project is still in the demonstration phase it should not be the main reason for not starting a real experiment.

A final practical implication of the research is the model of designing an demonstration SNM experiment. Although this model is purely based on a theoretical narrative it can be used in practice to design SNM experiments.

8. Conclusion

The potential for direct current in the office environment is clear. However, it cannot reach the market without first of all receiving some protection to help it become competitive in the current market.

On the technical side there are some low barriers that can all be overcome, on the rules and regulations side there are, as it seems, no barriers and only on the financial side a somewhat bigger barrier is found.

This means that in the basis we can say that there is a business case for DC in the office environment that allows the set-up of a SNM experiment. Keeping this in mind, we can also answer the main question of this research: How can a SNM experiment for direct current in the office environment make use of policy instruments?

8.1 Policy map

In total 84 different policy instruments in six categories were found spread out over the three geographical levels; Provincial, National and European. 55 of these are generic instruments and 29 have a niche focus.

The most interesting notions are that the Dutch government is the only one offering all six types of instruments, whereas the other offer only four (EU) or two (Provinces) of the types of instruments. Also in the subsidy part interesting differences are found between the parties, with the provinces only offering investment subsidies, whereas on the other hand the Dutch government only offers niche-subsidy tender instruments and the EU only offers generic sub-subsidy tender instruments. By doing this they can probably all reach their own specific goals in the best way.

8.1.1 Applicability of instruments

Considering the options offered by the existing policy instruments, a fairly large amount is already applicable to DC, mainly because these instruments are very generic. Next to that another large part of the instruments can be made applicable by undergoing a stretch-and-transform process, where the main goal is to include DC in the existing instrument, sometimes by simply explicitly stating DC as an energy saving option. This is likely to happen when DC has moved on from the demonstration phase to the pre-market phase and the actual energy savings are proven. When this happens it will also be under the influence of the energy saving obligating laws.

8.1.2 Application to the experiment

Out of the large amount of applicable instruments to DC only a small amount is applicable to this specific experiment. This comes from the extra boundary conditions, and the fact that most EU instruments focus on projects with large budgets. Still, seven instruments are deemed applicable to this experiment by providing some protection. These are:

- **Statutory obligations:** 'The Building Code'
- **Investment subsidy:** 'Kansen voor West II'
- **Subsidy tender:** 'SDE+' (when solar PV panels are added to the experiment, otherwise this one is non-applicable)

- **Fiscal incentives:** 'WBSO', 'RDA' and 'EIA' for the investments in both time and machinery for the experiment
- **Low interest loans:** 'Energiefonds Utrecht'

Knowing that these instruments influence the experiment, the impact on the business case becomes clear. The statutory obligation that is applicable to the experiment does not have a very big impact currently. The building code uses the NEN1010 standard for electrical installations in buildings, which is DC-proof.

The different financial instruments do show a lowering of the investment price and therefore an improvement of the business case. The actual impact of the fiscal incentives has been calculated since those costs are clear, and a good estimate has been made on the low-interest loans, which both show that the business case improves even further. Also the addition of solar PV panels and the application for SDE+ subsidy has been calculated and show an improvement in the business case.

The actual impact of any investment subsidies is however unclear, mainly because nobody can tell how much subsidy is granted to a project unless an actual application is made. It is however calculated how much money should be added to reach preferred payback times, which can be used when applying for any (investment) subsidies.

In the policy map also a series of instruments have been identified that are not yet applicable to DC, but that are likely to influence the energy price. These include a series of generic instruments aimed at energy reduction that might lead to higher prices. On the other hand the overproduction of sustainable energy systems at certain times might also lead to lower prices. The impact of this on the business case has also been calculated and this shows that a change in energy price shows that the gap in the financial case grows with about €10.000 for a 2% decline and shrinks with about €10.000 for a 2% rise in energy price. This makes for a -10% to +10% difference in the total financial business case.

Despite the protection offered by the policy instruments the business case remains negative for all energy prices. This should however not be a reason to kill the project since this should be treated as an experiment from which all team members can learn. The costs of this learning, or R&D, are then the extra costs that need to be paid in order to close the business case.

A first set-up of an actual experiment is given in and modelled into a six-step model, shown in figure 6.1. The main goal, as stressed throughout the experiment is the learning that all members of the team will do while running the experiment. Next to that the other aims of the SNM model are used in the designing, except for the empowering since there is no niche market yet.

8.2 Gap in the map?

One open question remains; the title question. Is there a "Gap in the map?" considering the policy instruments that are available for setting up a SNM experiment with DC in the office environment.

The answer, at least for the demonstration part in the innovation S-curve, is no. Although most of the instruments are all generic, the different policy instruments as described by both Foxon et al. (2005) and Haas et al. (2008) for the demonstration phase are available in the Netherlands so for now there is protection from policy instruments for any experiments taking place in this niche.

It is only when the next step, i.e. the actual creation of a protected market niche, is taken that a gap is found in the map. Although it is not necessary to have all instruments from both of the models there is still room for three types of instruments that do not exist yet. A specific tax deduction instrument can be quite easily made by extending an existing one (either the EIA or MIA/Vamil), just as with thepublic procurement, whereas the statutory obligations are much further away and less likely to be developed.

Keeping this in mind it is likely that for the coming years the gap will remain in existence when it comes to protection for a market niche. It is likely that this will exist until the technology has proven to be superior to the existing one and that it has the potential to create an actual market niche.

8.3 Further research

Both in theory and in practice advancements can be made upon this research.

8.3.1 Theory

As already discussed in chapter seven, there are some gaps in the literature on both policy instruments for energy saving innovations and on the use of the SNM model for innovations that are pre-niche market.

In this research a large amount of policy instruments were found that are applicable to DC, though only a small amount is applicable to this specific experiment. This was only looking into the demonstration phase of innovation, but there are two more phases (pre-commercial & supported commercial) that an innovation will go through before reaching the unprotected market. An interesting research gap is therefore to create a map of policy instruments in which all four phases of the innovation S-curve are handled for energy saving innovations, like the research Foxon et al. (2005) did for sustainable energy generators.

Another interesting gap in the literature comes from applying the SNM experiment loop to early stage sustainability innovations so that experiments can be developed with the basic idea of SNM behind it. However, in the demonstration phase the focus should be most of all on shielding and nurturing of the innovation and not yet on empowering since the niche market does not exist yet although this cannot be left out completely since it has to be treated in later phases.

Finally it would be interesting to extend the literature with some more business cases on this subject. First of all it is interesting to replicate this business case on a different type of office to check the generalizability of the results. Also, it is suggested to create a business case for the building of an entire new office, since in that case a clear comparison between AC and DC can be made. A third and final suggestion is to create a business case for the creation a micro grid on a small business park in combination with decentralized power generation of sustainable energy sources to see the impact of scaling up the DC micro grid to a larger scale.

8.3.2 Practice

The outcome of the research shows that DC in the office environment is theoretically a very interesting innovation. It is therefore proposed to run a practical experiment in which the business case can be put to the test and in which the actual learning-by-doing can take place.

This also means that the SNM experiment and the cycle coming from it can be tested in a real life situation, making it a more valuable tool with practical experience.

8.4 Final recommendations

As a final recommendation, a simple one: Just. Do. It. Pull the trigger, take a shot and start a real-life experiment. Because from doing something one can learn the most, especially when it comes to applying innovations in real life.

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Appendix A. List of interviewed stakeholders

Company	Title(s) interviewed stakeholders
ABB	Sales engineer
ABN AMRO	Advisor sustainability
Alliander	Multiple trainees working on DC projects
Direct Current b.v.	CEO
	Research intern
Emerson	Sales representative
Grontmij	Senior Projectleaders
	Junior Project team members
	Head of the Grontmij subsidy platform
Haagse Hogeschool	Researcher working on DC projects
Joulz	Business line manager decentralized networks, responsible for Direct Current
Leertouwer	Advisor Sustainable Energy focussing on DC
Rijksdienst voor Ondernemend Nederland	Advisor Energy Innovation
Stedin	Operational Grid Coordinator working on designing an electro technical experiment with DC
Wijffels Subsidie Advies	Advisor EIA subsidies

Appendix B. Design of the model for calculation of the business case

To calculate the total costs and efficiency gains of remodelling the office a model has been developed. In this appendix the different steps are shown in creating the model.

B.1 Step 1: Identification of the apparatus in the office.

As a first step in creating the model a tour was made through the entire ABN AMRO office Daalsesingel in Utrecht[7]. The tour led us from the garage and the café in the basement all the way up to the technical area at the roof of the building.

For each electricity using apparatus the following information was noted down:

- Name and short description
- Power rating (kW)
- Does it run on AC or on DC?
- Grid connection: 230V 1-phase or 400V 3-phase
- Number of apparatus with that power rating

After this tour for each apparatus the efficiency of the AC/DC conversion was looked up in the catalog of Garbesi, Vossos & Shen (2011).

B.2 Overview of apparatus

In total 53 different apparatus were found that are constantly connected to the building grid, divided over 5 different groups. These are presented in table B.1.

Of the above mentioned apparatus only one is currently running on DC: the telephones. All other apparatus are connected to either 230 or 400V AC.

7. ABN AMRO regional office Utrecht, Daalsesingel 71, 3511 SW Utrecht, The Netherlands.

To be able to do further calculations two apparatus were not further investigated; the electricity meter and the fuses. The electricity meter does not have to run on DC since the conversion from AC to DC will take place in the building thereby putting the meter outside the scope. Second, for the fuses it is assumed that these will be replaced with equally performing DC protection measures for which the costs and efficiency measures are included in the rectifier.

