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Assessment of local energy company performance
how to utilize renewable energy techniques locally

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ASSESSMENT OF LOCAL ENERGY COMPANY PERFORMANCE

How to utilize renewable energy techniques locally

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PREFACE

This thesis before you is the result of a research into local initiatives who utilize renewable energy, on behalf of the KENWIB initiative established by the municipality of Eindhoven. With the thesis I will complete the master Construction Management and Engineering, followed at the University of Technology in Eindhoven. For external feedback during the research, I cooperated with the sustainable energy consultancy company BuildDesk.

After a long search for an interesting and relevant research topic, I finally found a topic that satisfied both demands namely, Local Energy Companies. Finding a starting point was very difficult and how to begin a structured research even more. Completing this master thesis has therefore been an interesting journey with many confrontations along the way. Finally, I succeeded in finishing this thesis, however, not without the help of many others.

First, I would like to thank my parents and my girlfriend, for the numerous discussions we had about my research and for giving me new insights on the research. My girlfriend for who has checked every page of my thesis for spelling and grammar mistakes. Next to my family, I also want to thank my friends who supported and distracted me during this thesis.

Of course I would like to thank my supervisors from the TU/e and BuildDesk. Wim, thank you for your guidance, you have a subtle way of making the tension flow away during the talks, I appreciate that. Erik, for your enthusiasm, support and for letting me burst out with my story, helped me a lot. Pieter (from BuildDesk), for your extensive knowledge on the subject, many helpful documents, feedback and discussions about the energy sector. I hope this thesis provides you with new insights on this topic.

Bart Advokaat
Eindhoven, August 2011

MANAGEMENT SUMMARY

Is the transition to renewable energy possible and who should take the initiative? During the climate conference in Copenhagen 2009, governments have shown that they have no solution to offer. The unstable policy has led to a current bottom-up approach by the municipalities and other local stakeholders for example citizens. The society is done waiting for the established large energy companies to act.

It can be observed that Local Energy Companies (LECs) are arising rapidly in diverse locations throughout the Netherlands. These companies utilize renewable energy techniques locally and can also be called decentralized generation. However, creating a healthy business of utilizing renewable energy techniques seems to be difficult. This research will focus on analyzing and measuring the performance of existing local energy companies. Secondly, recent research has shown the enormous dimension and diversity of LECs in the Netherlands. More research is needed to give scientific underpinnings and to recognize structure within these businesses, on the aspects organisational, technical and financial.

The methodology applied in this thesis is benchmarking performance through Data Envelopment Analysis (DEA). Five parameters were identified to be useful in the benchmarking model namely; Input: installation size, investment per installed capacity, maintenance and operational costs and Output: energy output and revenue. A desk research was executed in finding the LECs in the Netherlands. Resulting in 66 identified local initiatives in renewable energy in the Netherlands. After a selection procedure twelve LECs were selected as Decision Making Units (DMUs) and included in the benchmarking model.

Which DMU is “the best practice” is difficult to conclude, looking at the results of the DEA test with all LECs from practice. It shows that heating producing companies are performing the highest in especially the cost efficiency measurement. In the basic technical efficiency measurement LECs utilizing wind energy are performing the most efficient. In the measurement with only electricity producing LECs a “best practice” can be signalled. With the assumptions of ECN (Energy research Centre of the Netherlands) calculated into comparable LECs, also included in the DEA measurement. It shows that one of the government LECs based on assumptions is the “best practice” namely, the one utilizing a manure fermentation.

From the benchmarking results many insights on the techno-economic and financial aspects were derived and values for the important parameter were determined. Other interesting findings were also found on the third aspect, organisational structure. The cooperative organisational model is dominant for initiatives established by residents. For municipalities a holding company (which is also a Ltd. Company) with an operation companies underneath it.

The results on all three aspects gave the input for the set of rules. Through a business case for district Gestel in Eindhoven an example of how to set up such an initiative is elaborated. The overall conclusion is that this research can be used by the practice as a supportive document and roadmap for establishing a Local Energy Company. For the first time a benchmarking model is set up for this kind of businesses. Since this is a very new dimension of the energy sector, there is much to learn and improve.

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1. INTRODUCTION

1.1. Context

Is the transition to renewable energy possible and who should take the initiative? During the climate conference in Copenhagen 2009, governments have shown that they have no solution to offer. The unstable policy has led to a current bottom-up approach by the municipalities and other local stakeholders for example social housing associations. The society is also done waiting for the established large energy companies to act. These fossil based energy companies have different agenda's then the municipalities. One cannot expect that fossil fuel/uranium companies will in general support renewable energy (RE) technologies (Hvelplund, 2006). Mainly because a change from fossil fuel based power system to a solar-, wind- and wave-based RE system implicates that the fossil fuel power companies will lose value added at the fuel level and at the power plant level. Secondly, as joint stock companies, they are very sensitive to even minor changes in turnover, so even if they should want RE technologies, often they would not have the financial freedom to carry through their implementation.

Secondly, it can be observed that organisations linked to existing technologies will initiate project proposals within their organisational framework. One cannot expect alternatives representing radical technological change to originate from such organisations. It is outside their discourse; it is not within their interest or perception (Lund, 2010). Fossil fuel and nuclear technologies are based on large power stations. In contrast, renewable energy and energy efficiency technologies will typically benefit from a wide distribution throughout their geographical areas of consumption. Along with the implementation of new technologies, new types of organisations are therefore likely to develop (Lund, 2010). These new types are at the moment developing locally and are called Local (Sustainable) Energy Companies.

Obvious is that actors and interests must unite to achieve a collective operation of local resources. The required transition and acceleration is at the moment insufficient. This is due to the fact that there is no problem owner of its collective (Municipality of Apeldoorn, 2009). The municipalities have set ambitious goals to become energy neutral, for instance the municipality of Eindhoven who set their goals on becoming energy neutral in the year 2040. By setting these ambitious goals these municipalities also become problem owners of achieving their goals. Where other market actors neglected the task of realising renewable energy installations and achieving energy neutral districts, the municipality is now fulfilling this task and is utilizing renewable energy projects through local energy companies.

Establishing a community energy project involves many complexities, whichever model of development is adopted and which Renewable Energy Source (RES) is utilized. These include legal conditions under which organisations or projects can operate, establishing a scheme's economic and technical viability (Dunning and Turner, 2005). Furthermore, it is essential to learn from previous experiences (Walker, et al., 2007); especially the last phrase is where this research associates with.

1.2. Problem statement

Transition towards renewable energy is in progress and multiple techniques for generating renewable energy are available and well researched. Firstly, it can be observed that Local Energy Companies are arising rapidly in diverse locations throughout the Netherlands. These companies utilize renewable energy techniques locally and can also be called a decentralized generation. However, creating a healthy business of utilizing renewable energy techniques seems to be difficult and how to organise this decentralized generation in urban districts is unclear. Therefore this research will focus on analyzing and measuring the performance of existing local energy companies.

Furthermore, recent research and studies have shown the enormous dimension and diversity of local renewable energy in the Netherlands and abroad. From these results it is not always clear, to what extent Local Energy Companies are successful or not. Often there is only a global image sketched of their organizational structure, technique and finance and factors for success and barriers, for example in report of ECN (2010). Therefore this new market dimension in energy with different business needs to be further examined, to discuss whether they are efficient and successful or not. More research is needed to give scientific underpinnings and to recognize structure within these businesses.

Problem:
Unclear is which aspects determine the performance of Local Energy Companies. Furthermore, structured research and scientific underpinnings on important aspects of Local Energy Companies are lacking, especially in the Netherlands.

1.3. Research goals

The goals of this research are to create a better insight into the relation between organisation, renewable energy techniques, finance and urban development. Secondly, create a set of rules to support local actors in developing renewable energy within Local Energy Companies. Furthermore, the research goal is to apply the set of rules in a case from a business approach to utilize renewable energy in urban districts. In this model different renewable energy techniques must answer to the demand of energy needs from a district.

The aim is to evaluate the performance and judge the efficiency of a Local Energy Company (LEC) and compare it with other LECs. To achieve more insight in the actual performance of Local Energy Companies that utilizes renewable energy techniques. Furthermore, to set up a benchmarking model were these new types of businesses in a new dimension of the energy market can learn from each other. The results will focus on integrating these companies within urban areas or cities.

1.4. Research questions

From the problem focus explained in the previous paragraph, the research questions can be derived. For this research the following main research questions are formulated;

Research questions:
Which aspects of Local Energy Companies determine their performance, which initiative can be signalled as "best practice" and how can local actors set up such an organisation considering the aspects.

Sub research questions are;

- RQ1: Who is taking initiative in a local energy company?
- RQ2: Is there a dominant organisational model?
- RQ3: How are the local energy companies utilizing renewable energy techniques including financial structures (which aspects determine performance)?
- RQ4: Which Local Energy Company is performing healthy and how it is financially organized?
- RQ5: Are local initiatives feasible in urban areas?

1.5. Research design

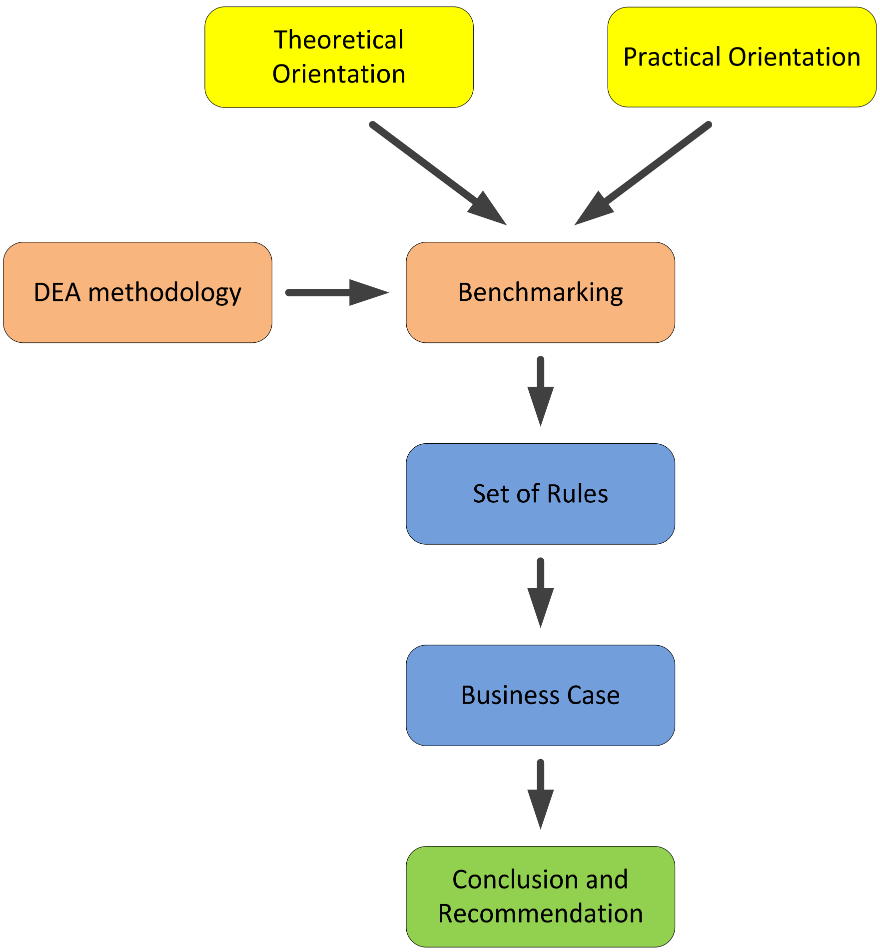


Figure 1: Research design of final thesis

1.6. Reading guide

This thesis consists of three main parts and under every part are a number of chapters. The first part has two chapters namely; Introduction and Theoretical orientation. In Theoretical orientation a literature study is executed in Local Energy Companies, focusing on definitions, stakeholders, ownership models, utilized Renewable Energy Techniques (RETs) and financial structures.

The second main part consists of the applied Research Methodology and Practical orientation. In the chapter of Research Methodology the applied benchmarking methodology Data Envelopment Analysis (DEA) is discussed and how it is applied in this thesis. Furthermore, the parameters for the measurement model are determined in this chapter". For the model input or data is needed, this is collected in chapter four "Practical orientation. First a desk research was executed for finding LECs in the Netherlands. Afterwards twelve LECs were selected as Decision Making Units (DMUs) included in the benchmarking model.

The final main part of this thesis consists of Results, Business case and Conclusion & Discussion. In the first chapter the measurement results of the DEA models are presented and elaborated. With the results a business case is set up for a district in Eindhoven, showing how the results of this research can be applied in practice. Finally, last chapter of this thesis is the Conclusion & Discussion, where the research questions are answered and important findings are once more discussed.

2. EXPLORATION OF LOCAL ENERGY COMPANIES

In the exploration a theoretical orientation is executed on LECs. Analysing what the scientific world knows about this topic and bringing the knowledge to a next level. This chapter is divided in the following aspects of LECs namely; definition, involved stakeholders, ownership models, utilized Renewable Energy Techniques (RETs) and financial structures. These subjects must bring insight in this new dimension of the energy sector, the Local Energy Companies.

2.1. A definition of Local Energy Company

There are a lot of interpretations of the term Local Energy Company (LEC). This section will introduce different definition types and names of a LEC. Finally, the choice for the definition of SenterNovem is explained and this definition used throughout the research.

2.1.1. Definition problems

Definitions problem starts with the question; what is a LEC? This problem start with the fact that in literature and practice various names exists for a LEC, for instance (NEWNRG, 2009);

- Municipal (Sustainable) Energy Company;
- Sustainable Energy Company;
- Sustainable Development Corporation;
- Local Energy Development;
- Energy Service Corporation (EU);
- Energy Company.

These various names contribute to the confusion because the names display a difference in initiative, ownership and operations. Is it a municipality who established a Local Energy Company or a profit driven project developer or a group of residents who are more social driven rather than making profit. In addition, there are also variations in the concept of renewable energy, for example a municipal waste company which burns waste into energy. However, transforming all kinds of waste (except biomass) into energy is in this research not an example of renewable energy. Furthermore, in this research a local initiative in renewable energy through a new established energy company is indicated as LEC.

Another question is; what is local and when is it a local initiative? Think of “local” to a radius of 60 Km (NEWNRG, 2009). A local initiative is when stakeholders are involved who operate locally and mostly generate, utilize and sale the renewable energy locally. For this reason, initiatives where enormous energy company are involved, for instance Nuon, E.ON, are excluded from this research. However, for local actors to be involved does not mean that the renewable energy must by generate locally. A precondition is that local actors have decision making power and profit from the economical or environmental benefits.

2.1.2. Different definitions

Different organisation and companies have published a definition about LEC. These will be discussed here, starting with Innovation Netwerk (2008). They define a LEC as a “Renewable utility from local resources as much as desirable in-ownership of end users.”

Another consultancy company (Tensor Energy, 2009) defines a LEC as a local energy company which initiates coordinates and / or manages renewable energy projects with primary aim to achieve climate goals of the municipality. These LEC’s are in most cases initiated by the municipality and the generated renewable energy is used locally. This definition applies to LEC’s initiated by the municipality and not in other cases, for example a LEC initiated by residents.

According to Build Desk (2010) a local sustainable energy company provides "the production and marketing of renewable energy at a local level, such as heat and cold, electricity and heat from biomass, solar and wind energy. The renewable energy is mostly sold locally to households and businesses”. While ECN defines a LEC more out of policy perspective, their definition is; “A local energy company is investing in renewable energy or energy efficiency projects based on business cases covering many years. There is lobbying by national governments or international organizations for further steps. They may be so active that an organization like the Rotterdam Climate Initiative, is certain areas in Brussels just as well known as the Dutch government” (ECN, 2010).

2.1.3. Project definition

In this research a Local Energy Company is seen as an autonomous entity, independent of the municipality, with the aim of one or more of the following activities to be implemented locally (SenterNovem, 2010):

- Production, delivery and management of renewable energy in their region.
- Financing and / or participation in the renewable energy projects.
- Energy savings.

The Local Energy Company (LEC) is seen as a promising option to give acceleration in producing renewable energy and energy efficiency (Agentschap NL, 2010). A LEC stands for variety of initiatives, which often involves the municipalities. The activities may relate to renewable heat as well as renewable electricity.

A characteristic of a local energy company is that it operates as a commercially independent entity. In addition, a LEC has a strong local focus. The production and / or supply of energy or energy savings take place in a geographically defined area. Often it is a partnership of local actors and citizens or a municipality or housing corporation. However, other market participants can also participate. Local energy companies are often set up for social returns, such as renewable energy supply or controlling energy costs for vulnerable residents.

To conclude this chapter a number of important preconditions of a LEC are elaborated and applied throughout this research, especially during data collection;

- Local actors (municipality, citizens, housing association and other private local actors) must have the power to make decisions and profit from the economical or environmental benefits.
- The established enormous energy companies must not have any decision making power or financial involvement in a LEC.
- The LEC must produce, deliver and manage renewable energy projects, or at least finance and / or participate in renewable energy projects.
- A Local Energy Company is seen as an autonomous entity.

2.2. Involved stakeholders

In the current decentralized generation a distinction is made between individual and collective systems. In this research the focus is on collective systems housed in a LEC. The realization of local integrated distributed energy systems is frequently challenging in a liberalized market. This is because the objectives of some actors involved in the process can be sensibly different from the ones of local government. In particular, these differences lie in economic and financial terms, for instance expected return on investment. Identifying local best practices requires the engagement of a broad variety of actors, ranging from local communities living and working in the areas to institutions operating at the sub-national level and private stakeholders (Manfren, Caputo, & Costa, 2011). In this research the following stakeholders are signalled to be involved in LECs and present in urban environment namely;

- Municipality.
- Housing associations.
- Residents or community organisations.
- Private investors
- The established large energy companies.

2.2.1. Role of the municipality

Municipalities have an essential role to play in ensuring appropriate conditions and applying measures for energy efficiency improvements; this was already known in 1997 by (Laponche, Jamet, Colombier, & Attali, 1997). Through a local energy company the municipality can achieve their ambitious goals of becoming energy neutral in for instance 2040. Currently, two models for a local energy company are known where a municipality is involved (Arcadis, 2010)namely;

1. **Physical model.**
   Municipality is co-investor and operator of local energy network.
2. **Virtual model.**
   Municipality facilitates cooperation or settlement between collective of local energy producers and users.

This final thesis will focus on the physical model; an example of such a model is shown below.

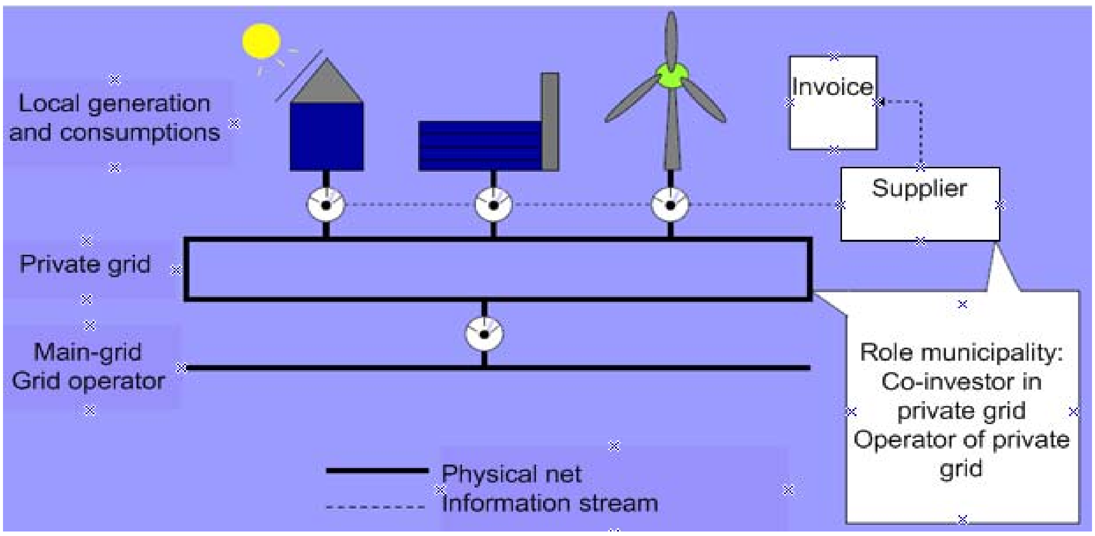


Figure 2: Physical model of a municipality involved in LEC, source Arcadis 2010

However, the municipality can also support local initiatives in a more facilitating role named as the virtual model. Many studies (e.g. (Tambach, Hasselaar, & Itard, 2010)) have indicated the need for local centres for sustainable building, and virtual knowledge centres to support local renewable energy initiatives.

In October 2009 the municipality of Woerden has established a LEC called Duurzaam Dienstenbedrijf Woerden (DDW). This LEC is involved in a sustainable urban development around the railway zone in Woerden. DDW exist of three partnering companies the holding DDW BV and two operating companies DDW BV and Grondwatersanering Woerden BV. Only shareholder for 100% is the municipality of Woerden, see figure 3. De business DDW BV is developer and is in the future a Local Energy Company. The most important argument for this organizational structure is that the municipality is safeguarded mostly for liability (ECN, 2010).

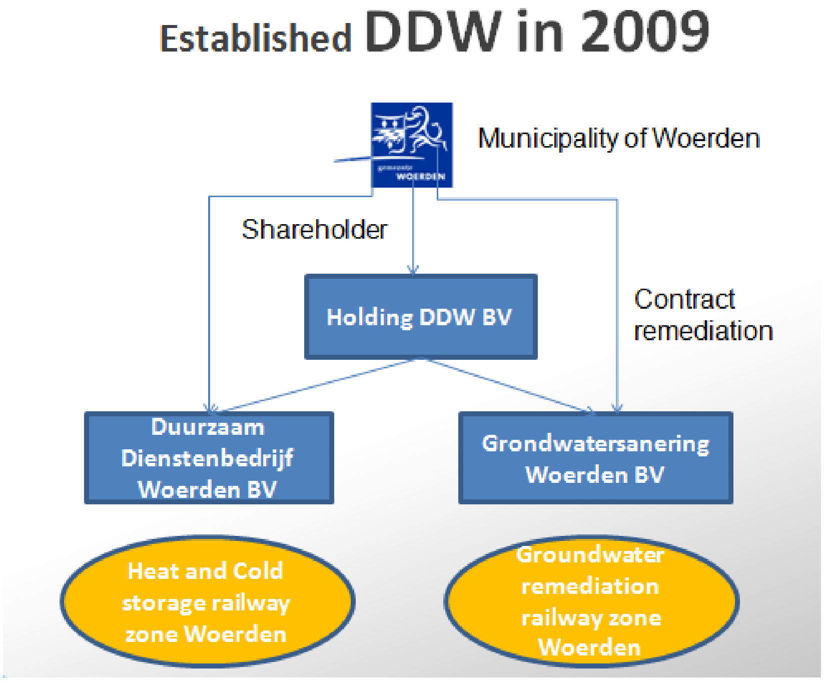


Figure 3: Example of a LEC established by a municipality

2.2.2. Housing associations

In energy efficient housing renovation processes, Dutch municipal governments are dependent on the cooperation of private investors. The reason for their dependence is that municipalities usually do not own dwellings. About 35% of the Dutch housing stock is owned by housing associations (www.cbs.nl). In general, housing associations and municipal governments are seen as important players in the transition process towards a more energy efficient housing stock. Housing associations play an important role as investors in the housing stock and they are well-organized compared to owner-occupiers (Tambach, Hasselaar, & Itard, 2010).

Patrimonium is the first housing associations in the Netherlands using a pellet-incinerator in a new building project as energy source for a collective heating system. For renewable energy projects, such as the management and operation of wood pellet-fired boiler Patrimonium has established its own Energy BV. In this way it also keeps some freedom to determine prices for residents and keep it below the level when outsourced to an energy company. Residents sign a contract with the Energy BV, with associated access and delivery. This guarantees that the heat is supplied to the residents. The Energy BV of Patrimonium takes the risks on their behalf. It is responsible for purchasing and supplying the pellets, maintenance of the boiler and the energy performance of the boiler. This must be carefully arranged in contracts with third parties.

2.2.3. Community organisations

In the example above the initiator is the municipality or a housing association and they play a large role in the further development of a Local Energy Company. In the municipality of Culemborg a local energy company called Thermo Bello is established were initiators are the citizens of district EVA-lanxmeer (Projectteam Warmtenet, 2009). It supplies renewable heat to the EVA-lanxmeer district which exists of 150 houses and a few companies.

Community organisations, which are members of the public, are the ones who invest in renewable energy locally. It can also be individuals who invest in renewable energy production. In the book (InnovatieNetwerk, 2008) four different citizen participation forms are distinguished, elaborated in table 1.

Citizen participation forms

Individual initiative	Individual citizens/households attempt to build for themselves.
Group initiative	A group of persons formulate a concept for their own environment and approaches stakeholders to realise their goals.
Target group orientation	Searching for a specific target group in a project. Representatives from this group form a board and are involved in the development.
Target group participation	A specific group of residents is gathered and organized. This group is participating active in the development and management of the neighbourhood.

Table 1: Citizens participation forms in a LEC

From residents a great force can come in realising sustainability of utilities. By giving residents' groups more influence over the development of their communities, it creates room for customization and creativity. The support for citizen participation in all new utilities can be built from the ground. Institutional stakeholders (e.g. housing associations and municipalities) have in these processes a more supportive and facilitative role. Individual initiatives are not further explored during this research, because I focus on group initiatives in a collective community.

2.2.4. Private investors

Unfortunately the above elaborated local actors cannot utilize renewable energy projects without the input of money from private investors or from banks through loans. To support local initiatives, municipalities can guarantee a bank loan. This will result in a lower interest rate on the loan for the LEC. Furthermore, the established large energy companies could invest in renewable energy but have different interests than local actors. Therefore, participating of large energy companies is ideally avoided in local renewable energy initiatives, especially when it comes to decision making power. This actor will be further discussed in next paragraph.

2.2.5. Large energy companies

Power producers, can either be companies deriving from utilities producing energy from conventional sources that have decided to be activated in the field of Renewable Energy Sources (RES) or Independent Power Producers (IPPs). These companies can be either newly entering companies or companies already engaged in the construction and trade of renewable energy technical equipment that have decided to enter the market as IPPs (Patlitzianas, 2007). These new entering companies are the LEC's utilizing RES, but are heavily opposed by the established large energy companies (Eneco, E-on and Nuon). However, these companies also get in utilizing local renewable energy resources, for example in Biomass power station in Sittard en Polderwijk (InnovatieNetwerk, 2008). Such initiatives are achieved by a combination of local citizens and involvement and guidance by the municipality.

As mentioned in de introduction chapter 1.1, the established large companies are losing value on two activities when investing in RES and it is also not their core business (Hvelplund, 2006) (Lund, 2010). Furthermore, energy companies would not normally be dependent on others, nor do they like to give others a look in their kitchen in terms of cost and fees. However, in terms of technique and RES the energy companies can be moved into the direction of LEC. In terms of decision making power, transparency and reduction of resident utility costs working with energy companies is less likely (InnovatieNetwerk, 2008).

New utility	Current situation
Renewable	Fossil
Decentralized, local	Central, large (international) companies
Self supplied	Dependent
Cooperatives	Consolidation
Partnerships	Supplier / customer
Transparency	Closed
Small margin	Profit maximization

Table 2: Current situation of energy sector versus new renewable utility

2.2.6. Conclusion

From the stakeholder analysis of actors who are involved in local renewable energy initiatives or in already established Local Energy Companies, the following conclusions are drawn;

- Municipalities are problem owner of realising renewable energy and establish LEC.
- The end-users must have power and interest in the LEC.
- Collaboration with municipality is important for business success.
- Large energy companies ideally have neither power nor interest in LEC.

Municipalities are problem owner of realising renewable energy and establish LECs. Since the government is working on the transition to slowly, multiple municipalities have taken actions by setting ambitious goals of becoming energy neutral around 2040. This has led to a number of municipalities establishing their own LEC to utilize renewable energy and there are more LEC's in prospect. In most cases the municipality is searching for collaboration with other local stakeholders, for example a housing association.

