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Team 1921 (Group G)

Green Ede or Green Energy

Feasibility study - Bio Energy as a sustainable solution for reaching energy goals in the municipality of Ede

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Preface

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We hope this report can contribute to the assessment of the sustainability of biomass use for bioenergy.

Executive Summary

This report was commissioned to assess the sustainability of the current energy system in Ede as well as the future situation (2020) in which 20,000 housing equivalents receive green bioenergy from the bioplants ran by MPD Groene Energy. Methods of assessment include literature review, stakeholder analysis, partial environmental assessment, interviews, sustainability indicator, and model calculations.

The MPD energy company uses forest and garden resources in order to supply energy to 10,000 equivalent households in Ede in 2017, around 350 TJ per year. In 2020, it is expected to supply bioenergy to 20,000 households in Ede, around 690 TJ per year. By calculation, about 15,452 tons of fresh wood per year are needed to fulfil the demand in 2017 and 43,485 tons of fresh wood per year in 2020. The percentage of potential forest wood sustainably harvested for bioenergy in our best and worst scenarios varies from 60% to 90%. The results of assessment indicate that the forests can sustainably be harvested for energy in 2017, but cannot reach the sustainable goal with the current system by 2020. For now, there are no studies similar to ours done in Ede which our results could be compared to, but the ‘The Netherlands scenario’ in our report can be compared with nationwide studies which show a slightly lower potential for biomass. According to calculation, bioenergy produced from forestry wood could fulfil only a 0.35% of the total energy demand of the Netherlands.

Due to time limitation and lack of data, the report has certain limitations. Specific amount and distribution of tree species in Ede remain unknown; different styles of forest management and harvesting methods will have a certain influence on the results of the study since forest ownership is quite complex; and deviation of model calculation exists. More research is needed to improve the accuracy of model calculations.

The model we made in principle could be used to calculate the bioenergy and full biomass potential for all other municipalities and provinces in the Netherlands with the assumption that similar installations as the one in Ede are used. Some other indicators related to indicator species’ and ‘soil quality’, such as common forest birds’ species and chemical and physical properties of soil, are recommended for further research.

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1. Introduction

1.0 Introduction of group

This study is conducted as part of the Academic Consultancy Training (ACT). ACT brings together multidisciplinary groups that work together on a real world project for an external client. Our team consists of a diverse group of enthusiastic masters students with different backgrounds. Overall, the team is composed of environmental scientists, but each member has a different focus. Hence, the team has expertise in forestry management, environmental assessment as well as environmental technology. Not only does the team have an interesting mix of academic background, the members come from all over the world, bringing together different perspectives and creativity in our approach to problem solving related to environmental degradation.

1.1 Background

1.1.1 Renewable energy and biomass

Each municipality in the Netherlands has a set of goals they have to achieve with respect to sustainability that are related to the national energy goals. On the national scale, the country. the country as a whole aims for 14% sustainable energy by 2020 and intends to be energy neutral by 2050. In 2015, the total consumption of energy in the Netherlands, regardless of the activity, was 2,241.5 PJ (StatLine, 2017). Of that total consumption, only 5.8% (132 PJ) could be attributed to renewable sources of energy. Taking these numbers into account, the aforementioned national goals of energy neutrality in the Netherlands by 2050 seem far off. In 2015, more than half of the renewable energy consumption originated from biomass, while the remainder represented wind, solar and geothermal energy (StatLine, 2017). This goes to show that the focus lies on biomass to meet the national and regional energy goals for 2020 in the Netherland. As far as Ede is concerned, it is up to the municipality to choose the most appropriate course of action to reach part of the goals of the Netherlands. The municipality consumed 10,000 TJ of energy in 2016. Of those 10,000 TJ, 11% (1,146 TJ) were sustainable, of which 44% were from biomass used in the municipality's district heating network (Duurzaamheid 2014 - Gemeente Ede, n.d). The municipality of Ede has opted for an ambitious target of reaching 20% sustainable energy in 2020.

The municipality of Ede (Figure 1.1 a) is inhabited by 110,000 citizens (Gemeente Ede, n.d), and is the 5th largest municipality in the Netherlands based on its size (E. van Tol, personal communication, June 12, 2017). One of the energy sources it chose to use to reduce greenhouse gas emissions was biomass since Ede is thought to encompass a great deal of biomass. Indeed, Ede is famous for its woods of which the municipality owns 2,461 hectares of forest (Borgman Beheer Advies, 2009). It also harbours the Hoge Veluwe National Park (Gemeente Ede, n.d). Nonetheless, biomass is not the only type of renewable energy used. It is through a combination of solar, wind, geothermal and biomass that the set goals will be achieved (E. van Tol, personal communication, June 12, 2017).

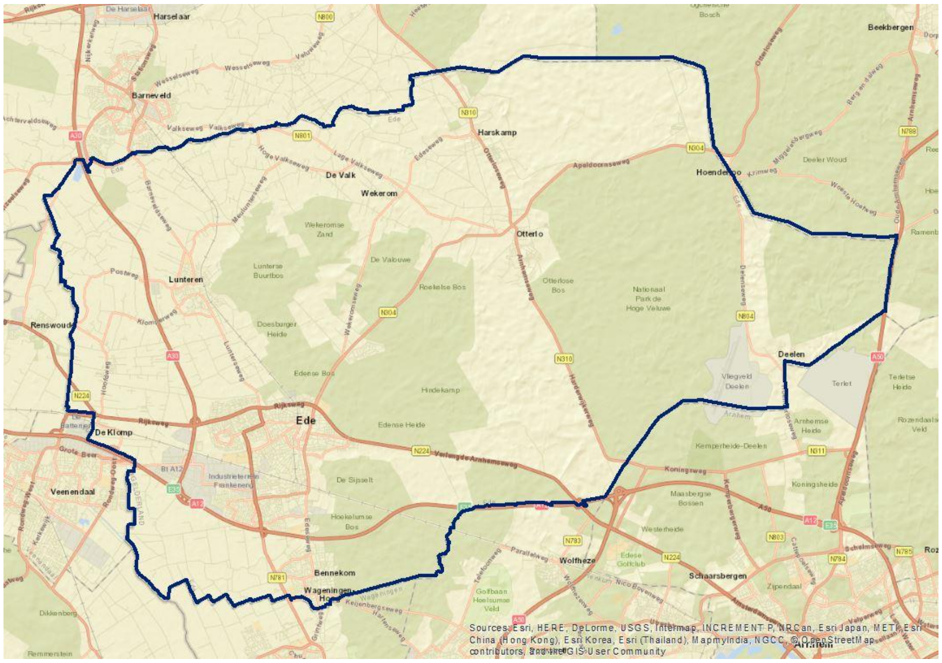

Figure 1.1a: Map of the municipality Ede (Based on data from Borgman Beheer Advies, 2009)

The use of biomass as substitution for fossil fuel is generally acknowledged as a sustainable development measure (Stupak et al., 2007). There are a number of advantages of utilizing biomass for energy over conventional sources. When biomass is produced locally, it provides more security in energy supplies as compared to importing energy sources from abroad. It can also provide jobs, benefitting the national economy. Furthermore, biomass has been commonly perceived as a CO_2 neutral source of energy. The carbon sequestered in biomass throughout its growing period will be released when burnt, while new vegetation will take up that released carbon, preventing addition of CO_2 to the atmospheric stock (Stupak et al., 2007). This is short carbon cycle, is often used to support the claim of CO_2 neutrality of bioenergy. CO_2 neutrality of biomass makes it a preferred energy source compared to fossil fuel based energy sources that are quite detrimental for the environment in terms of greenhouse gas emissions. However, concerns about its adverse effects for forestry, society, and the energy sector are raised at the same time. The CO_2 neutrality argument does not take into account that fossil fuel is needed for forest maintenance and wood processing (Schulze et al., 2012). Moreover, if the consumption of biomass exceeds the growth of forests, the pool of sequestered carbon that took decades to build up will be depleted and emitted in the atmosphere, thus completely defeating the initial purpose of preventing added CO_2 emissions (Schulze et al., 2012). There is the risk of increasing emissions of gasses and particles which have potential risks associated with them to human health and ecosystems (Stupak et al., 2007). The costs of waste deposits will be high if the waste cannot be recycled efficiently. There is also a greater likelihood of soil compaction due to increased activities in the forest with heavy machinery (Stupak et al., 2007). With the removal of biomass, the organic matter layer will slowly be depleted and could not adequately be substituted with fertilizer, which would constitute an additional expense in forest management (Stupak et al., 2007). Besides, removing biomass from a forest could add to habitat fragmentation to a certain extent which would be detrimental for biodiversity. From a forest conservation perspective, any increase in the demand for wood from forests is a potential threat. There are arguments that an increase in biomass harvest will result in younger forests, lower biomass pools, and a loss of other ecosystem functions (Schulze et al., 2012).

Nevertheless, in the Netherlands, biomass is used to reduce the impact of energy production and help reach sustainability goals, while preserving natural areas.

1.1.2 Overview of the current situation in Ede

MPD Groene energie BV (MPD) is the overarching company that owns the bioplants currently in Ede and runs the district heating network that provides green energy. The schematic presented below (Figure 1.1.b) gives a graphic representation of the chain of production. This paragraph provides an initial walk through the overview starting off with the bioenergy plants. Chapter 4.1 provides more in-depth descriptions of the inner workings of the plants.

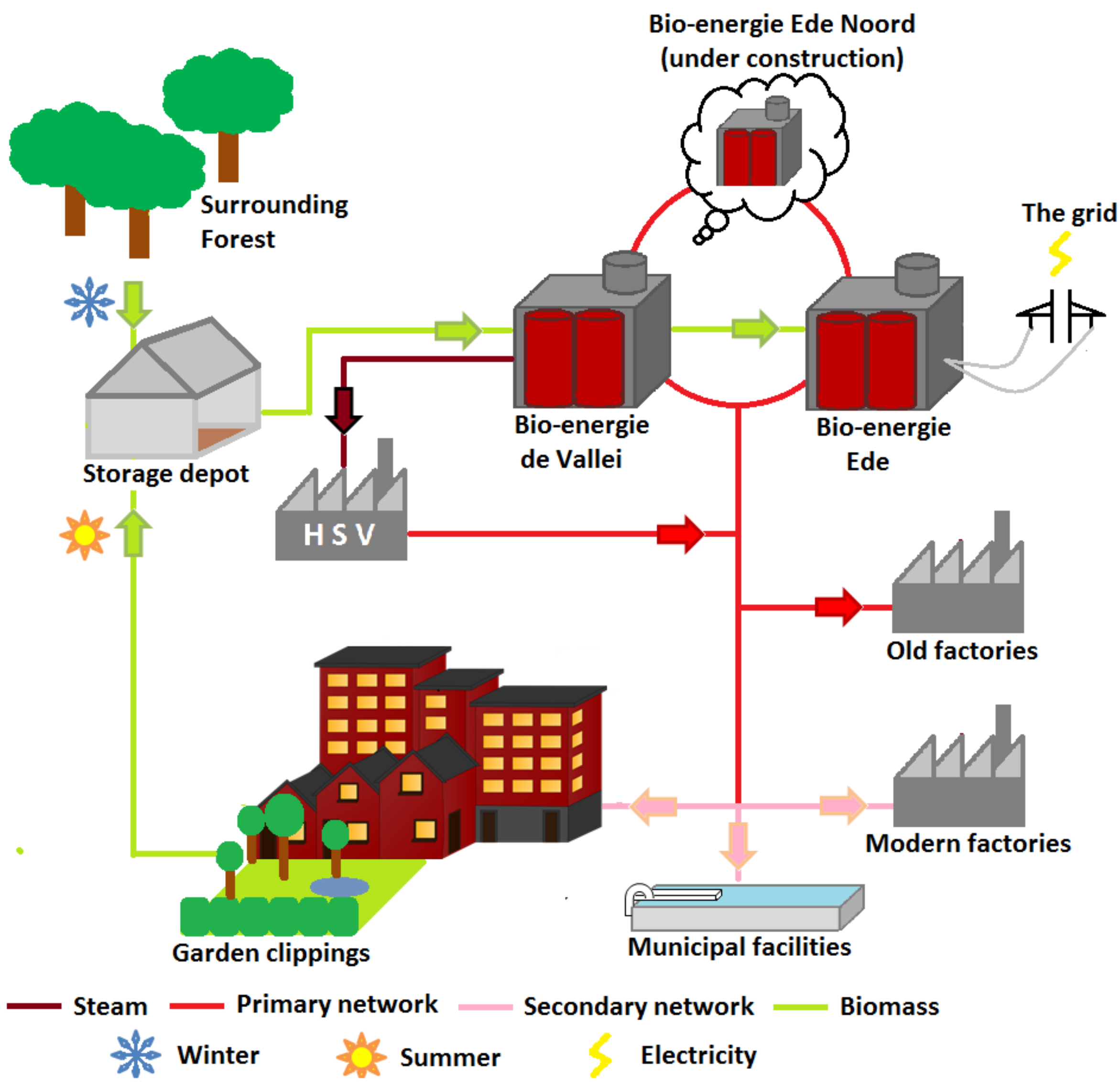

Figure 1.1b: Schematic representation of the bioenergy system

Currently two bioenergy plants are in existence, ‘Bio-energie de Vallei’ and ‘Bio-energie Ede’. Both plants run on woody biomass in the form of chips and shreds, and are outfitted with natural gas boilers to overcome peak demands. The main output is heat in the form of warm water, which is supplied to the ‘smart grid’. A smart grid is a district heating network that runs under the houses of Ede to provide spatial heating and warm tap water. In addition, ‘Bio-energie de Vallei’ supplies steam to HSV, a company that uses this steam to produce industrial foam and plastic parts. After HSV has used the steam, a portion of rest heat remains in the form of warm water which is directed back to the smart grid. ‘Bio-energie Ede’ produces electricity in addition to warm water, but it is a by-product. The amount of electricity generated is fixed by the heat demand. A third plant, to be ‘Bio-energie Ede Noord’ is currently under construction. This plant will make use of an entirely different type of biomass like grass, pine needles and tree leaves (V.Kleijnen, personal communication, June 19, 2017). The smart grid consists of a primary and a secondary network. Once heat is produced, it is delivered to the primary network of in the form of hot water at 105 degrees Celsius (V.Kleijnen, personal communication, June 19, 2017). Old buildings that still have relatively high heat quality demands are directly connected to this primary network. The primary network is also the source of heat to a secondary network via a heat exchanger. The secondary network works at a lower temperature of 65 degrees Celsius to supply newer buildings with heat and hot water (V.Kleijnen, personal communication, June 19, 2017). Although these new buildings could do with and even lower temperature, 65 is required by Dutch law to minimize risk with *legionella*.

The biomass input is composed of green garden waste and wood from forestry maintenance. The availability of each input is dependent on the season. The garden waste becomes available in spring and summer, biomass from forestry maintenance is only available in autumn and winter. Because of Dutch forestry law, it is only allowed to harvest from forests in winter (C.van Rijswijk, personal communication, June 20, 2017). As of now, most of the biomass is harvested in the region and the heat produced is to be used in the region. 80% - 90% of the biomass used comes from the municipality of Ede (Warmtebedrijf Ede, 2017; Valentijn Kleijnen, personal communication, 2017). For the remainder of this report, we will assume a value of 80%. Of that 80%, 35% is composed of garden waste and 45% from forest maintenance. The remaining 20% comes from neighbouring municipalities (Valentijn Kleijnen, personal communication, 2017). Transport of the biomass is therefore reduced, mitigating the impact of biomass production by reducing the distance between the power plant and its input (Warmtebedrijf Ede, 2017). Moreover, the municipality has been trying to deal with an exotic shrub species called Black cherry (*Prunus serotina*). This species covers over 1,000 hectares of the forest in Ede and is used as biomass input for the plants (Warmtebedrijf Ede, 2017).

1.2 Problem Definition

The objective of this research is to assess the sustainability of the energy system in Ede by doing a feasibility study for the current (2017) and future situation (2020). A feasibility study entails making an assessment of a plan or project. The underlying purpose of the feasibility study is an analysis of said plan or project. The outcome of the study should provide an answer as in whether whatever project under consideration should go forward. It should outline the direct and indirect implications such that a trade-off can be established. There is not necessarily a clear direction that ought to be favoured at the culminating point of the study. It should provide both benefits and drawbacks for decision makers to have an holistic view and make a decision representative of the actual reality of the system. In this case, the project involves providing bioenergy to the municipality of Ede. The group's objective apropos the feasibility study is to determine whether or not this bioenergy project is sustainable with respect to the environment.

To provide bioenergy, biomass is harvested from the forest of Ede, putting to question the sustainability of the project with regard to carrying capacity and ecology.

Sustainability in relation to forest management and the use of forest as a source of biomass involves ensuring that human activities, such as harvesting and other benefits derived from forests today do not negatively affect the opportunities for future generations to similarly benefit (Peter, 2002). This definition, aligned with that of the Brundtland Commision, has for some time been a generic definition used to define sustainability. The Ministerial Conference on the Protection of Forests in Europe (MCPFE) defines sustainable forest management as: “the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic, and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems” (Stupak et al., 2007). These definitions both include social, economic and environmental aspects in the assessment of the sustainability of practices conducted in a forest ecosystem. Regarding sustainable energy, the Global Resource Action Center for the Environment defines it as energy which in its production has little to no negative impacts of human health or the health of natural ecosystems, can be supplied to future generations, or based on a renewable resource (i.e biomass) that can be utilized with lesser impacts than fossil fuels and can meet the demands of today and tomorrow. Based on these definitions, an assessment of the sustainability of the system can be established.

This study has been commissioned by Stichting Milieuwerkgroepen (SME), an independent environmental group focused on nature and environmental protection in Ede. From their perspective, there is the fear of over harvesting biomass from the forest. Therefore, they have requested the expertise of a multi-disciplinary group of master students to make an assessment of whether it is possible or not to sustainably harvest biomass from the forest in Ede to provide bioenergy to the municipality. To achieve the objective, the biomass resource inputs and demand of energy in Ede need to be assessed. As long as this data is not calculated and analysed, whether the bioenergy use in Ede is sustainable or not cannot be determined. Thus, the first step is to determine what the biomass requirements are to meet the energy demand in Ede. Secondly, the factors which can influence the outputs of the energy production will be discussed. Finally, to predict the trends in sustainable energy applicable for Ede, the development of energy use in the future, by the year 2020, will be analysed.

The assessment will be made for the current situation (2017) in Ede, as well as the future situation (2020). In 2020, the municipality and MPD hope to provide 20,000 household equivalents with green bioenergy. The future assessment will be based on this projection. By understanding the functioning of the bioplant in its current state, i.e. know the input in terms of biomass to meet the current demand and the outputs generated by that technology, it would be possible to make extrapolations for the future the municipality has envisioned and determine whether it could be sustainable or not. This study will help determine whether it would be possible to meet the energy demand of the housing equivalents already envisioned by the municipality, using biomass harvested from Ede’s forest.

1.3 Research Aims

The aim of this project is to assess the sustainability of the current energy system in Ede as well as the future situation (2020) in which 20,000 housing equivalents will receive green bioenergy from the bioplants ran by MPD.

In order to reach the aim of the study several research questions should be answered. Those questions are divided in two research fields: technical aspects (process related), and forest management (input related)

1.3.1 Technical aspects

The general question which needs to be answered in that research field is: What are the factors which influence the outputs of the energy production?
Furthermore, many specific questions should be addressed and answered in order to reach the project purpose:

- How much energy is needed to produce currently in order to provide bioenergy to 10,000 housing equivalents?
- How much energy will be needed to produce in the near future in order to provide bioenergy to Ede (20,000 housing equivalent)?
- What is the efficiency of the current energy plant in terms of amount of wood burnt per unit of energy?
- What is the heat capacity of the wood that is used?
- Which techniques are used in the current production system process? Which techniques are expected to be used in the future situation?
- How could bioenergy production process fit at national level?
- How much wood is needed to keep bioenergy plants functional?

1.3.2 Forest management

The general question which needs to be answered in this research field is: What are the biomass requirements to meet the energy demand in Ede?
Furthermore, many sub-questions should be addressed and answered in order to fulfil the project's purpose:

- How much wood is currently harvested for bioenergy purposes?
- How much wood is available around Ede today?
- Which types of trees or shrubs are available?
- What are the specific input sources?

2. Methodology

2.1 Conceptual Framework: (DPSIR)

The DPSIR framework was first developed for the integrated environmental assessment of complex environmental problems (Kristensen, 2004). Drivers, pressure, state, impact and responses are linked in a causal chain to have a better understanding of the processes behind the environmental problem at hand. The end-game is to provide policy relevant information to decision makers to come up measure to mitigate or alleviate the problem. Drivers are the root cause of the pressure put on ecosystems. The change in the state of those ecosystem leads to impacts on both the environment and society, which require a response from policy makers. The DPSIR framework uses an interdisciplinary approach to set goals and achieve change (Rounsevell et al, 2010).

The DPSIR framework is detailed below for the issue regarding bioenergy and biomass harvesting in Ede:

- Driver: A driver is a societal need (Kristensen, 2004). In this case, the municipality has opted to use, amongst other energy sources, biomass to provide its citizens with green energy. This course of action was adopted to help meet the sustainability goals the city has set itself regarding energy neutrality. Ultimately, Ede would like to be self-sufficient when it comes to energy and be able to sustain the demand of its people by its own means. This bioenergy project is part of the energy transition that the city has undertaken to reduce its CO_2 emissions and phase out fossil fuel based energy sources. On a national scale, the Netherlands is attempting to become energy neutral by 2050. The different municipalities in the country have to comply to national regulation, but have the ability to choose how they reach the targets set as long as they abide by EU and national regulations. Using bioenergy is part of the plan to reach that goal for Ede.