B.3 Calculation of power use

For the other 51 apparatus an estimate is made of the time that it is used throughout one year. Using this information the total power use per year is calculated, assuming that each apparatus always uses it maximum power rating. For example, the coffee machine:

- Power rating: **3,6 kW**
- Number of coffee machines in building: **9**
- Time used: 12 hours a day times 254 working days per year = **3048 hours**
- Total power use per year: 3,6 (kW) x 3048 (hours) x 9 (machines) = **98.755 kWh**

This has been done for each separate apparatus leading to a total electricity use of 2,352,626 kWh per year. The output of these calculations is too high in comparison to the actual data, which show an electricity use of 900,000 kWh per year. The calculated values are however useful to determine how much energy can be saved per year. This is done by comparing the current usage to the usage when there is no

Table B.1. **Overview of the different apparatus in the building.**

#	Description	Vin	AC/DC	Power (kW)	Amount
	Building installations				
1	EV charger	230	AC	3,70	2
2	Electric gate parking garage	230	AC	0,750	2
3	Electricity meter	-	AC	-	-
4	Fuses	-	AC	-	-
5	Wastewater pump	230	AC	4,00	2
6	Heating element (at the area in which the water pipe enters the building)	230	AC	1,00	1
7	Drinking water pump	230	AC	0,550	1
8	Heating water pump	230	AC	0,400	2
9	Motor for elevator	400	AC	8,20	2
10	Frequency converter for elevator	400	AC	5,00	2
11	HVAC installation	400	AC	255	1
12	Cooling water pump	400	AC	5,50	3
13	Kitchen extractor fan	230	AC	2,50	1
14	Air conditioning pump (1)	400	AC	10,0	1
15	Air conditioning pump (2)	230	AC	0,151	1
16	Air conditioning pump (3)	400	AC	0,770	1
17	Thermal wheel	230	AC	0,400	1
18	Air conditioning input	400	AC	11,0	2
19	Air conditioning output	400	AC	7,50	2
20	Cooling unit server area (on the roof)	230	AC	0,330	2
21	Cooling fans cooling unit (on the roof)	230	AC	0,500	2
22	Pump heat exchanger outside (on the roof)	400	AC	1,00	3
23	Pump heating system degasification	230	AC	1,40	1
	Office area				
24	Coffee machine	230	AC	3,60	9
25	Large multifunctional printers/copy machines	230	AC	1,76	20
26	Small printers	230	AC	0,350	2
27	Computers	230	AC	0,240	526
28	Computer monitors	230	AC	0,022	526
29	Telephones	48	DC	0,0100	526
30	Fluorescent lighting	230	AC	0,0200	401
31	Meeting rooms small (max 6 persons)	230	AC	0,272	9
32	Meeting rooms large (over 15 people, including multimedia cupboard)	230	AC	0,320	17
	Kitchen/restaurant area				
33	Contact grill	230	AC	3,50	1
34	Refrigerator (8m3) (-2 degrees C)	230	AC	0,900	1
35	Fridge (4m3) (-18 degrees C)	230	AC	1,00	1
36	Cooling unit open presentation closed back	230	AC	0,500	2
37	Cooling unit open presentation no top closure	230	AC	0,700	1
38	Cooling work bench	230	AC	0,500	1

Table B.1 (continued)

#	Description	Vin	AC/DC	Power (kW)	Amount
39	Refrigerator drinks	230	AC	1,10	1
40	Warming showcase	230	AC	3,00	1
41	Grill	400	AC	9,00	1
42	Juice machine	230	AC	0,300	1
43	Dishwasher	400	AC	12,0	1
	Server area				
44	Uninterruptible power supply 1 - 60kVA	230	AC	6,00	1
45	Uninterruptible power supply 2 - 80kVA	230	AC	8,00	1
46	Computers/servers	230	AC	0,250	15
47	Computer monitors	230	AC	0,100	5
48	Cooling unit server racks	400	AC	7,20	2
	Café in the basement				
49	Refrigators	230	AC	0,200	2
50	Boiler (small)	230	AC	2,20	1
51	Fridge	230	AC	0,750	1
52	Beer pump	230	AC	0,110	1
53	Air conditioner café	400	AC	0,370	1

AC/DC converter at the apparatus. The usage without AC/DC converter is calculated by multiplying the current usage by the efficiency factor for the AC/DC converter of an apparatus. For the coffee machine this is the following:

- Yearly energy use: **98.755 kWh**
- Efficiency AC/DC converter: **0,87**
- Yearly energy use without AC/DC converter: 98.755 x 0.87 = **85.917 kWh**

B.4 Calculating efficiency

By calculating this for each separate apparatus and adding these all up the new efficiency of the system without AC/DC converter is calculated.

- Total energy use with AC/DC converter: **2.352.626 kWh**
- Total energy use without AC/DC converter: **2.061.321 kWh**
- Efficiency gain of losing the AC/DC converter at the apparatus: **12.4%**

Other efficiency gains in the system are made in reducing the cable losses. To determine the avoided losses in this part of the system a comparison was made for several cable thicknesses, lengths and amounts of Watts transported where the AC system voltage has been set on 230V and the DC voltage on 350V. On average this showed a value of 2.8% higher efficiency of the DC cable compared to the AC cable due to the lack of induction & skin effect.

On the other hand there are also two converters added to the system. First of all a rectifier is added just behind the meter for rectifying the incoming AC. For this rectifier an efficiency of 97% is assumed. Second a series of small 350Vdc/ 20Vdc converters are needed for low-voltage apparatus such as the computers and the LED lighting. For these converters an efficiency of 97% is assumed, though the designers aim at 98% efficiency (Stokman, CEO Direct Current B.V., 2015). These rectifiers are only added to the low-voltage apparatus that make up 14% of the total energy use, leading to a loss of 0.42% of the total energy use.

Scenario 1

Considering the above, the expected energy reduction for scenario 1 would be:

- **+12,4%** by losing the AC/DC converter
- **+2,8%** by less losses in the cables
- **-3,0%** by adding a central AC/DC converter
- **-0,42%** by adding low-voltage DC/DC converters
- In total: **11,8%** efficiency gain

Scenarios 2a and 2b

In scenarios 2a and 2b frequency converters are added to the electrical motors that are also assumed to be 97% efficient. Since electro motors in the building use about 57% of all the electricity this would lead to a reduction of (0,03 x 0,57=) 1.75% in the total energy use.

This leads to a total efficiency gain of:

- **+11,8%** efficiency gain (scenario 1)
- **-1.75%** efficiency loss due to frequency converters
- In total: **10%** efficiency gain for scenarios 2a and 2b

Scenario 3

Scenario 3 is the odd one out here since it only focusses on part of the building. In this part of the building however the relative losses are the highest in the AC/DC converters leading to the following efficiency gain:

- **+5.3%** efficiency gain (compared to the total) from losing the AC/DC converters in the office area
- **+2.8%** by less losses in the cables
- **-3.0%** by adding a central AC/DC converter
- **-0.42%** by added low-voltage DC/DC converters
- In total: **4.7%** efficiency gain of the total energy use

However, when comparing the energy use only on the groups effected in scenario 3 an efficiency gain of 13.7% is found, making this a very interesting part of the building to start the remodelling.

B.5 Prices

For each apparatus included in the calculation a price was sought to convert the apparatus so it can run on DC. To determine the price the following rules were followed:

- For a motor: find the price for a DC model with the same power rating at www.elektromotorshop.com
- When there is no DC model is available, pick the AC model with the same power rating and multiply the price by 5 to get an idea about the price for a DC model (Rotor B.V., 2015)
- Price of a frequency converter found on www.elektromotorshop.com
- Price of kitchen equipment found via Beuk Horeca, multiplied by 2 to be on the safe side for changing parts inside the apparatus
- The printers and all machines with a thermostat will need to undergo a small modification costing €100
- Computers, monitors and other multimedia apparatus, as well as the grills in the kitchen don't need any conversion

Also, for each apparatus an estimate has been made for the time needed to change the apparatus to make it run on DC. For this it is assumed that an electrician costs €50,- per hour. Next an estimate has been made for the costs of designing the changes in the electrical grid in the building. For scenarios 1 and 2 it is estimated that this will cost 100 hours, for scenario 3 it is estimated that this will costs 50 hours. For this a junior advisor will be used costing €79,- per hour.

Combining all this an estimate has been made for remodelling the entire building (scenarios 1 and 2) or only the office area (scenario 3a, b and c) by adding all costs up.

For the energy price the number mentioned for banks in the ECN Report ECN Energietrends 2014 is used (Gerdes, Marbus, & Boelhouwer, 2014). By combining this with the expected reduction in energy use the total savings in euros has been calculated.

Appendix C. Map of policy instruments

In the policy map all the found instruments have been placed. Per instruments there are 9 columns. Per column the following information can be found:

- **#** – Number of the policy instrument. A number with a letter behind it is a sub-instrument.
- **Issuer** – Institution that has issued the document in which the policy is described
- **Key goals** – The key goals of the instrument
- **Mechanism** – The mechanism that is used by the policy instrument to reach the expected outcome
- **Outcome** – The expected outcome of the policy instrument
- **App. DC** – Is this instrument applicable to DC? A 3-point scale is used, where 1 means not applicable, 2 means applicable after going through a stretch-and-transform process and 3 means directly applicable
- **Remarks applicability DC** – Remarks about the chosen point on the 3-point scale of DC applicability
- **App. exp**. – Is the instrument applicable to the experiment as described. Scale: Yes or No.
- **Remarks app. experiment** – Remarks about the applicability of the instrument to the experiment.