The end-users must have power and interest in the LEC, local actors profit from the benefits. This is important for two main reasons; firstly, more involvement of local residents and companies leads to higher acceptance of need for renewable energy. Secondly, involvement of local stakeholders will rise the own equity of the LEC, through their investments. Thus it becomes a healthier business but also the benefits will be for the local community.

Collaboration with municipality is important for business success, especially in new LECs. The municipality has a big role in triggering local actors for more involvement in a LEC and renewable energy. When eventually a LEC is established, collaboration with the municipality is important for many reasons namely for example; feasibility studies, contact with other local actors or a guarantee on bank loan.

The Large energy companies ideally have neither power nor interest in LECs. The large established energy companies have different interests than local actors when it comes to realising renewable energy, as just elaborated in paragraph 2.2.5. These companies operate totally differently than is necessary in a LEC. However, the large energy companies are very useful in performing the administration of LEC.

2.3. Ownership models

Community ownership through financial investment or managerial control has achieved projects in different degrees and ways. Projects can be 100% community owned, or may be developed under co-ownership arrangements with the private sector, for example community ownership of one turbine in a larger wind farm (Walker, 2008). Project can involve renewable energy production that is fed into the grid rather than being used locally, or can combine the locally owned production and consumption of energy. Today various legal and financial models of ownership have been adopted in local initiatives. In a scientific literature study two different streams can be signalled.

The first scientific stream is from the UK by researchers Walker, G.P., Devine-Wright, P., Evans, B., (2007). The second stream is from the US by researchers Bolinger, M., and Wiser, R. (2006), they have a number of publications on ownership models. Differences in these streams lie in the aspects of profitability and large investments in ownership models. The US stream excludes the cooperative model, because such a business does not have a profit target, it primarily serves its members. However, the UK stream finds the cooperatives model very important for the increasing participating of community organisation in local renewable initiatives. These streams are supplemented by literature from the Scandinavian situation and Dutch research institutes.

2.3.1. Cooperatives model

Cooperative energy and water companies are a new phenomenon in the Netherlands. The Dutch agricultural sector has a long and prosperous tradition of cooperative business forms. In recent years also energy cooperatives have emerged, which the agricultural sector and also other actors use to foresee in their own energy needs. An example is De Windvogel, a cooperative which realised and operates multiple wind turbines in the Netherlands. In the United States these kinds of cooperatives have existed since the thirties. These companies assume an association structure, in which local consumers are the members. To join, they pay a onetime membership fee, which is the association's investment capital (InnovatieNetwerk, 2008). After each year any profit it distributed among their members.

The cooperative energy company is not established for profit but to give its members reliable and cost effective utility services. In the UK Baywind is the best known example. It has set up the first cooperatively owned wind farms in the UK in the later 1990s, using a model transferred from Scandinavia (Walker, 2008). A co-operative society operates much like a traditional limited company except that the voting rights are distributed equally amongst the members, regardless of the number of shares held. Baywind has a minimum share holding of 300 and a maximum (by law) of 20,000 (www.baywind.co.uk, 2010). This model was also one of the main success factors behind the development of renewable energy in Denmark, since it was Danish tradition for co-operative neighbour ownership of energy technologies (Hvelplund, 2006). Thus, in 1996, a co-operative ownership model with around 120,000 individual wind turbine owners had a positive effect on the local acceptance of wind power projects. The multi-party cooperation requires mutual trust. The way to maintain this trust is transparency. Actual cost prices and revenues must be transparent for all stakeholders. Through the local and participatory design of LEC's, transparency can be realised (InnovatieNetwerk, 2008) .

Other ownership models are **Community charities**. This mostly takes the form of an association; they can manage energy projects, as with the biomass district heating network in Kielder, Nothumberland (Walker et al., 2007). Or **Shares owned by a local community organisation.** In this case, the community owns shares in commercial projects to provide a community benefit from local energy production. Finally, **Development trusts** are community enterprises working to create wealth in communities and keep it there. They trade on a 'not-for-personal-profit' basis, re-investing surplus back into their community and effecting social, economic and environmental, or 'triple bottom line', outcomes.

2.3.2. Farmers in the US

Farmers interested in owning a utility-scale wind project must choose from a variety of legal or business structures that could potentially be employed to finance, own, and operate the project. In the study of (Bolinger & Wiser, 2006) a list is constructed of potentially viable ownership structures through a limited liability company (LLC) in the US. Consisting of **multiple local investors/farmers**, **two types of "flip" structures**, and **onsite projects**. Perhaps surprisingly, this list does not include one of the most familiar business structures employed in the sector namely; cooperatives. The primary reason is that cooperatives are organized around the concept of patronage. This means that a cooperative exist to serve its member-owners. The cooperative member-owners benefit based on how much they use or patronize the cooperative, rather than how much they have invested in it. In fact, despite their reputation as such, very few European community wind projects are legally organized as cooperatives. Most Danish community wind projects, for example, are structured as general partnerships, while German "wind funds" are typically organized as limited partnerships (Bolinger, 2001).

Multiple local owners.

In this model, one or more farmers conceive of a farmer-owned wind project, and then solicit sufficient equity investment to support the project from among the local farming community. A LLC structure in which investors can buy shares (Bolinger & Wiser, 2006).

Minnesota-style "flip" structure.

The local farmer/landowner ("local partner") initially contributes as little as 1% of the equity in the LLC, with the corporate partner contributing up to 99%. During the first 10 years of the project, all cash flows and tax benefits from the partners proportional to their level of investment in the LLC. At the end of 10 years ownership in the LLC "flips" to 99% local, 1% corporate. At the time of the flip the corporate partner typically has the option to either maintain its 1% ownership position for the remaining life of the project, or else sell its 1% interest to the local partner at fair market value (Bolinger & Wiser, 2006).

Wisconsin-style "flip" structure.

This is a variant on the Minnesota-style flip structure, in which multiple local investors provide debt financing to the wind project. This is called a "flip" structure because ownership in the project effectively flips form the corporate investors to the local investors at the end of 10 years. A more accurate characterization would be that, unlike in the Minnesota-style flip, the local investors buy out the corporate investor's 100% stake in the project (Bolinger & Wiser, 2006).

On-site projects.
Finally, an on-site project designed to provide power to the farm, rather than selling it to a utility. This model is very straightforward, and involves a large end-use electricity consumer financing and interconnecting a utility-scale wind turbine on its side of the meter to supply on-site power and there displace power purchased from the utility (Bolinger & Wiser, 2006).

2.3.3. Ownership models in the Netherlands
In the Netherlands a LEC is conceivable in many variations and legal forms, which depending on ambition of the involved stakeholders. As described in paragraph 2.2.6. Conclusions, an important aspect in decentralised energy production and supplying renewable energy is often the involvement of end-users and other local actors. Creating awareness among consumers of energy and support for projects are key concepts.

To determine the legal framework in which participation of end-users can be structured, it is important to determine how the project is financed and what rights are granted to participants. A common method of financing is the founders of the LEC providing capital and later by possible joining participations. In these cases the legal structures of public or private limited liability company is often used (in Dutch the N.V. or B.V.), in which participation is achieved through shares. In addition, a cooperative legal form can be used, involving (negotiable) membership rights associated with subscription obligations. Or a foundation in which involvement of customers is structured through participation as members with an annual financial fee. Also other partnerships can be considered for example in Dutch the VOF or CV. Depending on the project, different legal forms are often combined in a group structure (Eversheds Faasen, 2009). In addition to direct participation in a LEC, it is also possible through an investment institution, for instance in the form of a CV, a mutual fund or limited liability participation (B.V. and N.V.) (Eversheds Faasen, 2009). In this construction, the participant becomes part owner of the assets or shareholder of the investment institution. It is then the investment institution who participates in a LEC.

2.3.4. Conclusion
The emphasis of ownership structures should be on minimizing dependence on subsidies, removing the high initial investment for the user and a model that can easily be expanded or replicated. According to the research by, (Municipality of Apeldoorn, 2009), the legal structure B.V. seems to most flexible in terms of participation, enter or exit company and taxations. Especially when not only the end-users are involved but also other market actors for example municipality, housing associations, private stakeholders. Based on examples / experiences elsewhere in the Netherlands and gives the context in the research by Apeldoorn. The following conditions for starting a LEC can be formulated (considering that multiple local actors are involved);

- A director’s role for the municipality (at the stage of formation of the LEC).
- High security for all participants, this justifies a lower rate of return for participants.
- Business activities are serving the whole energy chain.
- A LEC is streamlined along the principles of Corporate Social Responsibility;
    - Decision making power for the end-users.
    - Value creation utilized for (re) investments.
    - Legal links municipalities, market and users.

2.4. Utilized Renewable Energy Techniques

In the beginning of a local initiative in renewable energy two scenarios are possible, either a choice in a new Renewable Energy Technique or Source which is not yet proven on the market or a proven and well tested RET. Since this research focuses more on analysing the practice and learning from what has already taken place, rather than how RETs are going to develop. The choice for only selecting RETs that are solid market proven is easily decided. The market proven techniques which are selected in this research are solar panels PV, wind turbines, biomass and bio-gas installations and, heat and cold storage (including heat pumps systems). In this chapter the different techniques are further described with focus on performance facts and figures on investments, costs and yields etc. Not important is how these techniques are designed or constructed.

2.4.1. Solar energy

The 2010 global solar photovoltaic (PV) market size soared past the forecasts of the previous year, allowing prices throughout the PV chain to hold up much better than anticipated. Worldwide PV market installations reached a record high of 18.2 GW in 2010, representing growth of 139% Y/Y. The PV industry generated $82 billion in global revenues in 2010, up 105% Y/Y from $40 billion in 2009. Meanwhile, worldwide solar cell production reached 20.5 GW in 2010, up from 9.86 GW in 2009. Due to the recent sharp cuts in tariffs in Europe, the industry will need to stimulate positive PV policies across new markets and regions in order to be successful (Solarbuzz, 2010).

According to market research the prices of PV modules decreased a lot in ten years, see figure 4 below. The lowest retail price for a multi crystalline silicon solar module is $1.84 per watt (€1.23 per watt) from a US retailer. The lowest retail price for a mono crystalline silicon module is $1.80 per watt (€1.21 per watt), from an Asian retailer (Solarbuzz, 2010).

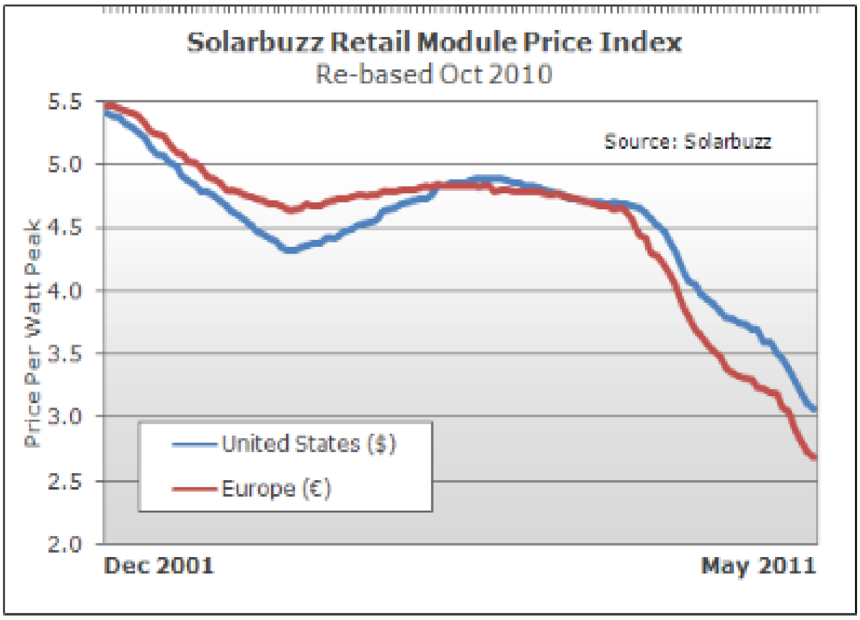


Figure 4: Solar panels module prices, source: www.solarbuzz.com

In the Netherlands a well known initiative is called WijWillenZon. This is a foundation with a large scale purchase concept, to make solar panels cheaper and available for everybody. An example of their offering, package B (www.wijwillenzon.nl, 2010);

- 12 Multi crystalline panels of 230 Wp, 164 cm x 99 cm c 5 cm.
- Together 2760 Wp, with an average production of 2350 kWh a year (number of Wp times 0,85 is average annual kWh in the Netherlands).
- Costs are for 12 panels, inverter and assembly materials € 5060 is € 1,83 per Wp (excluding taxes).

According to the market consultation for the SDE (ECN, 2011), investment costs of solar panels are around 2200 €/kWp. Or 2,20 €/Wp.

2.4.2. Wind energy

In the global market of wind turbines there are many players with comparable shares of the global market, see figure below. However, in the Netherlands two producers of Wind turbines Enercon (70%) and Vestas (24%) have the largest market share (www.windenergie-nieuws.nl/gegevens/statistiek) in 2010.

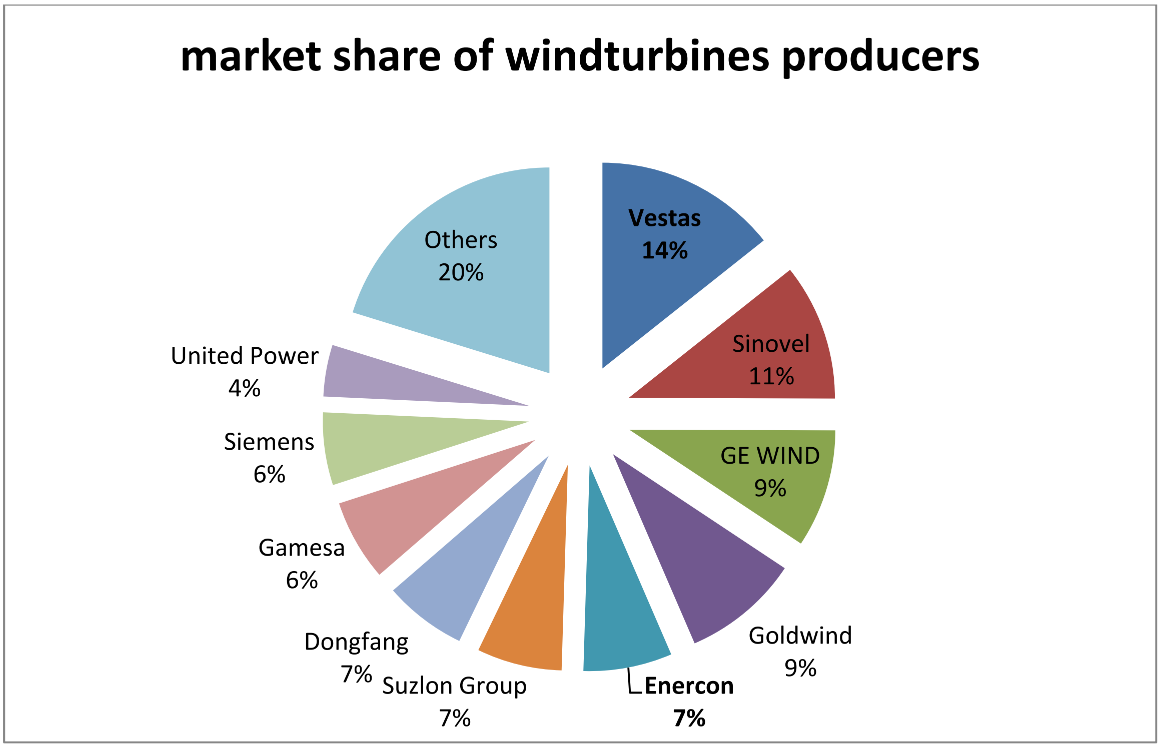


Figure 5: Global market shares of wind turbine producers, source: www.enercon.de

As shown in figure 6 below, the installed cost of wind power projects declined dramatically from the beginning of the industry in California in the 1980s through the early 2000s (falling by roughly $2,700/kW over this period), but have more recently increased. Among the sample of projects built in 2009, for example, the capacity-weighted average installed cost was $2,120/kW. This average increased by $170/kW (9%) from the weighted-average cost of $1,950/kW for projects installed in 2008, and increased again by $820/kW (63%) from the average cost of projects installed from 2001 through 2004. Project costs have clearly risen, on average, over the last five years (Wiser & Bolinger, 2010).

Some of the cost pressures facing the industry in recent years (e.g., rising materials costs, the weak dollar and turbine and component shortages) have eased since late 2008. As a result, while costs may – on average – remain high for a period of time. The developers continue to work their way through the dwindling backlog of turbines purchased in early 2008 at peak prices under long-term frame agreements. There are expectations that average installed costs will decline over time (Wiser & Bolinger, 2010).

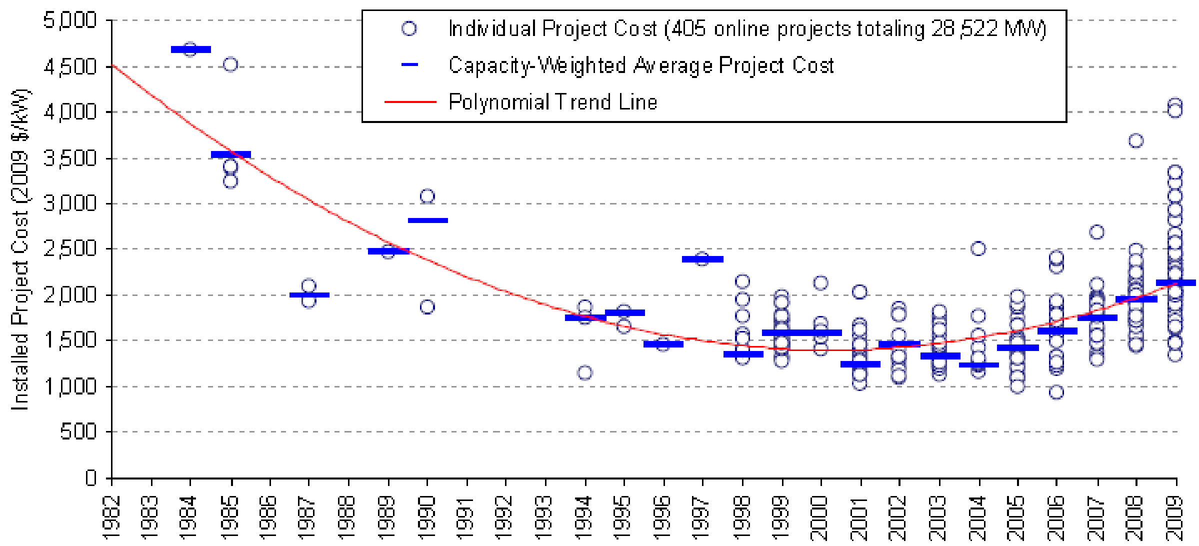


Figure 6: Cost of installed wind turbine project in the US, source: (Wiser & Bolinger, 2010).

In the table below, assumptions of investments, costs and performance are given according to AgentschapNL, 2010 (www.windenergie.nl) and (Pondera consult, 2009).

Specification	Assumptions	Example (15MW Windfarm)
Investment costs	1.430 €/kW	Amounts / Year
Defrayment	5% interest , depreciation 15 years	€ 2.066.542,-
O&M	0,011 €/kWh	€ 363.000,-
Grid costs	11 €/kW/Year	€ 165.000,-
Land costs	14 €/kW/Year private land 15 €/kW/Year land of government	€ 210.000,-
Taxes	18.603 €/year	€ 18.600,-
Other costs		€ 50.000,-
Total Costs		**€ 2.873.142,-**
Electricity sales	0,06 €/kWh	€ 1.980.000.-
SDE Subsidy	0,036 €/kWh (total always 0,096)	€ 1.188.000,-
Total yields		**€ 3.168.000,-**
Full-load hours **Electricity production**	2.200 Year 6.600.000 kWh/Turbine/Year	**Result € 294.858,-**

Table 3: Figures of wind turbine projects and example calculation

2.4.3. *Bio energy*

The market for bio energy is developing fast. Bio energy is energy which is generated from biological material (biomass). With biomass one can think of (www.platformbioenergie.nl);

- Arboriculture biomass (from public gardens and woods).
- Forest thinning from woods.
- Rest- and waste wood from the industry (e.g. from saw-mill).
- Vegetables- , fruit- and garden waste (GFT).
- Agricultural residues, like straw and manure.
- Vegetation which is especially cultivated for energy purposes (energy crops), like willows, poplars, hemp.
- Sludge (sewage sludge of communal or industrial water purifications, paper sludge).

Depending on the conversion-technique, bio energy can be transformed into the following products: electricity, heat and gaseous or liquid fuels. Transformation into bio energy can be accomplished in the following ways;

- Combustion.
- Gasification.
- Fermentation.
- Production of liquid substances.

The process from raw biomass materials mentioned above to bio energy is present in the scheme below. There are three different end products of bio energy; bio fuels, bio-electricity and bio-heat.

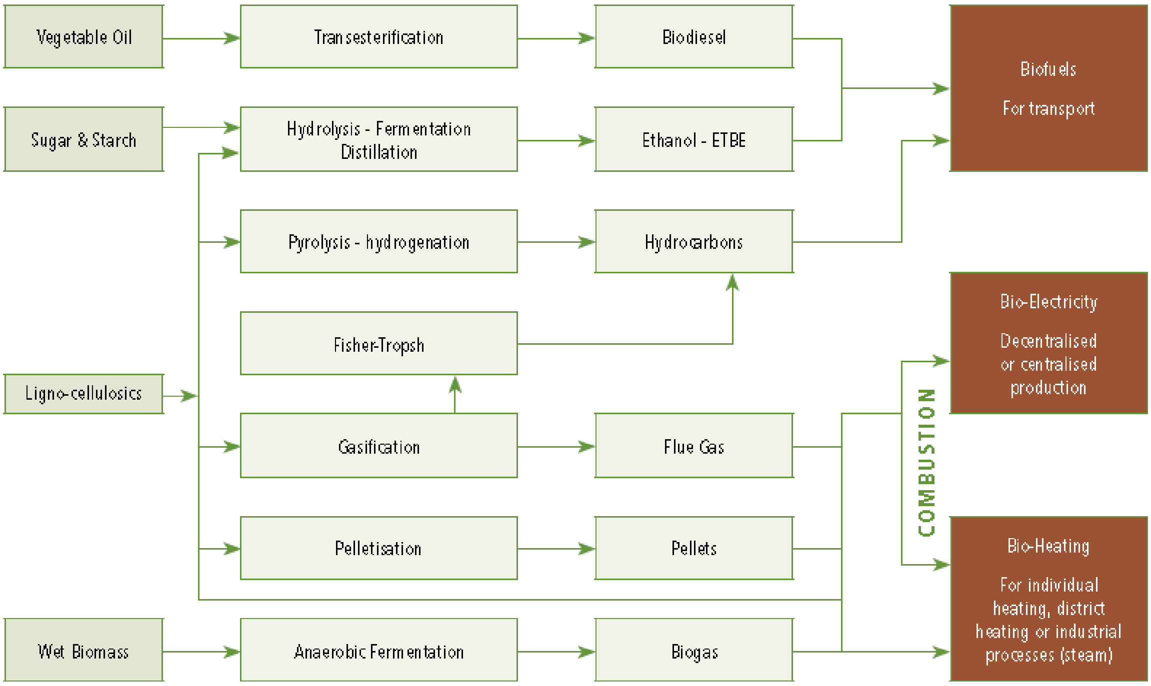


Figure 7: Diagram of possible transformation of biomass, from raw material to final use, source: European Biomass Industry Association 2010

In the Netherlands there exist about 150 bio energy installation throughout the country, see figure below with locations of installations on the map. The different colours of the points on the map represent different kind of installations; for instance green points are co-fermentation installations (http://www.b-i-o.nl/default.aspx).

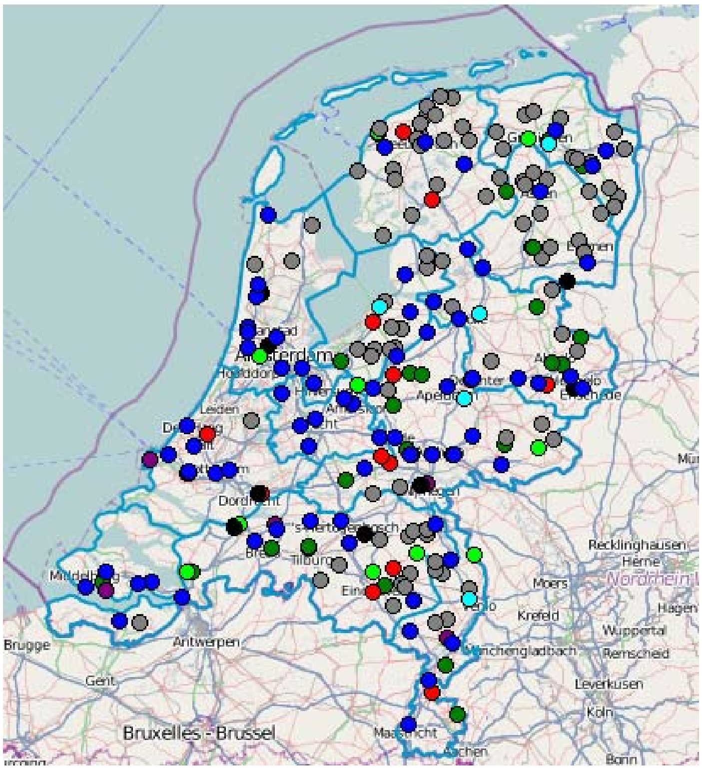


Figure 8: Locations of biomass installation in the Netherlands, source: http://www.b-i-o.nl/default.aspx

Average figures of bio energy installation on investments, costs and performance are difficult to combine. The numbers are very diverging and there are many techniques to invert biomass into bio energy. Furthermore, the yields are also depended on which technique is used to create bio energy, see SDE subsidy table in paragraph 2.5.4. However, there are enough examples of bio energy installation build in the Netherlands. Financial and performance figures can be derived from these installations. In the tables below are two examples given, one biomass installation with pellets in Schijndel operating since 1997 and one fermentation installations on fertilizer in Sterksel operating since 2002.

Schijndel

Capacity installation	7,4 MWth 1.400 kWe
Energy production	8,4 GWh / year 13.500 GJ / year
Availability	8.000 hours / year (91%)
Investments	€ 4.800.000,- € 3400 per kWe
O&M	€ 100.000 per year Excl. biomass costs
ROI Time	11 years

Sterksel

Capacity installation	45 kWth 31 kWe
Energy production	180.000 kWh / year
Availability	4600 ton fertilizer
Investments	€ 200.000,- € 6450 per kWe
O&M	Unknown
ROI Time	7 Years

Table 4: Figures of two biomass project in the Netherlands, source: www.agentschapnl.nl

2.4.4. Thermal energy

The energy from the soil can be divided into geothermal energy (geothermal energy from deep underground) Heat and Cold Storage (use of heat or cold in the shallow subsurface). These are renewable forms of energy that contribute to conservation of fossil fuels and the emissions of CO2. By using these sources of energy, buildings, houses, greenhouses and factories are heated and cooled in a sustainable way. In this research I will only on thermal energy in the shallow underground. There are two types of thermal storage systems: open systems and closed systems. Heat pumps are used in the upgrading of heat from the soil, groundwater, surface water and air / ventilation. They convert heat from a low temperature to heat with a sufficiently high temperature. This is not easy and expensive external driving energy (www.agentschap.nl).

The investment in a heat pump depends on the type of heat pump and varying from € 500 to € 2000/kWth, including installation costs and individual source systems. A collective based source of groundwater in terms of investment costs lies around € 1500/kWth in 2010. In the growing pump market those prices drop. The costs of an electric heat pump with source in the ground vary widely depending on capacity. For individual applications in new buildings prices should be considered between € 9,000 and € 20,000. The capacity of the plant is than at a level from 10 kWth. Project prices from ten to forty homes are considerably lower and in some cases well below € 10,000 (AgenschapNL, 2010).

In major renovation projects with individual heat pumps, the installation costs are between € 10,000 and € 15,000. Typically, this involves smaller homes with a reduced capacity (4 to 10 kW per system). Payback periods of heat pump systems are often longer than ten years. In the case of a moderate heat pump system the payback time is not improved yet. However, this situation changes because of the fall of heat pumps prices and improvements in the systems (AgenschapNL, 2010).