- Pressure: The pressure is the activities and physical processes that lead to the need being met (Kristensen, 2004). In this case, deforestation and harvesting of biomass may put stress on the forest ecosystems in Ede. This problem is the focal point behind this study. Ede has sustainability goals to meet, with respect to energy. The question that needs answering is whether it would be possible to meet the energy demand in Ede by sustainably harvesting biomass from the forest. With more households supposed to receive bioenergy in the near future, more biomass will have to be harvested to meet the growing demand, which means that more pressure will be put on Ede's forest.

- State: The state is the quality of environmental compartments (i.e. soil, water, air, etc.) resulting from the pressure put on the ecosystem (Kristensen, 2004). With ambitious prospect for bioenergy in Ede, more biomass might need to be harvested. The forest in Ede may lose many ecosystem services if there is an increase in demand for forest resources.

- Impact: The change in the quality of different environmental compartments has societal and ecological implications (Kristensen, 2004). With increased biomass harvesting, habitats may be fragmented, increasing the likelihood of the disappearance of certain species from the region. Soil fertility will be affected if the soil loses the litter and cover that protects it and provides essential nutrients. In case of soil erosion, productivity of the soil will decrease which will make it more difficult to produce biomass. The forest ecology may therefore be impacted. Moreover, recreational services provided by the forest will be lost when the citizens of Ede will have less forest for leisure. Loss of the air purification service provided by the forest will also increase the potential of people to suffer respiratory related health issues. The extent of these impacts is further considered in chapter 5.1.3.

- Response: The response is the policy or measure that ought to be put in place to mitigate the environmental problem (Kristensen, 2004). The aim of this study is to determine whether it would be possible to sustainably harvest biomass in Ede to meet the city's energy demand. Based on the outcome, policy relevant information will be presented to give an indication of the future energy system in Ede, considering the current situation. Recommendations on other options or sources of biomass go beyond the scope of this study. The team lacks both time and expertise to add that aspect to the study.

The DPSIR framework links cause and effect, and measures against an environmental problem, which is of the utmost relevance for this study. With this research, the DPSIR framework will be used to shed light on the environmental consequences of biomass harvesting, and help determine whether this energy option is sustainable.

2.2 Research Tools

2.2.1 Literature Review

One of the primary steps in conducting any research is to get an overview of the body of knowledge already available in the given field of interest (Kumar, 2014). That is part of the reasoning behind conducting a literature review. The literature review brings clarity in the initial stages of the research, as well as help set a theoretical and methodological foundation to build the remainder of the study upon (Kumar, 2014). When seeking answers to various questions, the literature review gives the researcher guidance in the direction he or she ought to turn their focus. It is needed to formulate relevant research questions that will contribute to the academic world, but also contextualize the findings (Kumar, 2014). By having a clear understanding of what has previously been researched, the gaps and misconstrued theories can be filled and rectified. The literature review allows for comparison of the findings with what has been done before to unveil fallacies and contribute new and improved insight to the existing body of knowledge. The literature review not only brings clarity to the research, but also helps focus on the gaps in knowledge, thus ensuring the relevance of the study (Kumar, 2014). Furthermore, with respect to methodology, knowing how previous research in the similar realm of investigation have been conducted will help define which research tools should be used to find the answers to similar type of questions (Kumar, 2014).

For the purpose of this study, literature on different research studies that have been conducted in the fields of forestry and ecology were reviewed. To understand the environmental impacts of harvesting biomass in the forest of Ede, literature on that particular aspect has to be surveyed. Studies have been conducted on the impact of removing biomass with respect to soil quality and the biodiversity of the affected ecosystems. Determining whether harvesting of biomass is sustainable or not, the functioning of the ecosystem has to be known, to assess whether the ecosystem is still optimally functional post biomass harvesting. Therefore to make a claim regarding whether it is possible to sustainably harvest biomass in Ede for the purpose of bioenergy production, an understanding of the current body of knowledge about forest ecology is a requirement. Moreover, there are various benefits and drawbacks of using biomass to produce energy. The literature review also explicated the technical aspects of using biomass as an energy source. The benefits of this energy source provide an understanding of the reasoning behind its selection for Ede, while the drawbacks showcase the dangers of this course of action. Besides, the literature review served as a tool for comparison. Throughout this study, calculations were made. To assess the reliability of the obtained results, a comparison with other studies and other model calculations was made. Thus, the contribution of this study to the existing body of knowledge will be made explicit.

2.2.2 Stakeholder Analysis

A stakeholder analysis is a tool used to elucidate the interest, power and interrelations of different actors involved in a project or in the decision making process (Varvasovszky et al, 2000). In the management of natural resources, different stakeholders have the ability to influence decision making (Prell et al, 2009). Stakeholders are individuals, organizations or any other institution, that is or could potentially be affected by a project under consideration (Varvasovszky et al, 2000). Projects have winners and losers. Some stakeholders will have something to gain while others will lose something that they benefited from. Depending on the power of each stakeholder, the decision making process can be bent towards a certain direction. By compiling data on stakeholders, it is possible to have a better understanding of how decisions have been taken in a particular context (Brugha et al, 2000). The underlying desires of the affected parties can explain why certain measures are favored over others. An understanding of the socio-political context is also necessary to understanding the stakeholders' reasoning, but also to formulate a data collection method (Varvasovszky et al, 2000). Depending on the type of society, the way in which stakeholders can be approached and the way they go about the management of natural resources is shaped by culture (Varvasovszky et al, 2000). The data on the stakeholders was collected through interviews. That data will be presented in a stakeholder graph, a table, but also extensively explained in the report.

With the project involving bioenergy in Ede, there are many different parties involved who all have different interests and seek different outcomes. The municipality of Ede has certain goals to meet with respect to sustainability, which is not the focal point of the MPD that is a private company. By having a clear overview of all affected parties, a better picture of how those different actors are connected can be established. For example, as the entirety of the forest in Ede doesn't belong to the municipality, each private owner has their own forest management practices on their land. The MPD requires inputs of biomass from both the municipality and private owners. The biomass thus comes from not one, but many different sources. Getting an overview of who owns what land in the region of Ede is a first step to understand current practices. A stakeholder analysis can provide this overview of the web of interconnected actors that are brought together around the bioenergy project. The extent of the forest and the use of the resources in those forests can in turn give indications on the sustainability of the system. Hence, the stakeholder analysis is a key tool to use for this study as part of the analysis.

2.2.3 Partial Environmental Impact Assessment

An Environmental Impact Assessment (EIA) is a tool used to improve the decision making process by ensuring that projects under consideration are conducted in such a way that the integrity of natural ecosystems is preserved. Information regarding the environmental impact of the project at hand is collected and presented to decision makers who will determine whether the project in question ought to move forward (Morris et al, 2001). Technically speaking, it is an assessment of the environmental impact of a project under consideration (Morris et al, 2001).

As a legal tool, the EIA is a prerequisite for any project. It is composed of three essential parts: an assessment of the potential impacts, potential mitigation measures, and lastly an environmental management plan. The first step of an EIA is the identification of the potential impacts of both direct and indirect environmental impacts as well as the extent of the area that could be affected (Morris et al, 2001). The physical aspects of the project could directly result in environmental degradation, for instance deforestation, or indirectly at a later time and in a different location, for instance downstream sedimentation. The most important part of the EIA is the determination of the environmental impacts that can ensue from a given project. It's only by understanding this first aspect that mitigation measures can be established. Thus, the second step of an EIA is the devising of measures that would potentially mitigate the aforementioned environmental impacts. The purpose of the mitigation measure is to prevent, reduce or compensate for the anticipated negative effects of the project (Morris et al, 2001). The last step constitutes the formulation of a management plan that includes most importantly monitoring of the impacts and mitigation measures put in place (Morris et al, 2001).

For this particular study, the only aspect of the EIA that was used was the first step, i.e the qualitative assessment of the potential environmental impacts of the project. Biomass harvesting in the forests of Ede for the purpose of bioenergy production has certain impacts on forest ecosystems. The EIA was the tool used to elucidate what those environmental impacts are on forest ecosystems in Ede. When biomass is removed from an ecosystem, different services are lost and the ecology of the ecosystem is affected as well. Defining mitigation measures and coming up with a management plan go beyond the scope of the study that is being conducted. Alternatives are not to be explored. The sustainability of the project is what is sought out, therefore solely the consequences of the harvesting of biomass were investigated throughout this study. The outcome of the EIA provided information on the consequences of the practices currently occurring in the forest of Ede and may influence future measures. Due to lack of both time and expertise, the team didn't conduct an entire EIA, but based itself on literature review to assess what is occurring in Ede.

2.2.4 Interviews

In order to collect data from people, the interview is one of the most commonly used tools (Kumar, 2014). It involves an interaction between an interviewer and an interviewee in which the interviewer attempts to draw answers from the interviewee with questions that are meant to yield the thoughts, feelings, beliefs, etc., of the respondents. Conducting an interview requires some skill. Not solely related to note taking and listening, but first and foremost determining the questions is a crucial step. The interviewer has the possibility to choose whatever format the questions ought to take, depending on the purpose of the interview, what is sought out of the interview, and the respondent himself/herself (Kumar, 2014). Depending on the degree of flexibility in the setting of the questions, the interview could take a structure or an unstructured form. Unstructured interviews show great flexibility in content and structure (Kumar, 2014). The order in which the questions are given isn't set in stone and the wording of the questions rests on the interviewer. Throughout the interview, there can be changes to the line of questioning depending on the context (Kumar, 2014). Unstructured interviews are predominant in qualitative research where the collected data is used as descriptors in the line of argumentation (Kumar, 2014). On the other hand, structured interviews have a predetermined set of questions that are formulated in a distinct way (Kumar, 2014). Structured interviews provide clarity and uniformity in the data collection. Semi-structured interviews are somewhere in between, a list of questions is prepared, but the interviewer has some flexibility to dig deeper or skip questions. Regardless of the type of interview, this data collection method is appropriate for complex situations, can deliver in depth information, and can be widely applied to any population type regardless age, gender or social status (Kumar, 2014). The choice of the data collection instrument, i.e. the interview, depends on the study itself, the type of information being collected, as well as the availability of the data (Kumar, 2014).

As far as this study is concerned, semi-structured interviews with open-ended questions were used to obtain information from different stakeholders that have been deemed substantially relevant. The reasoning behind conducting the interviews was to collect data on the input requirements for the bioplants, in what manner these requirements are met and to get a clear overview of the current situation. Hence, the municipality of Ede, MPD Groene Energie, WUR forestry professor Gert-Jan Nabuurs, and the commissioner SME were interviewed. First of all , the interview with SME shed light on the wishes of the commissioner and their perspective on what should come out of this study. The outcome that they sought was made explicit through the interview. Secondly, the municipality of Ede was interviewed to obtain data on the availability of biomass in Ede. The extent of the forest as well as the management practices undertaken with respect to harvesting of biomass was elucidated. The entirety of the forest in Ede does not exclusively belong to the municipality. There are many different private owners who have their own will when it comes to managing their forest. Nevertheless, the municipality has the possibility to offer maps and visual representations of the forests in Ede, delineating each section owned by the different owners. This provided more clarity for the stakeholder analysis, showcasing the interconnections of the different involved actors with respect to forestry. Furthermore, an understanding of the ecological consequences of biomass harvesting is an aspect explored in this study. To this end, professor Gert-Jan Nabuurs was an essential asset as part of the environmental impact assessment. Thirdly, the interview with MPD Groene Energie provided essential information regarding the bioenergy conversion process, the required inputs and the outputs derived from said process. The functioning of the plant is something that ought to be fully understood to link energy outputs to biomass inputs and determine whether the process is sustainable. The interview also helped unravel the interconnected web of companies and sub companies that makes up MPD Groene Energie, to bring clarity to the stakeholder analysis.

Throughout these different interviews, there was a recurrent question regarding sustainability, regardless of the field of expertise of the interviewee. The reasoning behind this was to have a clear understanding of each of the relevant actors' definitions of the term sustainable. Depending on the interests of the various stakeholders, their idea of sustainability varied. Therefore, the information obtained from the different stakeholders may be tainted with bias. Being aware of these biases brings objectivity. The credibility, legitimacy and saliency of the final output are dependent on the data itself, therefore being aware of possible biases emerging in the data is a necessity. If the data presents some bias based on the source, that bias should be notified in the report for the sake of clarity.

2.3 Development of Sustainability Indicators and Calculations

The input data for the calculation was based on the 6th forest inventory of Probos (Schelhaas et al. 2014). This national inventory was used for specific calculations for Ede.

2.3.1 Energy Demand calculation

In this study, only the annual energy consumption was taken into account. The calculations are following the next model. The *Equation 2.3.1a* shows the total bioenergy consumption by EDe.

$$E_C = H_{Eq} \times N_{ho} \qquad 2.3.1a$$

Energy consumption (Ec) is expressed in PJ/ year, house equivalent consumption (Ho) is the average energy used per year by one household in Netherlands in PJ and Nh is the number of household equivalent provided.

The total energy produced by the plant is splitting the year in two periods of six months each. The first one is considering winter where the plants are working at 100% of their capacity and another is in summer when the plants are working at 20 % of their capacity. The *Equation 2.3.1b* shows total energy produced. Where TE_p it is the total energy produced, B_{ci} is the biomass boilers total capacity , H_w and H_s are the working hours per winter and summer respectively.

$$TE_P = \sum_{i=1}^{4} B_{ci} \times H_w + \sum_{i=0}^{4} B_{ci} \times 0.20 \times H_S \qquad 2.3.1b$$

2.3.2 The energy provided by woodchips

The total energy consumption is provided by wood chips, garden clippings and natural gas. To compare the amount of wood chips needed to fulfil the energy demand, the fraction of energy produced only by wood chips was calculated. Therefore, the amount of energy provided by gas and garden clippings to E_C should be discounted. The *Equation 2.3.2a* shows how it was done.

$$E_{Pw} = E_C \times (1 - E_g) \times \left[1 - \frac{C_{Gw}}{C_W}\right] \qquad 2.3.2a$$

Energy provided by woodchips (E_{Pw}) is in PJ per year. E_g, the energy provided by gas, . C_{Gw} is the heat capacity from garden clippings and C_W is the heat capacity of wood extracted from the forest. The last two values are expressed in PJ/kg.

Regarding to amount of energy that could be extracted from wood chips, heat capacity (Fuchs 2010) of the wood chips strongly depends on moisture content percentage. In general if the moisture increases the heat capacity will decrease. Following the *Equation 2.3.2b*, the heat capacity (C_W) could be calculate knowing the moisture percentage (W_r) (Lieskovsky et al. 2014).

$$C_W = 18.708 - 0.2132 W_r \qquad 2.3.2b$$

In order to assess the wood chips consumption, two scenarios were considered. The first one is assuming all wood chips have 20 % moisture when burnt. In this case, the highest amount of energy available would be extracted from the wood chips hence the mass of wood chips will be as low as possible. On the other hand, the opposite scenario is considering all wood chips have 50% moisture. That would imply less energy extracted from the wood chips, so the mass of wood chips will be as high as possible.

The wood chips amount needed to run the bioplants is expressed in the *Equation 2.3.2c*.

$$m_w = \frac{E_{pw}}{C_W} \qquad 2.3.2c$$

m_W *is the wood chips mass used to produce the energy per year*.

2.3.3 Amount of wood chips extracted per area

The wood chips mass (m_W) calculated before is now divided by total forest area of Ede (A_{tF}) to get the amount of wood chips that is extracted per unit of area (m_A). *Equation 2.3.3* shows the relationship.

$$m_A = \frac{m_w}{A_{TF}} \qquad 2.3.3$$

2.3.4 Sustainable wood chip harvested

To calculate the sustainable wood chip harvested (S_{Wh}), the tree species specific growth rate (E_{gr}), the percentage of each tree species in the forest (P_T) and harvesting percentage (P_h), has is shown in the *Equation 2.3.4a* were all used.

$$S_{Wh} = E_{gr} \times P_T \times P_h \qquad 2.3.4a$$

S_{Wh} is a value in m^3/ha*year. The volume depends strongly on the wood moisture content. To compare it with m_A, S_{Wh} is converted in wood tons per hectare and year (S_{Whd}), using the dried density of wood (d_{dr}) and moisture percentage based on dry basis W_r following *Equation 2.3.4b* to get *Equation 2.3.4c*, where m_g is the mass wood with moisture, m_d is the mass of wood dried.

$$W_r = \frac{m_g - m_d}{m_d} \qquad 2.3.4b$$

$$S_{Whd} = (S_{Wh} \times \delta_{dr}) \times (W_r + 1) \qquad 2.3.4c$$

The sustainable wood chip harvested (S_{Wh}) is the total amount of wood that is harvested every year. Only part of this amount is used for bioenergy. This is taken into account in the scenarios.

2.3.5 Forest area

The potential for biomass per species per hectare per year was multiplied with the area a tree species covers in the region of interest. These tree cover areas are based on the 6th forest inventory from Probos. To determine the tree cover in Ede, the percentage of the area that was covered by a certain species in the research pots of the forest inventory were multiplied with the total area that is covered by forest in Ede.

2.4 Scenarios

Based on Boosten (2017), biomass harvesting is conducted in a specific way in the Netherlands. A certain percentage of the increment is harvested every year. That percentage is dependent on the species, considering their differences in growth rates, different amounts of each species is harvested every year.
The aforementioned equations will be used to make calculations based on the current situation and future scenario:

- How much biomass can be produced if one uses a normal harvesting regime in the whole municipality of Ede with the current average harvest levels per species based on Schelhaas et al. (2014).
- How much biomass can be produced if one uses a normal harvesting regime in the whole municipality of Ede with the current harvest level per species based on Schelhaas et al. (2014) with an exception of the forest owned by the municipality in which only 3000 tons of Black cherry is harvested in 2017 for bioenergy purposes.
- How much biomass can be produced if one uses a maximum sustainable harvesting regime in the whole municipality of Ede of 75%.
- How much biomass can be produced if one uses a normal harvesting regime in the whole municipality of Ede with the current harvest level of 75% with an exception of the forest owned by the municipality in which only 3000 tons of Black cherry are harvested in 2017 bioenergy purposes.

With reference to national level in Netherlands to assess wood harvesting potential the following scenarios are developed:

- How much wood could be extracted per hectare per year if one uses current harvesting in Ede and it is extrapolated to whole country.
- How much wood could be extracted per hectare per year if one uses maximum potential harvesting and it is extrapolated to whole country.
- How much wood could be extracted from forest in Netherlands How much wood could be extracted per hectare per year if one uses current harvesting in Ede and it is extrapolated to whole country.
- How much wood could be extracted from forest in Netherlands if one uses maximum potential harvesting and it is extrapolated to whole country.

3. Stakeholder Analysis

3.1 Overview of stakeholders

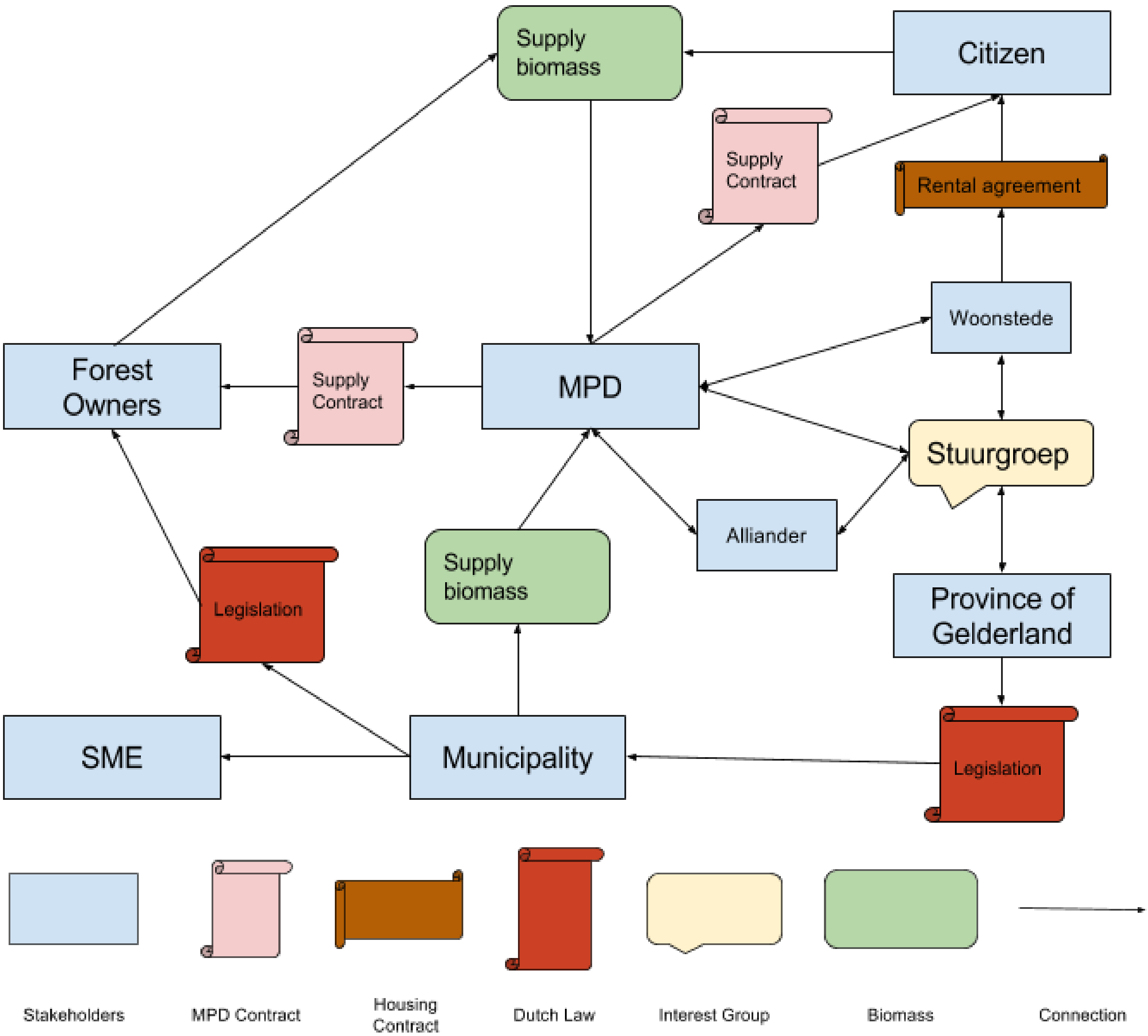

Figure 3.1: Representation of stakeholders and their connections to one another

Figure 3.1 gives a rough overview of the different actors and the connections between them. The four main stakeholders, MPD, SME, forest owners and the municipality of Ede will be described in more detail. Their interest, power and influence will be made explicit in the Description section of this chapter. Other's actors description will be elaborated in the annex.