The full policy map can be found on the next pages.

Table C.1. Overview of the policy instruments

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
				The Netherlands - Statutory obligations/(alleviated) legislation - Generic					
1	Besluit hernieuwbare energie vervoer 2015	Ministry of Infrastructure & Environment (I&M)	More sustainable transportation sector	Obligation to reach at least a percentage of 5% in 2015, up to at least 10% in 2020, after which new agreements will be made	Higher share of sustainable transportation fuels	3	Instrument aims at higher investments in electrical vehicles. Electric vehicles run on DC and some types are charged via DC, making this instrument indirect applicable to DC.	No	
2	Activiteitenbesluit Milieubeheer - Artikel 2.6 / 2.15: Energiebesparingsplicht	Min I&M	Reduce the energy use of companies	Obligation to take any measures that do so which have a payback time of less than 5 years	Higher investments in energy efficiency measures, lower emissions of GHGs	2	Law obliges companies to reduce their energy use and do any investments that have a payback time of 5 years max. DC shows reduced energy use, but currently with a longer payback time, so it will be made applicable when prices are reduced.	No	
3	Beleidsregel mededinging en duurzaamheid	Min. EL&I	Help sustainable inititiatives overcome competitive barriers	Alleviated regulations that gives room to companies to co-operate to achieve advantages over a longer period of time, where the initial costs may be higher for consumers	More sustainable ways of doing business	2	Room to temporarily alleviate the rules and regulations to test sustainable energy projects. DC is not explicitly named in this instrument, so it should be stretched to include DC to make it applicable.	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
4	Besluit experimenten decentrale duurzame elektriciteitsopwekking	Ministry of Economic Affairs (EZ)	Find best practices for the electricity grid of the future	Alleviated rules, exceptions from the electricity grid law	Best practices and examples of the electricity grid of the future	2	Instrument allows room for experiments with decentral energy generation, of which DC can be a part. DC is however not explicitly named in this instrument, which means that the instrument should be stretched to include this.	No	
5	BLKB2015-370, AM, Belastingen op milieugrondslag	Ministry of Finance	Lessen the impact on the environment	Taxes to be paid upon the amount used	Lower use of the taxed parts	2	Instrument obliges companies to pay taxes upon the amount of environmental burden such as CO_2 emissions. DC promises a higher energy efficiency, therefore making this instrument directly applicable if the higher efficiency is proven.	No	
6	Bouwbesluit	Ministry of Internal Affairs (BZK)	Enforce safe and sustainable buildings	Rules and regulations on every aspect of the building	Safety and sustainability for the users of a building	3	This instrument sets obligations for all buildings in the Netherlands, and is therefore also applicable to buildings using DC.	Yes	Current law
7	Energielabel utiliteitsbouw	RvO, Min. BZK	Influence customers to choose for more energy efficient buildings	Label each building that's rented/sold with a label that indicates the amount of energy it uses per squared meter	Higher investments in energy efficiency, customers choosing more energy efficient buildings	2	The EPC currently does not include DC. The EPC should be stretched to include DC distribution grids to make this instrument applicable.	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
8	Green Deal	RvO	Help sustainable innovations reach the market faster	Relieve of or clearer view on rules, bringing together market parties and providing comunication support	Faster time to market and easier testing	1	Green Deal Gelijkspanning is already closed 8A	No	
9	MJA3: Meerjaren afspraken energie efficientie	RvO	Reduce energy usage of companies	Agreement with companies	Reduced energy use	2	Agreement between the government and a series of large corporations to reduce their energy use. DC promises a reduction in energy use making this instrument applicable if it is proven.	No	
10	Ontwerp-besluit etikettering energieverbruik energiegerelateerde producten	Min. EL&I	Simulate the buying of energy efficient apparatus	Obligatory label with information about the energy use of the product	Higher sales in more energy efficient products and decline in less energy efficient products	2	Products that use DC are generally more efficient than their AC counterparts. The instrument is however solely aimed the consumption side. The instrument could be transformed to label electricity grids in buildings in the same way.	No	
11	Salderen	Ministry of Economic Affairs (EZ)	Promote the production of sustainable energy by consumers	Force energy companies to take back the energy that's produced by consumers when they are not using the electiricity	Higher investments in sustainable energy production by consumers	1	Indirect applicability due to higher output of sustainable energy generation systems using DC, however also opposing since it favors people to feed in their extra energy instead of using DC battery systems in their houses. Could be transformed to only allow DC systems.	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
12	Wet implementatie EU-richtlijnen energie-efficiëntie	Rijksoverheid	20-20-20	Rules and regulations on every aspect of energy efficiency	Reduced GHG emissions, higher investments in energy efficiency	2	Law obliges companies to reduce their energy us. DC promises a reduction in the energy use, therefore making this instrument applicable if it is proven.	No	
The Netherlands - Statutory obligations/(alleviated) legislation - Niche									
13	Besluit tot toepassing van Rijkscoördinatieregeling voor project transmissiesysteem op zee Borssele	Ministry of Economic Affairs (EZ)	Create an electricity grid on the sea	Obligation by the Ministry	Easier and faster connection of off-shore windfarms to the electricity grid on land	2	Instrument is applicable when it is decided to create a HVDC grid on the North sea. The instrument leaves room for choosing either AC or DC, so it can be stretched to make DC the preferred option.	No	
8 a	Green Deal gelijkspanning	RvO, Joulz, Siemens, Direct Current BV	Show feasibility of DC grids	Living lab, relieve of rules	More sustainable option	3	Green Deal for DC, directly applicable.	No	
8 b	Green Deal Zero-Emission stadsvervoer	Min. I&M and many others	Find best practices	Living lab	Best practices and cases in which inner city transport is done using zero-emission vehicles	2	DC not explicitly named, but DC techniques (battery powered Evs) are part of the Green Deal. This instrument could be stretched to include DC chargers for the battery powered EVs.	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
14	Ontwerpbesluit rendementseisen kolencentrales	Ministry of Infrastructure & Environment (I&M)	Close old coal-fired power plants	Minimum efficiency obligation that is higher than the efficiency of the oldest plants	Earlier phase-out of old coal-fired power plants	1	The instrument helps by growing the amount of sustainable generated energy, of which DC can indirectly benefit due to the enhanced performance of DC energy systems. However, the instrument can not be transformed to make it applicable to DC.	No	
15	Regeling garanties van oorsprong voor energie uit hernieuwbare energiebronnen en HR-WKK-elektriciteit	Rijksoverheid	Promote the production of sustainable energy	Give out warranties to each sustainably produced unit of Energy	Higher investments in sustainable energy, more sustainably produced energy	1	The instruments solely focusses on the generation of sustainable energy, not on other parts of the electricity system.	No	
	The Netherlands - Investment subsidies - Generic								
16	Energiesprong - Kantoor vol energie	Platform 31 for Min. BZK	Make existing buildings more efficient	Share knowledge, create market, give out subsidies	More sustainable built environment	1	FINISHED	No	
17	Ondersteuningsprogramma Energie	Vereniging Nederlandse Gemeenten	Provide support for more energy efficient buildings	Support from municipal level, subsidies?	Reduced energy use of buildings in a municipality	2	Instrument aimed at local governments that want improved energy efficiency. DC is currently not a part of this, so the instrument should be stretched to make DC a part this and so make it applicable to DC.	No	
	The Netherlands - Investment subsidies - Niche								
	None								