A couple of examples from nieuwenuts.wikispaces.com (2010) A heat pump system (power 425 kilowatts) including heat and cold storage for a warehouse of 20,000 m2 will cost about € 530,000 ex VAT. A central heat pump with cold storage for 70 dwellings (apartment three stories high) € 500,000 including VATS. A gas absorption heat pump for 70 dwellings (or for apartment's three stories high) costs about € 400,000 including VATS.

The initial investment of a heating network is relatively large. Once the heating network is once in the ground, however, little maintenance is required. It can last for years. Profit or loss is partly dependent on which accounting method is applied. A heating network which is rapidly depreciated seems to be making losses. In practice, however, remains a significant value from the network itself and the right to supply customers connected. When the grid is written off and the financing expenses are met, the cost decreases. Customers find that the price is not decreasing. The energy company achieves a much higher profit. The installation costs of a heating grid is according to a research by (University of Technology Eindhoven and Endinet, 2011) around €225 to €450 per m1.

2.4.5. Conclusion

An important conclusion which can be derived from this chapter, are the techno-economic parameters per Renewable Energy Technique (RET). These parameters will be discussed in chapter 4, to determine if they are important for measuring performance of LEC. In table 5 below all techno-economic parameter values are presented per all RET discussed in this chapter.

Techno-economic parameter / RET	Installation size	Investment cost	Operating hours	Fixed O&M costs	Variant O&M costs	Fuel costs
	MW	€/kW	Hours/Year	€/kW	€/kWh	€/ton
Manure co-fermentation	1,1	3100	8000	235	-	27,5
Green waste fermentation	1,5	4285	8000	445	-	0
Solid biomass 0-10 MWe	2,0	4445	8000	340	0,006	35
Solid biomass 10-50 MWe	25	3600	8000	250	-	27
Wind on land <6 MW	15	1350	2200	25,8	0,011	-
Solar Panels 1-15 kW	0,0035	3105	850	-	0,031	-
Solar Panels 15-100 kW	0,1	2145	850	-	0,025	-
Heat and cold storage (incl. Heat pump)	0,425	1247	Project based	Project based	Project based	-

Table 5: Theoretical conclusion of the techno-economic parameters, source (ECN & KEMA, 2010).

2.5. Financial Structures

Studies use a life cycle cost analysis in electricity generation systems, which allows the evaluation of all the costs associated with installing and operating any power system over its lifetime, thus allowing a reasonable comparison of different power sources (Menegaki, 2008). Yet because of the new participatory Local Energy Company structure, balance of the tariffs is expected. All stakeholders would have an interest in the continuity of the entire system. Tariffs must cover costs and buffers must be built for replacement and improvement.

2.5.1. Investments in renewable energy

Investments in renewable energy technologies must be made by multiple-purpose organisations. Thus, electricity savings must be implemented by private households and industries with only a limited awareness of consumption, and with the main objectives quite unrelated to simply producing or consuming heat or electricity (Lund, 2010). This has to be compared with the former situation in which investments in supply technologies were carried out by single-purpose organisations, such as utility companies, with energy production as their primary objective. Therefore Local Energy Companies are needed to invest and implement the radical technology changes.

The housing associations find a return on investment of 4 to 5% sufficient, while the large established energy companies wants a higher return on investment (ECN, 2010).

2.5.2. Energy Investment Allowance (EIA)

The Energy Investment Allowance (EIA) is a fiscal arrangement of support by the government for investments in energy-efficient operating means and in durable energy. When one make use of the EIA, an entrepreneur, will benefit twice; the energy costs will fall and less tax have to be paid. One may benefit from the EIA if two conditions are met (NL Agency, 2011);

- You are liable for income tax or corporation tax and the business is run for your own account in the Netherlands.
- You invest in operating means that comply with the requirements of the Energy List.

<u>Calculation example</u>

The fiscal profit for 2011 is €500,000. Corporation tax is 20% for the first band up to €200,000 and 25% above €200,000. You make new energy investments of € 300,000. The EIA is 41.5% of €300,000, which is €124,500. Fiscal profit now becomes € 375,500 (€ 500,000 - € 24,500). Without the EIA, you would have to pay € 115,000 in corporation tax. By making use of EIA, you are paying only € 83,875 in corporation tax. Your direct fiscal benefit is € 31,1125. The net EIA advantage is around 10%.

2.5.3. Exploitation model

Cash flows within the Local Energy Company. Large and small scale consumers pay for delivered renewable energy. The LEC buys renewable energy from wind farms or other producers and makes a profit. This profit flows back to the shareholders in the form of for example distribution of profits, see figure 9.

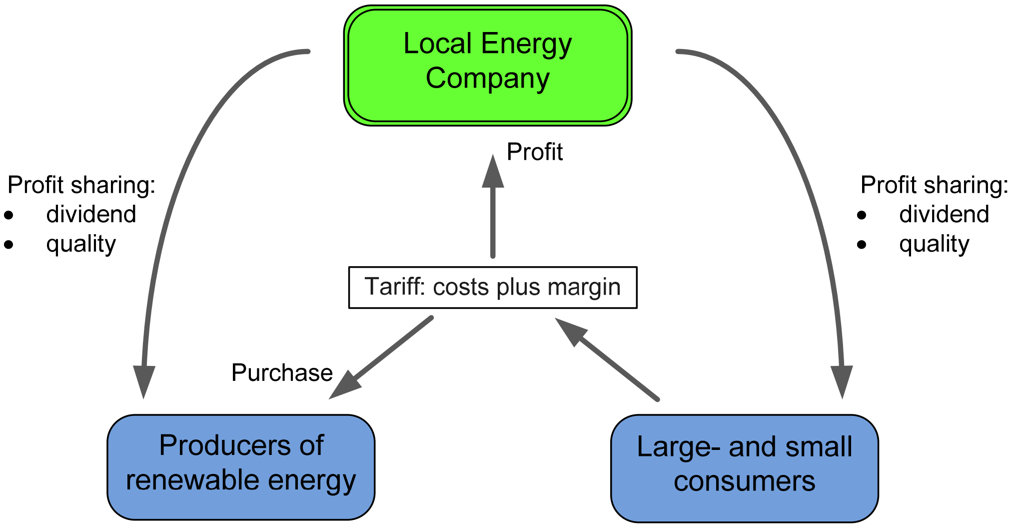


Figure 9: Cash flows in local renewable energy, source: (InnovatieNetwerk, 2008)

2.5.4. SDE Subsidy

The Dutch government has recently published the new SDE Subsidy (stimulation renewable energy production) amounts for renewable energy. Compared to the final standard of the basic amounts for 2010, many nominal amounts are unchanged. In some categories for fermentation of biomass there has been a slight decrease of the base amount. The base amounts for solar PV have fallen sharply, partly due to other calculation assumptions. In the table beneath are the SDE Subsidies given for renewable energy techniques (ECN & KEMA, 2010), which are also discussed in chapter 2.4. The SDE Subsidy is only for renewable electricity, the price for heat and cold supply is determined by the NMDA-principle. In June 2011 a new SDE Subsidy is published by the government, see appendix B.

Renewable energy technique	Basic amount 2011 (€ct/kWh)	SDE Subsidy duration (Years)	Calculated full-load hours
<u>Fermentation of biomass</u>			
Manure co-fermentation	18,2	12	8000
Green waste fermentation	13,4	12	8000
Other fermentation	15,4	12	8000
<u>Thermal conversion of Biomass</u>			
Solid biomass <10 MWe	21,3	12	8000
Solid biomass 10-50 MWe	12,2	12	8000
Liquid biomass <10 MWe	17,3	12	8000
Wind on land <6 MW	9,6	15	2200
Solar PV 0,6-1,5 kWp	33,3	15	850
Solar PV 15-100 kWp	28,0	15	850

Table 6: Base amount for renewable electricity 2011, source (ECN & KEMA, 2010)

2.5.5. Conclusion

Wind cooperative de Windvogel in collaboration with large energy Service Company Eneco has tested a new method with increased revenue from the generated electricity called the Self-supply model. Unlike existing initiatives, the participant receives no yield from its green electricity generation but from electricity itself. Subtlety lies in the fact that the electricity is now generated by the participant and over own generated electricity a resident does not have to VAT or other taxes. The efficiency goes up with about 50% against other existing local initiatives. The power company Eneco that supplies green electricity provides a balanced load on the grid and allows the domestic generation to be subtracted from the monthly electricity bill. According to the chairman of Windvogel, payment of own electricity is three times as profitable as an investment in other wind cooperatives, see figure 10 below.

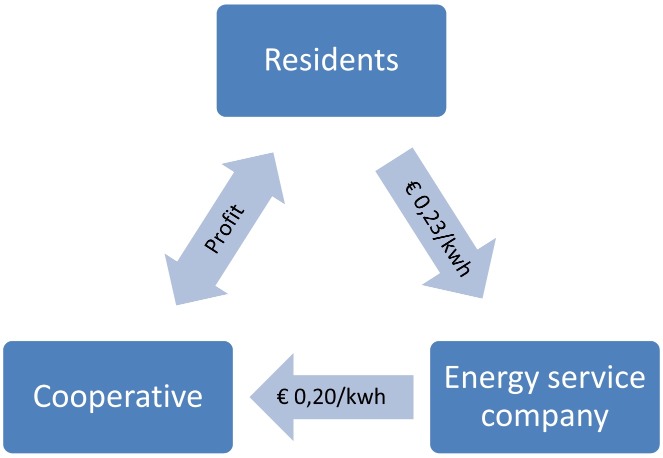


Figure 10: Self supply model with cash flow and actors

Important aspects to conclude in this financial chapter are the financial parameters for RETs. These parameters will be discussed in chapter 4, to determine if they are important for measuring performance of LEC. In table 5 below all financial parameter values are presented.

Financial parameter / RET	Share Equity	Interest	Return on Equity	Economical lifetime	Yields per kWh	Yields per GJ
	%	%	%	Years	€/kWh	€/GJ
Manure co-fermentation	20	6	15	12	0,182	-
Green waste fermentation	20	6	15	12	0,134	-
Solid biomass 0-10 MWe	20	6	15	12	0,213	-
Solid biomass 10-50 MWe	20	6	15	12	0,122	-
Wind on land <6 MW	20	5,1	15	15	0,096	-
Solar Panels 1-15 kW	0	2,6	2,6	15	0,333	-
Solar Panels 15-100 kW	15	5,1	15	15	0,280	-
Heat and cold storage (incl. Heat pump)	20	6	15	15	-	11,81 (plus 285,64 fixed)

Table 7: Theoretical conclusion of the financial parameters, source (ECN & KEMA, 2010)

3. BENCHMARKING LOCAL ENERGY COMPANIES WITH DEA

Identifying best practices at the community level embodies political rationalities for both local sustainable development and technological learning. However, the smaller the scale is, the harder is the process of transferring abstractions, categories, etc. (Manfren, Caputo, & Costa, 2011). Therefore, best practices should not be recognized as a source of general technical expertise, but rather as a type of intervention that can identify problems and provide useful insights. In general, some contradictions and tensions can be identified in local best practices. This chapter will elaborate benchmarking and the chosen method Data Envelopment Analysis (DEA), with the goal of identifying and measuring local best practices.

3.1. Benchmarking methodology

Benchmarking as a management technique has many definitions. Benchmarking can be divided into two main categories (Global Benchmarking Network, 2009): informal and formal benchmarking. Informal Benchmarking can be defined as an unstructured approach to learn from the experience of other organisations; therefore not following a defined process.

Formal Benchmarking is conducted consciously and systematically by organisations. It is divided in two categories: Performance Benchmarking and Best Practice Benchmarking. Performance Benchmarking compares the performance level of a specific process to identify opportunities for improvement and to set performance targets. Best Practice Benchmarking is searching for the best way or solution by studying other organisations that are high performers in particular areas of interest. The knowledge gained is then analysed in cases that are feasible in practice, and it will be adapted and incorporated in the organisation's own process. In this research Formal Benchmarking in the form of "Best Practice" will be executed on the performance of Local Energy Companies.

From a scientific research on benchmarking system, the following mathematical methods can be distinguished (Chung, 2011); Simple normalization (Simple), Ordinary Leas Square (OLS) (also called Simple Regression Analysis), Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA), the model-based method (Simulation), and Artificial Neural Network (ANN). I have chosen for DEA as method for benchmarking the LECs. The contribution of DEA in management sciences to assessing efficiency has been intensified in recent years (San Cristobal, 2011), especially in the Energy and Environment (E&E) research, which I will elaborate in paragraph 3.2.2. Furthermore, DEA is focused on assessing efficiency of a relative set of organisational DMUs and other methods are focused on regression line, rather than identifying the "best practice". In the next paragraph DEA is further explained and applications in E&E studies are discussed.

3.2. Data Envelopment Analysis (DEA)

DEA, first introduced by Charnes et al. in 1997, is a linear programming technique for comparing the efficiency of a relatively homogeneous set of organisational decision making units, such as schools, banks or business firms, in their use of multiple resources (inputs) to produce multiple outcomes (outputs) (Camanho, 2011). The comparison with the benchmarks also allows to determine the input and output targets corresponding to an efficient operation. This methodology can be interesting for the analysis of the strength and weaknesses of LEC's. For DEA beginners, (Scherman & Zhu, 2006) provided an excellent introductory material. The more comprehensive DEA expositions can be found in the recent publication by (Cooper, Seiford, & Tone, 2006).

DEA is a multi-factor productivity analysis model used for measuring the relative efficiencies of a homogenous set of decision-making units (DMUs) (Chung, 2011). Efficiency is defined as the reciprocal of the industry standard ratio of cost-to-income, emerges with a mixed desirability amongst the identified stakeholders (Avkarin, 2010). DEA also allows for the computation of the necessary improvements required in the inefficient unit's inputs and outputs to make it efficient. However, DEA is mainly a diagnostic tool and does not prescribe any improvement strategies to make inefficient units become efficient. Therefore, the results need to be analysed by the researcher and improvement strategies can be drawn by the researcher.

3.2.1. Basic DEA methodology

DEA compares units considering all resources used and outputs generated, and identifies the most efficient units or best practice units (branches, departments, individuals). This is achieved by comparing the mix and volume of outputs generated and the resources used by each unit compared with those of all the other units. In DEA, the organisation under study is called a DMU (Decision Making Unit). In short, DEA is a very powerful benchmarking technique (Scherman & Zhu, 2006).

Efficiency can be simply defined as the ratio of input to output. More output per unit of input reflects relatively a greater efficiency. If the greatest possible output per unit of input is achieved, a state of *absolute* or *optimum efficiency* has been achieved and it is not possible to become more efficient without new technology or other changes in the production process (Scherman & Zhu, 2006). The difference in efficiency will be due to the technology or production process used, how well that process is managed, and/or the scale or size of the unit. When more than one input and/or output are involved in the production process, inefficiencies can also be due to the mix of inputs used to produce the mix of outputs, which is referred to as allocative efficiency (Scherman & Zhu, 2006).

The linear programming technique is used to find the set of coefficients (u's and v's) that will give the highest possible efficiency ratio of outputs to inputs for the unit being evaluated. The formulas below provide a DEA mathematical model, in the model;

j = number of units (DMU) being compared in the DEA analysis

Uj = Unit number j

θ = efficiency rating of the unit being evaluated by DEA

Y_{rj} = amount of output r used by unit j

x_{ij} = amount of input i used by unit j

i = number of inputs used by the DMUs
r = number of outputs generated by the DMUs
u_r= coefficient or weight assigned by DEA to output r
v_i = coefficient or weight assigned by DEA to input i
DEA mathematical model; Objective Function (Maximize the efficiency rating θ for service unit o).

$$\text{Maximize } \theta = \frac{u_1\, y_{1o} + u_2\, y_{2o} + \ldots + u_r y_{ro}}{v_1\, x_{1o} + v_2\, x_{2o} + \ldots + v_m\, x_{mo}} = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$

This is subject to constraints when the same set of u and v coefficients is applied to all other units being compared, no unit (U) will be more than 100% efficient as follows:

$$DMU = \frac{u_1\, y_{11} + u_2\, y_{21} + \ldots + u_r y_{r1}}{v_1\, x_{11} + v_2\, x_{21} + \ldots + v_m\, x_{m1}} = \frac{\sum_{r=1}^{s} u_r y_{r1}}{\sum_{i=1}^{m} v_i x_{i1}} \leq 1$$

The classical model of DEA is presented in the figure below.

$$\max h_0 = \sum_{r=1}^{s} u_r y_{rj0}$$

$$\sum_{i=1}^{m} v_i x_{ij0} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij0} \leq 0$$

$$u_r, v_i \geq 0$$

Figure 11: Classical DEA model, source: (Cooper, Seiford, & Tone, 2006).

3.2.2. DEA applications in Energy and Environmental (E&E) studies

The application of decision analysis in E&E studies has been reviewed by Zhou et al. (2008). Among the wide spectrum of E&E modelling techniques, DEA, a relatively new non-parametric approach to efficiency evaluation, has also attracted much attention. DEA has been accepted as a major technique for benchmarking the energy sector in many countries, particularly in the electricity industry. The first DEA application in the electricity generation sector was the work of Färe et al. (1983), who measured the efficiency of electric plants in Illinois (USA) between 1975 and 1979, in order to relate the scores obtained to the regulation of the sector. Particularly, the analysis made by Pollitt (1996) on the productive efficiency of nuclear power stations using DEA is of relevance to understand this study approach. The general structure of a DEA model as well as the most widely used efficiency measures in E&E studies (Zhou, Ang, & Poh, 2008).

There are also specific studies linked to the efficiency in the renewable energy sector, for example the DEA application of Barros and Peypoch (2007), (San Cristobal, 2011) and (Iglesias, 2010). In the paper of Iglesias et al. (2010) the productive efficiency of a group of wind farms during the period 2001-2004 is measured using the frontier methods DEA and SFA. In that research an extensive definition of the productive process of wind electricity as their starting point is taken. A production relationship is established, which is similar to any traditional electricity generation technology and the researcher could define micro-economic production functions, given by the general formula:
E= $\int(K, L, F)$ Where E is the electrical energy, K the capital, L the labour and F the fuel.

In the study of (San Cristobal, 2011), the (Multi Criteria) DEA model is applied for evaluating the efficiency of 13 Renewable Energy Technologies. The input and output data used to perform the analysis are defined as follows;

- Inputs: Investment ratio (Euro / Kw), Implement period (years), Operating and maintenance cost (Euro / Kwh).
- Outputs: Power (MW), Operating hours (Hours / year), Useful life (Years) Tons of CO2 avoided (tCO2 / year).

These are just two examples of DEA applications in the renewable energy sector, there can be more found on the existing scientific database.

3.2.3. Solving Envelopment DEA Model as a Linear Program in Spreadsheets

This is an introduction and manual for the DEA-Solver mostly derived from (Cooper, Seiford, & Tone, 2006). There are two versions of DEA-Solver, the "Learning Version" (called DEA-Solver-LV) and the "Professional Version" (called DEA-Solver-Pro). This manual serves both versions. DEA-Solver was developed by Kaoru Tone. The platform for this software is Microsoft Excel 97/2000 or later. The "Learning Version" includes all models and can solve problems with up to 50 DMU's; The "professional Version" includes Malmquist, Scale elasticity, Congestion and Undesirable output models in addition to the "Learning Version" models and can deal with large-scale problems within the capacity of Excel worksheet. All the different models in "Learning Version" DEA-Solver are shown on pages 326-327 of (Cooper, Seiford, & Tone, 2006). The data file should be prepared in an Excel Workbook prior to execution of DEA-Solver. The format for such a data file is given in the books of (Cooper, Seiford, & Tone, 2006) and (Scherman & Zhu, 2006).

3.2.4. DEA model for Local Energy Companies

To determine how many DMUs are needed to prevent discrimination in the efficiency results. A thumb rule for a DEA model is that the number of DMUs must be twice as large as the inputs and outputs combined (Cooper, Seiford, & Tone, 2006). For example, when there are three inputs and three outputs used in a DEA model which is combined six, twelve DMUs are needed to conduct a representative measurement and to prevent discrimination in the efficiency. In the model developed in this research, the thumb rule is applied, making it a representative measurement.

The executed DEA models in this research are the basic CRR and Allocation models, giving extensive results on efficiency score. The different models are explained in detail below;

<u>CCR-I</u>

CCR is one of the most basic DEA models, which was initially proposed by Charnes, Cooper and Rhodes in 1978 (Cooper, Seiford, & Tone, 2006). The optimal weights of the input and outputs may vary from on DMU to another DMU. Thus, the "weights" are derived from the data instead of being fixed in advance. The weights are chosen in a manner that assigns a best set of weights to each DMU. The term "best" is used here to mean that the resulting input-to-output ratio for each DMU is maximized and relative to all other DMU when these weights are assigned to these inputs and outputs for every DMU. CCR input orientated aim at minimizing the inputs while satisfying at least the given output level. CRR-efficiency exists of two parts Radial and Technical efficiency. Radial efficiency is when the score of the DMU is one but there are nonzero slacks, which are excesses and shortfalls of inputs or outputs. Technical efficiency is when the score of the DMU is one and has zero-slacks, and then the DMU is also called CCR –efficient.

<u>Allocation models</u>

The preceding model focuses on the technical aspects of production. The allocation DEA models can be used to identify types of inefficiency which can emerge for treatment when information on prices and costs are known; this is the case in this research. There are two different situations: one with common unit prices and costs for all DMUs and the other with different prices and costs from DMU to DMU. Since in this research, the prices and costs are expected to be different from DMU to DMU. I will focus on the new cost-efficiency related model. Section 8.3 in the book of (Cooper, Seiford, & Tone, 2006) gives a good explanation of the new cost-efficiency model. The following efficiency models will be executed in the performance measurement of LECs;

$\boldsymbol{\theta}^*$ = CCR technical efficiency

$\overline{\boldsymbol{\theta}}^*$ = CCR New technical efficiency

$\overline{\boldsymbol{\gamma}}^*$ = New cost efficiency

$\overline{\boldsymbol{\alpha}}^*$ = New allocation efficiency

3.3. Determine the parameters

The inputs and outputs for this research are identified in collaboration with companies and combined with recent scientific research. Important to keep in mind is what the practice wants to know about LEC's and thus validate the parameters. In scientific research the following five inputs (I) and four outputs (O) are found (San Cristobal, 2011) and (Iglesias, 2010);

- Inputs: Investment ratio or capital, Implement period, Operating and maintenance cost, labour, fuel.
- Outputs: Power, Operating hours, Useful life and Tons of CO_2 avoided.

From the literature study in this research important aspects are organisational structure, renewable energy technique (RET) and finance. However, measuring of the organisational structure is difficult and this will be compared through an analysis to derive lessons learned for future LEC. This leaves the aspects, Techno-economic and Financial to identify useful parameters. These are as concluded in chapter 2.4 and 2.5, which are investment, installation size, operations and maintenance (O&M) and energy produced from aspect techno-economic. From the aspect of finance parameters are revenue, profit (subsidy), Return on Investment (ROI) and Payback time. Finally, the parameters are presented to the practice and discussed is, which parameters are necessary for comparing and establishing a LEC. All the parameters from different sources are presented in table 8 below.

Source	Inputs	Outputs
Theoretical orientation in LECs	Investment, installation size, O&M	Energy, Revenue, Profit, ROI, Payback time
Recent scientific research	Investment ratio, Capital, Implement period, O&M, Labour, Fuel	Energy, Operating hours, Useful life and Tons of CO2 avoided
Additional from experts		revenue per kWh or GJ, Cost of avoided GJ energy,
Conclusion	Installation size, investment ratio, O&M costs	Energy, Revenue

Table 8: Overview of Inputs and outputs from different sources

For the input parameter, indispensable are installation size, investment ratio and O&M costs. Other identified input parameters shown in table eight are incorporated within the three parameters. For instance Labour is taken into account in the O&M costs parameter. Selecting the output parameter is more complex, because it is important for whom the information is and what they want to know about the performance of LECs. Since this research focuses on business approach, therefore Tons of CO_2 avoided and Cost of avoided GJ energy are not important and excluded. Concluded is that Produced energy and Revenue are important in a business approach. Other for example Profit and Payback time can be derived from these output parameters.

3.4. Conclusion

Benchmarking as a management technique has many definitions. Benchmarking can be divided into two main categories (Global Benchmarking Network, 2009): informal and formal benchmarking. In this research Formal Benchmarking in the form of "Best Practice" will be executed on the Local Energy Companies performance. DEA, first introduced by Charnes et al. in 1997, is a linear programming technique for comparing the efficiency of a relatively homogeneous set of organisational decision making units, such as schools, banks or business firms, in their use of multiple resources (inputs) to produce multiple outcomes (outputs) (Camanho, 2011). The comparison with the benchmarks also allows to determine the input and output targets corresponding to efficient operation.

DEA has been accepted as a major technique for benchmarking the energy sector in many countries, particularly in the electricity industry. There are two versions of DEA-Solver, the "Learning Version" (called DEA-Solver-LV) and the "Professional Version" (called DEA-Solver-Pro). This manual serves both versions. DEA-Solver was developed by Kaoru Tone. The platform for this software is Microsoft Excel 97/2000 or later. Executed DEA model in this research are the basic CRR and Allocation models, giving extensive results on efficiency score.

Form the three different sources; theoretical orientation, recent scientific research and experts or practice, the following inputs and outputs are determined. There are three Input and two output parameters, consisting of techno-economic and financial parameters.

Inputs of LEC's are:

* Installation size (x 10^3/ kW)
* Investment ratio (x 10^3 Euro / kW)
* Maintenance and operational costs (x 10^3 Euro / kW)

Outputs of LEC's are:

* Energy (Giga Joule (or in kWh) / Year)
* Revenue (Euro x 10^3/ Year)

4. DATA COLLECTION

To be able to benchmark different Local Energy Companies, their data needs to be collected. In this chapter the process of data collection and the actual data is elaborated. The process steps of data collection consist of a problem focus, selection procedure for a LEC in the overview and procedure for included LECs in the DEA model. Afterwards, a desk research on finding the Local Energy Companies in the Netherlands is executed. This is followed by processing the information in a overview and identifying the proper LECs for in the DEA model. These process steps and the data findings are explained and presented in this chapter.

4.1. Problem focus

For the benchmarking model data is needed of the existing operating local initiatives utilizing renewable energy techniques, called Local Energy Company (LEC) in this research. There are two main problems in the data collection process. Firstly, finding the actual LEC in the Netherlands is one of the problems. To find these existing local initiatives, a desk research is executed. However not just every local initiative or LEC is satisfying to the pre-conditions. This is further elaborated in next paragraph; identifying procedure. Secondly, the selection of proper LECs, which will be included in the DEA models as DMU. An important aspect is finding sufficient data of the selected LECs to conduct a representative measurement.

4.2. Identifying procedures

As mentioned in chapter two definitions, a Local Energy Company is seen as an autonomous entity, independent of the municipality, with the aim of one or more of the following activities to be implemented locally (SenterNovem, 2010):

- Production, delivery and management of renewable energy in their region.
- Financing and / or participation in the renewable energy projects.
- Energy savings.

Local initiatives are in this research initiative where large established energy companies do not have decision making power and can only be involved in the administrative activities. This means that the large energy companies have not got a say in making decisions and do not have investments activities within these local initiatives. Otherwise, the local community does not profit from the benefits. Other pre-conditions for a LEC in this research;

- Local actors (municipality, citizens, housing association and other private local actors) must have the power to make decisions and profit from the economical or environmental benefits.
- The large established energy companies must not have the power to make decisions nor financial involvement.
- The LEC must produce, deliver and manage renewable energy projects, or at least finance and / or participate in renewable energy projects.
- A Local Energy Company is seen as an autonomous entity.

At first a desk research is done to make a list of the existing local initiatives, who have set up their own LEC. This list is presented in appendix A, were the name, location and technique of the initiative is presented. From this list twelve businesses are selected, mainly on the criteria if sufficient data could be extracted to conduct a DEA measurement. In the next paragraph the selected businesses are elaborated.