3.2 Main stakeholders

Table 3.2: Table of four main stakeholders

Classification	Actors/Stakeholder	Goals	Concerns/Ambitions	Actions
Private	MPD Groene energie	Profits	Company expansion	Harvest, shred and collect wood chips. Deliver heat to consumers.
	Other forest owners	Mixed goals due to the plurality of forest owners.	Mixed goals due to the plurality of forest owners	Harvest biomass
Public	Municipality of Ede	Energy neutrality	Meeting sustainable energy goals	Harvest and exterminate Black cherry from municipal forests
NGO	SME	Nature conservation	Concern over harvesting of biomass from the forest in Ede	Legal recourse/Writing opinion pieces

3.3 Stakeholder description

3.3.1 MPD Groene Energie (MPD)

MPD Groene Energie is the overarching company responsible for the energy production in Ede. It was founded in 2012 as a private company to ‘increase the speed of the energy transition’. Using biomass to provide Ede with energy is part of this energy transition. There are many gardens in Ede, and they can provide a significant amount biomass from maintenance during spring and summer, to produce affordable energy (V.Kleijnen, personal communication, June 19, 2017). Homeowners as well as owners of portions of the forest in Ede all provide biomass to MPD in the form of wood chips, full trees, or garden clippings (V.Kleijnen, personal communication, June 19, 2017). The company uses local sources of biomass to produce energy for the municipality itself. Currently, two bioplants using wood as input source are operational, while a third using grass and leaves is still under construction. The company has been growing since it was founded and has been able to impact more and more people in Ede by providing green energy.

The end game of the company is not determined by a conservationist perspective. According to MPD, for a project, such as the one undertaken, to be sustainable it has to generate profits (V.Kleijnen, personal communication, June 19, 2017). Considering that MPD is a private company, it is not surprising that the economic aspect trumps the environmental one in the decision making process. Even though the company seeks to a certain extent reduction in emissions of CO_2, ultimately profits need to be made for activities to be viable. Nevertheless, using biomass to produce energy is a means to reduce emissions of CO_2 in the atmosphere compared to oil and natural gas, and a cheaper alternative than other forms of renewable energy such as solar.

Furthermore, as part of the stuurgroep warmtenet, MPD works with other actors involved in the project. The purpose of this group is to come up with a plan to reach a shared goal. That goal is to connect 20,000 housing equivalents to the district heating network that provides the people of Ede with green energy generated from biomass. This interest group is where the ideas of the different actors are shared and where they can influence each other on the course of action that should be favoured. As they all have the same goal, their efforts are all geared towards the same end.

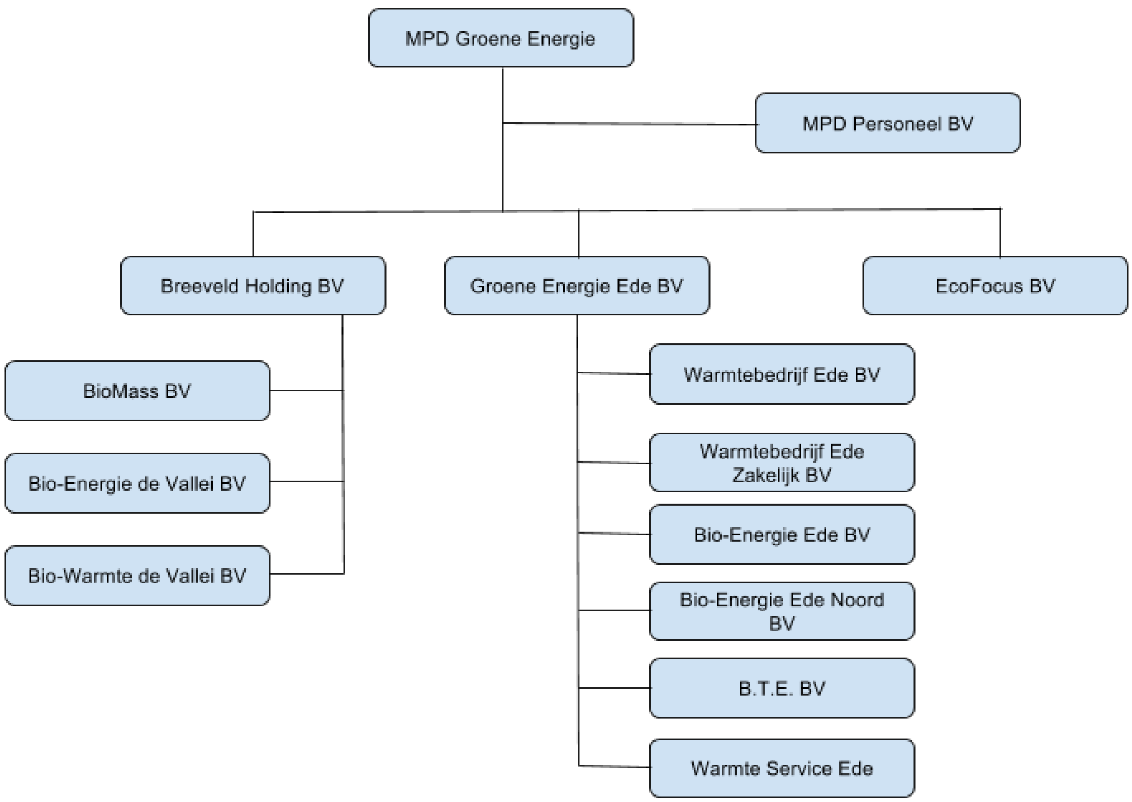

Figure 3.3.1: MPD Groene Energie company structure (V.Kleijnen, personal communication, June 19, 2017)

MPD has a complex company structure, involving many sub-companies that work in different chapters. An overview of the company structure is given in Figure. 3.3.1. The role and function of certain of the sub-companies is too extensive for this chapter, but are elaborated on in the annex. However, due to the complexity of this company, information about some of MPD's subsidiaries could not be accessed. The complete functioning of parts of the company remains unknown.

3.3.2 Municipality of Ede

The municipality is one of the most important actors. They have their own goals with respect to sustainability, which are more ambitious than the national goals. Indeed, the Netherlands as a whole aims for 14% sustainable energy, while the municipality of Ede has chosen to achieve

20% of sustainable energy by 2020 (E. van Tol, personal communication, June 12, 2017). Hence, when the private company MPD Groene Energie suggested to foster the energy transition in 2012 for Ede by extending their heating network, the municipality chose to share their ambition. The city opted to use biomass, amongst other sources of energy, to provide energy to local households and businesses instead of using oil and natural gas. The energy system therefore is a combination of solar, wind, geothermal and biomass as sources of energy. All these sources of energy put together help the municipality achieve their goal. There is much forest available in Ede, thus securing the input biomass source. Windmills are already present on the highway A30, and the municipality aims at building more, even though it may cause resistance from the local population due to aesthetic reasons and the danger windmills cause to bird species. Moreover, some buildings in Ede are already equipped with solar panels. Ede's source of biomass is so abundant that this option would be essential for the energy transition. This source of energy will also be instrumental in reducing emissions of CO_2 through the short carbon cycle.

In 2013 the municipality shared the ambition with the MPD for 20,000 housing equivalents to be connected to the heating network by 2020. Furthermore, they investigated the possibilities of connecting municipality property and even considered taking a minority share in the transport network of Bio-energie De Vallei (E. van Tol, 2015). Eventually the municipality decided against taking a share (Gemeente Ede, 2014). A few times a year, the stuurgroep warmtenet, a public interest group which the municipality chairs, along with affiliates of MPD Groene Energie, meet to discuss the progress in reaching the common goal of providing green energy to 20,000 housing equivalents. As long as the measures sought are in accordance with national policies, the municipality has the ability to choose whatever course of action they see fit to do their part in getting the Netherlands energy neutral by 2050.

Today, Ede uses 10 PJ of energy. The first step in the municipality's plan to become energy neutral is to save about 2 PJ, leaving 8 PJ to be produced sustainably (E. van Tol, personal communication, June 12, 2017). The municipality is responsible for granting permits. They are therefore responsible for all the infrastructure within its borders. Thus, they have the power to choose whichever energy option that is deemed more favourable, whether it is placing new windmills, installing solar panels, or building bioenergy plants, it is up to the municipality to decide. They have the power to decide what means would get them to their ultimate goal of energy neutrality and a reduction in CO_2 emissions. Hence, they have the power to control Ede's future when it comes to energy.

As owner of a portion of the forest in Ede, the decisions that are taken will impact the city's assets. The municipality owns in total 2,461 hectares of forest (Borgman Beheer advies, 2009). Whichever management plan with regard to bioenergy is put in place will impact the forest resources the city has at its disposal. Harvesting is primarily done to sell the wood, following FSC guidelines, while bioenergy production is one of the last uses of the harvested biomass (C.van Rijswijk, personal communication, June 20, 2017). As of now, essentially only the exotic species Black cherry (3,000 tons per year) is harvested by the municipality to provide MPD Groene Energie with biomass (E. van Tol, personal communication, June 12, 2017). The municipality is only concerned with the eradication of this invasive species and aims to have it reduced to 10% by 2022 (E. van Tol, personal communication, June 12, 2017). From that point on, the municipality will not provide any more biomass from their forest to MPD Groene Energie to use in their plants.

The municipality has not set regulations for MPD on how they should instruct their contractors about harvesting methods (E.van Tol, personal communication, June 26, 2017).

3.3.3 Stichting Milieuwerkgroepen (SME)

SME is the commissioner of this study. It is an independent environmental group with the aim of protecting nature and the environment in the municipality of Ede. Improving the state of natural systems in Ede is one of their main goals. They have expressed great concern over the integrity of forest ecosystems and animal species in Ede. By removing trees from the forest, many ecological services are lost. The recreational benefits people derived from the forest will be diminished due to smaller trees. The forest also protects the small villages in the area from wind deposited sedimentation. Besides, habitats will be fragmented risking the disappearance of certain species from the region. Those concerns are legitimate and should be addressed in order to assess the sustainability of the project MPD is expending.

SME is unsure whether it is possible to sustainably harvest wood on a large scale to provide Ede with energy. With the energy transition that Ede has undertaken over the past years, more housing equivalents are expected to be connected to the district heating network. That would imply an increase in the demand for biomass. Two bioenergy plants using wood from Ede have already been taken into commission, and a third that functions with grass, needles and leaves is currently under construction. Such an expansion can undoubtedly increase the pressure upon forest ecosystem in Ede. Hence, the cause for concern on SME's part.

SME does not have direct power to affect the municipality's decisions, but they have great interest in MPD's bioenergy project favoured by the municipality and try to influence decision making through lobbying and providing vision documents. The only way to challenge municipal decision is through the justice system (J.Klostermann, personal communication, May 22, 2017). Without actual institutional power, SME doesn't have many other options to alter the decision making process.

3.3.4 Other forest owners

The municipality is not the sole owner of the forest in Ede. The ministry of defence, the national park De Hoge Veluwe, Natuurmonumenten, Staatsbosbeheer, the Geldersch landschap and St. het Luntersche Buurtbosch are all owners of substantial parts of the forest in Ede, along with many other private owners (Figure 3.3.4). Each of those owners therefore has a stock of biomass that MPD could use to produce energy and meet the municipality's energy goal. As it was previously mentioned, the municipality only delivers Black cherry to MPD. Some forest owners like 'Staatsbosbeheer' harvest and process the material (to wood chips and -shreds) themselves, while others outsource this activity to BioMass BV, a sub-company of MPD Groene energie. The management practices of the other owners of the forest remains an unknown. It is then dependent on the desires of each different forest owners to choose whatever management option they see fit to tend to their lands. Some may seek monetary gain while other may be more interested in conservation. The integrity of the forest in Ede is dependent on what the owners of said forests choose to do. For the project under consideration to be sustainable, the method of harvesting ought to be sustainable as well. If harvesting is done extensively on a wide scale, the forest will slowly but surely lose many of its environmental and ecological benefits that many species of plants and animals depend on for their survival.

As owners of the land, they have the ability to do whatever it is they want on their land, as long as it is in accordance with governmental regulation. Considering the number of owners of the forest in Ede, contacting them all and synthesising the information obtained from them would have been a daunting task for which the team lacked the time. It therefore remains an unknown what other forest owner, other than the municipality, do with the resources (i.e. biomass) that they have at their disposal. Furthermore, each owner can use the biomass on their land differently, whether it is sold to make furniture or not cut at all, the management practices vary. This makes it even more difficult to know the true interests of the different owners. Nonetheless, they are still of the utmost relevance as they are the one who can grant access to biomass to MPD. With the Stimulering Duurzame Energieproductie (SDE+), the ministry of economic affairs aimed at fostering the proliferation of renewable energy, offering subsidies to producers of renewable energy (Stimulation of Sustainable Energy Production, n.d). That in turn will encourage forest owners to harvest the biomass on their land for monetary gain. They therefore have a choice that will be influenced by their interests.

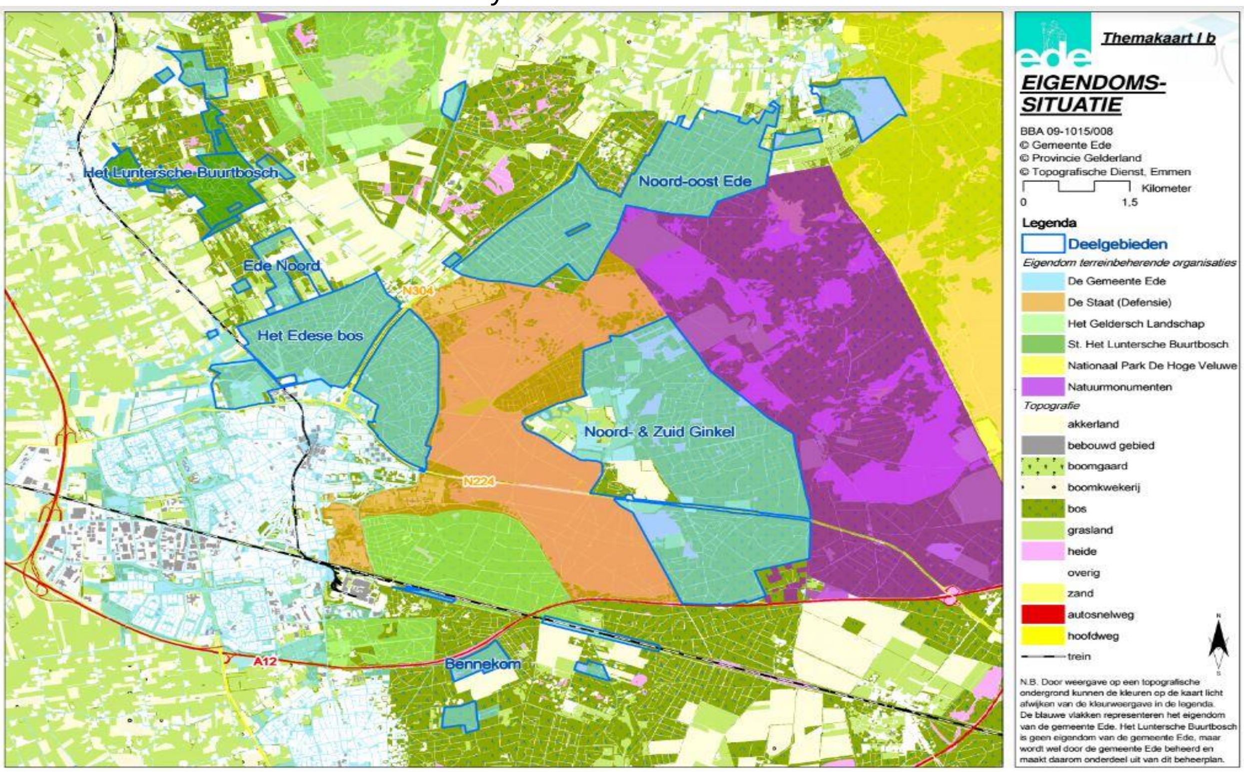

Figure 3.3.4: Map of forest ownership in Ede (J. van Gooswilligen, personal communication, June 13, 2017)

4. Feasibility Study - Technical Demand

4.1 The Production Process

4.1.1 Biomass input requirements

Between 35 and 45% of all biomass input is garden waste, 45% is from surrounding forests (Warmtebedrijf Ede, 2017; Valentijn Kleijnen, personal communication, 2017). For the remainder of this report, we assume the value of 35% for fraction of the biomass input from gardens. Biomass from garden input stems from local garden clippings. Most of this material becomes available in spring and summer, which is also the time when heat demand is low. For that reason, the accumulating biomass is dried and stored at a depot to use in winter. In winter, woody materials are harvested from the forests surrounding Ede. Currently, 'bioenergy de Vallei' is said to consume 24,000 tons of biomass per year and 'bioenergy Ede' consumes 18,000 tons per year. That makes for a total of 42,000 tons of biomass per year of which 17,010 tons come from the forests (Valentijn Kleijnen, personal communication, 2017).

The initial input design for the plant is showed in the table 4.1.1 (Kleijnen J.V. and Ing Steenmeijeren 2011). In this table is showed the expected amount and percentages consumption of the biomass for the factory one at the beginning of the project in 2011.

Table 4.1.1 Amount and type of biomass available for two bioplants in Ede

Biomass Type	%	Mass (tons per year)	
		First phase (2012)	Second Phase (2016)
Wood chip from forestry	> 50	4.475	13.100
Wood Chips meeting requirements of Austrian norm M 7133.	+/- 30	1.850	5.000
Wood chips from public parks of surroundings communities.	< 30	2.675	7.900
Total		9.000	26.000

Around 30% of the wood chips should follow the Austrian Standard 7133 (Önorm, 1998), (MPD Green Energy, 2017). The biomass moisture should be between 20 - 50%, cross sectional area maximum 12 cm^2, length maximum 30 cm and ash residue volume of maximum 5%. Using this standard to assess the quality of the biomass input, the factory ensures a high-efficiency. The moisture is the most important factor for the burning process. If the moisture is lower than 20%, temperatures within the furnaces will become too high. The systems operate in a temperature ranging around 900ºC (Kara energy systems, n.d.). When this range is greatly exceeded there is a risk of breakdown (Valentijn Kleijnen, personal communication, 2017). This means that the systems are not fit to use anything like dry wood pellets because the moisture content is usually less than 10 %.

4.1.2 Description of the wood-fired system

'Energy-plant' is the term used for a factory where fuel is burned to produce heat and/or steam and electricity. Throughout this burning process, the energy that is released is used to heat up water and/or produce steam. When combined with district heating, the hot water is pumped into an underground piping network which households can tap into, extracting heat for spatial heating, showers and tap water. In the case of Ede, woody biomass is used as a fuel for the energy output.

The wood-fired system is the furnace used to generate heat through burning biomass and is also known as wood-fired incinerator. The main outputs from this incinerator are hot water, ash and smoking gases. The wood-fired system has three main zones: heating up zone, firing zone and the burn-out zone. The heating up zone is composed of a transport system, an upper storage room, and a wood chips dryer. The wood chips arrive at the plant and are stored temporally in a supply container which is carried out by the transport system. From the supply container, the wood chips are delivered to the dryer using gravity. The dryer is an electric conveyor belt that uses gases from the economizer to heat up the raw material.

After drying, the chips and shreds are fed into the burning zone. The burning zone has an oven, boiler and economizer. The oven is constantly fed with air by two different ventilation systems. One is located under the oven ensuring the oven has enough air for combustion. The second one is located at the side of the oven to regulate the flow of air in the oven. It provides the right wood/air ratio to get maximum efficiency. In the boiler, water is heated up until steam is produced. Produced steam goes into a piping system (a heat exchanger) where the heat transferred to the smart grid. The water temperature will be increased to 105ºC and then be supplied to the heating district network. The economizer is a device that allows recirculation of steam generated for the boiler two more times by the heat exchanger which works a 250ºC.