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
The Netherlands - Subsidy tenders - Generic									
	None								
The Netherlands - Subsidy tenders - Niche									
18	Eureka-label	RvO	Provide exposure and additional help to innovations	Quality label	Higher succes (abroad) for the company	3	Applicable to DC projects, as long as co-operation is sought with other European countries	No	
19	Demonstratie energie innovatie (DEI) (TSE)	RvO	Show feasibility of the innovation and have high impact on Dutch economy	Subsidy tender	Projects with high impact on the Dutch economy and high levels of energy reduction	3	DC is a part of this instrument, subsidy has been granted to another project.	No	
20	Hernieuwbare energie (TSE)	RvO	Lower subsidy levels of SDE+	Subsidy tender	Show technology that allow current systems to produce more energy at lower prices	1	Instrument is aimed at the generation of sustainable energy, not at other parts of the electricity system.	No	
21	iDEEGO (TSE) (innovatie Duurzame Energie en Energiebesparing Gebouwde Omgeving)	RvO	Help the start of energy efficient innovations	Subsidy tender	Help innovations cross the chasm	2	DC not explicitly named. For certain applicablility this instrument should be stretched to include DC.	No	
22	Intelligente Netten	RvO	Accelarate transition towards smart grids	Subsidy tender	See iDEEGO	3	DC grid in Greenhouse PrimA4a is part of this program, program is currently finishing with final congress in september 2015	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
23	"Samenwerken Topsector Energie en Maatschappij STEM (TSE)"	RvO	Accelarate Energy transition	Subsidy tender	Deliver relavant knowledge and insights of human behaviour and acceptation	3	Instrument aims at the entire energy transition, of which is a part. However only applicable when the focus shifts to the "soft side" by considering the impact on users.	No	
24	Stimulering Duurzame Energieproductie (SDE+)	RvO	Enlarge the share of renewable energy on the Dutch grid	Subsidy tender, subsidy per kWh produced energy, where the amount of subsidy is higher when requests are later in the year	Higher share of market-ready, but higher priced sustainable energy production units	1	Subsidy tender aimed at the generation of sustainable energy. Indirect applicable due to higher output of systems using only DC. Could be stretched and transformed to create a market system for DC systems in buildings, though this is difficult.	Yes	Applicable when a large rooftop solar system is added (scenario 3c).
25	Subsidieregeling voor demonstratieprojecten, haalbaarheidsstudies en kennisverwerving (DHK) Closed, soon to be DHI (Investeringsvoorbereidingssubsidies)	RvO	Move part of the research to upcoming countries	Subsidy	Knowledge	3	Applicable to DC as long as the pilot project is done in a upcoming economy.	No	
The Netherlands - Fiscal incentives - Generic									
26	EIA	RvO	Make companies invest in sustainability	Tax deduction scheme by accelerated depreciation of 41,5% in year 1 after investment	Higher investments in sustainability for companies	1	The general instrument EIA cannot be made to fit, only specific sub-sections can be stretched and transformed	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
26 a	EIA Code 210000: Energieprestatie-verbetering van bestaande bedrijfs-gebouwen	RvO	Make companies invest in sustainability	Tax deduction scheme by accelerated depreciation of 41,5% in year 1 after investment	Higher investments in sustainability for companies	2	Considers EPC, the reduction in energy use due to DC is currently not explicitly quantified in this. The EPC should be stretched so DC becomes a part of it to make it applicable	No	
26 b	EiA Code 310000: Technische voorzieningen voor energiebesparing in of bij bestaande bedrijfsgebouwen	RvO	Make companies invest in sustainability	Tax deduction scheme by accelerated depreciation of 41,5% in year 1 after investment	Higher investments in sustainability for companies	2	DC is not explicitly named in this instrument and the calculated values for DC are too low to be able to apply. The instrument should be stretched considering the improved performance of DC grids so this instrument will be made applicable to DC or the performance of DC will have to improve.	No	
27	MIA (Milieu Investerings Aftrek)/Vamil (Willekeurige Afschrijving Milieu Investeringen)	RvO	Make companies invest in sustainability	Tax deduction scheme by 13,5%/27%/36% additional amortization from profit (MIA) or 75% amortization in a year	Higher investments in environmental friendly products for companies	1	The general instruments MIA/Vamil cannot be made to fit, only specific sub-versions can be stretched and transformed	No	
27 a	MIA code D6116: Duurzaam gerenoveerd of zeer duurzaam nieuw gebouw volgens BREEAM-NL	RvO	Make companies invest in environmental friendly products	Tax deduction scheme by 27% additional amortization from profit (MIA)	Higher investments in environmental friendly products for companies	2	DC is currently not a part of BREAAM scoring. BREAAM scoring should be extended to make it applicable to DC.	No	

Table C.1. (continued)

#		Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
27	b	MIA code E6117: Duurzaam nieuw of grootschalig gerenoveerd gebouw volgens BREEAM-NL	RvO	Make companies invest in environmental friendly products	Tax deduction scheme by 13,5% additional amortization from profit (MIA)	Higher investments in environmental friendly products for companies	2	DC is currently not a part of BREAAM scoring. BREAAM scoring should be extended to make it applicable to DC.	No	
27	c	MIA code G6115: Zeer duurzaam gerenoveerd of verdergaand zeer duurzaam nieuw gebouw volgens BREEAM-NL	RvO	Make companies invest in environmental friendly products	Tax deduction scheme by 36% additional amortization from profit (MIA)	Higher investments in environmental friendly products for companies	2	DC is currently not a part of BREAAM scoring. BREAAM scoring should be extended to make it applicable to DC.	No	
27	d	MIA/VAMIL code E6111: Duurzame renovatie bestaand utiliteitsgebouw volgens de maatlat van Groen Financiering	RvO	Make companies invest in environmental friendly products	Tax deduction scheme by 13,5% additional amortization from profit (MIA)	Higher investments in environmental friendly products for companies	2	The label of instrument 3 is needed. DC is however currently not included in the 'Regeling Groenprojecten' instrument, so the 'Regeling Groenprojecten' instrument should be stretched to include DC to make this MIA/Vamil code applicable.	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
28	Research & Development Aftrek	RvO	Stimulate all stages of R&D in companies	Tax deduction scheme for costs incurred, where below 150 R&D hours per month a forfait of 15eur/hour is paid; When more hours are made of costs are above 50.000eur an estimate is made	Higher spending on R&D	3	As long as DC is in the pilot phase the instrument is applicable.	Yes	DC is currently in pilot phase, so instrument is applicable.
29	Wet Bevordering Speur- en Ontwikkelingswerk	RvO	Stimulate all stages of R&D in companies	Tax deduction scheme for hours worked on R&D of 35% for the first 250.000 euro wage costs and 14% for wage costs above 250.000 eur	Higher spending on R&D	3	As long as DC is in the pilot phase the instrument is applicable.	Yes	DC is currently in pilot phase, so instrument is applicable.
The Netherlands - Fiscal incentives - Niche									
26 c	EIA code 210301: Debietregeling ventilator	RvO	Make companies invest in sustainability	Tax deduction scheme by accelerated amortization of 41,5% in year 1 after investment	Higher investments in sustainability for companies	3	Fans using DC motors are part of this instrument, therefore this instrument is applicable.	No	
26 d	EIA code 210506: LED-verlichtingssysteem	RvO	Make companies invest in sustainability	Tax deduction scheme by accelerated amortization of 41,5% in year 1 after investment	Higher investments in sustainability for companies	3	Applicable to lighting replacement with LED. Specific versions of DC lights can run on DC.	Yes	LED lighting is used in experiment.

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
26 e	EIA code 210601/ 220602/ 240601: HR-elektromotor	RvO	Make companies invest in sustainability	Tax deduction scheme by accelerated amortization of 41,5% in year 1 after investment	Higher investments in sustainability for companies	2	Instrument does not specifically name high efficiency DC pumps. The instrument should be stretched to include these to make it explicitly applicable to DC.	No	
26 f	EIA code 210602: Energieprestatie-verbetering van bestaande liften	RvO	Make companies invest in sustainability	Tax deduction scheme by accelerated amortization of 41,5% in year 1 after investment	Higher investments in sustainability for companies	3	Applicable to any type of DC motor and/or frequency converter, as long as energy label A is reached.	No	
26 g	EIA code 210905: Energiezuinig afzuigsysteem	RvO	Make companies invest in environmental friendly products	Tax deduction scheme by accelerated amortization of 41,5% in year 1 after investment	Higher investments in environmental friendly products for companies	2	This instrument is only aimed at measurement and control systems for fans, but not at the fans itself. Instrument should be stretched to include the actual fan to make it applicable to DC.	No	
26 h	EIA code 220212: Energiezuinige koel- en/of vries-installatie	RvO	Make companies invest in sustainability	Tax deduction scheme by accelerated amortization of 41,5% in year 1 after investment	Higher investments in sustainability for companies	3	Applicable to energy efficient cooling machines which give of a max. temperature of +16C. This can be reached by using high-efficient DC motors, thereby making this instrument applicable.	No	
26 i	EIA code 220222: Energiezuinige koeling van server-ruimten tot en met 100 m2	RvO	Make companies invest in sustainability	Tax deduction scheme by accelerated amortization of 41,5% in year 1 after investment	Higher investments in sustainability for companies	3	Applicable to any type of energy efficient cooling machines, inlcuding the models using DC systems.	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
26 j	EIA code 220604: Gelijkstroomventilator	RvO	Make companies invest in sustainability	Tax deduction scheme by accelerated amortization of 41,5% in year 1 after investment	Higher investments in sustainability for companies	3	Applicable to any fan that uses DC, also models that are outside of the building e.g. on the roof.	No	
26 k	EIA code 220912: Energiezuinige UPS	RvO	Make companies invest in sustainability	Tax deduction scheme by accelerated amortization of 41,5% in year 1 after investment	Higher investments in sustainability for companies	2	Currently only applicable to Rotary and 3-phase static UPS systems	No	
26 l	EIA code 221221/241221: Hoogfrequent hoogrendementslader voor tractiebatterijen	RvO	Make companies invest in sustainability	Tax deduction scheme by accelerated amortization of 41,5% in year 1 after investment	Higher investments in sustainability for companies	1	Only applicable to the AC technique of high frequency EV chargers.	No	
27 e	MIA/VAMIL code F3720: Oplaadpunt voor elektrische voer- of vaartuigen	RvO	Make companies invest in environmental friendly products	Tax deduction scheme by accelerated depreciation of 75% (VAMIL) in a random year and 36% additional amortization (MIA)	Higher investments in environmental friendly products for companies	3	Applicable to any EV charging system, including systems using DC.	No	
The Netherlands - Public procurement - Generic									
30	Energiegebruik vastgoed verminderen	Rijksgebouwendienst	Help innovations reach the market	Be launching customer for them	More successes of companies reaching the market with innovations	2	The government provides public procurement through this instrument, thereby focussing on innovations that reduce the energy use of their buildings. Applicable to DC when improved performance has been shown and the pilot phase is finished (i.e. Fit & Conform)	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
	The Netherlands - Public procurement - Niche								
	None								
	The Netherlands - Low interest loans - Generic								
8 c	C-152 Green Deal Expertisecentrum Financiering Duurzame Energieprojecten	RVO, Beraad Groenfondsen	Provide financing for sustainable energy production	Lower interest rates, reduced risk by sharing of information between RvO and banks	Higher investments into larger amount of sustainable energy production units	2	DC is currently not a part of this green deal, so this instrument should be stretched to include DC to make it applicable.	No	
31	Fund for Energy, Innovation, Sustainability and Technology – FEIST N.V.	RvO	Help starting entrepreneurs grow	Participation via Venture Capital	Growth of the company	3	Useful for start-ups working on DC.	No	
32	Nationaal Energiebespaarfonds	Ministry of Internal Affairs (BZK)	Make existing houses more energy efficient	Revolving fund of €300 million euros which gives out cheap loans	Growth in the number of energy efficient houses	3	Assuming higher energy efficiency of DC systems, home owners can get low-cost financing from this instrument. It is however not applicable to utility buildings.	No	
33	Regeling groenprojecten	RvO	Help Green projects reach cheaper financing	Label given out by the government, help by finding financers	Easier investments by people/companies in sustainable projects	2	DC not explicitly named, but the improved performance of DC grids considering the lower energy use should make this instrument applicable when this is proven.	No	
	The Netherlands - Low interest loans - Niche								
	None								