4.3. Overview of Local Energy Companies

The total list of found LECs from executed desk research is presented in Appendix A. In total 66 initiatives were found, sorted by Renewable Energy Technique (RET) and also initiators and location of LEC are given. In the figure below the number of LEC per initiator are given. One can see easily that most initiatives are initiated by Residents. Second are the municipalities, which are upcoming actosr that started a lot of new initiatives very recently. Within the group of private actors there are mainly waste companies and collective of horticulture and other private companies. The municipalities are already establishing many LECs as shown in the figure 13. However, sometimes these companies are established with other private actors to construct a Public Private Partnership (PPP). Private partners are so far mainly real estate developers and housing associations. In the group others, are research facilities and one nature society represented.

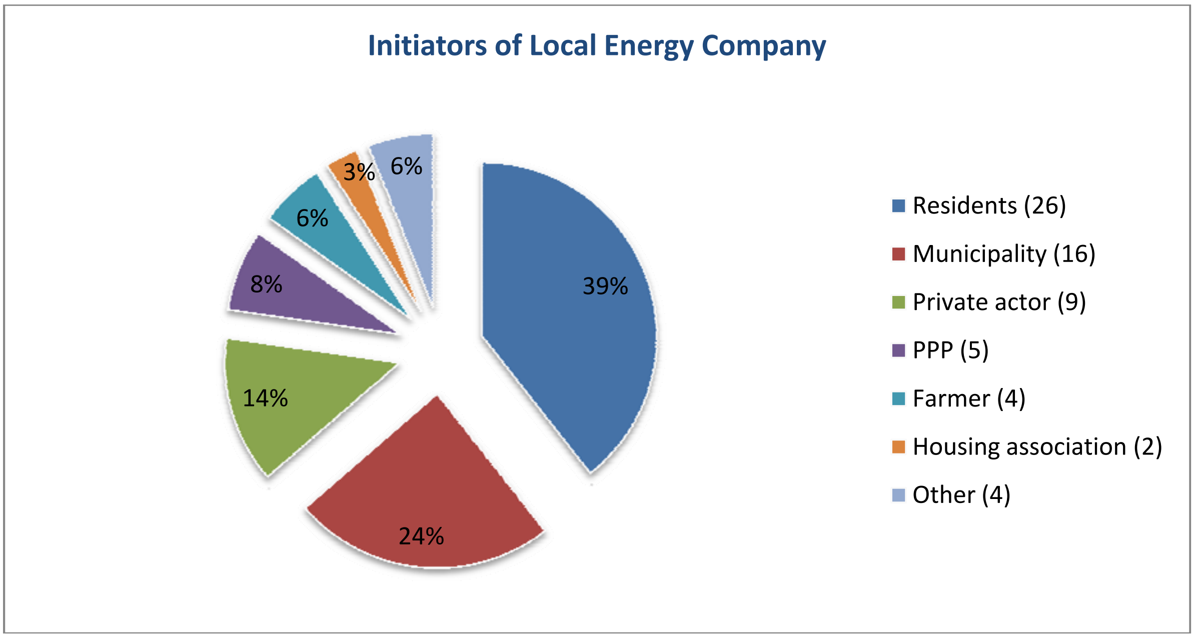


Figure 12: Overview of LECs per initiator in the Netherlands

4.4. The DMU's

In this paragraph all of the selected businesses are presented. From every DMU the organization, technique and financial structures are discussed. Finally, their inputs and outputs are presented in the parameters table, which will result in the actual performance of these businesses through DEA. The selected DMUs are;

1. Bio energy Eindhoven
2. Bio energy Fleringen
3. Patrimonium Energy B.V.
4. Thermo Bello
5. NDSM N.V.
6. Onze Energie
7. SVDW Windpark
8. Windvogel
9. Meewind
10. Zonvogel
11. Zon op Noord
12. Boer en Buur

4.4.1. DMU 1: Bio energy Eindhoven

The municipality of Eindhoven is working on the development of phase three of the urban development project Meerhoven. For the energy supply of the new location Meerhoven the municipality has formulated environmental goals of an Energy Performance on Location (EPL) of 7.0. The municipality aims for a share of the residential area (about 1500 houses and 10.000 to 20.000 m² GLA building facilities) in providing energy through a bio-energy installation on wood.

4.4.1.1. Organisational structure

The municipality of Eindhoven is initiator of the project and has set up an organisation in the form of a Steering Group. This steering group is responsible for the bio energy project and outsources all its activities to third parties, see figure 14 below. When the construction of the project is finished the operation and management is outsourced as well. The interest of the municipality is achieving environmental goals and return on investment.

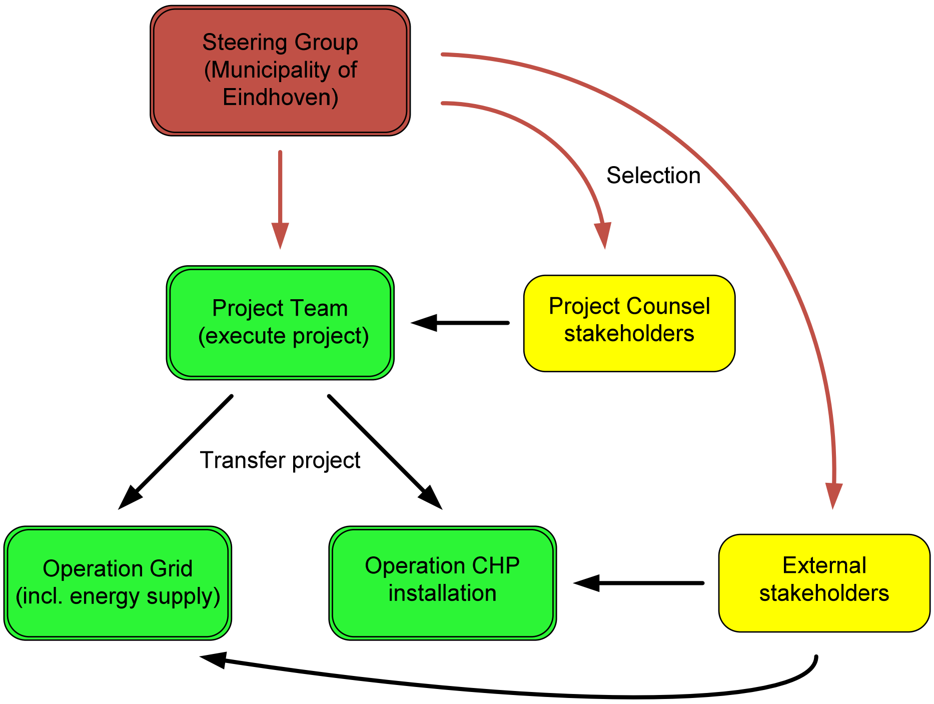


Figure 13: Organisational model bio energy Eindhoven

4.4.1.2. Financial structure

Total investment costs are €17.430.000. However, the subsidies of province € 1.000.000 and € 7.072.000 income from the connection costs of houses and offices. This remains an investment by the municipality of € 9.358.000.

Subsidies from the government SDE, for the produced electricity € 0,0177 per kWh for twelve years, minus the compensation for restitution of electricity to the grid. The bio energy power installation will supply annual 40.000 GJ of heat for € 22.00 per GJ, price level 2009.

The municipality will outsource the operation (manage and maintenance) of the power installation under direction to the market. The municipality of Eindhoven has made a contract with Essent to manage the heating grid in Meerhoven. The plan is to convert the existing houses with gas to connect with the heating grid.

4.4.1.3. The parameters

LEC: Bio energy Eindhoven

Organisational name	Key aspects	Advantages
Steering group	Outsourcing business activities	Project risks are transferred to other actor
	In control of total project	Have all the decision making power
	Biomass from own municipal area	Multiple year contract for supply biomass
	Outsourcing operations of installation and grid	No responsibility, only wants have ROI

Table 9: Assessment of organisational design bio energy Eindhoven

LEC: Bio energy Eindhoven

Parameters	Aspect	Value
(I) Techno-economic	Installation size	11500 kW
	Investment costs	1,52 x 10^3 Euro / kW
	O&M costs	880 x 10^3 Euro / Year
(O) Production	Energy	64192 GJ / Year
(O) Financial	Revenue	2.050 x 10^3 Euro / Year
	Return on Equity	12,50 %
	Payback time	14,8 Years (including grid)

Table 10: Values per parameter of bio energy Eindhoven

4.4.2. DMU 2: Bio energy farm (fermentation)

The Brothers Old Lenferink own one of the largest pig farms in the region of Twente. Since 2003 they also have one of the largest commercial biogas plants in the Netherlands. With the current price of electricity rising and the heat used for heating the stables and their own home, the installation is an important secondary source of income.

4.4.2.1. Organisational structure

This project is interesting because of the generation of bio energy using fermentation technique and not so much regarding the organisational design of this LEC. The bio energy installation is part of the farm and also the business activities. For instance purchase of fertilizer and the sales of energy are executed within the organisation of the farm. This lets the farm have a large secondary income and efficient in its use of waste. Interesting can be to expand this renewable energy project to a nearby neighbourhood, to make more efficient use of the generated heat. In Germany this concept is already implemented in several municipalities and with it achieving energy neutral. Therefore, the local project is taken into account within this research, to benchmark it against other renewable energy projects.

4.4.2.2. Financial structure

The pig farm of the brothers Oude Lenferink in Fleringen produces annually about 12.000 tons of pig manure. All the fertilizer is used in the fermentation installation. Total investment of the installation including electricity cables and small heat grid, was about € 616.000 (AgentschapNL, 2009). The payback time of the investment is due to current energy prices and SDE subsidy about six years. The silo of about 600 m³ manure is mixed with chicken manure that is collected from neighbouring businesses. The power plant has an electrical output of 143 kW (170 kW at optimal conditions) and a thermal power of 213 kW (253 kW at optimal conditions). The investment in the heat pipe from stables and farmers home to the CHP was about € 25.000,-. The electricity generated is around 900.000 kWh and is supplied to the grid. The investment in the required power cable was € 40.000,-. The project is financed by Equity of 20% and a bank loan for the other 80% of the investment costs.

4.4.2.3. The parameters

LEC: Bio energy Fleringen (fermentation)

Organisational name	Key aspects	Advantages
Farm	Part of the farm	Double profit in disposal of fertilizer and electricity
	Extra income	Farm gains more income from its products chain
	Expansion to neighbourhood	Local farms could collaborate with nearby neighbourhood for supply of heat

Table 11: Assessment organisational design bio energy Fleringen

LEC: Bio energy Fleringen (fermentation)

Parameters	Aspect	Value
(I) Techno-economic	Installation size	423 kW
	Investment costs	1,46 x 10^3 Euro / kW
	O&M costs	66 x 10^3 Euro / Year
(O) Production	Energy	3240 GJ / Year
(O) Financial	Revenue	164,700 x 10^3 Euro / Year
	Return on Equity	80,11%
	Payback time	6,24 Years

Table 12: Values per parameter of bio energy Fleringen

4.4.3. DMU 3: Patrimonium Energie BV

Patrimonium Housing Foundation is the first housing association in the Netherlands using pellet-incineration as a collective source of energy for heating in a new project. It concerns the construction of the Oranjetoren in Veenendaal. This project, mainly social rented apartments, is completed in September 2009. The pellet-incinerator installed in this building provides heating and hot water to the residents of Oranjetoren (60 apartments) and the adjacent 't Perceel (14 homes).

4.4.3.1. Organisational structure

A housing association has a large and complicated organisational structure. In the figure 15 below, the organisational structure of Patrimonium in Veenendaal is shown and Patrimonium Energie B.V. is circled green. This limited liability company is an operating business of the large Holding B.V. Therefore, it is not directly responsible and liable for the business activities of Energie B.V. If the Energie B.V. would not survive it would not harm the housing association and this is very important for the company but also their tenants. Furthermore, Patrimonium is also involved and shareholder in another well known local renewable energy initiative called DEVO, with a number of other actors and the municipality of Veenendaal.

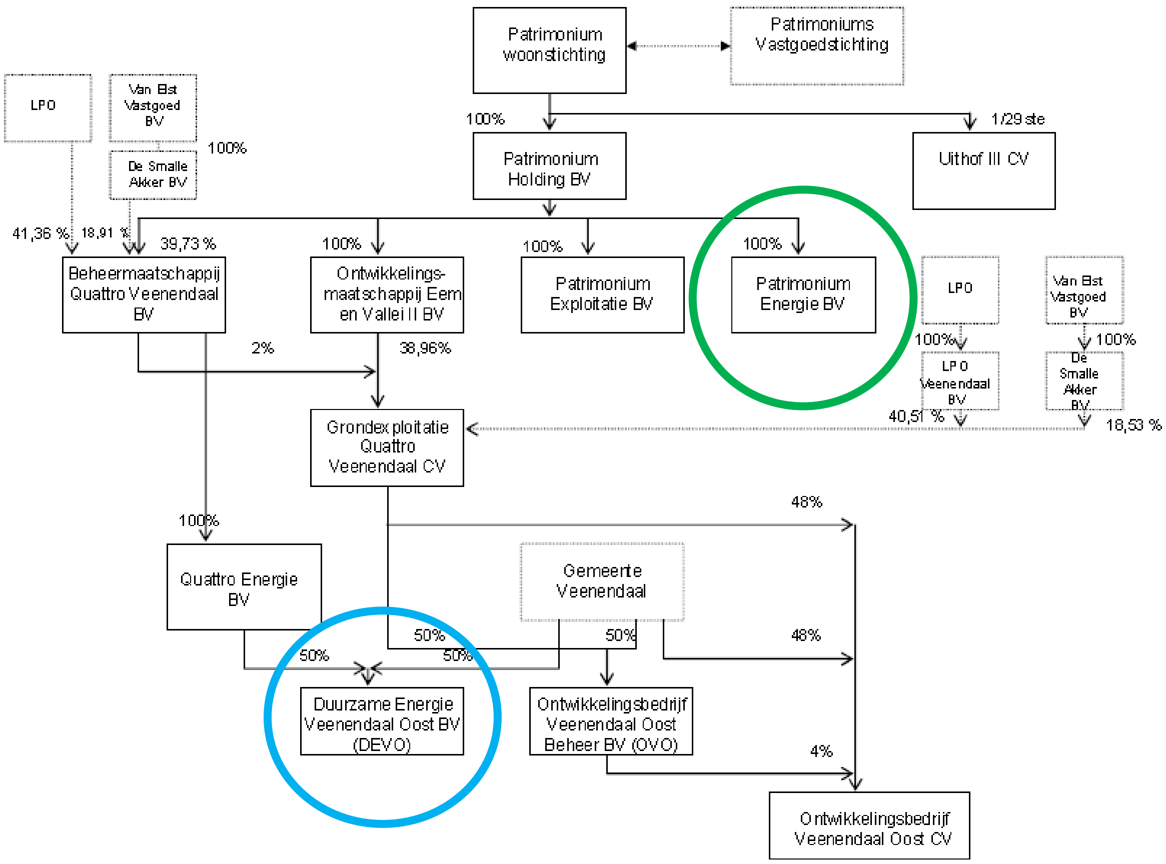


Figure 14: Organisational model housing association Patrimonium

4.4.3.2. Financial structure

There is not much financial information about Patrimonium Energie B.V. available. However, the project plans of this initiative are available on their website (www.patrimonium-veenendaal.nl). This information is used to fill in the parameters on the next page, along with some assumptions clarified in the introduction of this chapter.

4.4.3.3. The parameters

LEC: Patrimonium Energie B.V.

Organisational name	Key aspects	Advantages
Limited Liability Company (B.V.)	Transparency	Cost and activities
	Possibility of disposal company (B.V.)	When does not fit in mother company
	Social financial return	Make some profit
	Participation of actors	Share risks

Table 13: Assessment organisational design of Patrimonium Energie B.V.

LEC: Patrimonium Energie B.V.

Parameters	Aspect	Value
(I) Techno-economic	Installation size	400 kW
	Investment costs	0,53 x 10^3 Euro / kW
	O&M costs	29,674 x 10^3 Euro / Year
(O) Production	Energy	2.280 GJ / Year
(O) Financial	Revenue	48,635 x 10^3 Euro / Year
	Return on Equity	44,95 %
	Payback time	11,1 Years

Table 14: Values per parameter of Patrimonium Energie B.V.

4.4.4. DMU 4: Thermo Bello

The district EVA Lanxmeer in Culemborg is a laboratory of social innovation and Thermo Bello is one of the outcomes. Thermo Bello is a district energy company owned by local inhabitants of EVA Lanxmeer. As of the 1st of January , 2009 Thermo Bello produces heat according to the business plan which has been prepared by current management (the founders).

4.4.4.1. Organisational structure

Thermo Bello is a district energy company which is still developing. It is currently a private company with three founders (shareholders) who perform the management until the proposed organizational structure is fully completed. The final structure consists of the BV, a Foundation Administration office SAK (financial interest), a Supervisory Board (supervise) and a group of residents involved in the maintenance and development of Thermo Bello.

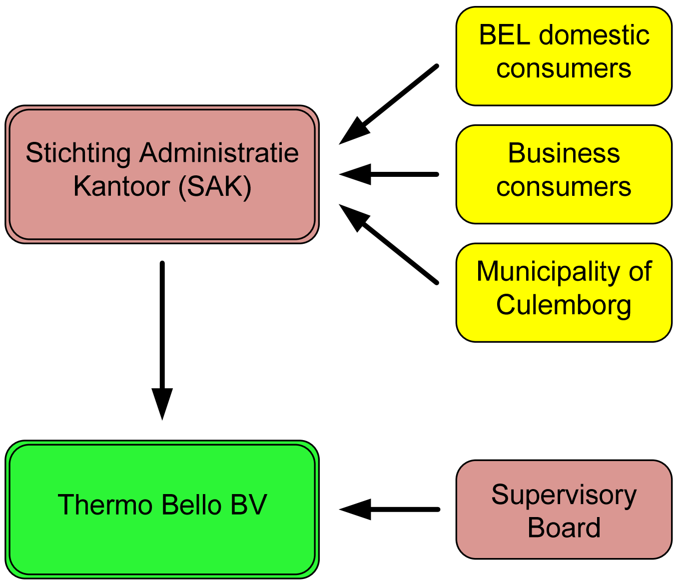


Figure 15: Organisational model Thermo Bello

Thermo Bello has the property (100% of its shares) transferred to the foundation administration office (SAK). The SAK has a board formed by representatives of the shareholders, which have complete control over matters on capital of Thermo Bello B.V. The foundation Administration office has issued certificates of shares, which are non-voting shares, on various categories of capital providers. The voting right is exercised by the representatives of the different categories in the foundation's board. This organizational structure, allows a smaller group of people make decision rather than a large group with difficulty of agreeing. An administration office reduces the risk of indecision and increases effectiveness.

4.4.4.2. Financial structure

The heat station is part of the Vitens water pumping station. This station provides the region with drinking water in Culemborg. The heat is provided by an electric heat installation (power 750kWth, producing approximately 7000 GJ / year). The required heat is drawn from the drinking water supply (water basin). At the station there are two boilers (2 x 500 kWth, about 2000 GJ / year) for heating in cold weather and failure to produce heat (or service failure). The financial operating costs are divided as follows (from bottom to top), see figure below. The largest costs are; the purchase of energy (45%) then the depreciation costs (20%) followed by maintenance (10%), interest, management (13%) costs and other remaining costs.

The turnover exists of two parts a fixed amount called vastrecht and turnover from the supplied heat to the customers. Thermo Bello supply's heat to two different customers, the domestic and business customers. In the figure below is the annual operating income (€ x 1.000) over time shown of Thermo Bello. In the third year of operation, a small profit is expected to be achieved. This figure shows the financial expectations without large increasing of prices. The rate of consumption of heat in the operating budget is coupled with a very moderate price of a gas evolution of 2% above inflation, which is the long-term trend over fifty years.

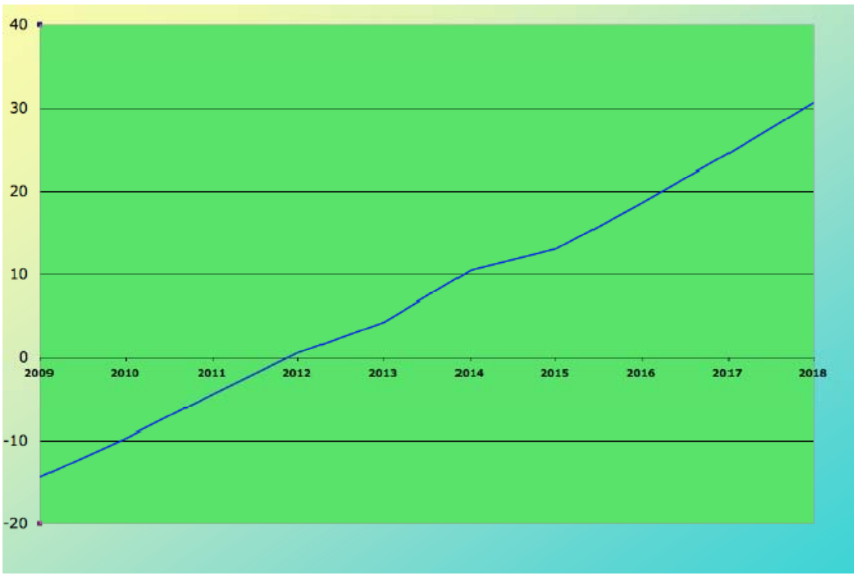


Figure 16: Annual operating income of Thermo Bello

4.4.4.3. The parameters

LEC: Thermo Bello

Organisational name	**Key aspects**	**Advantages**
Foundation	Multiple local shareholders	More equity and less debt
	No liability	Through underlying company
	Local decision making power	Also residents
Limited Liability Company	Board of directives have decision-making power	Speed up business activities, decision making
	First established, later the Foundation	Few local shareholders and establish process faster

Table 15: Assessment organisational design of Thermo Bello

LEC: Thermo Bello

Parameters	**Aspect**	**Value**
(I) Techno-economic	Installation size	1750 kW
	Investment costs	0,34 x 10^3 Euro / kW
	O&M costs	244,366 x 10^3 Euro / Year
(O) Production	Energy	9.104 GJ / Year
(O) Financial	Revenue	258,605 x 10^3 Euro / Year
	Return on Equity	9,49 %
	Payback time	14 Years

Table 16: Values per parameter of Thermo Bello

4.4.5. DMU 5: NDSM N.V.

The NDSM Wharf East, an area of seven acres, is being jointly developed by the end users of the area and the owner of the land (the municipality of Amsterdam). Several buildings on the site of NDSM have acquired the status of monument. The emerging artists on the Wharf have, in collaboration with energy developer NEWNRG, made a plan for the establishment of an energy company. The establishment of NDSM NV was completed in 2008.

4.4.5.1. Organisational structure

In this project stakeholders choose a legal form of NV, because of the following reasons; co ownership of the end users in the local energy company, easy access of other possible owners in LEC, decision power over investments and operations, relatively easily to upscale the company and the possibility to make use of tax benefits.

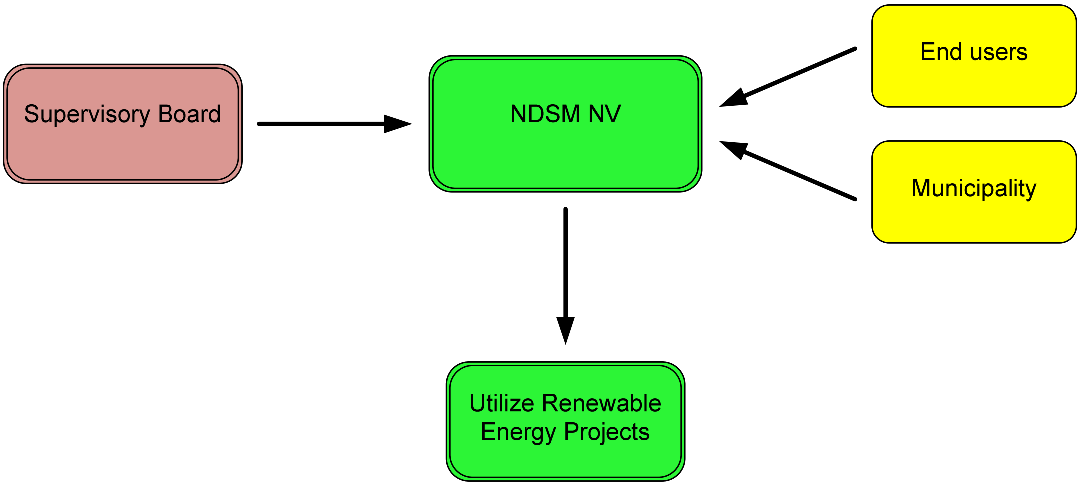


Figure 17: Organisational model NDSM N.V.

The goal is to make the site energy neutral, or even an energy supplier. Therefore, the renewable energy resources installed have to meet the energy demand that is required on the site.

4.4.5.2. Financial structure

The total investment budget for LEC NDSM NV is € 1.037.786. From this budget power installation of one wind turbine, a Heat pump including sources, generator, HR- gas installation and energy infrastructure are developed. About 52% of the investment costs are received through a bank loan. The remaining 48% of the budget is achieved by selling new shares to residents and companies.

4.4.5.3. The parameters

LEC: NDSM N.V.

Organisational name	**Key aspects**	**Advantages**
Limited liability company (N.V.)	Independent company	Local actors / shareholders not liable
	Diverse shareholders	Shares are easier to transfer than in a B.V.
	Local actors benefit	The residents and companies are receiving the profits

Table 17: Assessment organisational design of NDSM N.V.

LEC: NDSM N.V.

Parameters	**Aspect**	**Value**
(I) Techno-economic	Installation size	2450 kW
	Investment costs	0,424 x 10^3 Euro / kW
	O&M costs	232,442 x 10^3 Euro / Year
(O) Production	Energy	7800 GJ / Year
(O) Financial	Revenue	282,9x 10^3 Euro / Year
	Return on Equity	10,07 %
	Payback time	15 Years

Table 18: Values per parameter of NDSM N.V.

4.4.6. DMU 6: Onze Energie

Onze Amsterdam Noord Energie coöperatie U.A. is founded in 2009 by two entrepreneurs M. Boone and M. Gort. It is a totally independent company without profit targets and local residents are the shareholders. Their goal is to realize as much local renewable energy as possible and to let the shareholders profit from it.

4.4.6.1. Organisational Structure

The organization is dynamic and flexible and very compact. They have a director that is supported by volunteers and a supervisor. Director M. Boone is responsible for activities of the cooperative and the realization of the wind farm. The director is accountable to the supervisor(s). At the moment this is still only M. Gort, but they would like to expand the number of supervisors with representatives of the members. At the Annual General Meeting, new supervisors will be elected and appointed, see figure 19 organizational model of Onze Energie. Independent control and transparency are important for the proper functioning of the cooperative. The financial statements should be financial accountable for the supervisors, partners and for the annual general meeting.

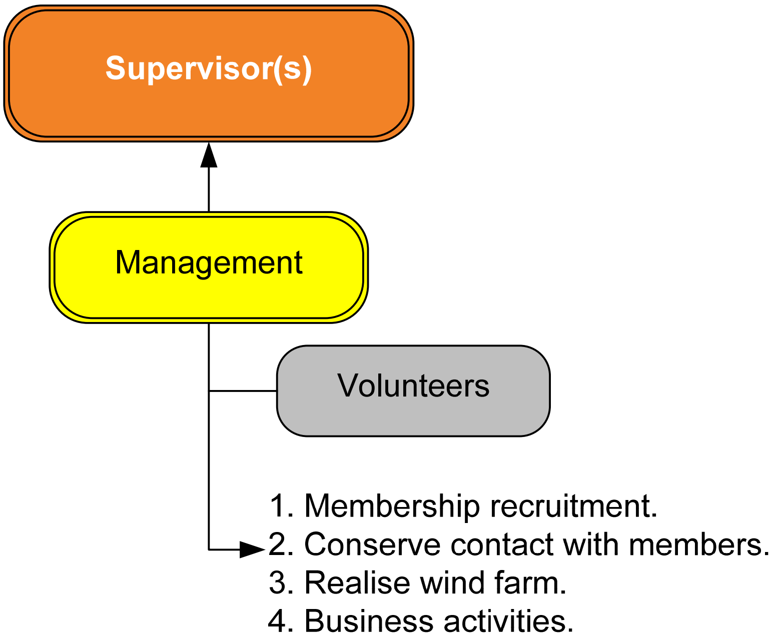


Figure 18: Organisational model of Onze Energie

The development and operation of wind turbines is a complex and specialized industry. Onze Energie does not possess this expertise and needs of a reliable partner to develop the wind farms. The selected partner must have interests in the development and producing of the wind park, by investing together in a separate company see figure below. The additional advantages are;

- The providing of extra security for banks (providing loans);
- Onze Energie needs less equity.