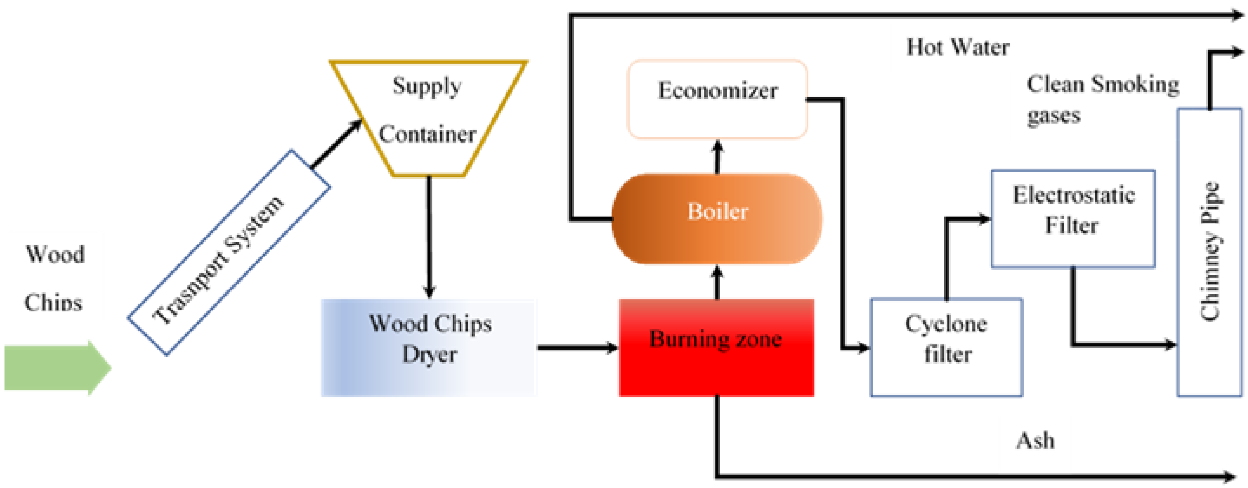

Figure 4.1.2: Wood fired system schematic drawing.

The burn-out zone is the zone where smoking gases are expelled from the oven, filter-cleaned and discharged to the atmosphere. The bottom-ash is collected regularly from the oven and dispensed following the legislation for this kind of materials.

The wood-fired systems run continuously depending of heating demand. In winter they work at 100% capacity most of the time. In the summer, when demand is low it works at around 20% capacity. Because the system is modular, there is no loss in efficiency when the plant operates at lower than maximum capacity (V. Kleijnen, personal communication, June 19, 2017). The gas fired systems are back up heating units, that are used in winter when the heating demand surpasses the maximum capacity of the two wood-fired systems.

Estimated efficiency for the system using Grafe firing is 85% (Dornburg and Faaij 2001). The efficiency stipulated in the beginning of the project is 90%.

4.1.3 Description of 'Bio-energie de Vallei'

'Bio-energie de Vallei' was the first biomass-based energy plant in Ede. It was taken into commission in 2013. The plant has two wood-fired incinerators. One has a capacity of 4.5 MW and is used to warm water to directly feed into the heating district. The other has a capacity of 7.3 MW and is used to produce steam at a pressure of 18 bar. The steam produced is delivered to HSV, a company that produces polystyrene products. The plant also contains two gas fired boilers of 6.5 MW each as a backup system for peak demands in winter (Valentijn Kleijnen, personal communication, 2017). The two gas burners operates with natural gas provided by means of the national network. The main outputs of those gas fired system are hot water and smoking gases. Figure 4.1.3 is the scheme of the plant.

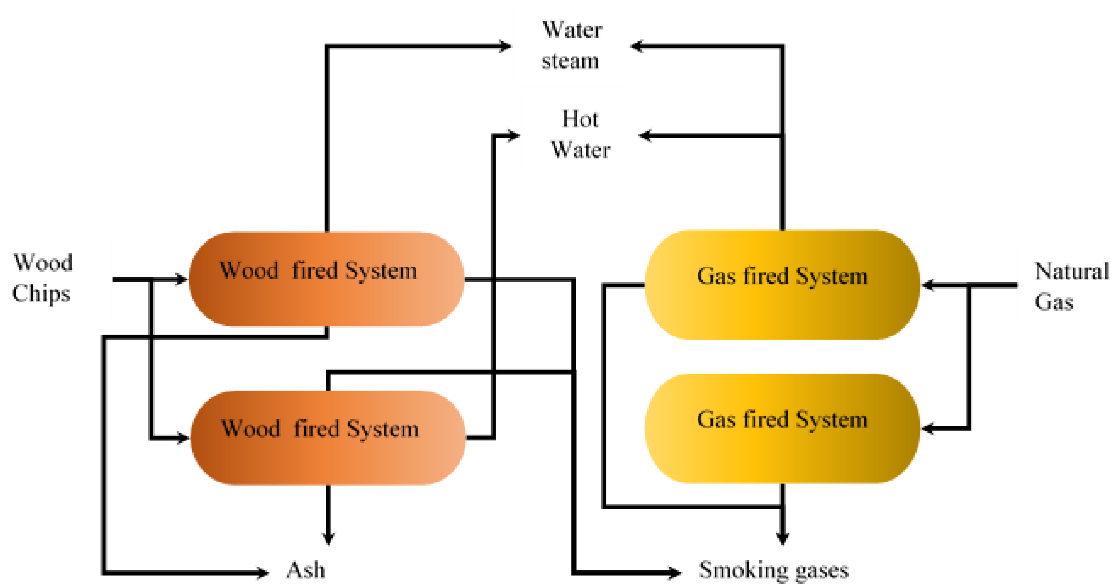

Figure 4.1.3: Bio-energie de Vallei schematic drawing

4.1.4 Description of Bio-energie Ede Plant

The 'Bio-energie Ede' plant is the second plant built in Ede and has recently become fully operational. The technology used here is similar to the plant previously mentioned. However, the steam produced is used in a steam turbine, a machine using steam to produce electricity. These kinds of plants are known as combined heat and power plants (CHP). Nowadays, these type of plants are accounted for as the most efficient plants, because the released energy can produce heat and power at the same time (Dornburg and Faaij 2001).

The configuration of the plant itself consists of two wood fired systems of 4.5 MW each and one gas fired system of 4.5 MW. The gas boilers only serve as a backup system. One wood fired system is used to produce heat and another one produces steam to feed the Stirling engine. Figure 4.1.4 shows the schematic overview of the plant.

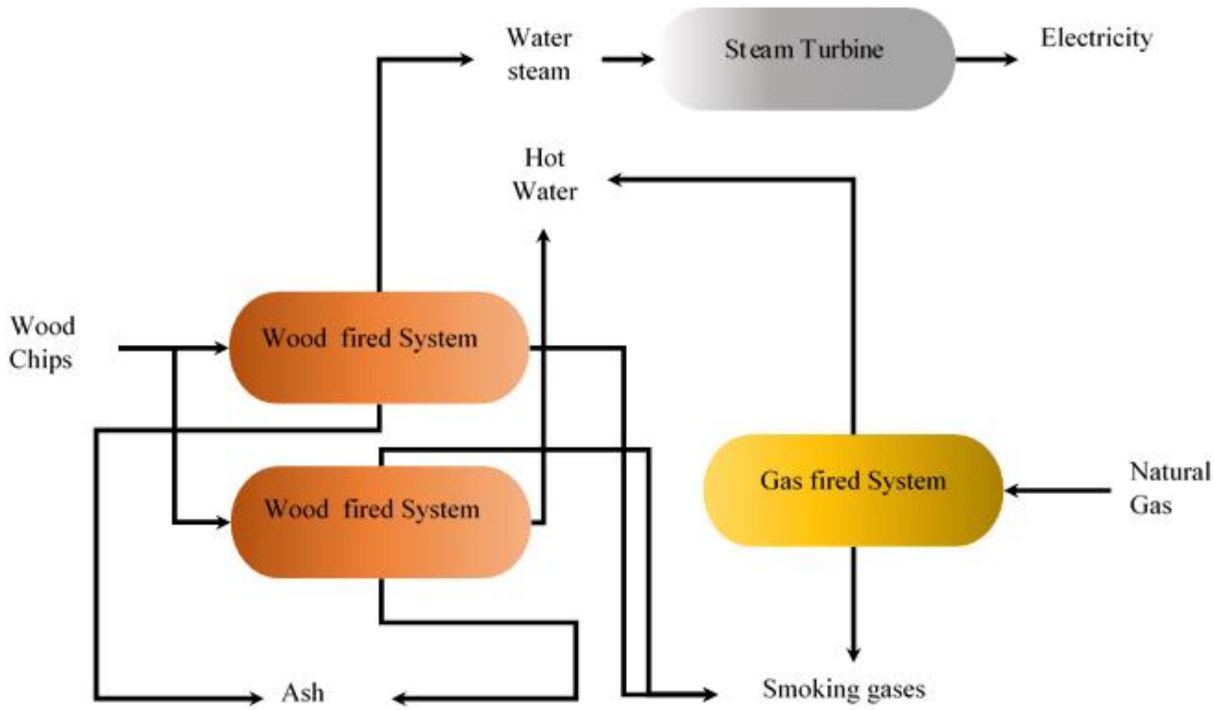

Figure 4.1.4: Bio-energie Ede schematic drawing.

4.1.5 Advantages & disadvantages of the technology used by bioplants

The technology used has many advantages, for example using the nonselective biomass technology allows for a wide variety of raw material as fuel (Strzalka et al, 2017). The biomass fired plants have relatively a clean combustion when compared to fossil fuels (Rahman 2013). Although the energy content of wood is lower than that of fossil fuels, it is easier to extract this primary energy. In wood fired systems therefore, the *relative primary energy* savings are between 53% and 113%. Thus, depending on the system, relative primary energy savings can be doubled or cut in half (Dornburg and Faaij 2001). The CHP technology also has economic benefits. CHP saves money because it produces two usable energy carriers from a single fuel (Panagiotis, 2011). In that sense using cogeneration is more environmentally friendly because less fuel is used (Swithenbank et al. 2011) compared to producing heat and electricity separately.

However, there are also some disadvantages regarding the use of this technology. The high investment cost of biomass combustion based plants in comparison to fossil fuels plants and the relatively low cost of fossil fuels are the main reasons why bioenergy does not contribute a higher proportion of the energy generated in the EU (Johnson and Tschudi 2012). The resultant trace gases and aerosols from biomass burning are important for the atmospheric radiative processes. Columnar content of aerosols is high during the burning period in addition to the drastic reduction of visibility (Badarinath et al. 2004). Biomass burning is also considered as one of the major factors affecting the global carbon cycle (Lin et al. 2013) and combusting biomass may lead to sulfur oxides, nitrogen oxides, hydrogen chloride, dioxin and furans, as well as heavy metal emissions (Runge, 2013).

4.2 Bioenergy demand

The energy production of an energy company is closely related to the demand of energy that it should cover. This demand can suffer fluctuations and depends on several such energy savings due to insulation which affect the current and future energy consumption hence the energy demand.

4.2.1 Trends in insulation and consumption of bioenergy

During the last 10,000 years, human population showed an exponential growth (Keinan & Clark, 2012). The International Energy Agency has gathered frightening data on energy consumption trends (Pérez-Lombard et al. 2008) and current predictions show that this growth will continue (Brounen et al. 2012; Pérez-Lombard et al. 2008; G-J.Nabuurs, personal communication, June 15, 2017). Energy use by nations with emerging economies will grow at an average annual rate of 3.2% and exceed by 2020 the average annual rate of developed countries (Pérez-Lombard et al. 2008).

The situation for the Northern part of the European Union, which includes the Netherlands, is very similar to the reported developed world averages in which 41% of the total final energy consumption comes from buildings with 30% being used in residential buildings (Yucel & Pruyt, 2011). Furthermore, the energy demand for space heating and hot water constitute the major portion, about 70% to 80%, of the delivered energy consumption within a building (Audenaert et al. 2008; Yucel & Pruyt, 2011). This significant share makes an energy transition in the residential sector one of the most important frontiers of sustainability transitions (Yucel & Pruyt, 2011).

The Netherlands has been using a set of national policies to comply with the EPBD directive and to reduce the energy consumption in residential buildings (Yucel & Pruyt, 2011). New dwellings follow that directive leading to an energy saving (Entrop et al. 2010) around 26% to 28% in comparison with buildings from the 80s and 90s (Brounen, Kok & Quigley, 2012; Majcen, Itard & Visscher, 2013) or up to 55% if the building was built in the 70s (Brounen, Kok & Quigley, 2012). However, due to the currently low demolition rate between 0.15% and 0.35% of the house-stock (Brounen, Kok & Quigley, 2012; Majcen, Itard & Visscher, 2013;Yucel & Pruyt, 2011) and the construction rate of about 0.8% of new dwellings (Brounen et al. 2012), the average energy efficiency improvement of the Netherlands house-stock is within 0.9% to 1.5% of energy saving (Hieminga, 2013; Brounen et al. 2012).

Nevertheless, this range of energy saving is under pressure since the outbreak of the financial and economic crisis as consumers buy less new and efficient appliances and the construction of new and energy efficient houses has fallen (Hieminga, 2013). Therefore, the energy consumption depends on two factors: intensity of the households energy consuming activities and whether the energy efficiency of the dwelling is economically profitable (Yucel & Pruyt, 2011).

According to Yucel & Pruyt (2011), there is a possibility to reduce the total energy consumption even though the increasing population and its consequent increase in energy demand which requires active policies, renovation and optimization of the Netherlands house stock. However, the current policies and the demolition and building rates lead to a slight increase of the energy demand with a maximum already reached nowadays which will be maintained in 2020; in 2040 that energy demand will be similar to the energy demand of 2000 (Figure 4.2.1).

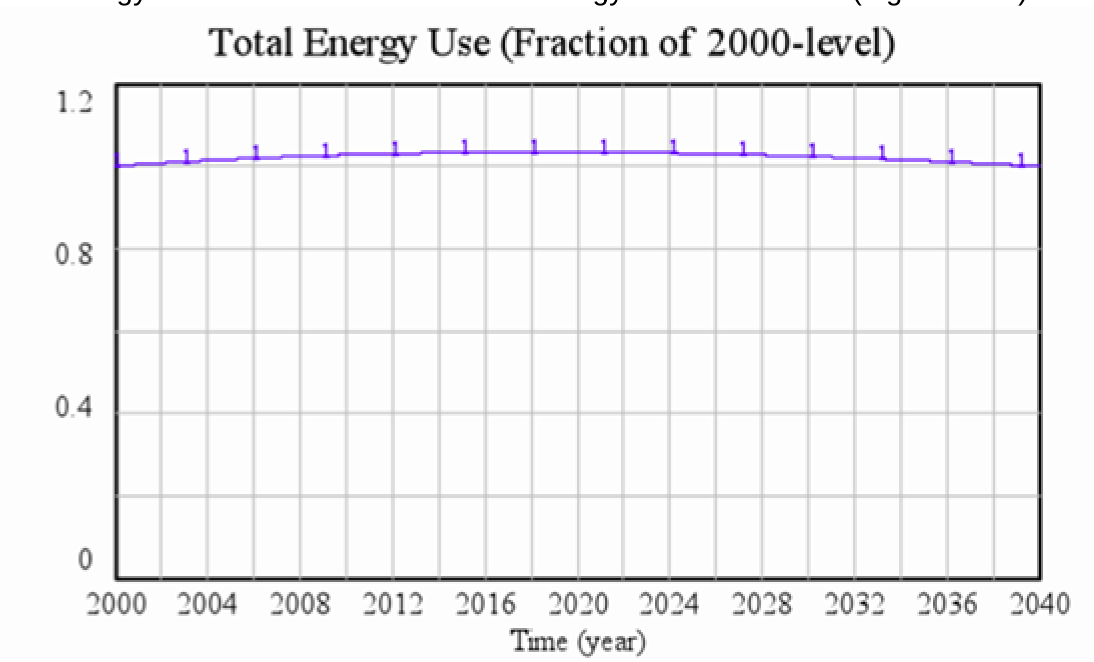

Figure 4.2.1: Fraction of 2000-level total energy use per year using collected data and predicting the future energy use with a model developed by Yucel & Pruyt in 2011 which considers the increasing number of dwellings, energy use, energy savings and transition to new buildings (Yucel & Pruyt, 2011).

In conclusion, although there is an improvement in the individual dwellings, the level of this improvement is not sufficient to compensate the increase in the total number households in the Netherlands by the current policies and practices (Yucel & Pruyt, 2011).

4.2.2 Households equivalents

Each household in the Netherlands requires different energy inputs depending on the year in which the house was built and the type of house (Entrop, Brouwers & Reinders, 2010). Local bioenergy plants and other types of energy plants supply energy to thousands of households or small businesses which require different energy inputs. Therefore, the equivalent household measure is used in order to normalize and calculate the amount of households to which energy may be supplied. Moreover, the equivalent household energy demand is an average of the energy needed by a family household and a bigger or a high energy demand building such as a small building can be considered as a certain amount of equivalent households (V.Kleijnen, personal communication, June 19, 2017).

Last decades the energy demand in each household varied widely as discussed in the section *5.2.1 Trends in insulation and consumption*. Moreover, in literature explanations of what is

meant by one household equivalent differ. A study by CE Delft, regarding possible utilisation of waste heat, equates one household equivalent to 100 m^2 of living space, which corresponds to an annual heat demand of 27 GJ (Leguijt et al., 2011). Another study by Programma Warmte Koude Metropool Regio Amsterdam (MRA, 2016) gives a value of 35 GJ per household equivalent per year. In the interview with MPD, Valentijn Kleijnen gave an estimate between 25 and 50 GJ per year per household equivalent, depending on the age and state of the building.
Another way to go about it is by calculating the heat demand from natural gas consumption. An average Dutch household consumed 1,250 m^3 of natural gas in 2015 (Centraal Boreau voor de Statistiek-StatLine 2017). Depending on either low or high caloric gas, this corresponds to a value between 46 and 52 GJ. From the above it was decided to set the heat demand of one household equivalent at 35 GJ per year (MRA 2016).

Furthermore, according to section 4.2.1, trends in insulation and consumption the value for equivalent household energy demand could change in the near future what will require to adapt that value in 2020 by 0.9% to 1.5% reduction of household equivalent energy demand; although in 2020 scenario the total energy demand is roughly the same as in 2017 (Yucel & Pruyt, 2011). Regarding MPD, they are supplying energy to 10,000 equivalent households (V.Kleijnen, personal communication, June 19, 2017) and they expect to supply 20,000 equivalent households in 2020 (V.Kleijnen, personal communication, June 19, 2017). The amount that this corresponds to in terms of energy is calculated afterwards.

4.2.3 Demand fluctuations and characteristics

Production of heat as a source of energy is crucial in order to fulfil the energy demand around the world (Audenaert et al. 2008; Yucel & Pruyt, 2011) and it is even more important in northern countries such as the Netherlands (Yucel & Pruyt, 2011). Bioproduction of that heat is what concerns this report and fluctuates depending on the countries and the season.

As long as the main production of bioenergy plants is about heat as warm water, on winter the demand is between three and four times higher than in summer (V.Kleijnen, personal communication, June 19, 2017). Furthermore, due to demand fluctuations the bioenergy plants need to adapt their production to the demand in order to minimize losses when heat is not needed (V.Kleijnen, personal communication, June 19, 2017). Therefore, in winter, the plants work at a maximum capacity and in summer they mainly work at a minimum capacity, which is 20% of the maximum (V.Kleijnen, personal communication, June 19, 2017).

Besides, the demand suffers daily fluctuations which are difficult to deal with during winter since the capacity needed at certain hours cannot be supplied by biomass boilers (V.Kleijnen, personal communication, June 19, 2017). That extra energy is supplied by gas boilers and corresponds to 30% of total energy supplied (V.Kleijnen, personal communication, June 19, 2017). In 2020, the aim is not to use any gas for extra demand (V.Kleijnen, personal communication, June 19, 2017).

4.2.4 Energy supplied by bioenergy plants

A bioenergy plant bases its production on the energy demand of the customers they are supplying (V.Kleijnen, personal communication, June 19, 2017), and its fluctuations are explained in section *5.2.3 Demand fluctuations and characteristics*. Therefore, there should be a distinction between the energy demand related to the amount of households to supply and the amount of energy produced by the energy plant. The energy produced by the plant should be higher than the demand of households to secure the supply of energy to all the customers, at all times. This means that the temperature in the district heating system should be maintained at all the times, even in summer time when the demand is low. In table 4.2.4 energy demand is calculated using equation 2.3.1 with the household equivalent defined in 4.2.2 and total energy produced is calculated using the equation 2.3.1.1. using the boilers capacities for each plant defined in 4.1.4 and 4.1.5. The boiler capacities for third plant will be similar to the second one (V.Kleijnen, personal communication, June 19, 2017).

Table 4.2.4: Model output in which the total energy demand is the one calculated from literature and the total energy produced is the one calculated from the plant characteristics, way functioning and new future installations.

Scenario	Units	Total energy demand	Total energy produced
2017	[TJ/year]	350	388
2020	[TJ/year]	690	556

5. Feasibility Study - Ecological Supply

5.1 Sustainable forest management

5.1.1 Partial environmental impact assessment

As 20% of all EU energy consumption will be based on renewable sources by 2020 with bioenergy as important contribution, there are some arguments that large-scale production of bioenergy from forest biomass will lead to many environmental problems, like soil degradation, younger forests, a loss of ecosystem functions, and deforestation (Schulze et al., 2012).

5.1.3.1 Greenhouse gas reduction

Carbon dioxide (CO_2) emissions from biomass combustion are generally assumed carbon neutral according to the theory of the short carbon cycle. The CO_2 released from combustion should approximately be equal to the amount of CO_2 sequestered through photosynthesis (Cherubini et al., 2011). However, there is disputation over the assumption that bioenergy combustion is carbon-neutral. One argument is that CO2 neutrality is not valid in the case of bioenergy because it neglects the plant growth and consequent carbon sequestration which would occur if an old forest had not been harvested. Also the use of fossil fuels in bioenergy production process, like harvesting and bioenergy processing are not taken into account (Schulze et al., 2012).