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
European Union - Statutory obligations/(alleviated) legislation - Generic									
34	Emissions Trading Scheme	European Union	Reduce GHG emissions	Obligatory scheme where companies have to pay to be allowed to put out GHGs	Reduction in the amount of GHGs that companies put out. More energy efficient ways of working	2	Instrument has an indirect effect on the development of DC. DC grids have a higher efficiency and so lower CO2 emissions, which leads companies to buy less certificates in the ETS. Applicable when technology has been proven.	No	
35	Ecodesign for energy-using appliances	European Union	Stimulate the design and production of energy efficient appliances	Legislation with minimal energy efficiency requirements	Reduced GHG emissions from the use of the appliances	2	This instrument uses legislation to enforce companies to design and manufacture more efficient appliances. This can transformed into an instrument that shows the efficiency of the electricity grid within buildings.	No	
36	Effort sharing decision	European Union	Reduce GHG emissions	Obligatory program where countries are responsible to reduce their total CO2 emission of the country, for parties not covered by the ETS	Reduction in the amount of GHGs that a country emits. More energy efficient ways of working and or using energy in general	2	Instrument is of indirect effect. The instrument obliges governments to do what they can to reduce the energy use of every company and person not covered under the ETS scheme. DC offers a reduction in the energy use, so therefore this instrument is applicable when the technology has proven itself.	No	
European Union - Statutory obligations/(alleviated) legislation - Niche									
	None								

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
European Union - Investment subsidies - Generic									
37	Cohesion Fund	European Union	Reduce the difference between EU countries	Subsidies and funding for projects	More equalized EU countries	1	Not available in the Netherlands	No	
38	European Regional Development Fund	European Union	Equalize the differences between the different countries	Subsidies to countries, further passed on to companies	Reinforce economic, social and territorial cohesion by redressing the main regional imbalances in the Union	1	Cannot be applied for directly. Subsidies are provided through the regional development programs (instruments 38a, 38b, 38c and 38d)	No	
European Union - Investment subsidies - Niche									
39	European Energy Programme for Recovery	European Union	Improve and Update the current energy system	Funding for Key Energy projects	A competitive, sustainable and secure energy supply for Europe	2	Program focusses on large electrical interconnectors between countries, which can be using DC. Not applicable to DC in buildings, but could be stretched to move the focus to DC in buildings.	No	
40	Connecting Europe Facility	European Union	Improve and Update the current energy system	Funding, accelarated licensing procedures and improved regulatory conditions	An integrated european energy infrastructure and energy market	1	Only applicable to HVDC projects that interconnect Europe.	No	
41	FET-Open - novel ideas for radically new technologies	European Union	Create more fundamental research	Provide subsidy to fundamental research projects with a technological opportunity	Higher investments in fundamental research	1	Instrument aimed at radical new ideas (Research). DC is currently further in the Demonstration phase so the instrument is not applicable.	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
42	GREEN VEHICLES 2014-2015	European Union	Optimal use of the possibilities of Evs	Research subsidy	Standardized methods and/or instruments aimed at electric vehicles	2	Research aimed at electrical vehicles, could be made applicable if DC chargers are included in the research project.	No	
43	NER 300 programme	European Union	Show feasibility of techniques	Funding for pilot projects	Higher investments in carbon capture and renewable energy R&D	1	Instrument is aimed at renewable energy and Carbon Capture and Storage, so not at distribution grids. Not applicable to DC.	No	
European Union - Subsidy tenders - Generic									
44	Horizon 2020	European Union	Enlarging the amount of research done in Europe, connecting research and innovation.	Subsidy tender	Higher investments in research and innovation.	1	Very broad instrument for which one can not apply directly. Only specific subinstruments can be applied for.	No	
44 a	Energy in Horizon 2020	European Union	Help innovation throughout the entire funnel	Subsidy tender	Higher investments of companies into energy research and innovation	2	Applicable to energy projects in general, not clear if applicable for DC. Instrument must be transformed by explicitly stating DC projects as a possibility to make it actually applicable.	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
44 b	Fast Track to Innovation in Horizon 2020	European Union	Faster time to market for innovations	Subsidy tender for the development of pilot projects to the market	Fast development, commercial take-up and/or wide deployment of sustainable innovative solutions (products, processes, services, business models etc.) in enabling and industrial technologies and/or for tackling societal challenges.; Time to initial market take-up no later than 3 years 3	3	Instrument aimed at general innovation projects in the pilot phase. DC is in the pilot phase so it should be applicable.	No	
44 c	Horizon 2020 dedicated SME Instrument Phase 1 and 2, 2014-2015	European Union	Help SMEs innovate	Funding for early phase research (50k lump sum, phase 1) and demonstration projects (phase 2), 500k - 2.5million, depending on research	More innovative SMEs in the field of energy (efficiency)	3	Instrument aimed at general innovation projects for SMEs. DC is a innovation project so the instrument should be applicable	No	
45	Interreg : European Territorial Co-operation	European Union	Increase cross-border co-operation	Funding for co-operation programs crossborder	Increased cross border co-operation, investments and workforce interchange	3	Subsidy scheme that focusses on cross-border co-operation. Applicable to DC when cross-border co-operation is used in a pilot project.	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
45 a	Interreg V-A - Belgium-The Netherlands (Vlaanderen-Nederland)	European Union	Increase cross-border co-operation	Funding for co-operation programs crossborder	Increased cross border co-operation, investments and workforce interchange	3	Subsidy scheme that focusses on cross-border co-operation between Belgium and the Netherlands. Applicable to DC when cross-border co-operation is used in a pilot project.	No	
45 b	Interreg V-A - Germany - The Netherlands (Deutschland - Nederland)	European Union	Increase cross-border co-operation	Funding for co-operation programs crossborder	Increased cross border co-operation, investments and workforce interchange	3	Subsidy scheme that focusses on cross-border co-operation between Germany and the Netherlands. Applicable to DC when cross-border co-operation is used in a pilot project.	No	
European Union - Subsidy tenders - Niche									
	None								
European Union - Fiscal incentives - Generic									
	None								
European Union - Fiscal incentives - Niche									
	None								
European Union - Public procurement - Generic									
	None								
European Union - Public procurement - Niche									
	None								

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
European Union - Low interest loans - Generic									
46	InnovFin Large Projects	European Investment Bank	Improve access to risk finance for R&I projects from larger firms larger firms; universities and public research organisa-tions	Loans and garantuees delivered directly by the EIB	Increased spending on R&I by (large com-panies)	3	Financing instrument with a general aim at innovation and demonstration at large firms, therefore also applicable to R&D for DC.	No	
47	European Energy Efficiency Fund (eeef)	European Union	Lower the barrier for investments in Energy Efficiency Measures by author-ities	Provide cheap loans and/ or equity investments, in co-operation with banks	Higher investments into energy efficiency measures, reduced GHG emissions fol-lowing from that	2	The instrument has a wide aim at investments in energy efficien-cy. When DC has proven its improved efficiency it can be made applicable.	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
European Union - Low interest loans - Generic									
46	InnovFin Large Projects	European Investment Bank	Improve access to risk finance for R&I projects from larger firms larger firms; universities and public research organisations	Loans and garantuees delivered directly by the EIB	Increased spending on R&I by (large companies)	3	Financing instrument with a general aim at innovation and demonstration at large firms, therefore also applicable to R&D for DC.	No	
47	European Energy Efficiency Fund (eeef)	European Union	Lower the barrier for investments in Energy Efficiency Measures by authorities	Provide cheap loans and/or equity investments, in co-operation with banks	Higher investments into energy efficiency measures, reduced GHG emissions following from that	2	The instrument has a wide aim at investments in energy efficiency. When DC has proven its improved efficiency it can be made applicable.	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
48	Private Finance for Energy Efficiency (PF4EE)	European Investment Bank	address the limited access to adequate and affordable commercial financing for energy efficiency investments	1.a portfolio-based credit risk protection provided by means of cash-collateral (Risk Sharing Facility), together with 2.long-term financing from the EIB (EIB Loan for Energy Efficiency) and 3.expert support services for the Financial Intermediaries (Expert Support Facility)	“to make energy efficiency lending a more sustainable activity within European financial institutions, considering the energy efficiency sector as a distinct market segment. **to increase the availability of debt financing to eligible energy efficiency investments.“**	2	Private financing fund having no specific aim. Can be applicable to DC when the story is right.	No	
European Union - Low interest loans - Niche									
	None								
Provinces - Statutory obligations/(alleviated) legislation - Generic									
	None								
Provinces - Statutory obligations/(alleviated) legislation - Niche									
	None								
Provinces - Investment subsidies - Generic									
49	Innovatief Actieprogramma Groningen (subsidie)	Province Groningen	More innovation in the province, better co-operation	Subsidy fund	Higher investments in innovation, more co-operation between different companies, grow the SMEs in the province	3	Subsidy scheme aimed at investments in energy. Applicable to DC.	No	