The construction is as followed: for the wind turbines a private company is founded by two shareholders. Onze Energie is shareholder for 50% and a developer for 50%. In the proposed structure, they ensure to be in control and the shares cannot be sold to a third party. This company invests and develops the wind turbines and is responsible for the operation.

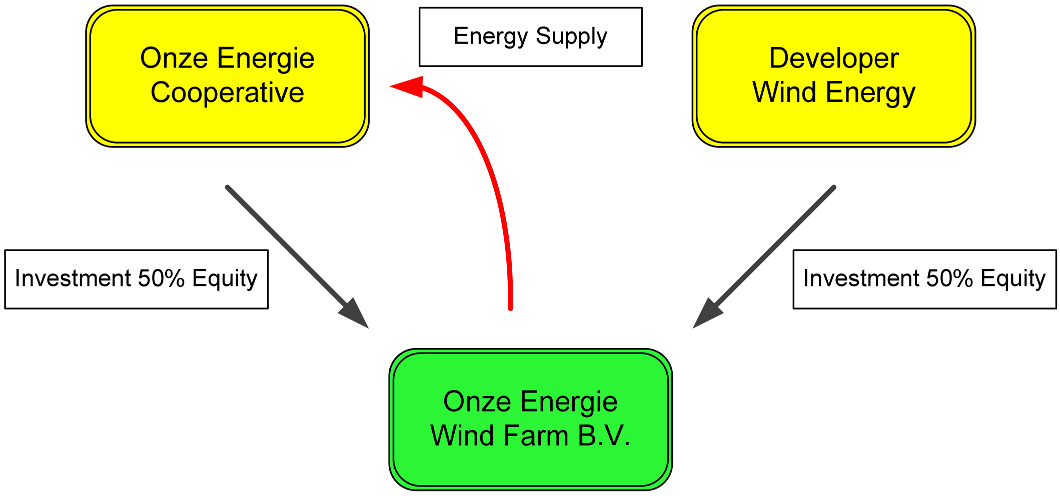


Figure 19: Organisational model of wind turbine project

The generated electricity is supplied to the existing network. The members can purchase the electricity at a reasonable price (see prices below) and therefore profit directly. In addition, the collaboration with the Local Energy Company will remain to not only supply the members of gas, but also with purchasing and selling electricity when the wind farms are not generating enough or a surplus of energy.

4.4.6.2. Financial structure

The goal of Onze Energie Cooperative is for 8.000 households to generate their own renewable energy, this is approximately 41 million kWh per year. To generate such an amount of energy an investment of €27 million is needed.
In their calculations Onze Energie expects a debt of about 70% and an equity investment of 30% which represents € 8,1 million euro. Since the company is only 50% shareholder in the Wind Farm B.V. They only have to invest €4,05 million euro. Onze Energy expects to build sufficient equity on three different ways;

1. The single input of members (€0,81 million);
2. The margin which they expect to gain from selling electricity and gas (€1,02 million);
3. Participation of other companies in the district and issuing larger shares (€2,5 million).

The developers, who hold the other 50% of the shares, are expected to want a return on investment between 6 and 8% on their investment. Despite Onze Energie does not have a profit target, they do strive to realize the same return for their members to balance the relationship and interest of the two shareholders. These return flows back through the cooperative to the members in an annual dividend. The dividend is calculated over the investment (shares) of the members.

Residents can become a member of the cooperative; they have to buy at least one share of €50 euro. Furthermore, members have the possibility of buying more shares and Onze Energie offers cheap green electricity and gas in collaboration with Greenchoice to all members.

4.4.6.3. The parameters

LEC: Onze Energie

Organisational name	**Key aspects**	**Advantages**
Cooperative	Independent company	No external influences
	Members are shareholders	Increase Equity, decision making by residents
	No profit targets	No high Returns expected
With Limited Liability Company	Invest with partners	Equity is divided by 50%
	Energy production to cooperation	Sell energy to members

Table 19: Assessment organisational design of Onze Energie

LEC: Onze Energie

Parameters	**Aspect**	**Value**
(I) Techno-economic	Installation size	2000 kW
	Investment costs	2×10^3 Euro / kW
	O&M costs	106×10^3 Euro / Year
(O) Production	Energy	18.000 GJ / Year (5.000.000 kWh/Year)
(O) Financial	Revenue	480×10^3 Euro / Year
	Return on Equity	31,17 %
	Payback time	10,70 Years

Table 20: Values per parameter of Onze Energie

4.4.7. DMU 7: SVDW Windpark;

This wind farm is an initiative of six farmers in the province of Flevoland. At the end of 1997 they started the project plan and applied for the necessary permits to construct a wind farm. In 2002 the seven wind turbines were placed along the Overijsselse Tocht in Flevoland.

4.4.7.1. Organisational structure

The six farmers have united in a cooperative called Windpark SVDW. Every farmer has an equal amount of shares of the total wind farm. The wind farm exists of seven wind turbines of producer Enercon and the turbines have a shaft at the height of 70m. The generated electricity is sold to the Windunie in the Netherlands, which is a renewable energy supplier like Greenchoice; see figure 21 below for the simple organisational structure.

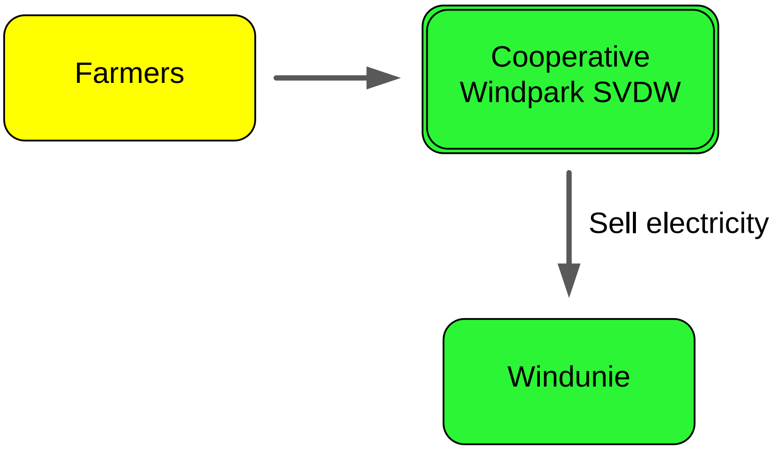


Figure 20: Organisational model SVDW Windpark

4.4.7.2. Financial structure

Although not much information about their financial structure is available I could discover most of the parameters to conduct a measurement. The wind turbines are Enercon E66, 1800 kW, which cost about €1.595.000 (www.newnrg.nl, 2010) in 2002. Information about the generation performance of the wind turbines are well reported on their website (www.windparksvdw.nl) and is on average 26 million kWh a year. The selling price of one kWh is including SDE subsidy 0,096 euro. The remaining business figures an assumptions is done according to the report of ECN as elaborated in the introduction of this chapter.

4.4.7.3. The parameters

LEC: SVDW Windpark

Organisational name	**Key aspects**	**Advantages**
Cooperative	Independent company	Can not harm any of the member's farm
	Members are shareholders	All local farms nearby location are involved
	Return go to the famers	Profit goes to the investors thus the farmers

Table 21: Assessment organisational design of SVDW Windpark

LEC: SVDW Windpark

Parameters	**Aspect**	**Value**
(I) Techno-economic	Installation size	12600 kW
	Investment costs	0,89 x 10^3 Euro / kW
	O&M costs	611,1x 10^3 Euro / Year
(O) Production	Energy	93600 GJ / Year
(O) Financial	Revenue	2.496 x 10^3 Euro / Year
	Return on Equity	84,41 %
	Payback time	6 Years

Table 22: Values per parameter of SVDW Windpark

4.4.8. DMU 8: Windvogel

This cooperative was established in 1991, with as goal to corporate own as much wind turbines as possible in the Netherlands. The cooperative currently operates four wind turbines. Two of them named "De Volhouder" in Halsteren and "The Windvogel" in Bodegraven (respectively installed in 1991 and 1994), each has a capacity of 80 kW. A third wind turbine "Gouwevogel" on De Gouwe in Gouda was posted in November 2000. This turbine has a capacity of 600 kilowatts, which is sufficient for approximately 300 households with clean electricity. In November 2005 in Ouderkerk a / d Amstel they replaced an 80 kW Lagerwey dated from 1992 by a modern two MW turbine placed by "De Amstelvogel", which can be provided in the power consumption of about 1,300 households.

4.4.8.1. Organisational structure

In the figure 22 below, the organisation structure of De Windvogel Group is shown. In this research only the cooperative De windvogel BA (underlined in figure 22) is taking into account. This cooperative is utilizing four wind turbines on different locations in the Netherlands as mentioned. De Windvogel Group is also investing in solar energy in the Netherlands and in other European countries, for example Germany. They have shares in solar projects Germany with a total energy generation of 199233 kWh in 2009.

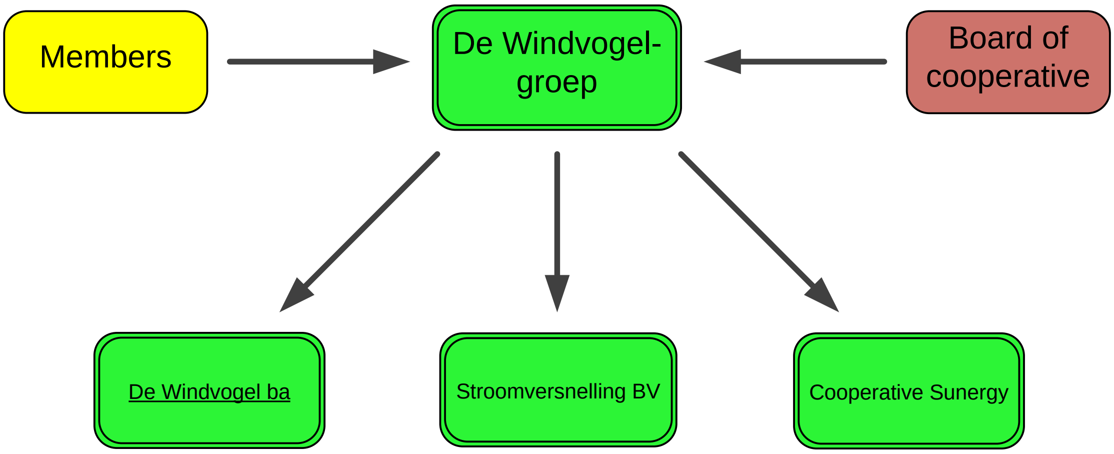


Figure 21: Organisational model Windvogel

4.4.8.2. Financial structure

Every citizen can become member of De Windvogel BA. To become member as citizen a subscription fee of € 50 must be paid, which is for the risk bearing capital of the cooperative. Thus the fee is not comprehensible returned to the citizen when ending membership. Furthermore, most members provide a loan to the cooperative, with this loan the member is contributing in the finance of a wind project and receive a return on investment of fluctuating rates determined each year. For example the construction costs of "De Gouwevogel" were about € 500,000. These costs are paid by loans from De Windvogel members, grants and loans from banks. Operating costs, including depreciation and interest of the turbines will be paid from the available income from the sale of clean generated electricity.

4.4.8.3. The parameters

LEC: Windvogel

Organisational name	**Key aspects**	**Advantages**
Cooperative	Transparent	All shareholders have decision making power
	Citizens only can buy shares	Profit from renewable energy
	Experiment with business model (self supply model)	More return on sales of renewable electricity

Table 23: Assessment organisational design of Windvogel

LEC: Windvogel

Parameters	**Aspect**	**Value**
(I) Techno-economic	Installation size	2755 kW
	Investment costs	0,99 x 10^3 Euro / kW
	O&M costs	167,794 x 10^3 Euro / Year
(O) Production	Energy	18114 GJ / Year
(O) Financial	Revenue	448,511 x 10^3 Euro / Year
	Return on Equity	33,92 %
	Payback time	9,69 Years

Table 24: Values per parameter of Windvogel

4.4.9. DMU 9: Meewind

This initiative arose from a study showing that offshore wind energy may have great value for the regional economic stimulation of province Noord-Holland in the Netherlands. The initiators have searched for a way to bind people to renewable energy. By citizens contributing in this company, they can benefit financially and can accelerate the transition. The power of large groups of citizens (financial and emotional) is used though this initiative.

4.4.9.1. Organisational structure

Meewind utilizes large wind farms on sea in front off the coast of the Netherlands and Belgium. Although this company is not utilizing renewable energy entirely locally. The involvement of citizens and other local stakeholders in province of Noord-Holland is necessary for the feasibility of the projects on sea. The citizens that participate and invest also profit from the wind farm. Therefore, future organisations that want to utilize renewable energy resources can learn from Meewind and therefore, it is analysed in this research.

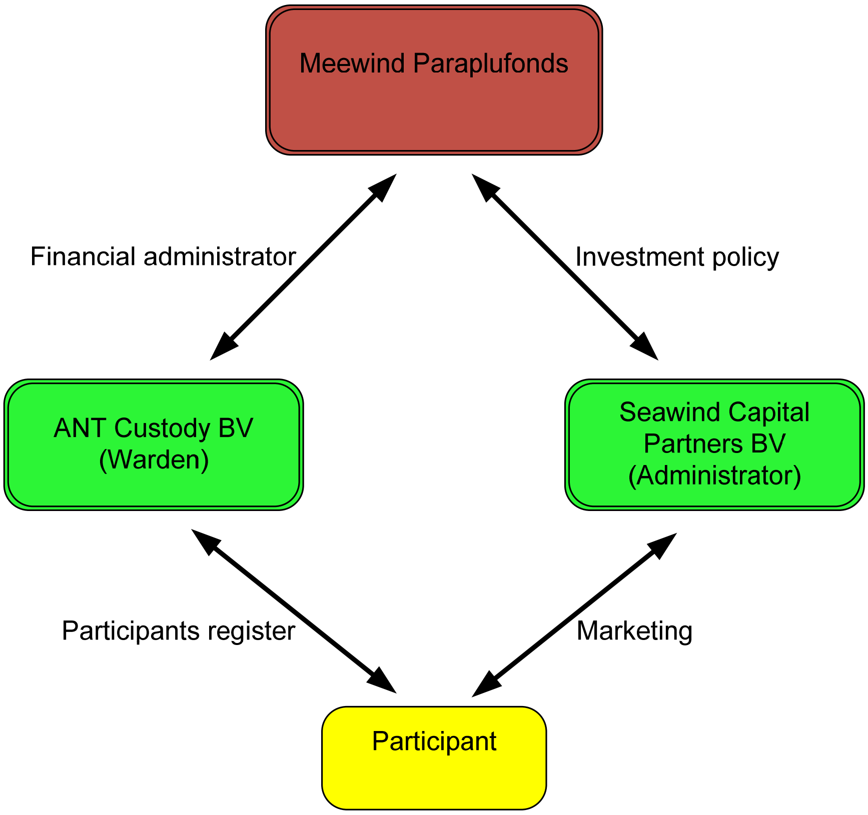


Figure 22: Organisational model Meewind

Unlike other organisations that utilizes wind turbines, Meewind is not a cooperative but an investment fund. Meewind is a mutual fund with a manager: Seawind Capital partners (SCP) Ltd and a keeper: ANT Custody BV. SCP Ltd has obtained permission from the Financial Markets Authority (AFM) and Meewind is registered as mutual fund with the AFM. The Contribution of the participants shall be paid into the account of the keeper ANT Custody. This financial institution has more than one hundred years of experience in asset administration.

4.4.9.2. Financial structure

The first project of Meewind was for the coast off Belgium. Investing in Belgium has its advantages and the conditions are better. The Belgian government takes large part of the cost of the cable for the power supply on their behalf. Furthermore, the wind farm project receives a twenty-year operating subsidy by the Belgium government. This creates a safe investment project with an expected return of around 10% during the twenty-year term. In the beginning project results are low, because of interest and depreciation. The costs increase during construction and decline through depreciation during operation. The net income increases as a result of rising electricity prices.

4.4.9.3. The parameters

LEC: Meewind

Organisational name	Key aspects	Advantages
Investment fund	Professional	Control on company by national authorities
	No burdens for investor	No knowledge needed on renewable energy, however knowledge needed in stocks
	Increase involvement citizens in renewable energy	Can simply buy shares and investment is done for them.

Table 25: Assessment organisational design of Meewind

LEC: Meewind

Parameters	Aspect	Value
(I) Techno-economic	Installation size	165.000 kW
	Investment costs	3,72 x 10^3 Euro / kW
	O&M costs	30921 x 10^3 Euro / Year
(O) Production	Energy	1.980.000 GJ / Year
(O) Financial	Revenue	104.280 x 10^3 Euro / Year
	Return on Equity	40%
	Payback time	7,00 Years

Table 26: Values per parameter of Meewind

4.4.10. DMU 10: Zonvogel

In Germany, for over ten years a very successful feed-in system is used, which has enabled Germany to become the leading economy in terms of solar energy. After Spain took over the scheme and developed solar energy in the same direction. INSnet Foundation, The Little Earth and WISE have in October 2008 set up initiative to insert such a system in the Netherlands.

The current government still opposes the introduction of such a system and its position shows no prospect of an early and drastic policy change. Therefore, we want to offer more opportunities through Zonvogel to all people and organizations to take the initiative. Zonvogel will assist in achieving the projects, with or without subsidy.

4.4.10.1. Organisational structure

A cooperative does not intend to make profits, but to achieve an optimal operation of a business based on common interest of members. Cooperatives are still very successfully applied in industry (Campina) and services (Rabobank). The cooperative also fits perfectly with the social trend of a growing need for transparency, local bonding, self-organization and responsibility.

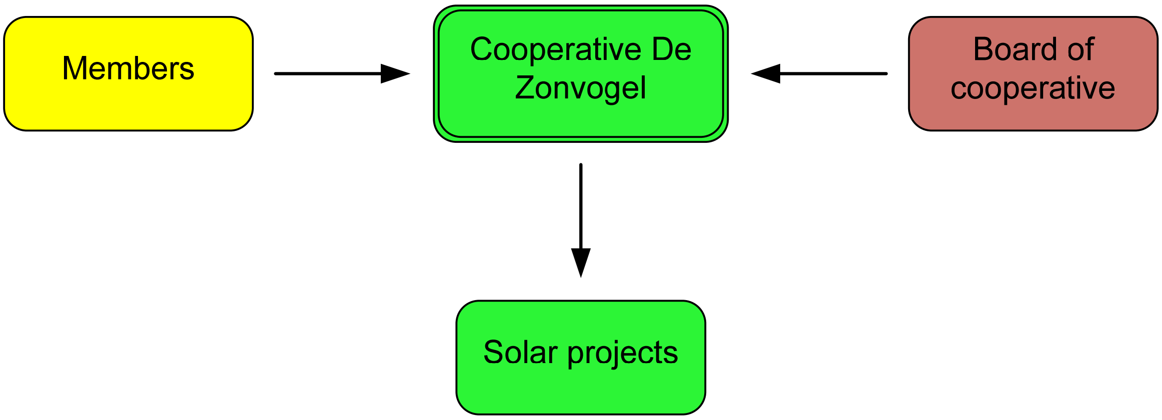


Figure 23; organisational model Zonvogel

Role of the cooperative constructs and manages the solar installation during the project time, which is 25 years. The investment, maintenance and operating costs are calculated per plot. Members of the cooperative have influence in its policy and are directly represented in the project organisation.

4.4.10.2. Financial structure

The benefits that are achieved by the citizens who invest in the solar projects of Zonvogel are for example; a member household consumption of 3.500 kWh, this member purchases two plots. On the yearly billing is shown, which is independent of your electricity supplier, a consumption of 3.500 – 600 = 2.900 kWh. Currently, this results of €160 per year. If the price of electricity increases with 3% a year, then over 10 years a yield of €210 euro a year is achieved. Members pay €29,75 euro subscription money each year and once € 1000 for one plot.

4.4.10.3. The parameters

LEC: Zonvogel

Organisational name	Key aspects	Advantages
Cooperative	Everybody can participate	Also without own roof
	Scale advantages through the corporate structure	Less dependent of subsidies
	Completely transparent	Members have all the decision making power

Table 27: Assessment organisational design of Zonvogel

LEC: Zonvogel

Parameters	Aspect	Value
(I) Techno-economic	Installation size	120 kW
	Investment costs	2,13 x 10^3 Euro / kW
	O&M costs	4,9 x 10^3 Euro / Year
(O) Production	Energy	367,2 GJ / Year
(O) Financial	Revenue	23,460 x 10^3 Euro / Year
	Return on Equity	9,20 %
	Payback time	13,74 Years

Table 28: Values per parameter of Zonvogel

4.4.11. DMU 11: Zon op Noord

The initiators of Zon op Noord are E. de Lange and G.J. Stolk from Ransdorp in the Netherlands. Zon op Noord is a sister organisation of Zon op Nederland also initiated by the same founders. These two cooperatives collaborate very closely together for administration, large purchase agreements and operations.

4.4.11.1. Organisational structure

Zon op Noord is a cooperative whose first priority is to manage and operate solar panels of their members which are placed on the roofs of public buildings. The aim is to maintain a limited number of members per local cooperative around 25 to 50 members and set up other local cooperatives for other projects, see figure 25 below. This will increase the involvement of the members (residents) as much as possible.

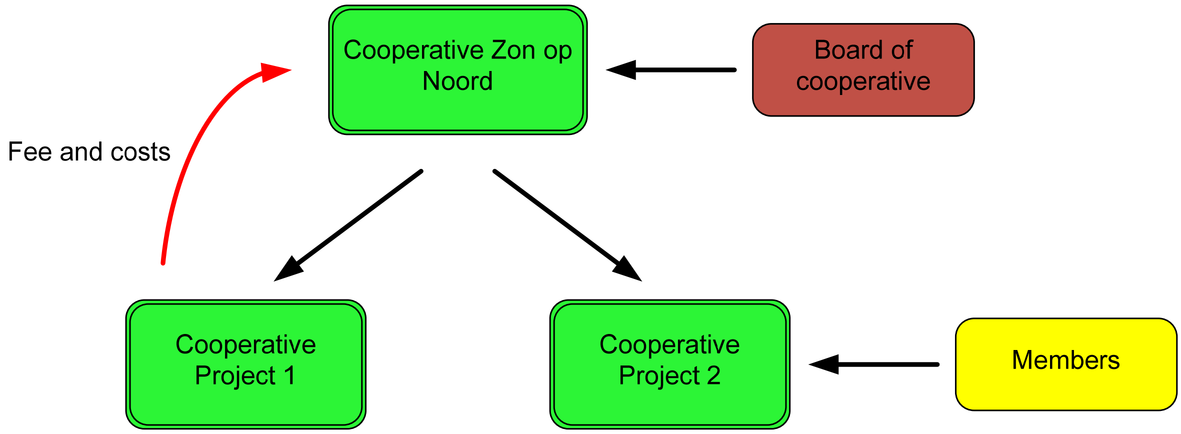


Figure 24: Organisational model Zon op Noord

4.4.8.11. Financial structure

Zon op Noord budgeted a price of €3,05 per Wp. This price includes the following elements; Solar panel, assembly material, cables, electricity converter, connection with grid and remaining installation work. When installing a solar panel of 210 Wp the cost price is €640,-. Besides the investment in the solar installation, there are additional costs in the form of membership fee of the cooperation of 10,- euro a year. In addition, Zon op Noord asks a annual contribution of 5,- euro per panel for maintenance, insurance, administration, etc. For the cooperative project one (see figure 25 above), the total costs are the investment plus the costs which have to be paid to the cooperative Zon op Noord. Return on investment with solar panels of 210 Wp is about 180 to 185 kWh a year. The yield per panel will be about €190,- including the SDE subsidies.

4.4.11.3. The parameters

LEC: Zon op Noord

Organisational name	Key aspects	Advantages
Cooperative	Involvement residents	Through this organisational interests of residents best represented
	Agreements with municipality	Easier to make agreements through a cooperative
	Small local cooperatives	To keep involvement of residents intensive

Table 29: Assessment organisational design of Zon op Noord

LEC: Zon op Noord

Parameters	Aspect	Value
(I) Techno-economic	Installation size	14,7 kW
	Investment costs	3,05 x 10^3 Euro / kW
	O&M costs	1,05 x 10^3 Euro / Year
(O) Production	Energy	45,9 GJ / Year
(O) Financial	Revenue	2,921 x 10^3 Euro / Year
	Return on Equity	6,52 %
	Payback time	15,00 Years

Table 30: Values per parameter of Zon op Noord

4.4.12. DMU 12: Boer En Buur

The initiator of Boer Zoekt Buur has developed a new version of farmers and residents working together in solar projects called Boer en Buur. In such projects a farmer make roofs available for placing solar panels in collaboration with residents, who invest in the panels.

4.4.12.1. Organisational structure

In figure 26 below the organisational structure is shown of this initiative. Residents can invest with shares of €3000,- in a cooperative. Joined in a cooperative the solar panels are placed on the roof of a farm. The solar panels produce energy which is then consumed locally, in your own house. After 25 years, the panels become in ownership of the farm, providing another 5-7 years of solar energy for the farmer. The farm itself can take shares in the solar plant, but no more than 49%. The first project with a farm is set up through this structure on September 21th of 2010.

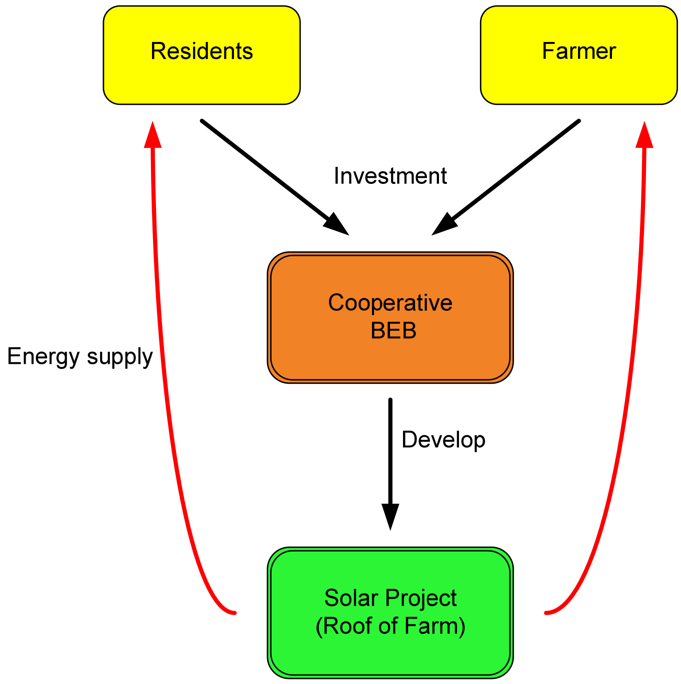


Figure 25: Organisational model Boer En Buur

4.4.12.2. Financial structure

Through this structure the self-supply model is applied, on which policy makers still are in debate over whether this form is aloud in the tax system on energy. This construction is very promising as it is profitable to invest even without SDE subsidy. A resident invest in the solar plant for €3000 that produces at least 800 kWh. The installation will produce energy for 25 years times 800 kWh a year is 20 000 kWh over 25 years. Instead of receiving 15 euro cents per kWh, that is now 23 cents per kWh. This is also expected to rise, because the prices of energy will increase. Basically, residents take an advance on their energy bill for the next 25 years and are insured for 25 years at least 800 kWh per share. The large energy company Greenchoice is realizing the new administrative settlement.