The discussion on the carbon neutrality of biomass harvesting has its origins in tropical forests management where old growth forest with a high carbon content after harvesting of biomass is converted in a young forest in which less carbon is stored (G-J.Nabuurs, personal communication, June 15, 2017). It takes time before the carbon debt repayment point is reached in which carbon emission savings are equal to the initial carbon stock (Mitchell et al., 2012). If one takes into account that the initial forest could also have grown further if no harvesting had been done it will take even longer before a so called ‘carbon offset parity point’ is reached in which carbon emission savings from not using fossil fuels equals the carbon loss of harvesting (see Figure 5.1.3.1). A study from Walker et al. (2010) found a carbon payback period of 21 years, comparing electricity produced from biomass to electricity produced using coal. When comparing biomass to natural gas the carbon payback period was 90 years. McKechnie et al. (2010), had similar results in which electricity produced from wood pellet is preferable over electricity produced by coal after 17-38 years.

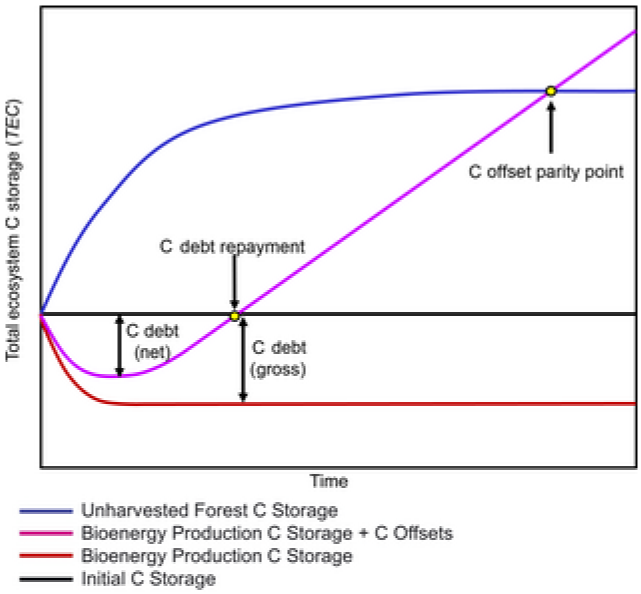

Figure 5.1.3.1: Visualisation of the carbon payback period and carbon offset parity point (Mitchell et al., 2012)

A study which combined a life cycle inventory (LCI) and forest carbon analysis summed the cumulative emissions of the bioenergy options and the forest carbon emissions (McKechnie et al., 2010). The result indicated that emission mitigation of carbon was delayed and reduced when reductions in forest carbon were taken into account. Total emissions of CO_2 initially increased since bioenergy was used. Emission from forest carbon loss exceeded the reduction of fossil fuel-based emissions by using bioenergy as substitution (McKechnie et al., 2010). However, the increased emission of CO_2 is temporary. In a 100-year period, the rate of forest carbon loss decreases with time while emission reduction due to utilization of bioenergy instead of fossil fuels continues to increase. A 'break-even' point where total emissions from bioenergy and reference fossil fuel are equal will be achieved after a time delay (McKechnie et al., 2010). It will only be possible to reach the goal to reduce net emissions of CO_2 after the break-even point. So, the time perspective is important to assess the carbon balance of the forest and bioenergy projects (Schlamadinger & Marland, 1996).

There are many factors which contribute to the net balance of carbon emission, including the growth rates of trees, efficiency of conversion of biomass to energy, the kind of fossil energy system that is replaced, and efficiency of wood products manufacturers (Schlamadinger & Marland, 1996). Thus, forest management and biomass utilization strategies are important to take into account when trying to reduce net carbon emissions. The time perspective is also an important component in the carbon balance of forestry and bioenergy projects (Schlamadinger & Marland, 1996).

It should, however, be clear that in temperate forests, the carbon neutrality issue is a lot less relevant than in the tropics as the harvested forest does not drastically differ from an initial stock (G-J.Nabuurs, personal communication, June 15, 2017).

5.1.3.2 Soil and site productivity

Soils are a very helpful indicator for forest management and are extremely important for tree growth and site productivity because they can transport nutrients and water to trees and provide habitat to microorganisms which are essential for decomposition and nutrient cycling (Janowiak

& Webster, 2010). There are many factors that contribute to soil productivity which include on site soil characteristics, vegetative cover, regulation and harvesting methods. Cumulative impacts of bioenergy-related management activities, such as intensive harvesting, may change erosion rates and the soil's nutrient balance (Janowiak & Webster, 2010).

Maintaining organic matter content and nutrients are essential to preserve soil quality (Janowiak & Webster, 2010). Organic matter is important for tree growth and to sustain life for microorganisms living in the soil. The amount of organic matter in the soil also plays a role in water retention, air flow and moderation of soil temperature fluctuations. Levels of organic matter in soil largely depend on the available amount of nutrient inputs and management activities (Janowiak & Webster, 2010). The sites and management activities which disturb the forest floor lead to different degrees of organic matter loss. More intensive forest management, due biomass production and harvesting, such as shortening rotation times or removing woody residues from the surface of the soil would reduce organic matter (Janowiak & Webster, 2010).

Intensively removing wood residue as biomass for bioenergy may have a significant negative effect on soil productivity because of concerns about whether adequate amount of nutrients can be maintained. Soil nutrients, like nitrogen, phosphorus, and calcium, are essential for plant growth in forest ecosystems. The amount of nutrients that are contained in small tree branches, buds and leaves, which are components of residue, is disproportionately higher than in tree woods (Janowiak & Webster, 2010). Some studies (Janowiak & Webster, 2010) indicate that excessive harvesting and whole-tree harvesting may cause nutrient deficiency and subsequent decline in growth and then lead to long-term productivity decline. However, research about biomass harvesting taking nitrogen deposition into account is still limited and more research is needed.

Excessive harvesting may also result in soil displacement, erosion and other textural or structural changes. The potential risks of these impacts on soil quality can be even exacerbated by greater removal of woody residues and other forest biomass for bioenergy (Janowiak & Webster, 2010). The pattern of biomass harvest can cause substantial increases in soil compaction but more studies are required to evaluate relation between changes in soil productivity and biomass harvesting.

5.1.3.3 Biodiversity and Forest Habitats

Sustainable forest management can be achieved if harvesting operations mimic natural stand dynamics and disturbance regimes. This kind of management takes biodiversity into account because biodiversity plays an important role in improving forest productivity and in providing habitat for wildlife and plant species in forests (Janowiak & Webster, 2010). Extraction of additional biomass from the forest may cause serious problems for biodiversity. Some species habitat may degraded leading to a loss of biodiversity. This all depends, however, on the management style that is used as intensive forest management may have both positive or negative impacts on species diversity. The level and pattern of harvesting are important to achieve sustainable goals in terms of forest management (Janowiak & Webster, 2010). A system-level assessment of trade-offs is also necessary to figure out how to balance biomass harvesting with maintaining forest biodiversity (Janowiak & Webster, 2010).

Biomass harvesting and increased removal of wood residues may also have impacts on dead wood and other forest residues which are structural components for biodiversity in forest ecosystem (Janowiak & Webster, 2010). Dead wood and forest residues can provide habitat for many other species, such as birds, amphibians, and mammals. Increased harvesting and removing of forest residue will lead to possible elimination of forest residue from intense harvesting for bioenergy and decrease the species composition and richness as a consequence (Janowiak & Webster, 2010).

To mitigate or prevent the aforementioned impacts on the environment, sustainable forest management is of the utmost importance. But before delving into this, there should first be an indication of what is meant by sustainability.

5.1.2 Definitions of sustainability

Sustainability is an old term that originates from forestry (Schmithüsen, 2013). The first notions of persistent use of forest are already mentioned in forest laws in the 13th century. In the German forest law for example, there was a general conviction that woodcutting should be carried out carefully and that some valuable tree species, such as fruit carrying trees, should not be harvested (Mantel, 1990). In the first known French law for waterways and forests (the Ordonnance du Brunoy) the owners of forests were required to visit their forests, and through sales ensure that those forests were preserved in a 'good condition' (Schmithüsen, 2013). The general consensus is that it was the German Hans Carl von Carlowitz who was the first to introduce the term 'sustainability' in his famous book: Sylvicultura oeconomica (Schmithüsen, 2013). 'Nachhaltighkeit' (sustainability) was here used in an economic sense. Von Carlowitz realised that the forest had been degraded in the centuries before him and as head of the Saxon mining administration he realised that in order to maintain the wood production that was necessary for the mines, harvested areas needed systematic replanting.

A leap in time shows that sustainability, as a term, has been developed over the years. The current definition on which most governmental and non-governmental organisations base their definitions of sustainability on is the one the UN World Commission on Environment and Development came up with. In the Brundtland Report they state that sustainable development is: 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). This term is broader than the 'Nachhaltigkeit' of Von Carlowitz and allows for more than one interpretation. It is important to realise what one considers future needs that need to be maintained in order to understand their actions and their outlook on life itself.

Some definitions were gathered on what 'sustainability' means to the stakeholders who are involved in bioenergy processes in order to get a feel of their priorities and also in order to develop a definition of our own that could be used in this report. Mrs. Klostermann explained that the definition the SME uses has to do with the 'broader approach on the functions of trees and forest'. These functions include housing of species richness, recreational value, and the mitigation of environmental impacts by forest and urban green spaces such as capture of dust, reducing traffic noise, and cooling the city (J.Klostermann, personal communication, May 22, 2017). Mr. Van Tol who is a climate policy-advisor for the municipality mentioned that he 'prefers to talk about energy and that sustainability is a vague term' (E.van Tol, personal communication, June 12, 2017). Sustainability means meeting your energy goals. Another employee of the municipality specialized in ecology explained that for him sustainability is: 'In general being in balance with what the earth can offer' (C.van Rijswijk, personal communication, June 20, 201). Mr. Kleijnen who is the director of the energy company responsible for providing bioenergy in Ede tends to the 'People, Planet, Profit' approach to the concept of sustainability (V.Kleijnen, personal communication, June 19, 2016). He is the only one that mentioned that for him, sustainability also means long term sustained profits. Mr. Nabuurs finally, who is a forestry professor for Wageningen University and Research specialized in European Forest resources put a great deal of emphasis in the need for ‘indicators that are needed to define sustainability’. The later might summarise the quest for a definition of sustainability best. It turns out that sustainability is a vague term and while it is interesting to see that some only care about the People part of sustainability, others about the Planet and a few include Profit which actually might be at the base of conflicts between actors. Research into ‘what is sustainable’ needed further quantification.

5.1.3 ‘9 Principles of Pro Silva’

Based on the commissioner of this report and the aim of our research, the ecological part of sustainability was chosen to be explored further. To further quantify sustainability, one could make use of principles that explain what is meant by sustainable management. While these principles are subjective, they do carry some legitimacy if they are supported by a broad group of professionals. Within the world of forestry, an example of such a group of professionals is the ‘Pro Silva’ movement. They are an European federation of professional foresters with active members in 24 countries including the Netherlands. The Dutch (and Belgian) forest management is largely based on the principles the Pro Silva movement came up with (Den Ouden et al., 2010).

The 9 principles for sound and sustainable forest management that the Pro Silva movement came up with according to Den Ouden et al. (2010) are:

1. Trees should be allowed to get old
2. The base of a forest ecosystem should be formed by endemic species
3. The forest should have a varied structure
4. Self-regulating processes are at the base of forestry
5. When harvesting wood as little damage as possible should be done
6. Small elements with high nature value should be projected and if necessary management of these elements should be adapted to be environmentally friendly
7. Clear-cuts are big disturbances for the microclimate of forests
8. A nature like forest contains dead wood
9. Mechanical or biological control of unwanted vegetation is preferred over chemical control

5.1.4 Indicator: sustainable harvest of increment

The two Pro Silva principles which are focussed on are: (1) Trees should be allowed to get old and (8) A nature-like forest contains dead wood. These two principles are extremely important for a well-functioning forest ecosystem and can be made measurable with the data that was gathered and supplied.

Old trees are important for certain mammal species, such as the squirrel (*Sciurus vulgaris*) and the European pine marten (*Martes martes*) (Broekhuizen, 1991). Older forests also have characteristic vegetation associated with them. Old forest plants are rare in the Netherlands and associated with old forest in which seed banks can be established (Tack et al., 1993). Old oak forest thus provide besides the usual ecosystem services also a ‘gene pool’ service.

A sufficient supply of varied stages of dead wood is essential for the ecology of the forest (Wijdeven, 2006). Especially invertebrates (Mabelis, 1983), moss and lichen communities (Barkman, 1983), as well as fungi (Barkman et al., 1983) need dead wood in order to survive. These species attract all kinds of other species, facilitating natural processes.

These principles that quantify ecological sustainability can be measured through one or more indicators. In this report, a sustainable harvest level will form the base of our indicator. The general principle holds that if one harvests exactly 100% of the increment every year the forest would neither grow nor decline. Increment is the net. growth of the forest in m^3 per hectare per year. However, if 100% of the increment is harvested, there is no dead wood added to the forest and the forest does not grow older which is important as explained above. The question then becomes: what is a sustainable level of increment that can be harvested?

In the current forests of the Netherlands, 65% of the increment is harvested. 10% is added to the dead wood and 25% is added to the growing stock according to the AVIH (n.d.). This matches with the 66% of the increment the National Park the Hoge Veluwe harvests (Den Ouden, 2014). Others claim that in the Netherlands, harvest levels are slightly lower (Oldenburger & Kuiper, 2005; Schelhaas et al., 2014; Nabuurs et al., 2016). The most specific data is per tree species and based on the 6th forest inventory by Probos. This data is gathered by Schelhaas et al. (2014) and based on over 3000 sample plots all over the Netherlands. What matters, also, is the potential which can be harvested sustainably. According to Spijker & de Jong (2012), forest owners could harvest until 80% of the increment while still harvesting sustainably. Nabuurs et al., 2016 mentions a similar value of 75-80%. Harvesting 70% of the increment is a normal amount to harvest to maintain forest development according to Borgman Beheer Advies (2009). Harvesting less would reduce the secondary growth (thickness) and would reduce to stability with regard to for instance wind throw and would not optimise forest growth.

Just knowing how much increment can be sustainably harvested does not give the full picture. One still needs to know how much of that harvest will go to bioenergy plants in the Netherlands and how much goes to other industries in order to determine the forests harvestable potential for bioenergy.

Based on an assessment Probos (Dutch NGO specialized in independent forest data 29 03 2017) made on wood flows (Boosten, 2017), the total amount of wood harvested in Netherlands was 580 ktons per year. In fact, 132 ktons are used for biomass, where 92 ktons are used in house chimneys, 20 ktons are used for bioplants in the Netherlands and 20 ktons are exported for bioenergy production to other countries. The percentage of wood used currently for bioenergy purposes is thus 3%. This number was chosen in this report as a reference value. Of all wood harvested, 3% go to biomass plants in the Netherlands. The other 97% goes to other industries, such as the timber industry. While this number seems low, it actually makes sense as biomass for energy is the cheapest wood product one can get out of the forest. The price of bioenergy wood is between €15 and €20 euros lower per m^3 than other non-bioenergy purposes (Fontein & Kuindersma, 2010). Only if wood cannot be used for anything else, it will be used for bioenergy (G-J.Nabuurs, personal communication, June 15, 2017). Additionally, calculations are also made to see if 50% or 100% of the harvest goes to bioenergy to see the full potential of bioenergy and because as of right now the specific data on wood flows of the forest and wood sector in Ede is unknown.

5.2 Biomass Supply

5.2.1 Biomass from forests

With an overview of the demand for bioenergy in the municipality of Ede, an assessment of the possibility to sustainably supply said demand can be made. Throughout this section, an inventory of the forested areas in Ede, but also in the Netherlands as a whole will be established. By knowing how much biomass there is, it is possible to estimate how much biomass can be harvested.

5.2.1.1 Forest Cover of Ede

An estimation was made for the total forest cover of Ede per species. There is data from the 6th forest inventory of Probos (Schelhaas et al. 2014) in which stratified sample forest plots have been inventorised all over the Netherlands, including in Ede. Based on these plots and the division of main tree distribution over these plots one can assess the relative distribution of these trees in Ede. Combined with the total forest area (11,009 ha) (CBS, 2017) an estimation can be made of the total forest cover per species (see Table 5.2.1.2).

Table 5.2.1.1: Area of tree species of all forest in Ede (Based on Schelhaas et al. 2014)

Number of plots in 6th forest inventory	Tree species	Forest inventory area (ha)	Percentage of forest cover	Estimated area (ha)
6	Red oak	660	5%	594.74
5	Birch	550	5%	495.62
6	Beech	660	5%	594.74
4	Douglas fir	440	4%	396.49
3	Norway spruce	330	3%	297.37
62	Scots pine	6825	56%	6150.15
11	Common oak	1211	10%	1091.26
3	Japanese larch	330	3%	297.37
1	Clear cut	110	1%	99.12
10	Not visited	1101	9%	992.13

5.2.1.2 Forest owned by the municipality

Not all 11,000 hectares of the forest are owned by the municipality. The municipality in fact only manages about 20% of the forest themselves (2461 ha) (Borgman Beheer Advies, 2009). The five big forests managed by the municipality (Figure 5.2.1.2) are split into sub-areas (Table 5.2.1.2). The Luntersche Buurtbos is not owned by the municipality by merely managed by them (Borgman Beheer advies, 2009). The other forests in the figure and table are owned by the municipality.

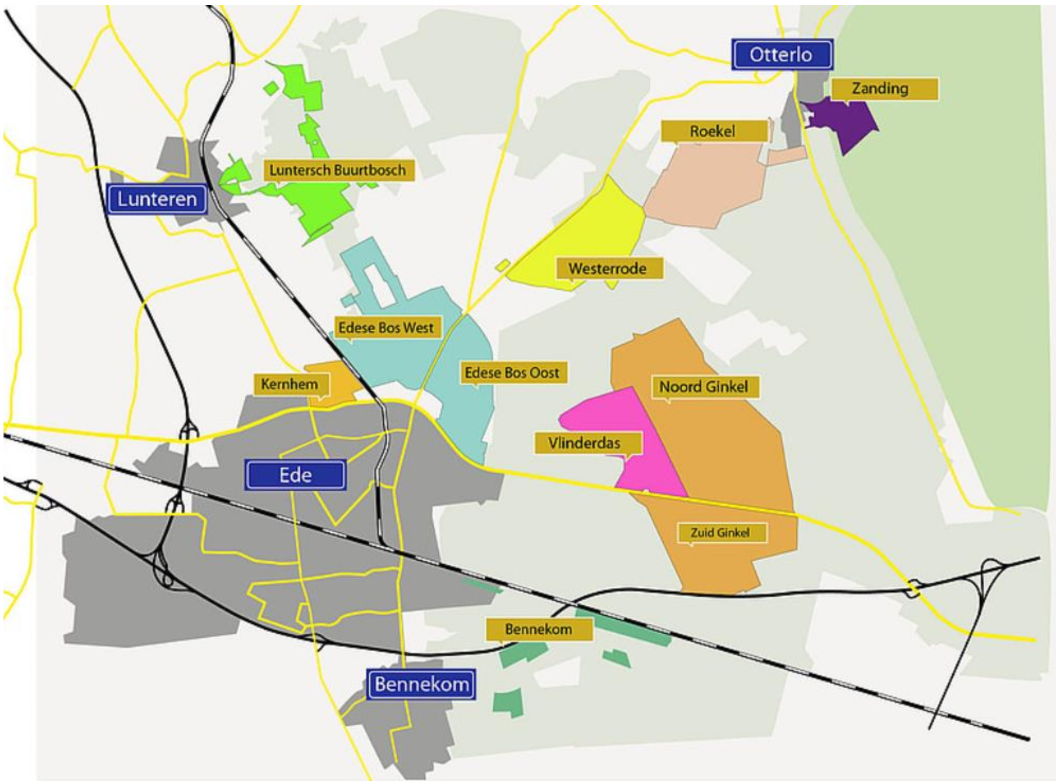

Figure 5.2.1.2: Map of the forests owned by the municipality of Ede (Borgman Beheer advies, 2009)

Table 5.2.1.2: Forest owned by the municipality (based on Borgman Beheer advies, 2009)

Forests owned by the municipality of Ede	Area size	Sub-areas	Area size
Het Edese Bos	498 ha	Landgoed Kernhem	59 ha
		Edese Bos – oost	197 ha
		Edese Bos – west	241 ha
		Total	**498 ha**
Noord- en Zuid Ginkel	1030 ha	Ginkel – Noord (north of the N224)	593 ha
		Ginkel – Zuid (south of the N224)	286 ha
		Landbouwencalve (Vlinderdas)	ca. 150 ha
		Total	1030 ha
Bennekom	77 ha	Prins Hendrikweg	19.9 ha
		De Heide (Oost Breukelderweg)	27.3 ha
		Celtic Fields (Panoramaweg/Bosweekweg)	8.2 ha
		Spoortalud west	4.2 ha
		Spoortalud oost	18.8 ha
		Total	**77 ha**
Noord-Oost Ede (Roekel, Otterlo)	603 ha	Peppelenburg & Westerrode	246 ha
		Roekel	271 ha
		De Zanding – Otterlo	74 ha
		De Belt	12 ha
		Total	**603 ha**
Ede-Noord + Luntersche Buurtbos	253 ha	Ede-Noord	117 ha
		Lutersche buurtbos (not owned by municipality just managed)	136 ha
		Total	**253 ha**
Total	**2461 ha**		

5.2.1.3 Forest areas in the Netherlands

The total amount of forest per species in the Netherlands (Table 5.2.1.3) is also based on the 6th forest inventory of Probos (Schelhaas et al. 2014). This is, especially when looking at the Dutch forest as a whole, the most recent and accurate data available.