Table C.1. (continued)

#		Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
38	a	Kansen voor West 2 (Operationeel Programma West)	Provinces Flevoland, Noord-Holland, Zuid- Holland & Utrecht	Higher investments in (amongst other) sustainable initiatives and innovation	Subsidy for innovation and sustainability initiatives	Higher investments in innovation by SMEs, higher investments in sustainability by all companies	3	Subsidy scheme aimed at investments in energy. Applicable to DC.	Yes	Experiment is scheduled in the Utrecht office. Utrecht is part of the Kansen voor West II scheme, so therefore this one is applicable for the experiment.
38	b	Operationeel Programma Noord	Provinces Friesland, Groningen & Drenthe	Higher investments in innovation, sustainable energy and energy savings	Subsidy scheme	Higher investments in innovation by SMEs, higher investments in sustainability by all companies	3	Subsidy scheme aimed at investments in energy. Applicable to DC.	No	
38	c	Operationeel Programma Oost	Provinces Gelderland & Overijssel	Higher investments in innovation, sustainable energy and energy savings	Subsidy scheme	Higher investments in innovation by SMEs, higher investments in sustainability by all companies	3	Subsidy scheme aimed at investments in energy. Applicable to DC.	No	

Table C.1. (continued)

#		Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
38	a	Kansen voor West 2 (Operationeel Programma West)	Provinces Flevoland, Noord-Holland, Zuid- Holland & Utrecht	Higher investments in (amongst other) sustainable initiatives and innovation	Subsidy for innovation and sustainability initiatives	Higher investments in innovation by SMEs, higher investments in sustainability by all companies	3	Subsidy scheme aimed at investments in energy. Applicable to DC.	Yes	Experiment is scheduled in the Utrecht office. Utrecht is part of the Kansen voor West II scheme, so therefore this one is applicable for the experiment.
38	b	Operationeel Programma Noord	Provinces Friesland, Groningen & Drenthe	Higher investments in innovation, sustainable energy and energy savings	Subsidy scheme	Higher investments in innovation by SMEs, higher investments in sustainability by all companies	3	Subsidy scheme aimed at investments in energy. Applicable to DC.	No	
38	c	Operationeel Programma Oost	Provinces Gelderland & Overijssel	Higher investments in innovation, sustainable energy and energy savings	Subsidy scheme	Higher investments in innovation by SMEs, higher investments in sustainability by all companies	3	Subsidy scheme aimed at investments in energy. Applicable to DC.	No	

Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
38 d	Operationeel Programma Zuid	Provinces Zeeland, Limburg & Noord-Brabant	Higher investments in innovation, sustainable energy and energy savings	Subsidy scheme	Higher investments in innovation by SMEs, higher investments in sustainability by all companies	3	Subsidy scheme aimed at investments in energy. Applicable to DC.	No	
50	Programma Zuiderzeelijngelden Noordelijk Flevoland	Province Flevoland	Higher investments in (sustainable) innovation	Subsidy scheme	Higher investments in (sustainable) innovation	3	Subsidy scheme aimed at investments in energy. Applicable to DC.	No	
Provinces - Investment subsidies - Niche									
	None								
Provinces - Subsidy tenders - Generic									
	None								
Provinces - Subsidy tenders - Niche									
	None								
Provinces - Fiscal incentives - Generic									
	None								
Provinces - Fiscal incentives - Niche									
	None								
Provinces - Public procurement - Generic									
	None								
Provinces - Public procurement - Niche									
	None								
Provinces - Low interest loans - Generic									
51	Energiefonds Brabant	Province Noord-Brabant	Higher investments in sustainable energy	Revolving fund with cheap loans	Higher investments in sustainable energy production	3	Fund aimed at investments in energy. Applicable to DC.	No	

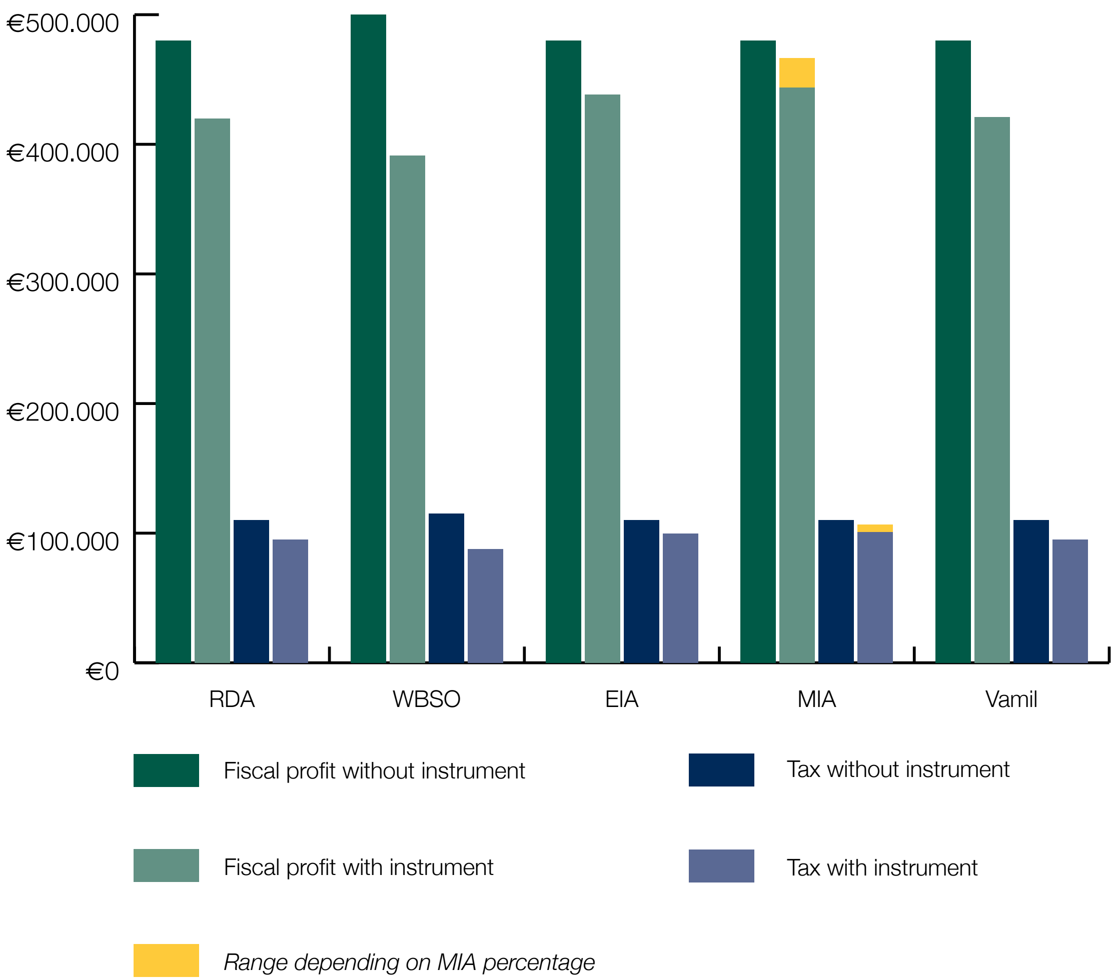
Table C.1. (continued)

#	Document name	Issuer	Key Goals	Mechanism	Outcome	App. DC	Remarks applicability DC	App. exp.	Remarks app. experiment
52	Energiefonds Overijssel	Province Overijssel	Higher investments in sustainable energy	Revolving fund with cheap loans	Higher investments in sustainable energy production and energy saving measures	3	Fund aimed at investments in energy. Applicable to DC.	No	
53	Energiefonds Utrecht	Municipality Utrecht	Higher investments in sustainable energy and energy savings	Revolving fund with cheap loans	Higher investments in sustainable energy production and energy saving measures	3	Fund aimed at investments in energy. Applicable to DC.	Yes	Fund of the region Utrecht for energy saving innovations
54	Fûns Skjinne Fryske Enerzjy	Province Friesland	Higher investments in sustainable energy and energy savings	Revolving fund with cheap loans	Higher investments in sustainable energy production and energy saving measures	3	Fund aimed at investments in energy. Applicable to DC.	No	
55	Limburgs Energie Fonds	Province Limburg	Higher investments in Sustainable initiatives	Revolving fund for cheap loans	Higher investments in sustainable energy production and energy savings, as well as innovation	3	Revolving fund aimed at investments in energy. Applicable to DC.	No	
	Provinces - Low interest loans - Niche								
	None								

Appendix D. Tax deduction instruments

Five general applicable policy instruments allow for tax deductions. In this appendix details and calculation examples are given for each instrument. A visual representation of the calculated examples is shown in figure D.1.