4.4.12.3. The parameters

LEC: Boer en Buur

Organisational name	Key aspects	Advantages
Cooperative	Citizens can invest in renewable energy.	Not having any burdens of installation or business
	Collaboration with local farmers	More local activity in renewable energy
	All shareholder benefit equally	Farmer does not have to loan the money and citizens can invest secure
	Collaboration with large energy company	Execute administration, higher return on sales of electricity

Table 31: Assessment organisational design of Boer en Buur

LEC: Boer en Buur

Parameters	Aspect	Value
(I) Techno-economic	Installation size	11,7 kW
	Investment costs	2,564 x 10^3 Euro / kW
	O&M costs	0,31 x 10^3 Euro / Year
(O) Production	Energy	36 GJ / Year
(O) Financial	Revenue	2,167 x 10^3 Euro / Year
	Return on Equity	7,22 %
	Payback time	13,85 Years

Table 32: Values per parameter of Boer en Buur

4.5. DEA model data sheet

From all the analysed LEC's values per parameter are derived as presented in tables per case above. These values are placed in a prepared data sheet, according to the format of Cooper, Seiford, & Tone (2006) further elaborated in paragraph 3.2.3. The parameters are the same for each LEC as determined in paragraph 3.2.5. Finally there are different kind of data sheet developed, one that includes all DMUs from. This data sheet is presented in the table 33 below.

Local Energy Company (LEC)	**(I)Installation** 10^3kW	**(C)Installation** 10^3Euro/kW	**(I)O&M costs** 10^3Euro/year	**(O)Energy** 10^3GJ/year	**(O)Revenue** 10^3Euro/year
Bio energy Eindhoven	11,500	1,52	880,00	64,19	2.050,00
Bio energy Fleringen	0,416	1,46	66,00	3,24	118,00
Patrimonium Energie	0,400	0,53	29,67	2,28	48,64
Thermo Bello	1,750	0,34	244,37	9,10	258,61
NDSM-Wharf	2,450	0,42	232,44	7,80	282,90
Onze Energie	2,000	2,00	106,00	18,00	480,00
SVDW Windpark	12,600	0,89	611,10	93,60	2.496,00
Windvogel	2,755	0,99	167,79	18,11	448,51
Meewind	165,000	3,72	30.921,00	1.980,00	104.280,00
Zonvogel	0,120	2,13	4,90	0,37	23,46
Zon op Noord	0,015	3,05	1,05	0,05	2,92
Boer En Buur	0,012	2,56	0,31	0,04	2,17

Table 33: DEA data sheet of all analyzed DMUs

However, this is the first time energy companies which produce heat or heat and electricity are compared with companies producing solely electricity. Local initiatives in producing heat for use in built environment are still very scarce. Therefore these kinds of companies are outnumbered compared to electricity producing companies. Furthermore, there is more data and knowledge available, for example, at the government about electricity producing LEC. This has led to a second measurement of benchmarking focusing on the LEC that produce renewable electricity locally. In the second measurement three companies of the previous data sheet have been excluded, named Patrimonium, Thermo Bello and NDSM-Wharf. The two bio energy companies are still present, because a large part of their income is based on the sales of electricity. To fill the gap in the data sheet the basic amounts determined by AgentschapNL and ECN in paragraph 2.4. are also calculated and included in the data sheet, see table below. In this measurement the in practice operating businesses are compared with theoretical established cases. There are two versions of the second benchmarking, because of the new SDE+ has just been published. The differences are analysed and resulted in a second data sheet for this benchmarking, presented in table below. The differences are mainly found in the financial parameters, the techno-economic have not change with the new SDE subsidy.

Local Energy Company (LEC)	(I)Installation 10^3kW	(C)Installation 10^3Euro/kW	(I)O&M costs 10^3Euro/year	(O)Energy 10^3kWh/year	(O)Revenue 10^3Euro/year
Bio energy Eindhoven	11,500	1,520	880,000	6.720,000	2.050,000
Bio energy Fleringen	0,170	3,622	66,000	900,000	118,000
Onze Energie	2,000	2,000	106,000	5.000,000	480,000
SVDW Windpark	12,600	0,890	611,100	26.000,000	2.496,000
Windvogel	2,755	0,990	167,794	5.031,660	448,511
Meewind	165,000	3,720	30.921,000	550.000,000	104.280,000
Zonvogel	0,120	2,130	4,900	102,000	23,460
Zon op Noord	0,015	3,050	1,050	12,700	2,921
Boer En Buur	0,012	2,564	0,310	10,000	2,167
Manure fermentation	1,100	3,100	1.083,500	8.800,000	1.601,600
Solid biomass 0-10 MW	2,000	4,445	1.651,000	16.000,000	3.408,000
Solid biomass 10-50 MW	25,000	3,600	14.350,000	200.000,000	24.400,000
Wind on land < 6 MW	15,000	1,350	750,000	33.000,000	3.168,000
Solar Panels 1-15 kWp	0,004	3,105	0,092	2,975	0,991
Solar Panels 15-100 kWp	0,100	2,145	2,125	85,000	23,800
Solar Panels self supply	0,100	2,145	2,125	85,000	19,550

Table 34: Data sheet including only the electricity producing DMUs with old SDE

Local Energy Company (LEC)	(I)Installation 10^3kW	(C)Installation 10^3Euro/kW	(I)O&M costs 10^3Euro/year	(O)Energy 10^3kWh/year	(O)Revenue 10^3Euro/year
Bio energy Eindhoven	11,500	1,520	880,000	6.720,000	2.050,000
Bio energy Fleringen	0,170	3,622	66,000	900,000	118,000
Onze Energie	2,000	2,000	106,000	5.000,000	480,000
SVDW Windpark	12,600	0,890	611,100	26.000,000	2.496,000
Windvogel	2,755	0,990	167,794	5.031,660	448,511
Meewind	165,000	3,720	30.921,000	550.000,000	104.280,000
Zonvogel	0,120	2,130	4,900	102,000	23,460
Zon op Noord	0,015	3,050	1,050	12,700	2,921
Boer En Buur	0,012	2,564	0,310	10,000	2,167
Manure fermentation	1,100	3,100	1.083,500	8.800,000	1.504,800
Solid biomass < 10 MW	2,000	4,445	1.651,000	16.000,000	2.736,000
Solid biomass > 10 MW	25,000	3,600	14.350,000	200.000,000	30.800,000
Wind on land < 6 MW	15,000	1,350	677,400	24.600,000	3.168,000
Solar Panels > 15 kWp	0,100	2,145	2,500	100,000	11,000
Solar Panels self supply	0,100	2,145	2,130	85,000	19,550

Table 35: Data sheet including only the electricity producing DMUs with new SDE

5. RESULTS AND SET OF RULES

The prepared data sheets as presented in paragraph 4.5, are executed in the DEA Solver program. Different models which are executed are discussed in paragraph 3.2.4. The results of the DEA benchmarking measurement are presented in paragraph 5.2. Thereafter per aspect; organisational, technical and financial, the results are presented and discussed. Finally, in the conclusion a "Set of Rules" is established, which are used in the development of the business case in next chapter.

5.1. Benchmarking DEA results

The results of the first data sheet as presented in paragraph 4.5, are executed in DEA on Technical as well as Allocation and overall efficiency are given in table below.

No.	Efficiency DMU	CCR Score	New technical Score	New Cost Score	New Allocative Score
1	Bio energy Eindhoven	0,586025228	0,562856964	0,269831396	0,479396034
2	Bio energy Fleringen	0,68570392	0,754695463	0,44700859	0,59230327
3	Patrimonium Energie	0,60171778	1	0,702884073	0,702884073
4	Thermo Bello	0,475795132	1	1	1
5	NDSM-Wharf	0,320460148	0,84224051	0,62658653	0,743952022
6	Onze Energie	1	1	0,294101494	0,294101494
7	SVDW Windpark	0,901980036	1	0,545506605	0,545506605
8	Windvogel	0,716502545	0,777255169	0,43405252	0,558442758
9	Meewind	1	0,818801033	0,390889664	0,477392734
10	Zonvogel	0,878678233	0,903527777	0,211177287	0,233725285
11	Zon op Noord	0,64060213	0,557457145	0,146899564	0,263517232
12	Boer En Buur	1	1	0,162046514	0,162046514

Table 36: DEA results of all DMUs including all efficiency measurements

From the results, it can be indicated that the best performer is not easily identified because none of the DMUs has all its efficiency scores equal to one. However, a number of results can be derived from this measurement. Regarding the cost-based measures LEC Thermo Bello received full efficiency marks even though it fell short in its CCR efficiency score. Conversely, although Thermo Bello almost has the worst CCR score (0,476), its lower unit costs are sufficient to move its cost-based performance to the top rank. The obtained CCR score of Thermo Bello shows that this LEC still has room for input reductions compared with other technically efficient DMUs. This means that the operation and management costs are too high compared with other LEC, especially considering the relatively small installation size.

On the other hand, DMU Boer En Buur is rated worst with respect to cost-based measures, although it receives full efficiency marks in terms of CCR scores. This gap is due to its relatively high cost structure. This DMU needs reductions in its unit costs to attain good cost-based scores. Derived from this result is that solar panels are still too expensive compared with the other RETs. This result is amplified by DMU 10 and 11, although the results show when scale of initiative is increased the performance also increases. Overall one can derive that DMUs utilize wind energy score the best.

In the second measurement only renewable electricity producing LECs are included as explained in paragraph 4.5. The results show that the best performer is DMU 10 Manure fermentation, with all its efficiency scores being equal to one. Reason is that although with fermentation the investment costs are high, the O&M costs are lower because manure is a waste product of farmers. Furthermore, the SDE subsidy is relatively high, so the returns are high which leads to a high profit. One remark is that it is the theoretical manure fermentation business with the best performance. Nevertheless the DMU 2, with the same RET also has a performance above average.

By comparing the in practice operating DMUs with the theoretical DMUs it indicated that the theoretical DMUs scores are better than the scores of the practical DMUs. Looking at the different scores per RET, it shows that DMUs who utilize wind energy perform comparable with the theoretical case. The largest difference is found in the DMUs utilizing bio energy with solid biomass. The theoretical solid biomass DMUs are performing a lot better than the practical ones. Although it is just one case in practice, it seems that this RET can improve performance in practice by far. Again as in the first measurement solar energy have the highest unit costs and therefore is the most expensive RET.

No.	Efficiency DMU	CCR Score	New technical Score	New Cost Score	New Allocative Score
1	Bio energy Eindhoven	0,483001857	0,552706027	0,249696671	0,45177121
2	Bio energy Fleringen	0,901157532	0,674992832	0,566391659	0,839107664
3	Onze Energie	1	1	0,484375	0,484375
4	SVDW Windpark	0,901980036	1	0,898430533	0,898430533
5	Windvogel	0,706950719	0,793292305	0,714868559	0,901141426
6	Meewind	1	0,80036182	0,361721612	0,45194761
7	Zonvogel	0,698642527	0,684203459	0,195419311	0,285615789
8	Zon op Noord	0,548426797	0,444583029	0,135937969	0,305765088
9	Boer En Buur	0,764281206	0,764281206	0,149954659	0,196203515
10	Manure fermentation	1	1	1	1
11	Solid biomass 0-10 MW	1	1	0,81620292	0,81620292
12	Solid biomass 10-50 MW	1	0,917125778	0,861111111	0,93892368
13	Wind on land <6 MW	0,9328	0,986343381	0,631481481	0,640224787
14	Solar Panels 1-15 kWp	1	0,961762422	0,169883961	0,176638177
15	Solar Panels 15-100 kWp	1	1	0,236238121	0,236238121
16	Solar Panels self supply	0,958695652	0,958695652	0,194052742	0,202413291

Table 37: DEA results of the electricity only DMU with old SDE

In comparing the differences between the old en the just new published (9th of June) SDE subsidy, not many differences are found. Overall the practical DMUs perform relative slightly better compared to the new theoretical DMUs, than compared to the old theoretical DMUs.

No.	Efficiency DMU	CCR Score	New technical Score	New Cost Score	New Allocative Score
1	Bio energy Eindhoven	0,523208976	0,557553127	0,26575903	0,476652388
2	Bio energy Fleringen	0,876661619	0,678047111	0,566391659	0,835327884
3	Onze Energie	1	1	0,484375	0,484375
4	SVDW Windpark	0,901980036	1	0,898430533	0,898430533
5	Windvogel	0,706950719	0,793292305	0,714868559	0,901141426
6	Meewind	1	0,807321616	0,384990253	0,476873461
7	Zonvogel	0,791663874	0,774873472	0,207990144	0,268418201
8	Zon op Noord	0,601821433	0,492669899	0,144682517	0,2936703
9	Boer En Buur	0,874857781	0,794285026	0,159600865	0,200936515
10	Manure fermentation	1	1	1	1
11	Solid biomass < 10 MW	1	0,858080414	0,697412823	0,812759284
12	Solid biomass > 10 MW	1	1	0,861111111	0,861111111
13	Wind on land < 6 MW	0,890059961	0,974433531	0,470740741	0,483091689
14	Solar Panels > 15 kWp	0,863880597	0,863880597	0,180652681	0,20911765
15	Solar Panels self supply	1	1	0,206535667	0,206535667

Table 38: DEA results of the electricity only DMUs with new SDE

5.2. Organisational structure

Studying the identified local initiatives and especially in depth the selected DMUs, there are a number of resemblances found with different stakeholders. The results can be divided in two streams of ownership models belonging to two different groups of stakeholders. Group one includes the residents and group two the larger local actors, mainly the municipality, housings associations and other private stakeholders. Group one the residents corresponding with 39% of the identified LEC in the Netherlands, have one dominate organisational model, presented in figure below. The residents are mostly organized in a cooperative ownership model, or in a few cases a foundation, which has comparable legal rights. Main advantages of local residents being shareholder are; having decision making power (including subscription money, spend on starting costs of projects), transparency, little possibility of liability and the cooperative is streamlined along the principles of Corporate Social Responsibility. This implies that the organisation has no profit goals, but must be a healthy operating business. In some cases there is another operating company established beneath the mother cooperative. This operating company can adopt different legal forms, for instance a Limited Liability company or cooperative. It is established to decrease the possibility of liability if the project fails. In this case the operating company will declare bankruptcy and not the mother organisation, where all the residents have their shares. This form is especially useful when multiple projects on different locations and / or different RETs are utilized.

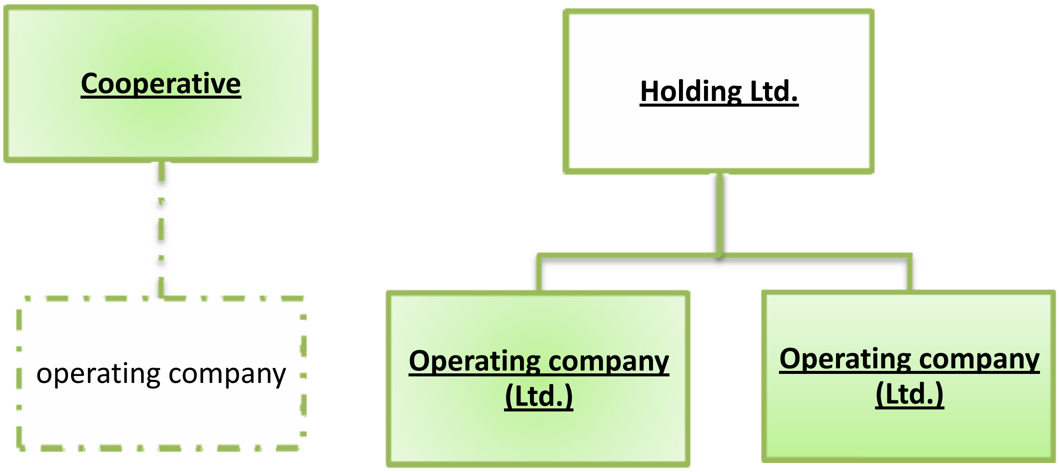


Figure 26: Dominant organisational models: on the left for the residents and on the right for other initiators

The second stream of ownership model form, including all the remaining local actors, is presented in the figure above on the right. The organisational structure consists of a main holding where all the shareholders are represented. To avoid that the mother organisation is liable and thus the shareholders, operating companies in the form of Ltd. are established. In this way it can also operate next to their other core businesses, for example in the case of a housing association. Furthermore, it prevents the possibility of the holding going bankrupt or liable. For example the municipality of Apeldoorn with DeA, adopted this organisational structure, it has no direct relationship with the organisation of the municipality. They are the only shareholder of the Holding, in some cases divided with local private stakeholders. The operating company is responsible for all the business activities of a LEC. The activities are realising the renewable energy project and the operation and management afterwards. This last activity is sometimes outsourced to external parties.

5.3. Techno-economic

The results of this aspect exists of two parts, the first part elaborates the results about who is utilizing what in a LEC. Secondly, the techno-economic parameter results of installation size, investments and operation and management are discussed. This is underpinned by the DEA results and comparing the parameters separately.

5.3.1. Different local stakeholder utilize different RETs

In the figure below, LECs initiated by residents in the different techniques are presented. It shows that 38% of the initiatives are in wind energy, mostly in a cooperative ownership model form. Secondly, solar energy is a fast increasing technique where residents are taking collective initiatives in, also in a cooperative ownership form. The multiple techniques initiatives are in the feasibility phase of the different techniques. They have not yet decided in which RET specifically. However, many are combining solar PV with other renewable techniques. Few residents initiate a LEC in heat (and cold) utilizing businesses.

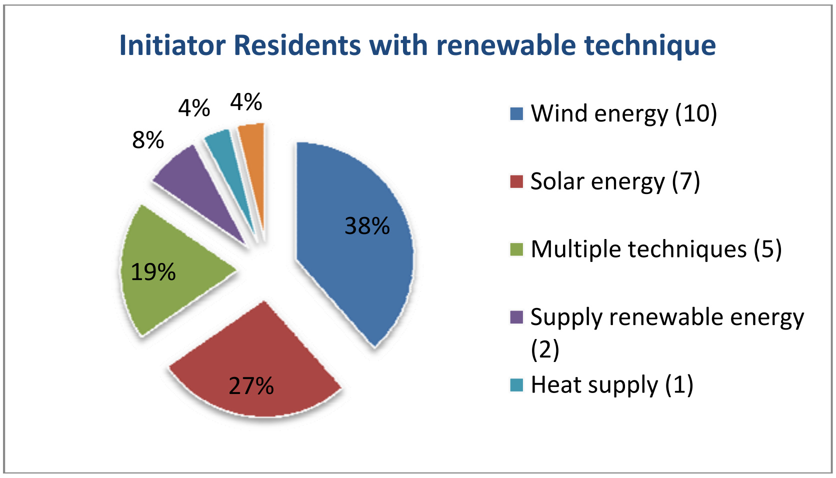


Figure 27: Initiative by the residents per RET

Interesting results is the difference initiators in different RETs, as mentioned residents develop initiative in wind and solar energy. Other local stakeholders develop initiatives in heat producing LECs and larger and multiple renewable installations. This comes with other techniques especially bio energy, heat and cold storage and Geothermal energy. For instance LECs initiated by the municipality, presented in the figure below confirms this result.

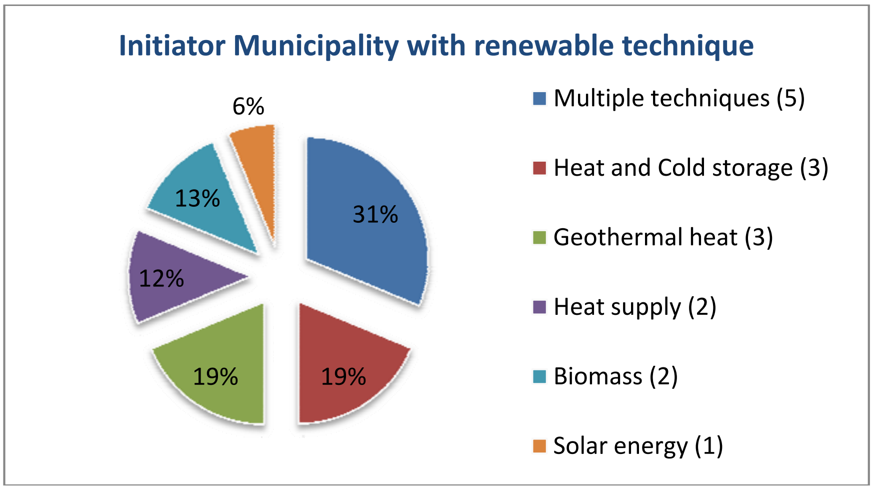


Figure 28: Initiatives by the municipality per RET

5.3.2. Techno-economic parameters results

To compare the results of the values from techno-economic parameters, the four tables below give insights on the difference in values per Renewable Energy Source (RES). In the first table heat utilizing LEC are shown with the values of techno-economic parameters. Interesting is that Thermo-Bello has low investment costs due to acquisition of existing installation and grid. However, as expected the maintenance costs are high because the grid is older. Furthermore, these are relatively small heat (and cold) producing grids, in the case of Patrimonium the installation is in a building with apartments. This decreases the costs of the grid, because it is very compact and thus makes the LEC more financially feasible.

Techno-economic parameter Technique (LEC)	**(C)Installation** 10^3 Euro/kW	**(I)O&M costs** 10^3 Euro/kW
Patrimonium Energie	0,530	74,185
Thermo Bello	0,340	139,638
NDSM-Wharf	0,420	94,874

Table 39: Overview of the techno-economic parameters of heat producers

In the case of Eindhoven the investment costs of the biomass installation are very high, especially when compared with the calculations of ECN, see table below. Even the costs for the heat grid, are according to ECN assumptions, in the case of Eindhoven are on the low side. The values of the O&M costs parameter is between the ECN assumptions. Therefore, concluded is that this value can be applied in future practice. The reason that the O&M costs are slightly lower is because the biomass fuel for the installation is purchased from the own municipality. The bio fermentation installation in Fleringen has good values for the techno-economic parameters compared with ECN assumptions. Although investment per kW installation is higher, this is because the installation is older and the technique is improvement now. This results in a lower investment per kW installation value. The O&M costs are much lower due to the fact that the biomass fuel for the installation in the case of Fleringen is manure waste from its own company.

Techno-economic parameter Technique (LEC)	**(C)Installation** 10^3 Euro/kW	**(I)O&M costs** 10^3 Euro/kW
Bio energy Eindhoven	6,239	778,761
Solid biomass 0-10 MW	4,445	825,500
Solid biomass 10-50 MW	3,600	574,000
Bio energy Fleringen	3,622	388,235
Manure fermentation	3,100	985,000

Table 40: Overview of the techno-economic parameters of bio energy

The LEC in wind on land are performing well when compared to ECN assumptions. Especially the early established LECs have profited from lower investment per kW and O&M costs have not changed much. LEC Onze Energie have budgeted high investment costs compared to other LEC and ECN assumptions. This maybe is due to the difficult location, however, they could question if the calculations are correct. The results show that wind on sea is expensive, both parameters have high values compared with wind on land, see the table below. Both with investment costs and O&M costs values are three times as high, this should be taken into account when considering wind on sea.

Techno-economic parameter Technique (LEC)	(C)Installation 10^3 Euro/kW	(I)O&M costs 10^3 Euro/kW
Onze Energie	2,000	53,000
SVDW Windpark	0,890	48,500
Windvogel	0,990	60,905
Meewind	3,720	187,400
Wind on land < 6 MW	1,350	50,000

Table 41: Overview of the techno-economic parameters of wind energy

The LEC in utilizing solar energy are performing comparable with ECN assumptions. Clearly seen in the results are the scale advantages in the costs of solar panels. For instance LEC Zonvogel has a lower investment value per kW than ECN calculations. However, the O&M costs of Zonvogel are higher; this is maybe a high value for security reasons. Zon op Noord also has much higher O&M costs than ECN assumptions. These results show that the assumptions of ECN are probably too low; a higher value of this parameter is advised. LECs utilizing solar panels should make the installation as large as possible to reduce the investment and O&M costs and thus both values of the parameters. Furthermore, the prices of solar panels are still decreasing fast, this also reduces the investment costs and is also the reason that investment costs of the LECs differ a lot.

Techno-economic parameter Technique (LEC)	(C)Installation 10^3 Euro/kW	(I)O&M costs 10^3 Euro/kW
Zonvogel	2,130	40,833
Zon op Noord	3,050	71,429
Boer En Buur	2,560	26,496
Solar Panels 1-15 kWp	3,105	26,350
Solar Panels 15-100 kWp	2,145	21,250
Solar Panels self supply	2,145	21,250

Table 42: Overview of the techno-economic parameters of solar energy

5.4. Financial

In this paragraph the financial results are presented and discussed. Again as in the previous paragraph of the techno-economic results, four tables are set up to give insights on the different values of the financial parameters. The discussion is supplemented with the results of the DEA measurement. The four tables are divided in sort of RES; biomass, wind, solar and heat.

In the first table heat (and cold) producing LECs are compared. Striking are the differences in revenue per GJ, ranging from 19,868 to 28,410. Clearly most LECs can expect revenue of around 22,000 euro per GJ, according to prices in 2009. The results of profits, relatively compared to the amount of energy output, do not differ much. An important aspect is thus when a LEC is considering supplying and selling heat (and cold) is the height of the revenue per GJ. This will determine whether the renewable energy project is feasible or not. Furthermore, the results show that compact installation, building related or for a few larger apartment complexes, are more feasible due to small infrastructure.

Financial parameters Local Energy Company (LEC)	**(O)Energy** 10^3 GJ /year	**Profit** 10^3 Euro/year	**Per GJ** Euro / GJ
Bio energy Eindhoven	40,000	480,000	22,000
Patrimonium Energy	2,280	18,961	21,333
Thermo Bello	9,100	14,239	28,410
NDSM-Wharf	4,200	50,458	21,000
DEVO Veenendaal	-	-	19,868

Table 43: Overview of the financial parameters of heat producers

In table 44 the LECs with bio energy are compared. This is difficult to compare, because there is a lot of difference in the installation size. Furthermore, the installations need biomass which must be purchased. Only the fermentation installations have sometimes biomass available for free, from for example, their own farm company. This is a big advantage for these LECs that is why their performance is better.

Financial parameters Local Energy Company (LEC)	**(O)Energy** 10^3 kWh/year	**Profit** 10^3 Euro/year	**Per kWh** Euro / kWh	**New SDE+** Euro / kWh
Bio energy Eindhoven	6.720,000	480,000	0,174	-
Solid biomass 0-10 MW	16.000,000	1.757,000	0,213	0,170
Solid biomass 10-50 MW	200.000,000	10.050,000	0,122	0,150
Bio energy Fleringen	900,000	52,000	0,131	-
Manure fermentation	8.800,000	518,800	0,182	0,170

Table 44: Overview of the financial parameters of bio energy

In LECs who are utilizing wind energy fewer differences are found in the yields per kWh. The reason is, that almost all LECs receive SDE subsidy from the government, see the table beneath. Furthermore, this SDE subsidy ensures that LECs in wind energy are very profitable. The new SDE+ Subsidy also does not change the situation much for utilizing wind turbines. Differences between the subsidies are a small increase in yields per kWh as shown in the table below. However, full load hours are decreased resulting in the same revenue in the old and the new situation.

Finally interesting results are LECs or projects utilizing wind on sea. While practice has shown in the case of Meewind that 0,190 euro per kWh is more than enough to make the project profitable. The government has planned a SDE subsidy in the new situation of 0,138 euro per kWh for Wind on sea. The Dutch government wants to stimulate wind on sea projects in the coming years and the height of the subsidy in the case of Meewind is not necessary to make the project feasible.

Financial parameters Local Energy Company (LEC)	**(O)Energy** 10^3 kWh/year	**Profit** 10^3 Euro/year	**Per kWh** Euro / kWh	**New SDE+** Euro / kWh
Onze Energie	5.000,000	374,000	0,096	-
SVDW Windpark	26.000,000	1.884,900	0,096	-
Windvogel	5.031,660	280,717	0,089	-
Meewind	550.000,000	73.359,000	0,190	0,138
Wind on land < 6 MW	33.000,000	2.418,000	0,096	0,110

Table 45: Overview of the financial parameters of wind energy

Output in produced energy by LEC in solar energy is very low, when compared with other RET for example wind energy. However, collective initiatives also establish LECs in utilizing solar panels. The results show clearly that larger projects are performing better, scale advantages are important for lower investment costs. There are two different ways of receiving the yields per kWh. Either through the SDE Subsidy or through the so called “Self Supply model”, this is without subsidies. In the old SDE situation, LECs who receive subsidy have higher revenue. However, in the new SDE situation subsidy is much lower and the Self Supply model is more profitable. This is also what all LEC in solar energy are trying to achieve, setting up profitable business without SDE subsidy.