Table 5.2.1.3 Forest areas in the Netherlands (Based on Schelhaas et al. 2014)

Tree species	**Area (ha)**
Red oak	8696
Birch	24767
Beech	15410
Ash	13099
Acer	3853
Common Oak	64283
Popular	12328
Willow	6274
Black alder	8916
Other endemic broadleaf species	5614
Other exotic broadleaf species	198
Bushes	1651
Corsican Pine	9797
Douglas fir	18933
Norway spruce	12769
Scots pine	111835
Japanese larch	18162
Austrian pine	4073
Other coniferous species	3412
Clear-cut	5284
Not visited	22345
Total forest area in NL	**373482**

5.2.1.4 Data of tree harvesting

Table 5.2.1.4a, shows the amount of the increment per species harvested in the Netherlands, based on the average increment of those species. It also shows the percentage of the increment that is harvested per species based on actual Dutch management practices. Based on Boosten (2017), 3% of what is harvested is used as input source for bioenergy production. Hence, the table below provides the actual amount of biomass in m^3 per ha per year that harvested per species that also is used for biomass in bioenergy plants. As explained in the methodology the potential for biomass is also investigated if 50% or 100% of what is harvested is used for bioenergy.

Table 5.2.1.4a: Average harvest data per species (Based on Schelhaas et al. 2014)

Tree species	**Average increment (m^3/ha/yr)**	**% increment harvested**	**Felling (m^3/ha/yr)**	**Biomass potential (3% - 50% - 100 %) (m^3/ha/yr)**		
Red oak	7.9	58%	4.6	0.14	2.3	4.6
Birch	4.6	26%	1.2	0.036	0.6	1.2
Beech	7.2	36%	2.6	0.078	1.3	2.6
Ash	10	24%	2.4	0.072	1.2	2.4
Acer	7.9	24%	1.9	0.057	1	1.9
Common Oak	6.2	31%	1.9	0.057	1	1.9
Popular	7.7	91%	7	0.21	3.5	7
Willow	7.8	76%	5.9	0.18	3	5.9
Black alder	6.7	19%	1.3	0.039	0.7	1.3
Other endemic broadleaf species	5.8	38%	2.2	0.066	1.1	2.2
Other exotic broadleaf species	11.9	25%	3	0.09	1.5	3
Bushes	2.6	31%	0.8	0.024	0.4	0.8
Corsican Pine	9.7	57%	5.5	0.17	2.8	5.5
Douglas fir	13.9	56%	7.8	0.23	3.9	7.8
Norway spruce	12.2	61%	7.5	0.23	3.8	7.5
Scots pine	6.2	48%	3	0.09	1.5	3
Japanese larch	8.9	66%	5.9	0.18	3	5.9
Austrian pine	8.9	16%	1.4	0.042	0.7	1.4
Other coniferous species	11.7	63%	7.4	0.22	3.7	7.4
Clear-cut	0.5	40%	0.2	0.006	0.1	0.2

Table 5.2.1.4b provides the same information as the previous table. It gives the actual amount of biomass in m^3 per ha per year that is harvested per species out of the increment. In Table 5.2.1.4b, it is assumed that 75% of the increment is harvested regardless of the species. This would imply that overall, a greater amount of biomass is removed from the forest.

Table 5.2.1.4b: Potential harvest data per species, assuming 75% of increment is harvested (Based on Schelhaas et al. 2014)

Tree species	**Average increment (m^3/ha/yr)**	**% increment harvested**	**Felling (m^3/ha/yr)**	**Biomass potential (3% - 50% - 100%) (m3/ha/yr)**		
Red oak	7.9	75%	5.9	0.18	3	5.9
Birch	4.6	75%	3.5	0.10	1.7	3.5
Beech	7.2	75%	5.4	0.16	2.7	5.4
Ash	10	75%	7.5	0.23	3.8	7.5
Acer	7.9	75%	5.9	0.18	3	5.9
Common Oak	6.2	75%	4.7	0.14	2.3	4.7
Popular	7.7	75%	5.8	0.17	2.9	5.8
Willow	7.8	75%	5.9	0.18	2.9	5.9
Black alder	6.7	75%	5	0.15	2.5	5
Other endemic broadleaf species	5.8	75%	4.4	0.13	2.2	4.4
Other exotic broadleaf species	11.9	75%	8.9	0.27	4.5	8.9
Bushes	2.6	75%	2	0.058	1	2
Corsican Pine	9.7	75%	7.3	0.22	3.6	7.3
Douglas fir	13.9	75%	10.4	0.31	5.2	10.4
Norway spruce	12.2	75%	9.2	0.27	4.6	9.2
Scots pine	6.2	75%	4.7	0.14	2.3	4.7
Japanese larch	8.9	75%	6.7	0.20	3.3	6.7
Austrian pine	8.9	75%	6.7	0.20	3.3	6.7
Other coniferous species	11.7	75%	8.8	0.26	4.4	8.8
Clear-cut	0.5	75%	0.38	0.011	0.17	0.38

5.2.1.5 Total wood harvested

The biomass input for the bioplants is discussed in section *4.1.1 Biomass input requirements*. Thus, the extent of wood chips that should be used is calculated following Equation 2.3.2 and 2.3.4 for the two scenarios proposed: 2017 and 2020. The totals of gas consumption per year are respectively 30% and 0%.

Taking into account a minimum moisture content of 20% and a maximum of 50%, the heat capacity of the wood calculated from Equation 2.3.3, varies from 8.8 to 11.4 GJ/ton. In fact in the MPD factories are getting heat capacities between 12 and 3 GJ/ton (V.Kleijnen, personal communication, June 19, 2017). The difference between those two values is due to the fact that the company also use garden waste as input, which may lead to a decrease in the heat capacity of burned biomass. Notwithstanding, in a study performed in Australia (Shwe Hla & Roberts 2015), gardening clippings had at 29% dried based a moisture value for C_{gw} of 10.1 GJ/ton. At 46% dried based moisture a value for C_{gw} of 7.8 GJ/ton was found. 46% moisture content was the value used for the calculations of our report.

Table 5.2.1.5 shows the total wood requirement range, giving the amount of wood that should be harvested to produce the energy demanded by the district heating system. The lowest range value is calculated using W_r of 20% for the wood chips and the highest one using W_r of 50% for the wood chips.

Table 5.2.1.5: Model output which compares the total wood needed to fulfil the demand of energy from wood and the total amount of wood that can be harvested sustainably from Ede's forest cover (wood with different uses).

Scenario	**Units**	**Total wood demand range**	**Total wood that could be harvested sustainably**
2017	[ton/year]	15,313 - 15,591	26,890
2020	[ton/year]	43,094 - 43,877	26,890

5.2.2 Biomass from garden residues

Utilizing garden waste as source of biomass has been suggested to be environmental friendly due to its negative net greenhouse gas emissions (Shi et al., 2013). It can also avoid greenhouse gas emission when it is landfilled. Garden waste biomass is biodegradable and includes different forms of organic matter, such as leaves and wood debris, grass clippings, small branches, and tree pruning (Shi et al., 2013). In this project, the quantities of municipal waste are analysed based on the data from Statistics Netherlands (CBS) (Statistics Netherlands, 2017).

According to the data collected by Statistics Netherlands (Statistics Netherlands, 2017), amounts of bulky garden waste and untreated wood from household waste were 456,000 and 348,000 tons respectively for the whole Netherlands in 2015. Amounts of municipal waste in kilogram per capita of bulky garden waste and untreated wood were 18 and 17. As the population of Ede was estimated at 113,448 by CBS in 2017, the total amounts of bulky garden waste and untreated wood from household waste in Ede corresponds to 2042 and 1929 tons. In total, there will be 3971 tons of garden residues available as biomass for energy. As about 35% of all biomass input of the bioplants in Ede comes from garden waste and residue, about 14,700 tons of garden waste and residue are required to meet the demand of bioenergy. So, there have to be other sources of garden waste and residue than the data indicated by CBS, such as the parks in Ede. Further research will be needed to figure out those input sources of garden waste and residue.

6. Feasibility Study - Matching Demand and Supply

6.1 Ede scenario

In order to assess the sustainability of the bioenergy production, the two outputs described in the previous chapters have to be compared: total fresh wood demand and total fresh wood available. From the total fresh wood available an indicator has been calculated, the amount of forest that could be harvested per area and per year.

Current harvesting practice allow for different amounts of biomass to be harvested per species based on the increment, ranging from 19% to 91% (Schelhaas et al. 2014). The amount harvested is dependent on the species being considered. Considering that species have different characteristics, notably growing rate, they ought not to be uniformly harvested. Table 6.1a gives a comparison of the current harvesting practices, as elaborated by Schelhaas et al in the 6th forest inventory of Probos, opposed to an uniform harvesting of 75% of the increment regardless of the species. 75% was chosen as it is the maximum amount that could be sustainably harvested.

Table 6.1a: Specific harvesting sustainable rate from Ede's forest cover in both current harvesting practices and potential maximum harvesting.

	Units	Current harvesting practices	Potential maximum harvesting
Specific harvesting sustainable rate	tons/ha/yr	1.55	2.44

Table 6.1b: Total fresh wood available by sustainable harvesting or current harvesting practices from Ede; it also considered if all the cover could be harvested or considering that from the forest owned by the municipality only Black cherry is harvested.

	Units	Current harvesting practices	Potential maximum harvesting
All forest harvested	tons/yr	17073	26890
Only Black cherry from the municipality	tons/yr	16256	23879

As shown in Table 6.1b there are four different scenarios to provide fresh wood from Ede's forest cover. The "all forest harvested" scenario implies that harvesting is done in all forests in Ede, not only the ones owned by the municipality, and also including Black cherry in municipality owned forest. However, the wood is also used for other purposes besides bioenergy production. According to Boosten (2017), an assumption of 3% of wood from harvesting for bioenergy had been made. Nevertheless, due to the lack of knowledge about the fraction of fresh wood used in Ede for bioenergy, an uncertainty analysis of the percentage of fresh wood harvested that is used to produce bioenergy has been carried out. Thus, the percentage of wood harvested which is needed in order to fulfil the demand in both current and future situations, also considering the four different wood harvesting scenarios was determined.

6.1.1 Current harvesting practices in 2017 scenario

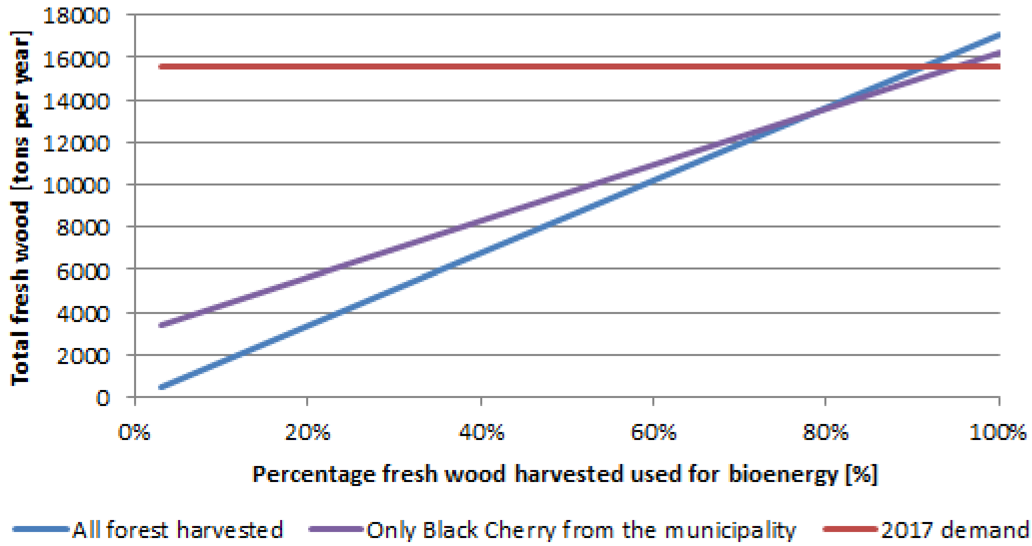

Figure 6.1.1: Graph of the 2017 scenario which compares the current fresh wood need in tons per year against either harvest of the whole area with current values or from the forest owned by the municipality where only Black cherry is harvested.

As shown in Figure 6.1.1, in 2017, it is possible to produce enough bioenergy to fulfil the total demand of 10,000 housing equivalents with the current harvesting practices if between 90 to 95% of the total fresh wood harvested from Ede's forest cover is used to produce this bioenergy.

6.1.2 Current harvesting practices in 2020 scenario

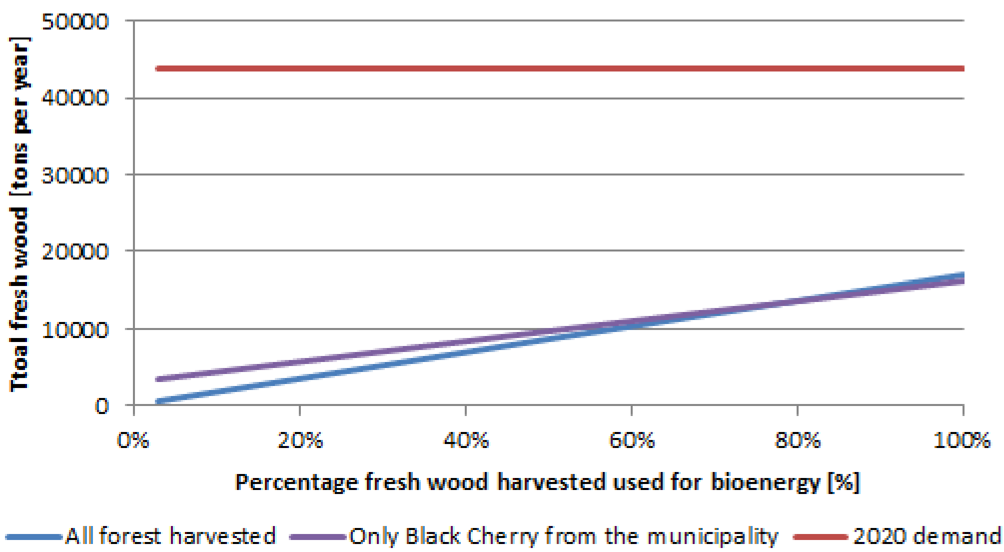

Figure 6.1.2: Graph of the 2020 scenario which compares the future fresh wood need in tons per year against either harvest of the whole area with current values or from the forest owned by the municipality where only Black cherry is harvested.

As shown in Figure 6.1.2, in 2020 it is not possible to produce bioenergy enough to fulfil the total demand of 20,000 housing equivalents with the current harvesting practices. Nevertheless, up to one third of the demand can be supplied but the total demand cannot be fulfilled with woody biomass considering the current system.

6.1.3 Potential maximum harvesting practices in 2017 scenario

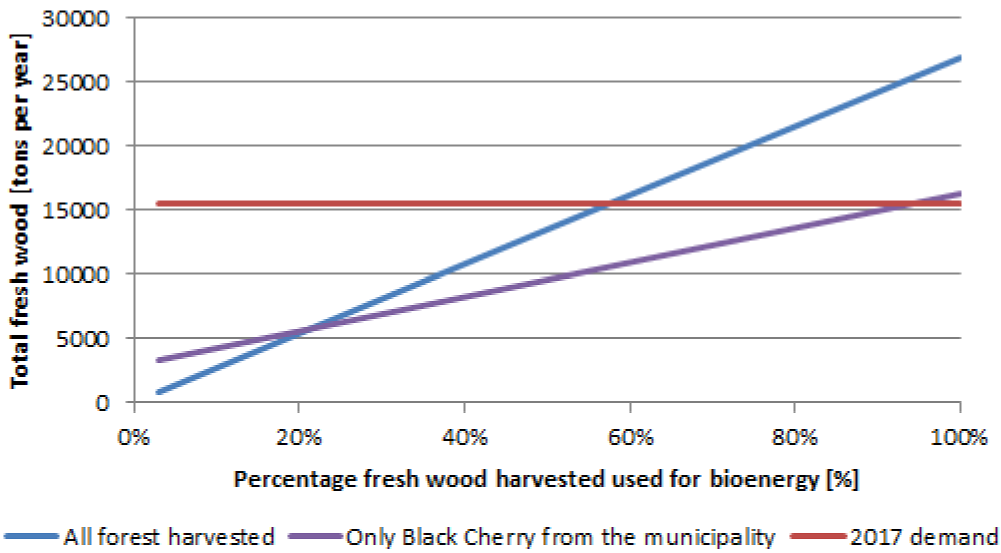

Figure 6.1.3: Graph of the 2017 scenario which compares the current fresh wood need in tons per year against either harvest of the whole area with maximum potential values or from the forest owned by the municipality where only Black cherry is harvested.

As shown in Figure 6.1.3, in 2017 it is possible to produce enough bioenergy to fulfil the total demand of 10,000 housing equivalents by sustainably harvesting the maximum amount of fresh wood. However, there is a huge difference in the percentage of wood harvested if either the total forest cover is harvested or only Black cherry is harvested from municipality owned forest. If all the forest is harvested around 55% of fresh wood from harvesting is needed, on the other hand up to 90% of the harvest is needed if the municipality only harvests Black cherry.

6.1.4 Potential maximum harvesting practices in 2020 scenario

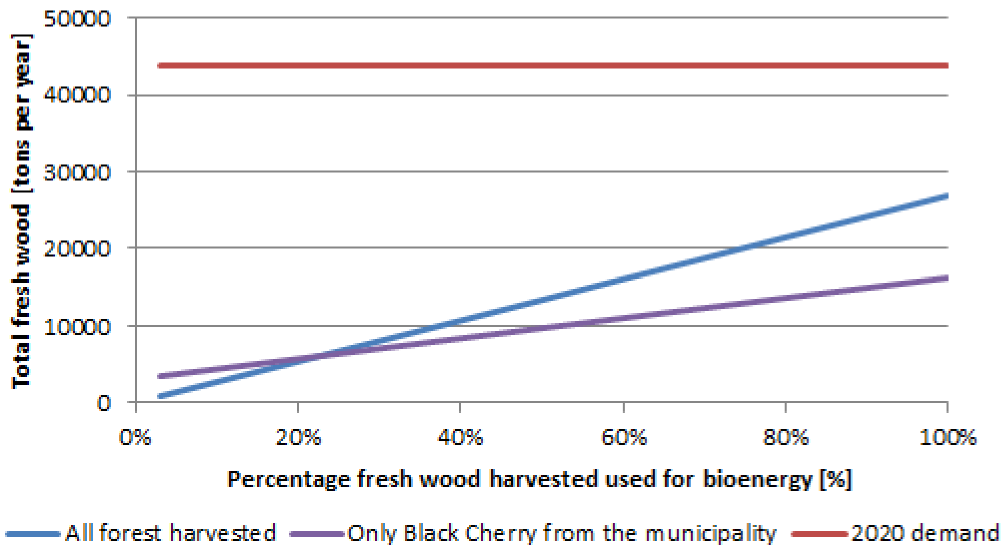

Figure 6.1.4: Graph of the 2020 scenario which compares the current fresh wood need in tons per year against either harvest of the whole area with maximum potential values or from the forest owned by the municipality where only Black cherry is harvested.

As shown in Figure 6.1.4, in 2020 it is not possible to produce enough bioenergy to fulfil the total demand of 20,000 housing equivalent by sustainably harvesting the maximum amount of fresh wood. Nevertheless, up to a half of the demand can be supplied if all the forest is harvested and more than one third if the municipality only harvests Black cherry. In conclusion, the total demand cannot be fulfilled with wood considering the current system.

6.2 The Netherlands scenario

Regarding the entire Netherlands, the model can also be used to calculate the specific harvesting rate for the Netherlands if proper data is available (Table 6.2a). As described in section *5.2.1.3 Forest areas in the Netherlands* the total forest area in the Netherlands is 373,482 ha.

In table 6.2a it is shown the total fresh wood which can be harvested sustainably has an specific harvesting rate in tons per hectare and per year following either current harvesting practices or increasing that harvesting until the potential maximum harvesting (75% of the increment).

Table 6.2a. Specific harvesting sustainable rate from the Netherlands forest cover in both current harvesting practices and potential maximum harvesting.

	Units	**Current harvesting practices**	**Potential maximum harvesting**
Specific harvesting sustainable rate	tons /ha /yr	1.54	2.57

Table 6.2b shows both scenarios: current harvesting practices and potential sustainable harvesting in 2017. Moreover, it shows the tons per year for bioenergy considering either 3%, 50% or 100% of the biomass harvested is used for bioenergy.

Table 6.2b: The Netherlands bioenergy calculations by using the model based on the area size and general composition of its forests.

Netherlands Scenario	Units	Current harvesting			Potential maximum increment harvested for biomass		
		3%	50%	100%	3%	50%	100%
Total wood for bioenergy	tons/yr	17298	288299	576597	28851	480857	961714
Total plants maintained	-	1	14	29	1	24	48
Total equivalent households supplied	-	4324	72075	144149	7213	120214	240429
Total energy produced	PJ/yr	0.15	2.52	5.05	0.25	4.21	8.41

Nowadays, a maximum of 48 plants in which biomass is the input could be maintained according to the area and forest composition of the Netherlands. The Netherlands demands 2406 PJ per year (Centraal Bureau voor de Statistiek, 2017) in order to fulfil all its activities which include transportation, heating but also electricity production; hence it is a general value, regardless of the activity. According to that, bioenergy, in the form as it is produced in Ede, could cover only a 0.35% of the total energy demand of the whole Netherlands.