Figure D.1. Examples of the impact of five tax deduction policy instruments on the fiscal profit and corporate tax to be paid.
The error bar for MIA shows the range of deduction depending on the class under which the investment is classified.



D.1 RDA

60% deduction of the investment costs in R&D (excluding personnel) from the fiscal profit on top of the regular amortization.

D.1.1 Example calculation

Investment in a machine for the research of a USB 3.1 plug

- EBITA in 2015: €500.000
- RDA eligible investment: €100.000
- Amortization period: 5 years
- Amortization per year: €100.000 / 5 years = €20.000 per year
- Fiscal profit: €500.000 - €20.000 = €480.000
- Corporate tax: 20% over profits up to €200.000; 25% over profits above €200.000
- Tax to be paid without RDA: €200.000 x 20% + 280.000 x 25% = €110.000
- RDA deduction: €100.000 x 60% = €60.000
- New fiscal profit: €500.000 - €20.000 – €60.000 = €420.000
- New corporate tax to be paid: €200.000 x 20% + €220.000 x 25% = €95.000

Difference: €110.000 – €95.000 = €15.000, so 15% of the investment costs are deducted from the corporate tax

D.2 WBSO

Deduction of the taxes paid upon wages for time spent on R&D. Over the first €250.000 of wage taxes 35% may be deducted, between €250.001 and €14.000.000 wage taxes 14% may be deducted and over €14.000.000 no more deduction is possible.

D.2.1 Example calculation

Investment in the research of a USB 3.1 plug done by employees

- EBITA in 2015: €500.000
- Corporate tax: 20% over profits up to €200.000; 25% over profits above €200.000
- Tax to be paid without RDA: €200.000 x 20% + 300.000 x 25% = €115.000
- Wage tax paid over WBSO eligible hours: €400.000
- WBSO deduction: €250.000 x 35% + €150.000 x 14% = €108.500
- New fiscal profit: €500.000 – €108.500 = €391.500
- New corporate tax to be paid: €200.000 x 20% + €191.500 x 25% = €87.875

Difference: €115.000 – €87.875 = €27.125, so about 6,8% of the paid wage taxes are deducted from the corporate tax

D.3 EIA

41,5% of the investment costs can be deducted in year 1 from the fiscal profit on top of the regular amortization

D.3.1 Example calculation

Investment in 20 charging points for EV (code 241221)

- EBITA in 2015: €500.000
- EIA eligible investment: €100.000
- Amortization period: 5 years
- Amortization per year: €20.000
- Fiscal profit without EIA: €500.000 - €20.000 = €480.000
- Corporate tax: 20% over profits up to €200.000; 25% over profits above €200.000
- Tax to be paid without EIA: €200.000 x 20% + 280.000 x 25% = €110.000
- EIA deduction in year 1 (41,5%): €100.000 x 41,5% = €41.500
- New fiscal profit: €480.000 – €41.500 = €438.500
- New corporate tax to be paid: €200.000 x 20% + €238.500 x 25% = €99.625

Difference: €115.000 – €99.625 = €10.375, so just over 10% of the investment costs are deducted from the tax

D.4 MIA

A deduction of the fiscal profit added on top of the regular deduction, with values of 13,5% (classes B&E), 27% (classes A&D) and 36% (class F&G) depending on the classification of the product. Classes A, B, & F can be combined with the Vamil.

D.4.1 Example calculation

Investment in 20 chargers for EVs (Code F 3720)

- EBITA in 2015: €500.000
- MIA eligible investment: €100.000
- Amortization period: 5 years
- Amortization per year: €20.000
- Fiscal profit without MIA: €500.000 - €20.000 = €480.000
- Corporate tax: 20% over profits up to €200.000; 25% over profits above €200.000
- Tax to be paid without MIA: €200.000 x 20% + 280.000 x 25% = €110.000
- MIA deduction in year 1 (36%): €100.000 x 36% = €36.000
- New fiscal profit: €500.000 - €20.000 – €36.000 = €444.000
- New corporate tax to be paid: €200.000 x 20% + €244.000 x 25% = €101.000

Difference: €110.000 – €101.000 = €9.000, so 9% of the investment costs are deducted from the corporate tax

D.5 Vamil

Allows a company to amortize 75% of the value of the investment in any year chosen by the company to make optimal use of this instrument. The other 25% are amortized in the normal period. Only applicable to a select set of products (classes A, B, C & F of the MIA/Vamil).

D.5.1 Example calculation

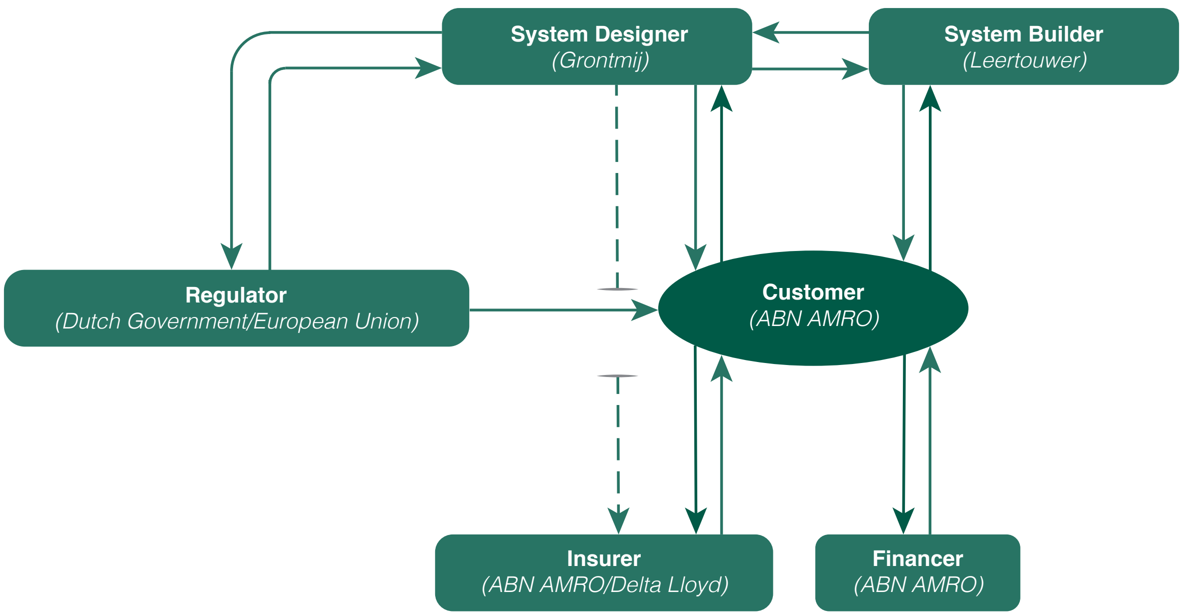
- Investment in 20 charging point for EVs (Code F 3720)
- EBITA in 2015: €500.000
- Vamil eligible investment: €100.000
- Amortization period: 5 years
- Amortization per year: €20.000
- Fiscal profit without Vamil: €500.000 - €20.000 = €480.000
- Corporate tax: 20% over profits up to €200.000; 25% over profits above €200.000
- Tax to be paid without Vamil: €200.000 x 20% + 280.000 x 25% = €110.000
- Vamil amortization in a self-chosen year (75% Vamil + 5% regular): 80% x €100.000 = €80.000 amortization
- New fiscal profit: €500.000 – €80.000 = €420.000
- New corporate tax to be paid: €200.000 x 20% + €220.000 x 25% = €95.000

Difference: €110.000 – €95.000 = €15.000, so 15% of the investment costs are deducted from the corporate tax

Appendix E. Stakeholder map

For the design of the experiment a stakeholder map has been created. The central stakeholder is the final user for this project. From this stakeholders' point of view the first and second order relations are mapped. The first map *(figure E.1)* shows only the first order relations, the second map *(figure E.2)* also shows the second order relations. The third map *(figure E.3)* adds the types of flows between the different stakeholders. The full details of the flows between the different stakeholders is presented in table E.1.

Figure E.1. First order stakeholder map.