Financial parameters Local Energy Company (LEC)	**(O)Energy** 10^3 kWh/year	**Profit** 10^3 Euro/year	**Per kWh** Euro / kWh	**New SDE+** Euro / kWh
Zonvogel	102,000	18,560	0,230	-
Zon op Noord	12,700	1,871	0,230	-
Boer En Buur	10,000	1,857	0,217	-
Solar Panels 1-15 kWp	2,975	0,899	0,333	-
Solar Panels 15-100 kWp	85,000	21,675	0,280	0,110
Solar Panels self supply	85,000	17,425	0,230	-

Table 46: Overview of the financial parameters of solar energy

5.5. Conclusion

The DEA measurements and comparing every DMU with each other and with the ECN assumptions, has given many insights and results. All the parameters included in this research are analysed and some differences in values of the techno-economic and financial parameters where found. This has lead to the new values for the parameters as presented in the tables below.

Techno-economic parameter / **RET**	**Installation size**	**Investment cost**	**Operating hours**	**Fixed O&M costs**	**Variant O&M costs**	**Fuel costs**
	MWe	€/kWe	Hours/Year	€/kW	€/kWh	€/ton
Manure co-fermentation	1,1	3.350	8000	235	-	27,5
Green waste fermentation	1,5	4.285	8000	445	-	0
Solid biomass 0-10 MWe	2,0	5.000	8000	340	0,006	35
Wind on land <6 MW	15	1.500	1760	25,8	0,011	-
Solar Panels 15-100 kW	0,1	2.130	850	-	0,025	-
Heat and cold storage (incl. Heat pump)	0,425	1.000	8000	Project based	Project based	-

Table 47: Set of Rules of the techno-economic parameters

Financial para-meter / **RET**	Share Equity	Interest	Return on Equity	Economical lifetime	Yields per kWh	Yields per GJ
	%	%	%	Years	€/kWh	€/GJ
Manure co-fermentation	20	6	15	12	0,182	22,00
Green waste fermentation	20	6	15	12	0,134	22,00
Solid biomass 0-10 MWe	20	6	15	12	0,213	22,00
Wind on land <6 MW	20	5,1	15	15	0,096	-
Solar Panels 15-100 kW	20	5,1	15	15	0,280	-
Heat and cold storage (incl. Heat pump)	20	6	15	12	-	22,00

Table 48: Set of Rules of the financial parameters

6. THE BUSINESS CASE

In this chapter the results of previous research and set of rules are formed into a business case. The business case is set up for the practice and validates this research to apply the set of rules in a final case. The content of the business case consists of the background, scenarios for energy savings, and multiple solutions for renewable energy generation and business model. Finally, the process of establishing a Local Energy Company is evaluated. The fundamentals of this business case can be applied in most situations. However, the plan is writing to situation for Eindhoven. This should be accounted for when setting up a business case elsewhere.

6.1. Background

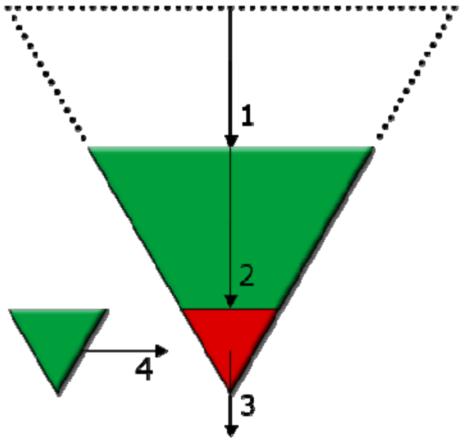
The municipality of Eindhoven has set the ambitious goal to become energy neutral in the year 2040. To achieve this goal renewable energy must be generated in the amount the municipality consumes within the municipal boundary. This business case elaborates how to utilize Renewable Energy Techniques (RES) in a new established Local Energy Company. Recently the counsel of municipality of Eindhoven has approved a plan to set up such a company. The case is consistent with what the municipality has planned, however, multiple stakeholders are considered. To set up a business case an area needs to be selected, to make it tangible and prevent as much assumptions as possible. In consultation with the municipality district Gestel in Eindhoven is selected as area of the business case. The focus lies in the "Vogelwijk" Bennekel within that district, see figure 29 below.

Figure 29: Business case location, district Gestel in Eindhoven, source google maps

First the energy consumption of the selected area is analysed and determined. According to the "Trias Energetica", the next step is to save as much energy as possible. Therefore, three scenarios for energy savings are elaborated in next paragraph. Then three scenarios for generating the remaining energy demand through different combinations of Renewable Energy Techniques (RET) are set up. With the different solutions variants feasible is determined through the financial figures. Finally, the organisational structure and the decision making process is made clear.

6.2. Scenario's for energy savings

The total energy consumption in the selected area is 34.825.034 kWh per and 11.070.144 m³ gas a year. These numbers are the actual measured energy consumptions in that area. Total gas converted to heat is 387.455 GJ per year. Following the principles of Trias Energetica, which is a way of dealing with energy, the first step is to reduce the demand for energy. The focus of this business case lies on renewable energy generation. However, this first step of energy savings must be considered for making a realistic case for the second step renewable energy generation. The third step of this principle is efficient use of fossil fuels or more preferred purchase of green energy. The Trias Energetica principles are shown in figure below.



Step **1**: Save as much energy as possible.

Step **2**: Generate renewable energy.

Step **3**: Efficient use of remaining fossil fuels energy.

Step **4**: Complementary to step 3, purchase green energy.

Figure 30: The Trias Energetica principles, figure developed by BuildDesk

In the selected area many different buildings are constructed, 12% of the dwellings date from before the WWII. About 44% dates from after 1970 and the other 44% of the dwelling are constructed in the period around 1945-1969. According to AgentschapNL who have a registration system for energy labels, the average in the municipality of Eindhoven is label D with Energy Index (EI) of 1,90. In the table below different energy savings scenarios are presented, this is the first step of the Trias Energetica principle.

Current energy label, to new label	**m³ Gas consumptions current situation**	**Total costs for improvements**	**Annual consumption of m³ gas**
D = D	11.070.144 m³	€ 0,-	0%, 10.837.451 m³ 411.757 GJ
D → B	11.070.144 m³	€ 23.395.080,-	65%, 7.044.343 m³ 267.642 GJ
D → A+	11.070.144 m³	€ 81.757.000,-	49%, 5.191.678 m³ 197.252 GJ

Table 49: Energy saving scenarios

The number of Dwellings in Gestel is 6.289 and a surface of 683 (incl. Genneper Park) hectares, with a strong urbanity of 2000 addresses per km² (eindhoven.buurtmonitor.nl, 2010). The second Scenario costs € 3.720,- per dwelling and the third scenario costs €13.000,- per dwelling (energiebesparingverkenner woningen, 2010).

6.3. Solutions variants for energy generation

In a study executed by Eindhoven University of Technology in collaboration Endinet, research is done into which Renewable Energy Sources (RES) have potential and to what extent for Eindhoven (Eindhoven, 2011). Investigated RES were; biomass, geothermal, rest heat, solar boilers, solar PV and wind. In this case two of these sources are excluded namely; rest heat and solar boilers. Rest heat is simply not a renewable energy source and solar boilers are not a potential renewable technique to operate in a LEC. Furthermore in the research of University of Technology Eindhoven and Endinet (2011), is analysed if the RES are realistic to utilize in Eindhoven. Only the RES wind was not found realistic. However, in this business case a solution variant will include wind energy to give insights on the difference in results. Geothermal energy is replaced by Heat (and Cold) Storage, this RES has proven successful utilization in a LEC. Geothermal is at the time of writing not proven successful in a LEC yet. The above mentioned techniques are combined in the following scenarios. The goal of the different scenarios is in the first place to generate renewable energy as much as is consumed in the business case. Furthermore, to utilize RET in a LEC as financially optimal as possible.

The energy consumed in location of the business case is; 34.825.034 kWh, which is in every scenario the same amount. Plus the extra consumed kWh due to cooking on electricity instead of gas is 200 kWh per household (consumentenbond, 2011), is in total 1.257.800 kWh extra. This brings the total consumed electricity at 36.082.834 kWh a year or 36,1 GWh. The gas consumption declines, because cooking is on electricity, with an average of 37 m³ per household, makes in total 232.693 m³ gas. This is taken into account in the energy saving scenarios above and thus can the total numbers of GJ be maintained.

RES	Scenario 1	Scenario 2	Scenario 3
Biomass solid	90.000 GJ, 9 GWh	90.000 GJ, 16 GWh	90.000 GJ, 9 GWh
Biomass fermentation	90.000 GJ, 9,1 GWh	90.000 GJ, 16 GWh	90.000 GJ, 9 GWh
Heat (and cold) Storage (incl. pump)	90.000 GJ	90.000 GJ	90.000 GJ
Solar PV	18 GWh	4,1 GWh	4,1 GWh
Wind	-	-	14 GWh
Heat grid	40 km1	40 km1	40 km1
Total	270.000 GJ 36,1 GWh	270.000 GJ 36,1 GWh	270.000 GJ 36,1 GWh

Table 50: variant solutions for the generation of renewable energy

The parameters

The energy demand of the business case location must be generated by renewable energy sources. Firstly, the energy demand was determined followed by scenarios for energy savings at the location. Then energy generation scenarios are set up, with different use of RETs and different levels of use per technique. To produce the financial figures for the business case, the Techno-economic and Financial parameters (set of rules) give the values for the calculations. These are given in the tables of chapter results in paragraph 5.5 conclusion. In the first table the Techno-economic parameters and in the second table the financial parameters are given.

6.4. Business model

In this chapter the business model for the case is elaborated, consisting of organisational design and figures of the different solutions. Finally, the best solution of variant is presented and discussed.

6.4.1. Organisational design

As elaborated in this research it is important to have collaboration with as much local stakeholders as possible. There are two kinds of local stakeholders, the participating stakeholders in the LEC and the collaboration stakeholders at the location of the LEC. Collaborating stakeholders are actor for example, a local school or company who can make their roofs available for solar panels or willing to switch to heat (and cold) in advance. The participating stakeholders in the LEC are, of course, more important. This certainly applies for local residents, without involvement of them in the LEC the feasibility of the project is very low. Furthermore, the residents can contribute in increasing the equity of the LEC by their involvement and becoming shareholder of the LEC. The following participating shareholders can be identified and are crucial for the success of the LEC;

- Residents
- Municipality
- Social housing association
- Philips and other local companies

Organisational models can be designed as followed, see figure 31 below. The above mentioned shareholders are represented in the Holding or a Cooperative. This company is steering the underneath established operating company. All the business activities are hosted in the Operating Company, which is also Limited Liability Company or in Dutch a B.V.

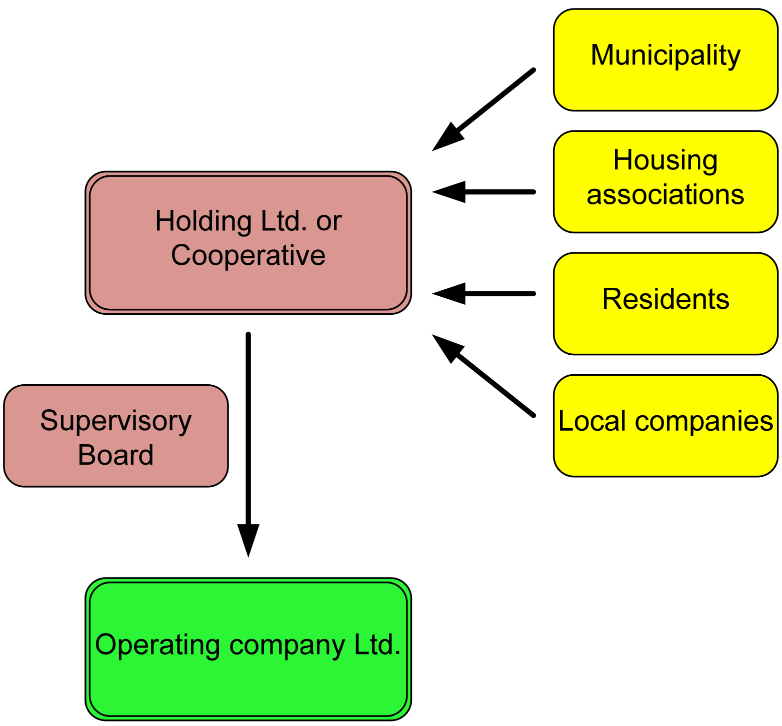


Figure 31: Organisational structure recommended in this business case

6.4.2. *Figures of the different solutions*

SOLUTION VARIANT 1:

Techno-economic parameter	**Installation size**	**Investment costs**	**Total investment**	**Operating hours**	**O&M costs**	**Total O&M costs**
RES	MW	Euro/kW	Euro	Hours/year	Euro/kW	Euro
Manure co-fermentation	0,62	3.350,00	2.077.000,00	8.000,00	685,00	424.700,00
Green waste fermentation	0,60	4.285,00	2.571.000,00	8.000,00	445,00	267.000,00
Solid biomass < 10 MWe	1,20	5.000,00	6.000.000,00	8.000,00	800,00	960.000,00
Wind on land < 6 MW	0,00	1.500,00	0,00	1.760,00	50,00	0,00
Solar Panels 15-100 kW	21,18	2.130,00	45.113.400,00	850,00	35,00	741.300,00
Heat and cold (incl. pump)	3,12	1.000,00	3.120.000,00	8.000,00	103,00	321.360,00
Heat grid (m1)	40.000,00	250,00	10.000.000,00	0,00	0,00	0,00
TOTAL			68.881.400,00			2.714.360,00
Total installation size MWe	23,56					
Total installation size MWth	9,36					

Financial parameters	**Energy**	**Energy**	**Yield GJ**	**Yield GWh**	**Revenue**	**Gross income**	**Interest**	**Repayment**	**Profit b. t.**	**Net income**
RES	GJ	GWh	Euro/GJ	Euro/GWh	Euro x1000	Euro x1000	Euro x1000	Euro x1000	Euro x1000	Euro x1000
Manure co-fermentation	45.000,00	4,50	22,00	170.000,00	1.755,00	1.330,30	99,70	138,47	1.092,14	813,64
Green waste fermentation	45.000,00	4,60	22,00	150.000,00	1.680,00	1.413,00	123,41	171,40	1.118,19	833,05
Solid biomass < 10 MWe	90.000,00	9,00	22,00	170.000,00	3.510,00	2.550,00	288,00	400,00	1.862,00	1.387,19
Wind on land < 6 MW	0,00	0,00	0,00	110.000,00	0,00	0,00	0,00	0,00	0,00	0,00
Solar Panels 15-100 kW	0,00	18,00	0,00	230.000,00	4.140,00	3.398,70	1.840,63	2.406,05	-847,97	-631,74
Heat and cold (incl. pump)	90.000,00	0,00	22,00	0,00	1.980,00	1.658,64	149,76	208,00	1.300,88	331,724
Heat grid	0,00	0,00	0,00	0,00	0,00	0,00	480,00	400,00	-880,00	-655,60
TOTAL	270.000,00	36,10			13.065,00	10.352,64	2.981,49	3.723,91	3.647,23	930,045

Total installation MWe	23,56	Equity share	13.776,28	(Euro x 1000)
Total installation MWth	9,36	Debt share	55.105,12	(Euro x 1000)
Heat grid (km1)	40,00	Taxes	25,5	%

SOLUTION VARIANT 2:

Techno-economic parameter	Installation size	Investment costs	Total investment	Operating hours	O&M costs	Total O&M costs
RES	MW	Euro/kW	Euro	Hours/year	Euro/kW	Euro
Manure co-fermentation	1,00	3.350,00	3.350.000,00	8.000,00	685,00	685.000,00
Green waste fermentation	1,00	4.285,00	4.285.000,00	8.000,00	445,00	445.000,00
Solid biomass < 10 MWe	2,00	5.000,00	10.000.000,00	8.000,00	800,00	1.600.000,00
Wind on land < 6 MW	0,00	1.500,00	0,00	1.760,00	50,00	0,00
Solar Panels 15-100 kW	4,82	2.130,00	10.266.600,00	850,00	35,00	168.700,00
Heat and cold (incl. pump)	3,12	1.000,00	3.120.000,00	8.000,00	103,00	321.360,00
Heat grid (m1)	40.000,00	250,00	10.000.000,00	0,00	0,00	0,00
TOTAL			41.021.600,00			3.220.060,00
Total installation size MWe	8,82					
Total installation size MWth	9,36					

Financial parameters	Energy	Energy	Yield GJ	Yield GWh	Revenue	Gross income	Interest	Repayment	Profit b. t.	Net income
RES	GJ	GWh	Euro/GJ	Euro/GWh	Euro x1000	Euro x1000	Euro x1000	Euro x1000	Euro x1000	Euro x1000
Manure co-fermentation	45.000,00	8,00	22,00	170.000,00	2.350,00	1.665,00	160,80	223,33	1.280,87	954,25
Green waste fermentation	45.000,00	8,00	22,00	150.000,00	2.190,00	1.745,00	205,68	285,67	1.253,65	933,97
Solid biomass < 10 MWe	90.000,00	16,00	22,00	170.000,00	4.700,00	3.100,00	480,00	666,67	1.953,33	1.455,23
Wind on land < 6 MW	0,00	0,00	0,00	110.000,00	0,00	0,00	0,00	0,00	0,00	0,00
Solar Panels 15-100 kW	0,00	4,10	0,00	230.000,00	943,00	774,30	418,88	547,55	-192,13	-143,14
Heat and cold (incl. pump)	90.000,00	0,00	22,00	0,00	1.980,00	1.658,64	149,76	208,00	1.300,88	331,724
Heat grid	0,00	0,00	0,00	0,00	0,00	0,00	480,00	400,00	-880,00	-655,60
TOTAL	270.000,00	36,10			12.163,00	8.942,94	1.895,12	2.331,22	4.716,60	1.202,734

Total installation MWe	23,56	Equity share	8.204,32	(Euro x 1000)
Total installation MWth	9,36	Debt share	32.817,28	(Euro x 1000)
Heat grid (km1)	40,00	Taxes	25,5	%

SOLUTION VARIANT 3:

Techno-economic parameter	Installation size	Investment costs	Total investment	Operating hours	O&M costs	Total O&M costs
RES	MW	Euro/kW	Euro	Hours/year	Euro/kW	Euro
Manure co-fermentation	0,62	3.350,00	2.077.000,00	8.000,00	685,00	424.700,00
Green waste fermentation	0,60	4.285,00	2.571.000,00	8.000,00	445,00	267.000,00
Solid biomass < 10 MWe	1,20	5.000,00	6.000.000,00	8.000,00	800,00	960.000,00
Wind on land < 6 MW	8,00	1.500,00	12.000.000,00	1.760,00	50,00	400.000,00
Solar Panels 15-100 kW	4,82	2.130,00	10.266.600,00	850,00	35,00	168.700,00
Heat and cold (incl. pump)	3,12	1.000,00	3.120.000,00	8.000,00	103,00	321.360,00
Heat grid (m1)	40.000,00	250,00	10.000.000,00	0,00	0,00	0,00
TOTAL			46.034.600,00			2.541.760,00
Total installation size MWe	23,56					
Total installation size MWth	9,36					

Financial parameters	Energy	Energy	Yield GJ	Yield GWh	Revenue	Gross income	Interest	Repayment	Profit b. t.	Net income
RES	GJ	GWh	Euro/GJ	Euro/GWh	Euro x1000	Euro x1000	Euro x1000	Euro x1000	Euro x1000	Euro x1000
Manure co-fermentation	45.000,00	4,50	22,00	170.000,00	1.755,00	1.330,30	99,70	138,47	1.092,14	813,64
Green waste fermentation	45.000,00	4,50	22,00	150.000,00	1.665,00	1.398,00	123,41	171,40	1.103,19	821,88
Solid biomass < 10 MWe	90.000,00	9,00	22,00	170.000,00	3.510,00	2.550,00	288,00	400,00	1.862,00	1.387,19
Wind on land < 6 MW	0,00	14,00	0,00	110.000,00	1.540,00	1.140,00	489,60	640,00	10,40	7,75
Solar Panels 15-100 kW	0,00	4,10	0,00	230.000,00	943,00	774,30	418,88	547,55	-192,13	-143,14
Heat and cold (incl. pump)	90.000,00	0,00	22,00	0,00	1.980,00	1.658,64	149,76	208,00	1.300,88	331,724
Heat grid	0,00	0,00	0,00	0,00	0,00	0,00	480,00	400,00	-880,00	-655,60
TOTAL	270.000,00	36,10			11.393,00	8.851,24	2.049,34	2.505,42	4.296,48	1.095,602

Total installation MWe	23,56	Equity share	9.206,92	(Euro x 1000)
Total installation MWth	9,36	Debt share	36.827,68	(Euro x 1000)
Heat grid (km1)	40,00	Taxes	25,5	%

In the tables above the different solutions for generation of renewable energy is elaborated and a indication of the financial structure is given. The different solutions give many insights in what happens in a business when different multiple RETs are utilized and in different installation sizes. Remarkable is the fact that solar panels are not profitable in their first year in any of the solutions, so installation size only has influence on the degree of losses. Generating renewable electricity by other means is thus advisable at this time with the calculated values of the parameters in this research. However, values of parameters are changing rapidly, especially of solar energy for example the investment costs are decreasing almost every month.

In the third solution wind energy is part of the utilized RES. Although the area in and around Eindhoven is not the best suited location for wind turbines, it must not be excluded so easily. Since in the new SDE subsidy the full load hours are decreased and yield per kWh increased, wind turbines become profitable in more areas. When, in this solution, only three relatively small wind turbines are placed, there contribution of energy generation is already large as shown in the third solution above. Furthermore, wind turbines have low O&M costs while the total investment is slightly higher than in solution two. Also the net income is not much lower, therefore, even wind energy must be considered in the area of Eindhoven.

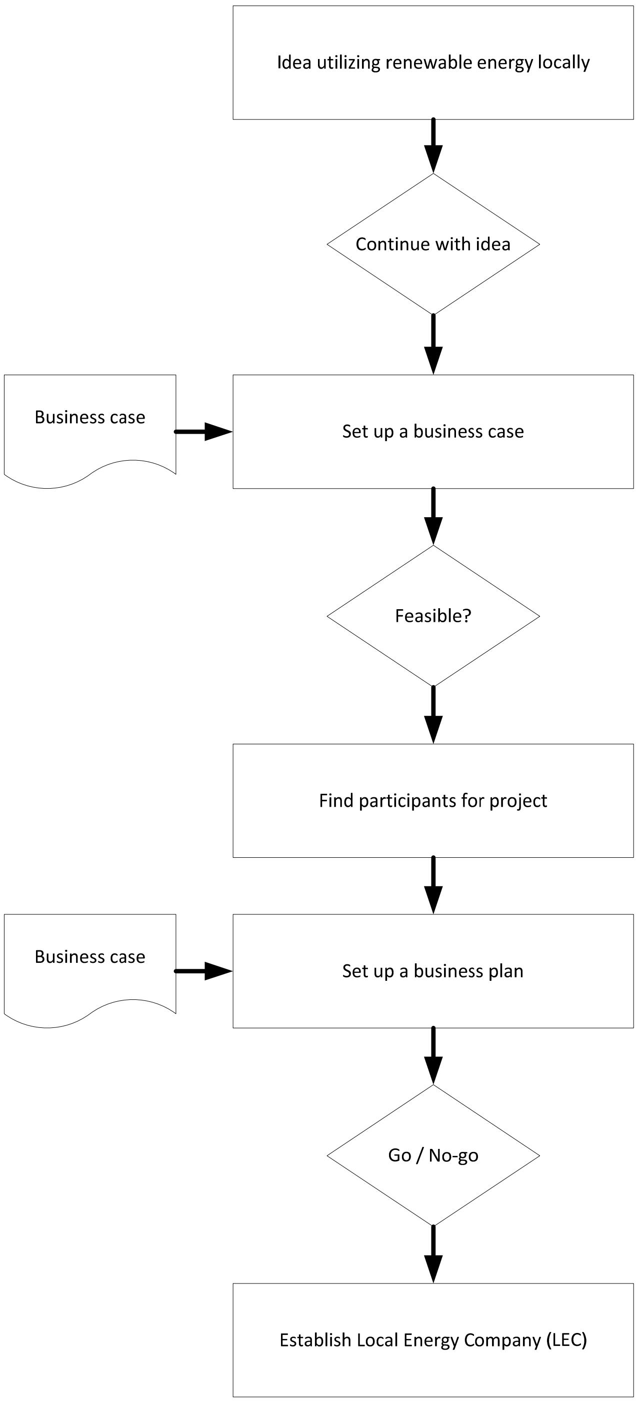
For the biomass installations the KW electric capacity is leading for the total size and capacity of the installation. When the capacity of the installation is 1 MWe, the thermal capacity is about three times as high. This capacity easily generates the needed heat that is given in the solutions. In the energy sector it is custom to calculate in MWe capacity, this is also applied throughout the research.

Of all the variant solutions, number two shows the best financial figures. With the lowest investment costs and the most profit in the first year of operation. However, O&M costs are the highest in this solution; this is due to the biomass installations which produce the largest part of the renewable energy. The solution has one disadvantage; the needed biomass must come from outside the municipality the Eindhoven, because the available biomass in Eindhoven is already used for existing installations.

6.5. Process model for initiatives in renewable energy

An initiative in renewable must pass through a process; this is modelled in the figure below. The end of the process will finally result in establishing a LEC. Per process step comments are mentioned, explaining the step and where support can be found in this report for undertaking the step. The rectangle steps are the process steps, with often underneath a decision making activity. Next to two of the process steps are documents, these need to be elaborated during the activity to be able to make a decision and go to the next phase. The process model ends in establishing a LEC and the next activity would be to realise the project.

<u>**Process model**</u>



<u>**Comments per step**</u>

Possible stakeholder with idea:

- Residents
- Municipality
- Horticulture
- Housing associations
- Local companies

Is the stakeholder going to elaborate the idea?
Put time and effort in the idea.
R-App A: Look at initiatives websites why to continue.

Business case is an instrument to make the idea tangible.
R-H6: For example business case, also units per RET.

R-H6/H4 DMUs: Are (financial) figures feasible the for project .Compare with other initiatives with the same RET. Secondly, is stakeholder going to try to realise the project?

There are many examples of initiatives where a PPP or local stakeholders are collaborating.
R-H2 stakeholders/H4DMUs: Examples of stakeholders and cooperation of different stakeholders.
<u>The goal is to achieve Equity.</u>

Business plan of Thermo Bello is available on their website for example.
R-H4 DMUs/H5- Set of Rules/ App A: Examples of other initiatives and organisational models and the value of parameters in H5.
App. A for additional initiatives not elaborated in this report.

Is the project feasible, is it financialy in order? The next step is realisation of the project and to establish a LEC.

Figure 32: process model for local initiatives in renewable energy

6.6. Conclusion

To create an energy neutral district the Trias Energetica steps are applied. Although this research focuses on the second step, renewable energy generation, energy savings can be expected. The expected demand for energy must be considered when establishing a LEC, especially for the heat supply component. For future demand, three scenarios are elaborated and scenario two is concluded the expected situation. The new energy demand must be generated by renewable energy sources. This is possible on different manners and it depends on the environment factors present at the location. Solution two for renewable energy generation seems to be most profitable for this business case. The financial figures are as follows;

Energy savings investment	€ 23.395.080,-	From energy label D → B

<u>Local Energy Company</u>

Energy generation investment	€ 41.021.600,-
Net income per year	€ 1.202.734,-
Income over 15 years	€ 18.041.010,-

In the calculation is assumed that all the generated heat and electricity can be sold. The total investment is paid back in 15 years, while most installation and grid have a longer life time in practice. If the Self Supply model would be applied for all techniques, yields would be 23 eurocent for all sold kWh. This would increase the profits substantial and make the project more feasible. On the other side, if no SDE subsidy is granted then yields from electricity would be very low. Resulting in a large decrease of the profits and making the project not feasible.