7. Discussion

7.1.Explanation of the result from 6 and discussion on whether forest is harvested sustainably in Ede

The results from the calculations indicate that the forests can be sustainably harvested for energy in 2017, but it is impossible to reach the sustainability goal with the current system by 2020.

In 2017 the total amount of energy needed by 10,000 housing equivalents is 350 TJ per year, hence the energy produced by the bioenergy plants can fulfil energy demand. The energy production is higher even than energy demand. This is due to the fact that the district heating system needs to work at a minimum temperature in summer to ensure safe working levels for the system. Additionally, the energy company could increase its own energy output by increasing the operation capacity in summer but the demand fluctuations do not make it feasible. In 2020 the energy demand of 20,000 households equivalents will increases to 690 TJ per year according to the calculations. The energy will be provided by the two plants that are already in place with the addition of a third plant. For 2017, the energy produced it is enough to cover the energy demand of district heating system, but in 2020 the total energy produced in 2020 will be 556 TJ per year. The demand will be higher than the capacity than the three plants can deliver.

According to MPD, the total biomass from forests used each year in the two plants in 2016 was 17,010 tons (V.Kleijnen, personal communication, June 19, 2017). This value is about 64% of the amount of wood that can be harvested sustainably. In the 2020 scenario, the plants would use 163% of the wood that can be sustainably harvested from the forest, following the current energy production patterns, same energy fluctuations and using the same bioplants.

With regard to sustainable wood harvesting from the forest, the results from chapter 6 indicate that in 2017 using current practices including the Black cherry from municipality, the bioenergy production by the MPD company can be done sustainably. However, looking at 2020 the amount of wood required from the forest is higher than could be sustainably harvested, even when the municipality forests are included and 100% of the harvest is used for bioenergy.

At the national level, following current harvesting, i.e. 3% of the harvested increment for biomass, the amount of wood is only enough to run one plant. In all cases in order to run more plants and provide more energy, it is necessary to raise the amount of wood harvested for bioenergy production. Although, at current harvesting rates, energy output might be 3.8% of the total renewable energy produced in Netherlands and 0,26 % of the total energy consumption. If the potential maximum increment harvested for biomass is 100%, the energy output would be 6.1 % of the renewable energy produced at the national level and 0.36% of the total energy consumption. So far, bioenergy production based on wood fired systems would contribute really low proportion of the national renewable energy goals.

7.2 Quality assessment

The objective of this project is to assess the sustainability of current and future energy system in Ede. Considering time limitation, the report is a combination of literature review, stakeholder analysis, environmental assessments, model calculations, and interviews. Careful considerations have been made with regard to the aim of the research as well as the methods. With more time, money and expertise, a more detailed analysis could be made if certain aspects are taken into account.

7.2.1 Difference in definition of sustainability

First of all, defining sustainability is complex. Different stakeholders have different definitions of sustainability based on their own interests and perspectives. Whether the bioenergy plants are sustainable or not varies with what one defines as sustainable. In this report, it was difficult to describe what is sustainability is in a general sense. The definition given by the UN World Commission on Environment and Development, for instance, is quite broad. To avoid misunderstanding and conflicts at the base of the study, 9 principles of pro silva are used to evaluate sustainable forest management in this study instead of using a general definition. Of these 9 principles only 2 have been tackled, which leaves space for further research. Furthermore, if one is also interested in other aspects of sustainability, for instance, the economic aspect of sustainability, a whole new approach should be used.

7.2.2 Complexity of forest ownership

The ownership of forest in Ede is complex. There are some main owners of forest, such as De Gemeente Ede, The government (Ministry of Defence), and the Nationaal Park De Hoge Veluwe (see Figure 7.2.2). However, there is also much forest owned by private owners. Each private owner may own a certain amount of trees, from several trees to thousands, of which no data can be found. This makes it difficult to do an integrated analysis and complicates making accurate calculations for whole region. Except the data and information provided by Municipality of Ede and Borgman Beheer Advies, the specific amount and distribution of tree species are still unknown. Thus, more information and further research about forest ownership are needed.

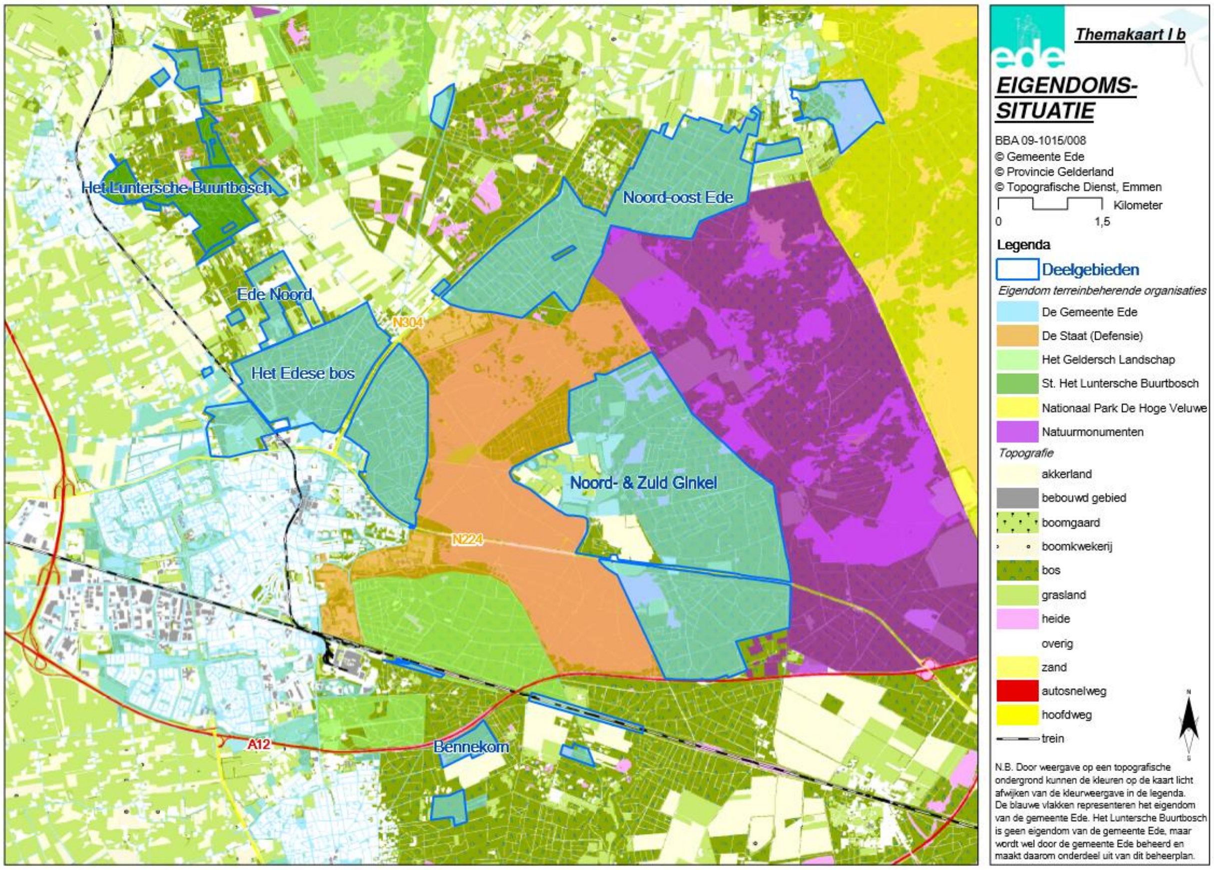

Figure 7.2.2 Owners and topography of municipality in Ede (J. van Gooswilligen, email communication, June 13, 2017)

7.2.3 Different harvesting and management styles

As there are many separate owners of forests in Ede, different harvesting and forest management styles are used. Different forest owners have their own interests and management plan for tree harvesting and regrowth. Styles of forest management and biomass utilization strategies have significant impact on soil productivity, biodiversity and carbon emission (Schlamadinger & Marland, 1996) by changing tree species, density, and amounts of forest residues (Janowiak & Webster, 2010). Also, different forest owners have different preferences regarding the tree species to be harvested. For example, the municipality of Ede harvests only Black cherry as biomass source for bioenergy in their forest while other owners may use other tree species. In general, the styles of forest management and harvesting methods will have a certain influence on the results of the study. By using average harvesting numbers in the 'normal harvesting scenario' we took into account differences between management styles on a national scale, but the proportion of nature oriented forest owners vs. production oriented forest owners might be different in Ede compared to the general proportion in the whole country. The maximum harvesting potential (75% of the increment) is really a maximum number as all forest are assumed to be used for wood production. This is not necessarily a problem as the goal of this number is to show the full potential in the edges of production but is good to realise that reality is much more complex.

7.2.4 Protected areas

In the model calculations it is assumed under the ‘normal harvesting’ scenario that in Ede there is the same proportion of protected areas in which less or no harvesting takes place as in the Netherlands as a whole. It was not possible to check this assumption. In the ‘full potential’ scenario’ it is assumed that harvesting takes place in all forest within the borders of the municipality, this is a simplification of reality. As the goal of that calculation was to show the edge of what is possible (while still being sustainable) this is not a problem. However, if one would like to conduct more complex but precise calculations one could take into account the natura 2000 areas and nature reserves located in Ede.

7.2.4.1 Guidelines EU ‘natura 2000’

Natura 2000 is the largest coordinated network of protected area in the world which stretches across all 28 EU countries. It covers 18% of EU’s land area and almost 6% of its marine territory, and offers protection to many valuable and threatened species and habitats (European commission, 2017). The objective of this network is to ensure the long-term survival of listed species and habitat under Birds Directive and the Habitats Directive. Figure 7.2.4.1 is the map of Natura 2000 Habitat types of Municipality in Ede. The red and dark green area indicated in the map represent respectively beech forest and old oak forest distributed in Ede. These areas are relevant to take into account to determine what can be done sustainably in the forest with respect to forest management.

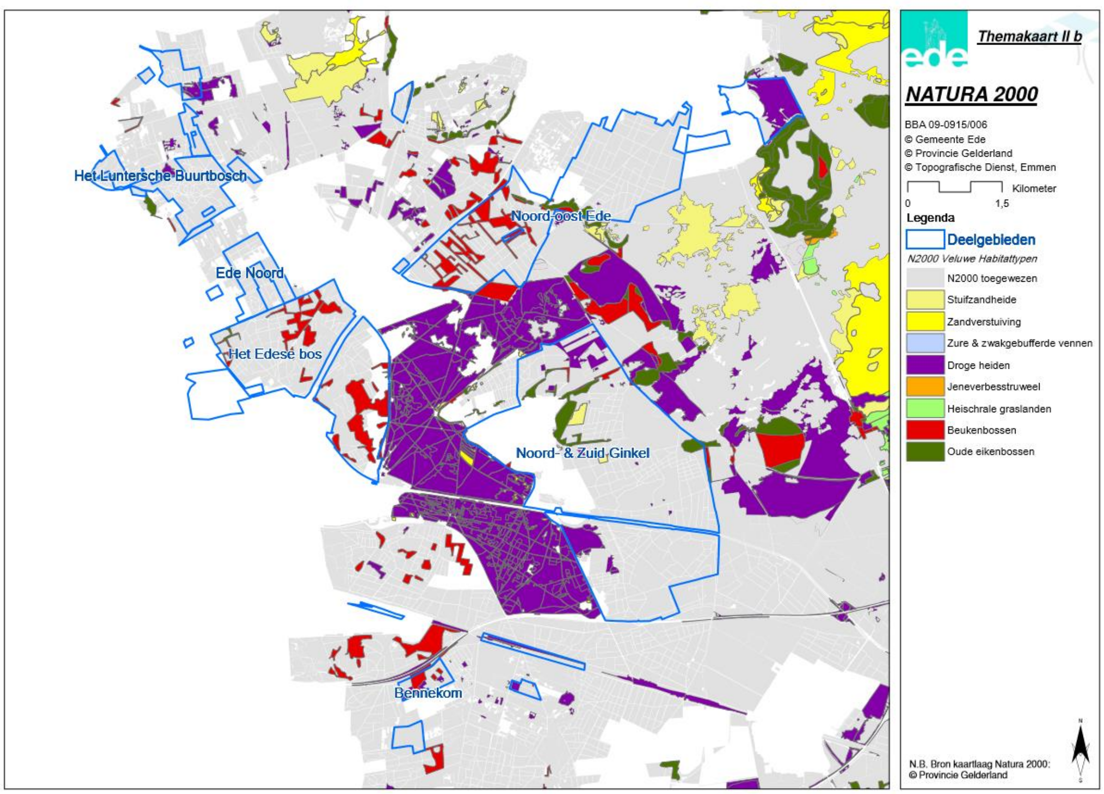

Figure 7.4.2.1: Natura 2000 Habitat types of Municipality in Ede (J. van Gooswilligen, email communication, June 13, 2017)

The Netherlands has a large responsibility to protect Old Oak Forest (EU-code 9190) as this is a rare habitat type which only exists in the Northwest-European lowlands (Ministerie van Economische Zaken, n.d. a). These forest need poor, acidic, sandy soils. The most important species are Common Oak (*Quercus petraea*) and Birch (*Betula*). In the second layer one can find Rowan and Aspen. In some areas high densities of Black cherry have become a real plague.

The Netherlands is also important for the atlantic distribution network of the Beach-oak forest with holly (EU-code 9120) (Ministerie van Economische Zaken, n.d. b). There are two forms of this habitat type. One in which there is little beech (*Fagus sylvatica)*and holly (*Ilex)* has grown into full grown trees, the other has many beech and holly in the second layer. In Ede the later one is most likely to be present based on the fact that the map the municipality provided indicates this habitat type as beech forest.

These two habitat types are mainly vulnerable with respect to eutrophication and salinization (see Table 7.4.2.1). One also has to be careful with pollution, optical disturbances, mechanical disturbances and direct human effects on pollution dynamics and species composition. Mechanical disturbances can include everything from the trust from windmills to compression of the soil by harvesters and is with respect to this study probably the most important factor to take into account.

Table 7.4.2.1: Disturbance sensitivity (Ministerie van Economische Zaken, n.d. a & n.d. b)

	Natura 2000 habitat type	
Spatial effects	**Old oak forest (9190)**	**Beech-oak forest with holly (9120)**
Area loss	Sensitive	Sensitive
Fragmentation	Sensitive for specific animals	Sensitive for specific animals
Chemical effects		
Acidification through nitrogen deposition	Not sensitive	Not sensitive
Eutrophication through nitrogen deposition	Very sensitive	Sensitive
Sweetening	Not sensitive	Not sensitive
Salinization	Very sensitive	Very sensitive
Pollution	Sensitive	Sensitive

Physical effects		
Dehydration	Not sensitive	Not sensitive
Rewetting	Not relevant	Sensitive
Change in flow rate	Not relevant	Not relevant
Change of flood frequency	Not relevant	Not relevant
Change of substrate dynamics	Not relevant	Not relevant
Mechanical effects		
Noise disturbance	Not relevant	Not relevant
Light disturbance	Not relevant	Not relevant
Vibration disturbance	Not relevant	Not relevant
Optical disturbance for typical animals	Sensitive for specific animals	Sensitive for specific animals
Disturbance through mechanical effects	Sensitive	Sensitive
Direct human effects		
Changes in population dynamics	Sensitive for specific animals	Sensitive for specific animals
Conscious change of species composition	Sensitive	Sensitive

7.2.4.2 Nature reserves

The municipality of Ede themselves decided that some nature areas deserve special protection. These areas are shown in Figure 7.2.4.2. About 400 ha of the forests owned by the municipality received the status of nature reserve (Borgman Beheer Advies, 2009). While the status of nature reserves has no formal meaning in this context as there is not a set of special regulations that have to legally be taken into account by the municipality, these areas are managed differently from the other forest areas. Extensive management is leading in the nature reserves (Borgman Beheer Advies, 2009). There is one exception though. Indeed, Black cherry is actively controlled in and around the nature reserves. Its management is, in fact, strongly concentrated around the nature reserves.

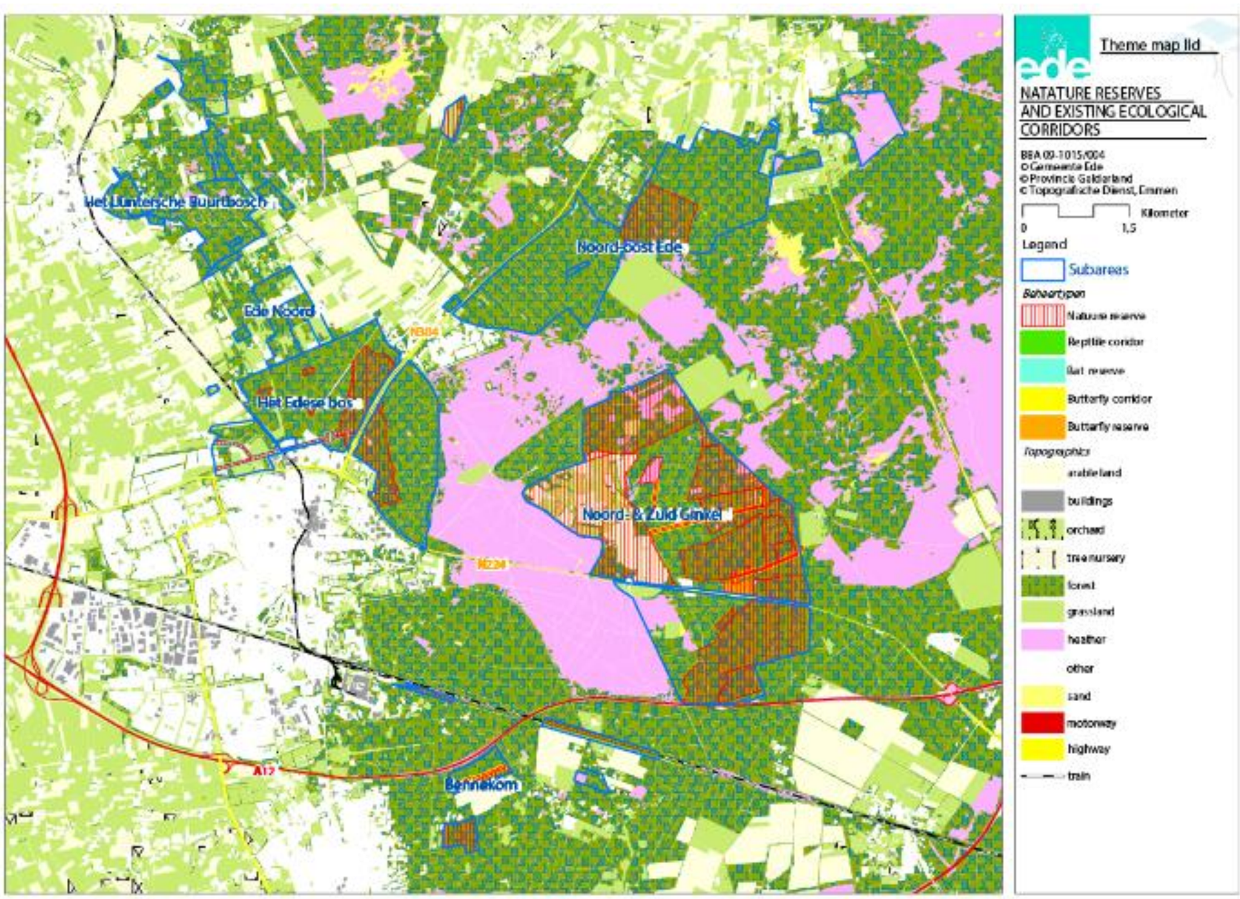

Figure 7.2.4.2: Nature reserves and ecological corridors in the municipality of Ede (J. van Gooswilligen, email communication, June 13, 2017)

7.2.5 Lack of GIS data

Map of tree species distribution in municipality owned forest in Ede

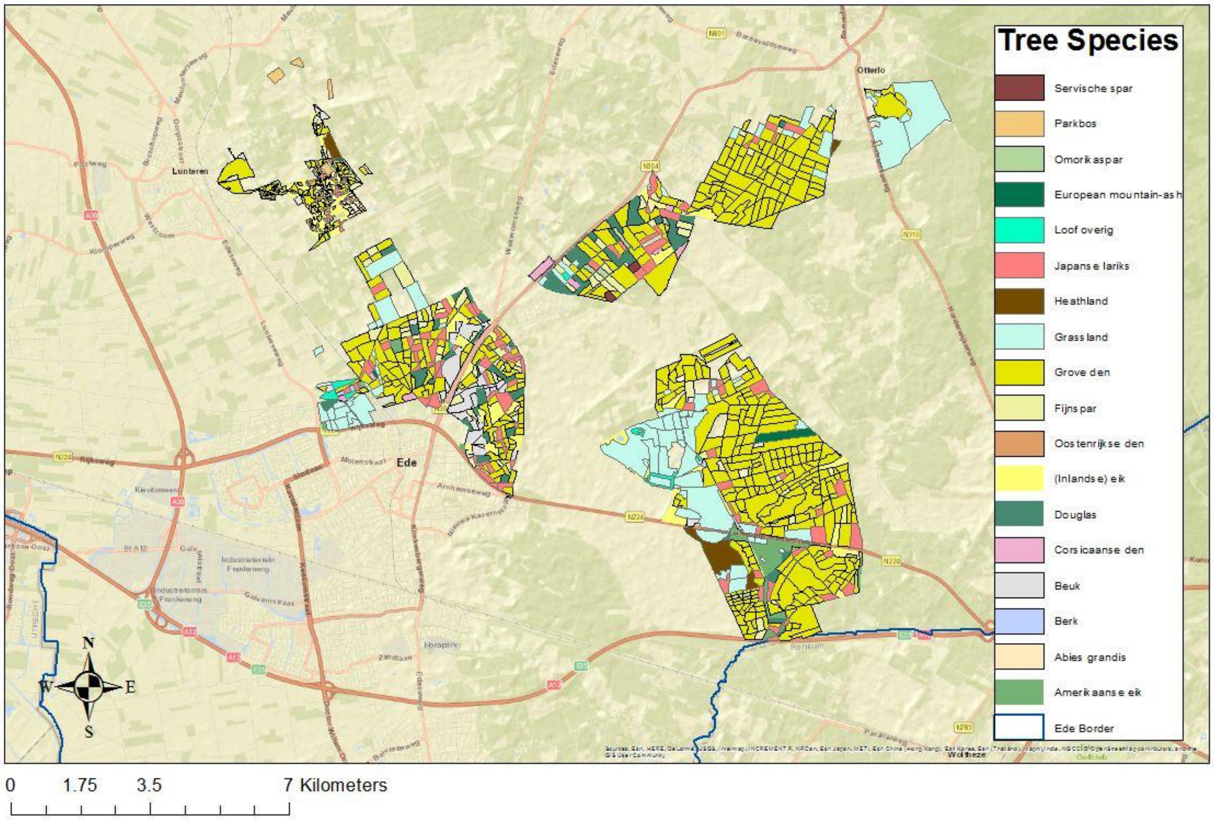

Figure 7.2.5 Map of distribution of tree species of municipality owned forest in Ede (Based on data from Borgman Beheer Advies, 2009)

Our study and model use data from the 6th forest inventory to assess the type of forest and the species distribution one has in a certain area. This forest inventory is one of the few data sources available. The fact that it is based on over 3,000 permanent and temporary plots makes it a rather valid source for the an assessment of all the forest in the Netherlands. However, the 6th forest inventory data is less accurate when used to estimate species cover when looking at smaller areas, such as the municipality of Ede. One of its other downsides is that only the main tree species are easily found. For more accurate studies one could dive into the extensive data the 6th forest inventory actually gathered besides main tree species or one could use GIS. Maps like Figure 7.2.5, could be used to make more accurate estimations on the forest in an area. Before model calculations could be used based on GIS data, a company should probably be hired to make a full overview of an area. These model calculations would also be much more complex and extrapolation of the model would be more difficult. An example where GIS was used is the study by Tolkamp et al. (2006) in which the biomass potential for Staatsbosbeheer (the state forest service) was calculated using extensive amounts of GIS data.