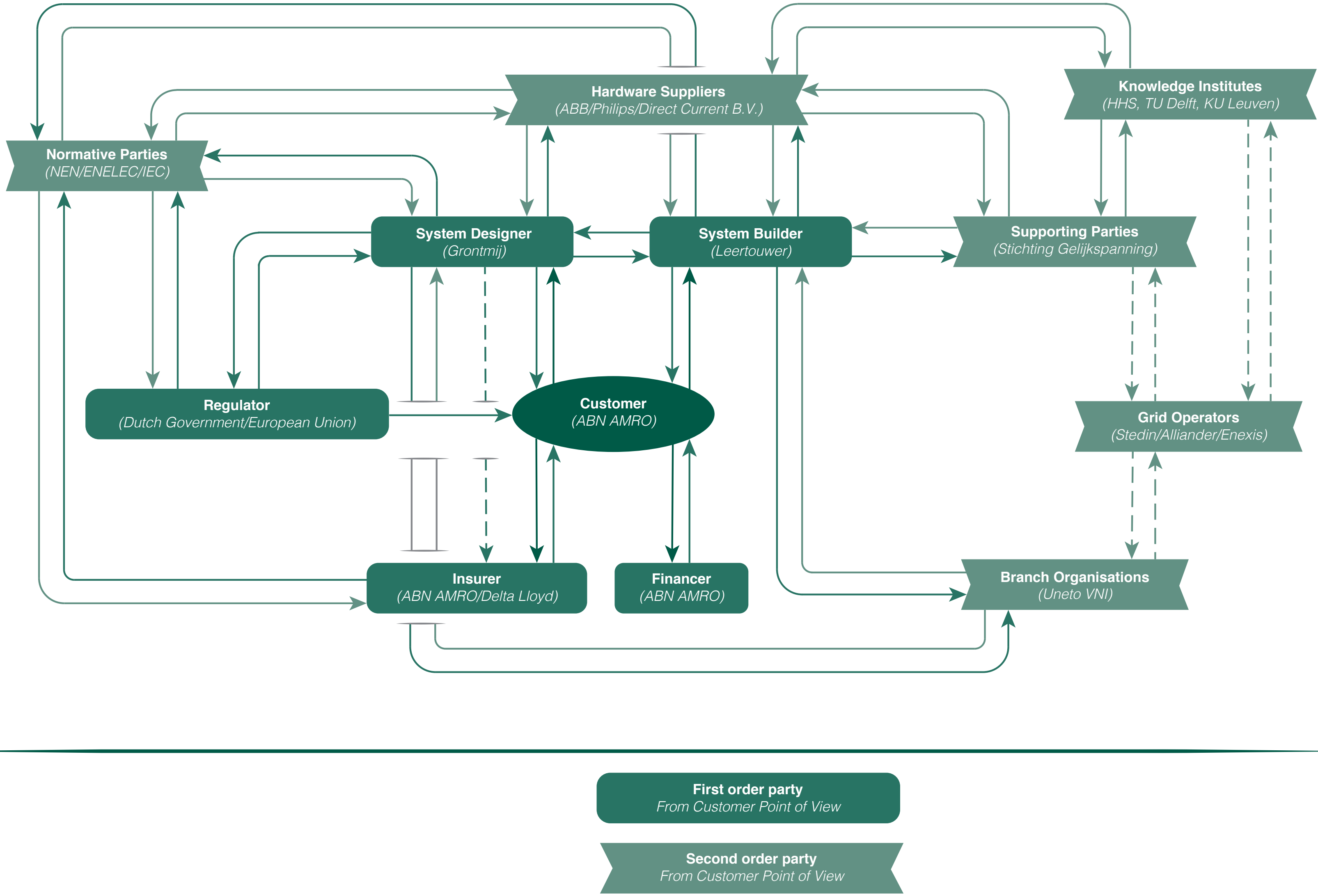


Figure E.2. Second order stakeholder map.

Stakeholder scheme 1st and 2nd order

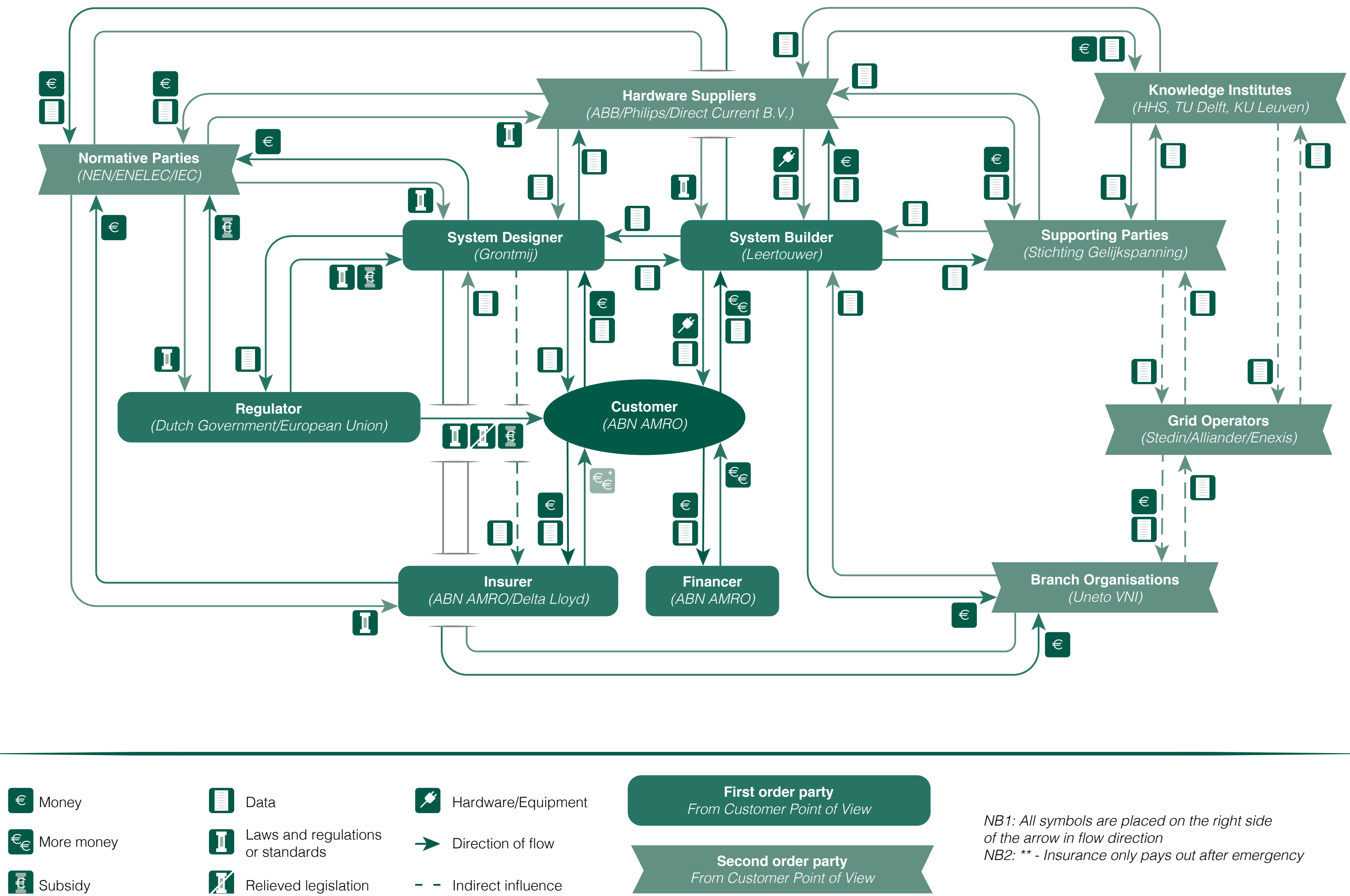


Figure E.3. Second order stakeholder map including flows between the different stakeholders.

Table E.1. Overview of the flows between the stakeholders

X means flow from stakeholder to itself. **-** *means no flow from stakeholder to other stakeholder.*

Flow from… / Towards…	Customer	Financer	System Designer	System Builder	Insurer	Regulator	Normative parties	Hardware Suppliers	Knowledge Institutes	Supporting Parties	Grid Operators	Branch Organisations
Customer	x	Loan	Information about the new system Declaration of safety (applying to NEN1010 or equal)	Hardware of the system Information about how to use the system (NEN3140 applicability)	Pay-out after emergency/ failure	Laws and regulations about building safety Relieved legislation for the experiment Subsidy for the experiment	-	-	-	-	-	-
Financer	Information for loan request Interest payments	x	-	-	-	-	-	-	-	-	-	-
System Designer	Information about the current system Wishes and needs for the new system Payments	-	x	Information about practical building experience that can be used while designing	-	Applicable laws (bouwbesluit) Subsidy for the experiment	Applicable NEN standards (NEN1010 – NEN3140)	Information about the products as requested by the designer	-	-	-	General electro-technical information
System Builder	Data about the current system Payments	-	Designs of the electrical infra-structure in the building	x	-	Applicable laws (not visualized in stakeholder scheme)	Applicable NEN standards (NEN1010 - NEN3140)	Hardware Installation and maintenance information	-	Informal information exchange	-	General electro-technical information
Insurer	Insurance payments Information about the new system that shows that it is safe	-	Indirect flow of information about the safety of the system and norm applicability	-	x	-	Applicable NEN standards	-	-	-	-	-
Regulator	-	-	Information about the safety of the experiment	-	-	x	Applicable NEN standards that are used in legislation	-	-	-	-	-

Table E.1. (continued)

Flow from… / Towards…	Customer	Financer	System Designer	System Builder	Insurer	Regulator	Normative parties	Hardware Suppliers	Knowledge Institutes	Supporting Parties	Grid Operators	Branch Organisations
Normative parties	-	-	Payments to access standards	Payments to access standards Information to influence the creation of new standards	Payments to access standards	Yearly subsidy	x	Payments to access standards Information to influence the creation of new regulations	-	-	-	-
Hardware Suppliers	-	-	Request for equipment with certain specifications	Request for product X Payments for products	-	Applicable laws (not visualized in stakeholder scheme)	Applicable regulations (NEN3140 – CE marking)	x	Information about product development	Information about product development	-	-
Knowledge Institutes	-	-	-	-	-	-	-	Research payments Information about product development	x	Information about product development, general DC knowledge	Informal information exchange	-
Supporting Parties	-	-	-	Informal information exchange	-	-	-	Information about product development Sponsorship	Informal information exchange Information about product development	x	Informal information exchange	-
Grid Operators	-	-	-	-	-	-	-	-	Informal information exchange	Informal information exchange	x	(In)Formal information exchange
Branch Organisations	-	-	Subscription fees	Subscription fees	-	-	-	-	-	-	Subscription fees Informal information exchange	x