7.2.6 Deviation of model calculation

Because of the lack of reliable data from literature and other sources, some calculations are based on the numbers obtained by reasonable assumptions which have already been discussed. The results, though somewhat affected, will not change the conclusion. The amount and distribution of different tree species for the whole Ede region are not available. Tree species' specific heat capacities cannot be defined since it depends on specific moisture contents in wood and proportions of different trees as biomass sources are unknown. A reasonable assumption to come up with a general heat capacity was made. Moreover, the energy conversion efficiency and loss of energy in transportation may also lead to uncertainty in calculations. More research and study are needed to improve the accuracy of model calculations.

7.2.7 Smart grid Efficiency

There have been concerns over the efficiency of the smart grid in the delivery of heat through the heating network. A Finnish study found that the heat lost from the pipes of the heating network was proportional to the temperature difference between the water inside the pipe and the ground that surrounds it from the outside (Fang et al, 2014). Furthermore, given the constant speed at which the water travels in the pipe, the water temperature decreases exponentially with the distance travelled (Fang et al, 2014). This study pointed out a real problem with centralized heating networks. Throughout the transport of water through the pipes, a tremendous amount of heat is lost overall, compared to what was emitted from the energy producer. With this lack of efficiency the biomass input will not be used to its fullest potential due to losses incurred during transportation of the heat. Another study looking at heat distribution networks in the Netherlands also came to the conclusion that much heat was lost through the distribution network (Niessink et al, 2015). The study found that 15% of the heat produced is lost during transport, varying with the material, diameter and structure of the network (Niessink et al, 2015).

7.3 Future prospects

There are two future prospects that need to be considered when thinking about the sustainability of bioenergy in Ede in the long run. First of all, there is the decision on Black cherry. Secondly, other sustainable energy sources could be developed to provide heat to the inhabitants of Ede.

7.3.1 Discussion on Black cherry

Black cherry, which is the only tree the municipality harvests for bioenergy is considered a pest. The municipality wants to get rid of this exotic tree species by harvesting high amounts each year. In 2022 the amount of Black cherry should be reduced to 10% of the cover it had in 2009 (Borgman Beheer Advies, 2010). There is, however, an ongoing discussion on the 'pest' status of Black cherry.

The species was first introduced in the Netherlands in 1740 in the Hortus of Leiden (Nyssen et al., 2013). It was later used in experiments with exotic species in which exotic species were sought to fulfil the wood shortage of the 18th and 19th century where it was far from successful compared to species such as Douglas fir *(Pseudotsuga menziesii)* and Japanese Larch (*Larix kaempferi)* which could be used to produce much higher quantities of wood. Black cherry was used for reforestation to cover drift sands and its high nutrient leafs were used to improve soil quality. Not until the 1950's, Black Cherry was labelled a pest as it competed with other species regeneration in clear-cut forest systems. The foresters' negative opinion on Black cherry was later taken over by the nature organisations in the 1970s and 1980s (Nyssen et al., 2013). They felt that Black cherry had a negative impact on biodiversity without any scientific proof. A period of reflection on the Black cherry approach was quickly ended by a subsidy system for Black cherry control by the Dutch government.

Now there are again scientists who doubt whether Black cherry control is the best approach (Nyssen et al., 2013; G-J.Nabuurs, personal communication, June 15, 2017). Nyssen et al. (2013) explain that Black cherry has a relatively short life cycle, thus will never dominate forests. It has a positive effect on old growth forest flora while light demanding (heather) species might be troubled by the extra shade it provides. Black cherry can be associated to about 177 insects which is allot for an exotic species, a number which is most likely to increase as the species does not have a long history in the Netherlands (Nyssen et al., 2013). In the new integrated forest management, Black cherry also no longer is a problem for wood production as the goal is no longer to produce a monoculture of pines (which competed with Black cherry and birch after a clear-cut) but a mixture of pines and broadleaf species of different age classes. The wood of the Black cherry has a high quality and can be sold for a reasonable price.

The municipality of Ede makes a choice of controlling Black cherry but this choice might change. Either way alternative biomass sources should be found to replace the Black cherry if either Black cherry is more or less eradicated in 2022 or if the municipality changes its management strategy with regard to Black cherry. The municipality already explained that they will not start to harvest anything else besides Black cherry with for bioenergy production (E.van Tol, personal communication, June 12, 2017). This problem might not be extremely important as Black cherry harvesting by the municipality would only supply about 6% of the woody biomass in the future scenario and could be easily replaced by other tree species or by other sources of bioenergy.

7.3.2 Other sources of energy

By 2022, Black cherry is expected to be completely eradicated from municipality owned forest (E.van Tol, personal communication, June 12, 2017). At that point the municipality will not provide any more biomass to MPD. On MPD's hand, they claim to have more than enough biomass to keep their plants functioning as of now (V.Kleijnen, personal communication, June 19, 2017). Yet with an increase in energy demand, there will also be a need for an increase in biomass input. MPD has considered future options and opted to start working on the construction of a third bioplant that functions with grass instead of wood (V.Kleijnen, personal communication, June 19, 2017). Therefore in the future, grasslands of Ede will have an added function: producing biomass for energy production. This future prospect will reduce the stress on forest ecosystems and mitigate the negative impacts that biomass harvesting has on the forest. Grasslands have a faster growing rate than forests. With the proper management, enough biomass can sustainably be produced for the bioplant. MPD is also working with the municipality to investigate 'climate parks' to grow extra woody biomass in and around Ede but as of right now, they are only in a very early pilot stage with this project (E.van Tol, personal communication, June 12, 2017).

Other than natural sources of energy, industrial sources are also an option to explore. Through the district heating network, a heat cascade can link different enterprises and companies. As their industrial activities generate heat, that heat can be reused by other companies or households, thus closing a little more the system. The Kalundborg Symbiosis is an ideal example of such an industrial ecosystem where the by-products of one industry is used as an input resource for another. By reusing waste from one industrial process to feed into another, outputs from the system are reduced, and less inputs are required, thus closing the cycle a little more. Optimization of the district heating network will then result in a reduction of biomass required to generate heat. More housing equivalents will then be able to receive heat, while less biomass is actually being burnt. The DWA ‘opportunity study’ which was conducted in 2014 was commissioned by the municipality. It estimated that heat to 110 housing equivalents could be provided by using rest heat from biofermentation from the sewer plant located at the Dwarsweg (DWA, 2014). Fermentation of roadside grass and manure could provide another 910 housing equivalents with heat. Industrial rest heat could potentially provide heat to 1,570 housing equivalents (DWA, 2014). The biggest alternative to provide heat to the heating network instead of bioenergy plants would be geothermal heat. While the soil in Ede and surroundings is not suitable for production of geothermal heat from earth layer between 2 and 4 km deep, ultra-deep sources (6 km deep) are being investigated (DWA, 2014). Around 2020 a geothermal heating source for Parenco, the paper factory in Renkum, could provide heat to at least 17,000 housing equivalents (DWA, 2014). More research is needed to investigate the full potential and risks associated with these other energy sources.

7.4 Extrapolation possibilities

The model we made in principle could be used to calculate the bioenergy potential for all other municipalities and provinces in the Netherlands, if they would use the same bioenergy plants as MPD. The bigger the area that is looked into, the higher the precision of the model as more data points of the 6th forest inventory can be used and deviations from the average management styles and harvesting regimes of the Netherlands would be lower.

The model can also be used to calculate the full biomass potential of the Netherlands with again the big assumption that similar installations as the one in Ede are used. Extrapolation to other countries would not be possible for a number of reasons. Even the Belgian forests are completely different from the one’s in the Netherlands as they are located on much more nutrient rich loamy soils compared to location of the forests in the Netherlands (Den Ouden et al., 2010). There are also differences in forest management, species composition, bioenergy technology, and many more to take into account.

7.5 Suggestions for further research

Using increment as an indicator only addresses the first and the eighth principle of the nine Pro Silva principles. The limitation of using this indicator is that the other 7 principles are not being taken into account. Those other 7 principles are mainly related to the impact of the method of harvesting that is used by the forest manager has on forest ecology. Other indicators could be used to assess this impact. The most relevant and measurable indicators we think would be related to ‘birds’ or ‘soil nutrients’.

7.5.1 Common forest bird species

According to Updated Pan-European Indicators for Sustainable Forest Management proposed by the FOREST EUROPE Advisory Group (Forest Europe growing life, n.d.), occurrence of common breeding bird species related to forest ecosystems can be used as an indicator of maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems.

Although there are still some arguments about using birds as biological indicator, using bird population trends as biodiversity indicators has many advantages. Birds are widespread, diverse and mobile, and sensitive to both anthropogenic and natural environmental changes

(Gregory & van Strien, 2010). They are easily observed, surveyed, identified, and censused. Their long-term time presence in the forest allows for data collection over a long time frame and evaluate species trends (Gregory & van Strien, 2010). The approach of measuring is well developed and the cost of collecting and data analysis is relatively inexpensive. Birds can play an important role of bioindicator and communication tool to raise awareness of biodiversity issues in forest ecosystem while many other taxa cannot (Gregory & van Strien, 2010).

Sovon regularly does bird inventories and might have the data necessary for a study looking into birds as an indicator. One would have to compare forests in which there is biomass logging and, all other things being equal, in which there is no harvesting going on with respect to biomass. Another option would be to compare the bird species in the past in an area where no logging took place with the species now in which there is logging activity.

7.5.2 Chemical and physical properties of soil

Chemical and physical soil properties, such as the pH of forest soil could also be used as indicator of maintenance of forest ecosystem health and vitality according to Updated Pan-European Indicators for Sustainable Forest Management proposed by the FOREST EUROPE Advisory Group (Forest Europe growing life, n.d.). Burger and Kelting set a series of criteria of sustainability at the forest stand level and emphasized the soil-based indicators to assess intensively managed forests (Burger & Kelting, 1999). Soil productivity is discussed as a good indicator for sustainable forest management which can indicate multiple functions of soil, like production of plant biomass, carbon storage, and regulation of water quality and yield (Burger & Kelting, 1999). The following ten steps are outlined as monitoring approach to assess soil productivity (Burger & Kelting, 1999):

1. Establish the forest site type for the monitoring process;
2. Identify soil functions;
3. Identify soil attributes that influence function;
4. Select a minimum set of indicators that serve as measurable surrogates of soil attributes;
5. Use a weighted additive model to combine and quantify the net change in soil indicators;
6. Establish baseline conditions against which to compare management-induced changes in soil indicators;
7. Validate relationships between indicators and soil productivity;
8. Monitor all management practices that cause change in soil indicators;
9. Implement a sampling scheme for measuring indicators across space and time;
10. Analyse trends in indicators and change and adapt ‘sustainable forestry practices’ (SFPs).

7.6 Comparison of results

In 2014 an inventory showed that on the demand side there are 15,000 housing equivalents available that could be provided with heat from a green heat network (DWA, 2014). Houses and other buildings need to be concentrated enough in order for extending the network to pay-off. This study also estimated that other energy sources besides the first two bioenergy plants were needed to provide heat to provide heat to these 15,000 houses. However, in the same study they already mention the ambition to increase the number of housing equivalents that receive green heat. This ambition has only grown in the last couple of years and as of right now bioplants are still the only source of heat. Alternatives are under investigation (E.van Tol, personal communication, June 12, 2017) but are still not in place. Our results confirm the need for alternative sources of energy, or a shift if bioenergy input sources, in order to reach the ambitious targets of the municipality.

A study looking at the full potential of the forests of Staatsbosbeheer (the state forest service) showed that 1,000,188 m^3/yr could be used for biomass if all 90,811 ha of state forest service owned forest is used for bioenergy. In this study they look at a harvest intensity of 100% of the increment of which 100% is used for biomass (Tolkamp et al., 2006). That would translate to 11 m^3/ha/yr which is higher than the numbers that were used in our model. This is mainly due to the differences in harvesting intensity and partly due to the fact that the Tolkamp study also includes branches in its calculations. The total woody biomass production would be 35% higher if branches are included according to Tolkamp et al. (2006). If this is taken into account our model might be slightly underestimating the biomass potential of Ede.

There are no studies similar to ours done in Ede which our results could be compared to. There are, however, nationwide studies that look at biomass input which could be compared to our 'The Netherlands scenario'. An estimation of Spijker et al. (2007) that took into account that not all wood produced will be used for biomass shows that in 2020 about 0.2 million tons of dry matter will be available for bioenergy. If the harvest intensity is increased they show that 0.3 million tons of dry matter will be the total amount of Dutch wood available for bioenergy in 2020. Boosten & Oldenburger (2014) expect that in 2020, 0.44-0.54 million tons of woody biomass from forests and landscape will be used in the Dutch bioenergy sector which could either be from the Dutch forests or from import. These results correspond to the results in which about 30-35% of what is harvested is used for biomass. This is a reasonably high number. In other words, our study shows a slightly lower potential for biomass. These differences might partly be explained by our study not including forests in which no harvest took place in the current harvesting scenario. Another explanation might be that estimations on forest development were not included in our study and these other studies made assumptions ten and three years ago about the forest in 2020.

8. Conclusion

A calculation model to assess sustainability was made which was used to analyse different scenarios and to get a clear overview of the factors that affect the sustainability of Ede its bioenergy production system.

The MPD energy company uses forest and garden resources in order to supply energy to 10,000 housing equivalents in Ede in 2017, which is around 350 TJ per year. In 2020, it is expected to supply bioenergy to 20,000 housing equivalents in Ede, which is around 690 TJ per year.

To do so, MPD has two bioenergy plants in 2017 and a third one will have been opened by 2020 which will work with several biomass sources, mainly gardening waste and forest maintenance waste from Ede’s region. Two plants that are in operation now consist of two installations: (1) Heat boiler which uses biomass to heat up water and deliver it through the primary and secondary network of the smart grid and (2) Steam boiler which uses the biomass to produce steam. The boilers utilized in such process can burn waste and maintenance resources while other biomass plants cannot use them due to their properties.

Depending on the quality of the input provided, the energy content varies from 8.8 GJ per ton of wood to 11.4 GJ per ton of wood. However, the plant itself produces 8.9 GJ per ton of fresh wood received as an input and the future is expected to have roughly the same efficiency which, according to the model calculation, is around 88%.

In the near future the same techniques are expected to be used in the process itself although the plant input will slightly vary since the third plant is going to burn grass, pine needles and tree leaves (V.Kleijnen, personal communication, June 19, 2017). The plants themselves are not expected to change in terms of technology, hence their efficiency will remain similar but the smart grid network might improve. The supply network ought to keep improving and reuse outputs in order to reduce losses and leverage the energy produced from biomass.

From the model, it is calculated that an amount of about 15,452 tons of fresh wood per year is needed to fulfil the demand in 2017 and 43,485 tons of fresh wood would be required in the year 2020. All of this wood is obtained from Ede’s forest cover in which scots pine (*Pinus sylvestris*) and common oak are the most abundant trees. Black cherry is also very prolific in Ede’s municipality owned forest and considered as an invasive species.

Currently, the production system could be sustainable if 60% of the potential forest wood sustainably harvested is used to produce bioenergy in the best scenario; that percentage could be up to 90% if the worst scenario is considered though. Since the total amount of fresh wood which can be harvested sustainably is 26,890 tons per year within the municipality of Ede , there is no chance to supply bioenergy sustainably in 2020 by the actual production system from wood. Future smart grid network improvements, lower dependence from wood and more from (garden) waste among others improvements could make the bioenergy system sustainable but further research and studies should be carried out to see if that is possible.

Bioenergy is considered to be a renewable energy source that could help reaching the 14% of sustainable energy of the total consumption in the Netherlands. Nevertheless, according to the forest cover area of the Netherlands only a 0.35% of the total energy consumption could be potentially covered with bioenergy if similar installations as the ones in Ede are used.

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Annex

MPD Groene Energie

The description of this company can be found in section 3.3.1. Information on certain of the subsidiaries of MPD Groene Energie is elaborated below. Considering the complexity of the company's structure, information on certain of the affiliates could not readily be accessed or was simply unavailable to the team. Only a general overview of what was believed to be the main branches of the company was explored.

Warmtebedrijf Ede BV

Warmte Bedrijf Ede is a sub-company of MPD Groene Energie which is focussed on only one region unlike the overarching MPD. On the website of Warmte Bedrijf Ede they explain that they are the ones providing green Energy in Ede.

Biomass BV

Biomass BV is part of the MPV Groener energie group. This company is in charge of providing Bioenergie De Vallei with the biomass required to run the plant. The company's activities will be dependent on the state of the forest. They also have to abide by the rules and guidelines of forest management set by the national government.

Bio-energie de Vallei bv

Bio-energie De Vallei bv is the company that gets the energy out the full sources. They run the power plant and are responsible for the production process.

Bio-warmte de Vallei bv

Bio-warmte De Vallei is responsible for building and maintaining the primary heating network. It is still unclear whether Bio-Warmte De Vallei only build and maintain the network and Alliander is the company that actually owns it.

Bio-energie Ede bv

Bio-energie Ede is the company that owns the second bioenergy plant in Ede. Their bioenergy plant is located on the 'Kenniscampus'. This second bioplant was built in 2013 to provide energy for 3,000 households in Kernhem and Veldhuizen.

Actors involved in the public interest forum 'Stuurgroep Warmtenet'

The large ambition of Bio-energie De Vallei to extent their heating network in 2013 to 20,000 houses made the municipality of Ede realise they needed a platform to discuss the public interests related to bioenergy. This platform was called the 'stuurgroep warmtenet' (Gemeente Ede, 2014). The municipality of Ede chairs this group. The alderman Environment is the chairman. Other partners are: Bio-energie De Vallei, Woonstede, the province of Gelderland, Nuon and Alliander. The Stuurgroep asked consultancy agency DWA to look at possibilities of extending the heating network. The stakeholders not already mentioned before, are described in this section.

Woonstede

Woonstede is an housing corporation who supplies housing to people with a relatively low income. They agreed in 2012 together with Nuon and Bio-energie De Vallei to switch the heating supply of 3,000 of their houses in Kernhem and Veldhuizen to heating from bioenergy from the Dwarsweg (Woonstede, 2012). The people living in these houses have remained customers of Nuon. Woonstede owns together with Nuon the distribution network in the neighbourhood of Kernhem (Gemeente Ede, 2014). This is the network in the neighbourhood itself. For the other neighbourhoods it is unclear who owns the distribution network.

Province of Gelderland

The province of Gelderland is responsible for matching economic use and conservation in the Veluwe area (Borgman Beheer Advies, 2009). They are also responsible for the execution of Natura 2000, the European nature network (Borgman Beheer Advies, 2009). They have a lot of influence as they are high on the decision making ladder. On the other hand, they are not in charge of local decision making at the municipality level.

Nuon

Nuon is a Dutch utility company which provides electricity, gas and heating to houses in the Netherlands, Belgium and the United States. They were the first to build a heating network in Ede in the Neighbourhood of Kernhem. At the end of the 90s about 1,100 houses were connected to this network that was powered by a temporary gas installation (Gemeente Ede, 2014).

Aliander

Alliander is an utility company which is responsible for the distribution of energy in Ede as well as other big parts of the Netherlands. Originally they were part of Nuon. We think they own the transport network, but this needs further investigation. This is the network from the bioenergy plant to the neighbourhoods.