The organisational model is developed according to the results found in this research. Setting up operation companies underneath the mother company is a way of moving liability. It also creates the opportunity of establishing more operation companies next to the existing one. These companies should be divided in locations, for example in the business case called Gestel. The practice is still searching for the correct organisational model, dividing into the different RETs is not convenient for operations.

In figure 30 the location of the business case, two areas are circled. These are existing renewable energy installations, one biomass next to a swimming pool and a heat and cold storage installation on the High Tech Campus. The new LEC, should investigate if they could collaborate with these existing installations. Maybe this will reduce investment and other costs and thus a healthier business.

7. CONCLUSION & DISCUSSION

The final chapter of this research consists of two paragraphs; the conclusion of this research and discussion and future research. In the first paragraph the final conclusions are presented and the on forehand determined research questions are answered. In the discussion paragraph the final conclusions and the most important findings are discussed ones more. The expected research goals are also discussed and in what extent they are reached. Furthermore, from the discussion, recommendations are derived for future research on this topic.

7.1. Conclusion of this research

The on forehand research question are determined before the actual research began. These research questions were derived from reading into the topic and finding gaps or lack of scientific evidence. The research questions are all presented beneath, which are the same as in paragraph 1.4.

Main research question:
Which aspects of Local Energy Companies determine their performance, which initiative can be signalled as "best practices" and how can local actors set up such an organisation considering the aspects.

Sub research questions are;

- RQ1: Who is taking initiative in a local energy company?
- RQ2: Is there a dominant organisational model?
- RQ3: How are the local energy companies utilizing renewable energy techniques including financial structures (which aspects determine performance)?
- RQ4: Which Local Energy Company is performing healthy and how it is financially organized?
- RQ5: Are local initiatives feasible in urban areas?

7.1.1. Conclusion on main research questions

The main research questions actually consists of three parts; which aspects determine performance, which initiative can be signalled as "best practice" and how can local actors set up such an organisation considering previous findings. Each separate part will be concluded beneath.

Firstly the aspects that determine the performance can be divided into two groups namely; the techno-economic and the financial parameters. There are many techno economic parameters which are presented in paragraph 2.4 "conclusion". However, I concluded that the most important techno-economic parameters, who determine the performance, are;

- Installation capacity or size.
- Investment costs per kW.
- O&M costs.

The same applies for the second group, the financial parameters, there are many financial parameters shown in paragraph 2.5 “conclusion”. However, the financial bases that determine the performance are;

- Renewable energy generation.
- Yields per kWh or GJ.
- Return on Investment.

Of course other financial parameters are not disposable and are important for determining if the project is feasible. When determining performance of the LEC, these are the important techno-economic and financial parameters and they give good insights in the performance level.

The second part about “best practices” is difficult to conclude. When looking at the results of the DEA test with all LECs from practice. It shows that heating producing companies are performing the highest in especially the cost efficiency measurement. In the basic technical efficiency measurement LECs with wind energy are performing the most efficient. However, not one “best practice” can be concluded but the LEC Thermo Belle is the closest to full efficiency.

In the measurement with only electricity producing LECs a “best practice” can be signalled. With the assumptions of ECN calculated into comparable LECs also included in the measurement. It shows that one of the government LECs based on assumptions is the “best practice” namely, the manure fermentation. The majority of the LECs from ECN perform more efficiently than the LECs from practice. Only the LECs utilizing wind energy is reaching close to their performance level. Thus the conclusion is that assumptions set by the Dutch government are not yet achieved in practice.

Finally, how can local actors set up a LEC in the Netherlands? With this question a new aspect is important for business success and efficient performance namely, the organisational model of the LEC. During this research twelve LEC were investigated on all three aspects as described in chapter 4. Concluded can be that LEC can be established in multiple ways and not one organisational or ownership model is the correct one. For more explanation on these models I refer to chapter 4.4 “DMUs” and “Theoretical Orientation” chapter 2.3. In the next paragraph further conclusion on organisational models are given with sub research question two. When local actors want to establish a LEC, they should at least consider the three aspects namely; the techno-economic parameters, financial parameters and organisational models.

7.1.2. Conclusion on sub research questions

In the introduction of this chapter Conclusion & Discussion five sub research questions were set up. These questions will be answered in this paragraph in order beginning with RQ1.

RQ1: Who is taking initiative in a local energy company?

After an extensive desk research on finding LECs in the Netherlands, in total 66 initiatives were found. All the signalled initiatives are documented in Appendix A. As elaborated in Chapter 4.3 most initiatives are established by residents. However, the municipalities are a very active local stakeholder at the moment, establishing LECs all over the Netherlands. All the (local) stakeholders that have, or in collaboration with other stakeholders, initiated a LEC are;

- Residents.
- Municipalities.
- Private local companies (mainly waste companies).
- Housing associations.
- Farmers.
- Nature organisations.
- Research organisations.

Especially the top five have proven to establish a LEC with the goal of becoming a successful business. Concluded can be that two groups are taking the most initiatives; the residents and municipalities. Therefore, I conclude that these stakeholders are important to collaborate with in future LECs.

RQ2: Is there a dominant organisational model?

In the answer of the previous sub research question, two groups are very active in establishing LEC namely, residents and municipalities. Both stakeholders have developed a dominant organisational model for a LEC. Below on the left is the cooperative model for residents and on the right the holding model with operation companies underneath it for municipalities. Of course this is not always the case for all LECs initiated by these stakeholders. However, the conclusion is that these organisational models are used often and thus dominant. Furthermore, most other (semi) private local actors are operating LECs through the organisational model on the right. The model now used by residents is derived from the farmers who are already using the cooperative model for years. Thus these are the dominant models for LECs in the Netherlands.

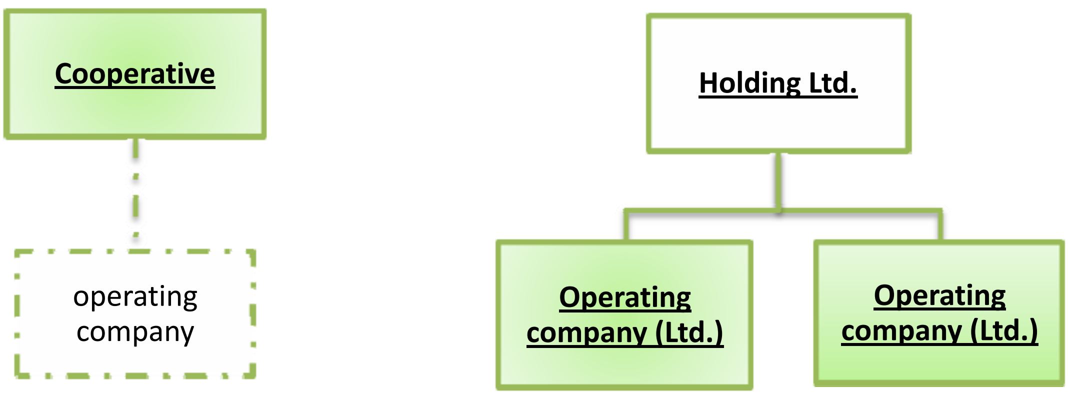


Figure 33: Set of Rules for the organisational structure of a LEC

RQ3: How are the local energy companies utilizing renewable energy techniques including financial structures (which aspects determine performance)?

As mentioned in the answer of the main research questions, the techno-economic parameters and financial parameters are the most important aspects. The tables presented in the conclusion of chapter 5.5., give the values of parameters determined during this research. These values are also used in the business case, giving an example on how to use the parameter in a real case. The parameters give the ability for local stakeholders to make decision on the feasibility of the LEC. The third important aspect is the organisational model. This aspect determines how the involved stakeholders are organised and who benefits from the LEC. This aspect is extensively analysed and conclusions are giving on how to set up such an organisation. Finally, the analysed DMUs presented in chapter 4.4 give good insights on how to utilize RETs and how the three aspects are elaborated.

RQ4: Which Local Energy Company is performing healthy and how it is financially organized?

The analysed LEC (or DMUs) from practice indicate that it is possible to set up a profitable business with utilizing RETs. Although most companies still are very dependent on especially the SDE subsidy from the government. There are now establishing new initiatives utilizing solar panels without subsidy, but applying the self supply models figure 34. Through this model the yields per kWh are higher than when the energy is sold to the grid. Furthermore, this model ensures that the local community benefits from the profit. The LEC Windvogel has applied a self supply model with wind energy generation and it was successful. I think this is a good start in making RETs profitable and without subsidy.

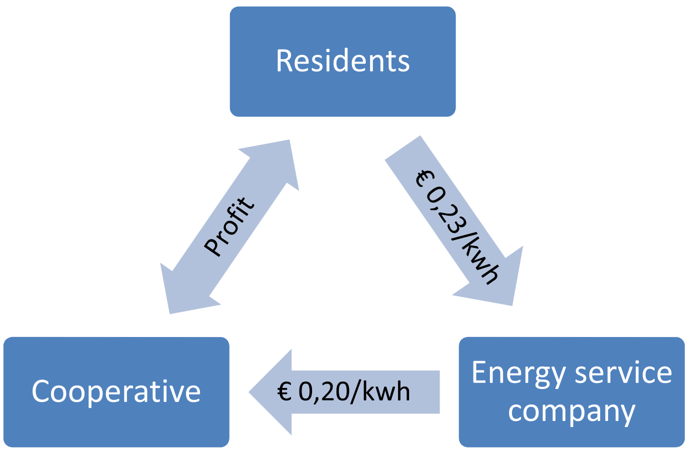


Figure 34: Self supply model with cash flow and actors

RQ5: Are local initiatives feasible in urban areas?

This depends on many aspects, not by simply elaborating the three aspects which are signalled in this research, a profitable LEC arises. Also for instance the right attitude of local stakeholders is very important for creating a successful LEC. However, this research must be seen as a roadmap, an instrument that can serve as a handle while setting up a LEC. The business case in this research, gives an example on how the most important aspects of a LEC can be elaborated. It implies that local initiatives are feasible in urban areas and the first municipalities and other organisations have proven this fact. The conclusion is thus, when the right circumstances are created a LEC in urban environment must be possible and creating a healthy business as well.

7.2. Discussion and future research

First the research goals are discussed and followed by the most important findings. Secondly, a critical note on my research is given, where improvements may be made if I should do it again. Finally, some recommendations for future are presented and where other researchers can connect with this research.

7.2.2. Discussion of research goals

The research objectives are presented in paragraph 1.3 and I will discuss them further below. Summarized were the goals to determine the important aspects of LECs and to create a set of rules to establish such a company. With the final objective of creating a business approach model wherein the aspects are elaborated and a set of rules is applied.
To achieve the goals, the aim is to evaluate the performance and judge the efficiency of a Local Energy Company (LEC) and compare it with other LECs. Furthermore, to set up a benchmarking model were these new types of businesses, in a new dimension of the energy market, can learn from each other. The results will focus on integrating these companies within urban areas or cities.

The research goals elaborated above are achieved in this thesis. In paragraph 7.1 "conclusion" the three important aspects of a LEC are signalled. Through the analyses of existing LECs from practice the values and elaboration of the aspects are determined. The set of rules existing of the three organisational, techno-economic and financial parameters are applied in a business case on a district in Eindhoven. Through this explanation, I can conclude that the research objectives are achieved.

The aim of this research was also to evaluate or assess the performance of existing LECs in the Netherlands. Firstly, a desk research was done to signal all the LECs in the Netherlands, which meet the pre-conditions determined in this research. With the use of Data Envelopment Analysis (DEA) methodology a benchmarking model of LECs is set up. The measurements show that to signalling a "best practice" is very difficult, but it has given many insights in the performance of different LECs which utilize different RETs. The overall goal is adding knowledge to this very new dimension of the energy sector. To give the practice a structured handle which they can use when setting up new local initiatives in generation of renewable energy.

7.2.3. Discussion of the findings and critical note

With the elaboration of every chapter during this research new question arose of course, some were included. However, time and knowledge did not allow taking everything in to consideration and research boundaries had to be made. Looking at the boundaries and executed research afterwards, some action could be done otherwise. This will be discussed here and my research approach is criticised and the findings are discussed. The important findings which will be discussed are;

- Theoretical orientation.
- LECs.
- The benchmarking model.
- Business case.

During the theoretical orientation limitations were set up, especially with taking time in to account. Chosen was to exclude the legal issues from this research. However, when establishing a LEC, legal question arises and these should be handled in practice. Furthermore, I have chosen to elaborate RETs, which are applied in practice and beyond the first phase of the market entree. Of course there are more RETs which a local initiative could utilize, for instance geothermal energy in deep grounds. Through these two points can be questioned whether the right limitations and choices are made in this research.

In the beginning of this research I have made preconditions for signalling a LEC. Other researchers have done this differently, for example the involvement of large energy concerns in LECs. Furthermore, how local are the LECs can be criticized, because some initiatives are not really locally established. However, these companies show the involvement of local stakeholders, especially citizen and have applied innovative organisational and business models. Analysing these companies gives new insights and learning elements and, it is therefore, important to include these examples of LECs.

For the benchmarking model I have applied DEA, for multiple benchmarking tools. As discussed in chapter three. DEA is applied in many energy sector related research and also in the field of generation of renewable energy. However, another researcher could choose for a different methodology with maybe different results. Also the application of other DEA models or with other parameters is a possibility and one might obtain different results. For the first time in benchmarking heat producing and electricity producing companies are compared. Talking with experts this is still questionable, because the sector is usually calculating in a different manner. However, for operating a profitable business in utilizing RETs, information on how much CO_2 is saved is not important. This aspect should be further researched and the benchmarking model should be further elaborated with new knowledge and more LECs.

Finally, the developed set of rules is applied in a business case for a district in Eindhoven. It shows what should be done to become energy neutral and how the LECs can be elaborated in this district. Of course different elaborations of the LEC are possible. In addition, the values of the parameters are changing continuously, because of, for example, prices of RETs or through innovation of RETs increasing their performance. The business case is a theoretical situation not all local actors are approached. The case is elaborated to give more knowhow on the subject and how to use the roadmap in practice.

7.2.4. Recommendations future research

In every research new questions arise which are not answered during the research, these can be elaborated in future research. Furthermore, recommendation can be given for parts of this research which can be further analysed, or parts which fall outside the limitations of this research. The recommendations for future research are;

- Expansion of the benchmarking model and more research in comparing all renewable energy producing LECs.
- The legal issues around LECs and in utilizing RETs.
- Analyse LECs with other RETs which are not included in this research.
- Update the list of LECs and changes in the values of the parameters.
- A more practical elaboration of the business case, make a real practical possible case.
- Additional research is needed in heat producing companies.

LIST OF ABBREVIATIONS

DEA	Data Envelopment Analysis
DMU	Decision Making Unit
ECN	Energy research Centre of the Netherlands
GJ	Giga Joule
GWh	Giga Watt hour
kW	kilo Watt
kWh	kilo Watt hour
LEC	Local Energy Company
MWe	Mega Watt electric
MWth	Mega Watt thermal
PPP	Public Private Partnership
RES	Renewable Energy Source
RET	Renewable Energy Technique

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APPENDIX A: LIST OF LECs in the Netherlands

Nr.	Name	Location	Technique	Initiator
1	Bio-energiecentrale Meerhoven	Eindhoven	Biomass / CHP	Municipality
2	Noordhollandse Energie Cooperatie (NHEC)	Zijdewind	Biomass and Biogas	Municipality
3	Patrimonium Energie BV	Veenendaal	Biomass / Heat	Housing association
4	Businessplan Boerderij Plus	Enschede	Biomass	Private consulting
5	Biomassa energiecentrale Sittard (BES)	Sittard	Biomass	Private actor
6	HVC energie	Alkmaar	Biomass and Biogas	Private actor
7	Orgaworld Biocel	Lelystad	Biogas	Private actor
8	Oude Lenferink biogas installation	Fleringen	Biogas	Farmers
9	Nij Bosma Zathe	Groningen	Biogas	Universiteit Wageningen
10	Biogas installation praktijdcentrum	Sterksel	Biogas	Praktijkcentrum Veehouderij
11	Biomassa-installatie	Beetsterzwaag	Biomass	Nature society De Alde Delte
12	Stichting Duurzaam Bergkwartier	Amersfoort	Heat and Cold Storage	Municipality
13	DEVO	Veenendaal	Heat and Cold Storage	Municipality
14	Ode Energie B.V.	Amsterdam	Heat and Cold Storage	Municipality
15	De wieren Energie bv	Sneek	Heat and Cold Storage	Housing association
16	Stichting Kinetisch Noord / NDSM Werf	Amsterdam	Heat and Cold Storage	Artists / Municipality
17	Warmtebedrijf Hengelo	Hengelo	Heat	Municipality
18	Stadsverwarming Purmerend B.V.	Purmerend	Heat	Municipality
19	Thermo Bello BV	Culemborg	Heat station/pumps	Residents
20	Park Strijp Energy B.V.	Eindhoven	Heat and Cold extraction	PPP
21	Warmtebedrijf Eneco Delft BV	Delft	Heat pumps	PPP
22	Hoogeland energie	Naaldwijk	Rest Heat from greenhouses	PPP
23	Wko arnhem centraal	Arnhem	Geothermal Heat	Government
24	Mijnwaterproject	Heerlen	Geothermal Heat	Municipality
25	LDEB Meppel	Meppel	Geothermal Heat	Municipality
26	Aardwarmte Den Haag v.o.f.	Den Haag	Geothermal Heat	PPP
27	Aardwarmtenetwerk Pijnacker	Pijnacker	Geothermal Heat	Private actors
28	De Windvogel	Gouda	Wind energy	Residents
29	Onze Energie	Amsterdam	Wind energy	Residents
30	Kubbeweg BV	Biddinghuizen	Wind energy	Residents
31	Westfriese windmolen cooperatie	Hoorn	Wind energy	Residents
32	Meerwind	Hoofddorp	Wind energy	Residents
33	Kennemerwind Cooperatieve Windenergie Vereniging	Noord-Holland	Wind energy	Residents

34	Noordenwind	Friesland	Wind energy	Residents
35	CWW Waterland	Waterland	Wind energy	Residents
36	Zaanse Energie Kooperatie	Zaanstad	Wind energy & other	Residents
37	CWW Waterland	Waterland	Wind energy	Residents
38	Windpark SVDW	Dronten	Wind energy	Farmers
39	Windmolenpark Hagenwind	Aalten	Wind energy	Farmers
40	Meewind	Haarlem	Wind energy on sea	Residents / private actors
41	Ecowind Burgersvlotburg	Zijpe	Wind energy	Private actor
42	Stad van de Zon	Heerhugowaard	Solar PV	Municipality
43	Zon op Noord	Amsterdam	Solar PV	Residents
44	Cooperatieve Vereniging de Zonvogel BA	Amsterdam	Solar PV	Residents
45	Doorzon	Friesland	Solar PV	Residents
46	Boer ZOEKT buur (boerENbuur)	Beneden Leeuwen	Solar PV	Residents (farmers)
47	Stichting Xpositron	Amsterdam	Solar PV	Residents
48	De Zutphense EnergieTransitie (ZET)	Zutphen	Solar PV	Residents
49	Zonne-energie in Oosterhesselen UA	Oosterhesselen	Solar PV	Residents
50	Meerzonnestroom	Rural area	Solar PV	Farmers
51	Zoneco Energie B.V.	Lochem	Solar PV	Private actor
52	Spoorzone PV C.V	Tilburg	Solar PV	PPP (Private actors more)
53	Duurzaam Dienstbedrijf Woerden (DDW)	Woerden	Multiple	Municipalitiy
54	Duurzame energiecoorporatie Apeldoorn DeA	Apeldoorn	Multiple	Municipality
55	Lokale Energie Ferwerderadiel (LEF)	Ferwerderadiel	Multiple	Municipality
56	Energie Cooperatie Dordrecht	Dordrecht	Multiple	Municipality
57	Duurzame Energie- en Ontwikkelingsmaatschappij (DE-on)	Flevoland	Multiple	Municipalities and Province
58	Grunneger Power	Groningen	Multiple	Residents
59	ADEM	Houten	Multiple	Residents
60	Energie-u	Utrecht	Multiple	Residents
61	Energiecoorperatie Biesland	Den Haag	Multiple	Residents
62	Stichting Duurzaam Heeten	Heeten	Multiple	Residents
63	Cooperatie Deltawind	Oude-Tonge	Multiple	Private actor
64	Texel energie	Texel	Supply renewable energy	Residents
65	Amelander Energie Coorperatie	Ameland	Supply renewable energy	Residents
66	Vaanster energie	Bilthoven	Investor renewable energy	Private actor

APPENDIX B: SDE+ SUBSIDY

The new SDE+ Subsidy published by the Dutch government in June 2011 (www.agentschapnl.nl)

	Categorie	(sub)categorie	Fase 1 (juli)	Fase 2 (september)	Fase 3 (november)	Fase 4 (december)	Subsidielooptijd (jaren)	Maximaal aantal vollasturen	Uiterlijke termijn ingebruikname (jaren)
			Basisbedrag (€ct/kWh)	Basisbedrag (€ct/kWh)	Basisbedrag (€ct/kWh)	Basisbedrag (€ct/kWh)			
Hernieuwbare elektriciteit (HE)	Stortgas of biogas AWZI/RWZI (HE)	Stortgas of biogas AWZI/RWZI (HE)	0,060	0,060	0,060	0,060	12	8 000	4
	Biomassa (HE)	Thermische conversie biomassa > 10MW	0,090 - 0,154	0,110 - 0,154	0,115 - 0,154	0,115 - 0,154	12	8 000	4
		Allesvergisting (HE)	0,090 - 0,140	0,110 - 0,142	0,122 - 0,142	0,122 - 0,142	12	8 000	4
		Co-vergisting van dierlijke mest (HE)	0,090 - 0,140	0,110 - 0,171	0,130 - 0,202	0,150 - 0,205	12	8 000	4
		Thermische conversie biomassa <= 10MW	0,090 - 0,140	0,110 - 0,171	0,130 - 0,194	0,150 - 0,194	12	8 000	4
	Afvalverbranding	Afvalverbranding	0,110 - 0,131	0,110 - 0,131	0,110 - 0,131	0,110 - 0,131	15	4 080	4
	Windenergie op land	Windenergie op land < 6 MWe	0,113	0,120	0,120	0,120	15	1 760	4
		Windenergie op land >= 6 MWe	0,113	0,120	0,120	0,120	15	2 400	4
		Wind in meer >= 3 MWe	0,113	0,138	0,163	0,188	15	2 000	4
	Wind op zee	Wind op zee	0,113	0,138	0,163	0,188	15	3 180	5
	Waterkracht	Waterkracht >= 5 m	0,071	0,071	0,071	0,071	15	4 800	4
		Waterkracht >= 0,5m en < 5m	0,090	0,110	0,122	0,122	15	3 800	4
		Vrije stromingsenergie < 0,5 m	0,090	0,110	0,130	0,150	15	2 250	4
	Fotovoltaïsche zonnepanelen	Zon-PV >= 15kWp	0,090	0,110	0,130	0,150	15	1 000	3
	Overig	Geothermie	0,090	0,110	0,130	0,150	15	6 500	4
		Osmose	0,090	0,110	0,130	0,150	15	8 000	4
Hernieuwbaar gas (HG)			Basisbedrag (€ct/Nm3)	Basisbedrag (€ct/Nm3)	Basisbedrag (€ct/Nm3)	Basisbedrag (€ct/Nm3)			
	Stortgas of biogas AWZI/ RWZI (HG)	Stortgas of biogas AWZI/ RWZI (HG)	0,288	0,288	0,288	0,288	12	8 000	4
		Stortgas of biogas AWZI /RWZI (HG) groen gas hub	0,170	0,170	0,170	0,170	12	8 000	4
	Biomassa (HG)	Allesvergisting (HG)	0,620	0,637	0,637	0,637	12	8 000	4
		(Co-)vergisting dierlijke mest (HG)	0,620	0,760	0,767	0,767	12	8 000	4
		Allesvergisting (HG) groen gashub	0,579	0,579	0,579	0,579	12	8 000	4
		(Co-)vergisting dierlijke mest (HG) groen gas hub	0,620	0,713	0,713	0,713	12	8 000	4

EXTENDED SUMMARY

ASSESSMENT OF LOCAL ENERGY COMPANY PERFORMANCE
How to utilize renewable energy techniques locally

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ABSTRACT
Governments have shown that they have no solution to offer. The unstable policy has led to a current bottom-up approach by the municipalities and other local stakeholders, to take the initiative in generation of renewable energy. However, little research is executed is this new dimension of the energy sector. This thesis focuses on benchmarking the new Local Energy Companies in DEA and analysing these businesses on three aspects; organisational, techno-economic and financial. The results are a set of rules for establishing new local initiatives who are utilizing renewable energy. Overall conclusion is for the first time a DEA benchmarking model is set up for this kind of businesses in the Netherlands, there is much to learn and improve from each other. Identifying a "best practice" is difficult in the first measurement, since none of the DMUs had all efficiency scores equal to one.

Keywords: Local initiatives, Utilize RETs (Renewable Energy Techniques), Organisational models, Financial structures, DEA (Data Envelopment Analysis)

INTRODUCTION
Is the transition to renewable energy possible and who should take the initiative? During the climate conference in Copenhagen 2009, governments have shown that they have no solution to offer. The unstable policy has led to a current bottom-up approach by the municipalities and other local stakeholders for example social housing associations. Furthermore, the society is also done waiting for the established large energy companies to act. These fossil based energy companies have different agenda's than the municipalities. One cannot expect that fossil fuel/uranium companies will in general support renewable energy (RE) technologies (Hvelplund, 2006). Mainly because a change from fossil fuel based power system to a solar-, wind- and wave-based RE system implicates that the fossil fuel power companies will lose value added at the fuel level and at the power plant level. Secondly, as joint stock companies, they are very sensitive to even minor changes in turnover, so even if they should want RE technologies, often they would not have the financial freedom to carry through their implementation.

It can be observed that organisations linked to existing technologies will initiate project proposals within their organisational framework. One cannot expect alternatives representing radical technological change to originate from such organisations. It is outside their discourse; it is not within their interest or perception (Lund, 2010). Fossil fuel and nuclear technologies are based on large power stations. In contrast, renewable energy and energy efficiency technologies will typically benefit from a wide distribution throughout their geographical areas of consumption. Along with the implementation of new technologies, new types of organisations are therefore likely to develop (Lund, 2010). These new types are at the moment developing locally and are called Local (Sustainable) Energy Companies.

Establishing a community energy project involves many complexities, whichever model of development is adopted and which Renewable Energy Source (RES) is utilized. These include legal conditions under which organisations or projects can operate, establishing a scheme's economic and technical viability (Dunning and Turner, 2005). Furthermore, it is essential to learn from previous experiences (Walker, et al., 2007); especially the last phrase is where this research associates with.

Problem statement

Transition towards renewable energy is in progress and multiple techniques for generating renewable energy are available and well researched. It can be observed that Local Energy Companies are arising rapidly in diverse locations throughout the Netherlands. These companies utilize renewable energy techniques locally and can also be called decentralized generation. However, creating a healthy business of utilizing renewable energy techniques seems to be difficult. Therefore this research will focus on analyzing and measuring the performance of existing local energy companies. Furthermore, recent research and studies have shown the enormous dimension and diversity of local renewable energy in the Netherlands and abroad. Often there is only a global image sketched of their organizational structure, technique and finance and factors for success and barriers, for example in report of (ECN, 2010). Therefore these new market dimension in energy with different business needs to be further examined.

RESEACH METHODOLOGY DEA

DEA, first introduced by Charnes et al. in 1997, is a linear programming technique for comparing the efficiency of a relatively homogeneous set of organisational decision making units, such as schools, banks or business firms, in their use of multiple resources (inputs) to produce multiple outcomes (outputs) (Camanho, 2011). The comparison with the benchmarks also allows to determine the input and output targets corresponding to an efficient operation. This methodology can be interesting for the analysis of the strength and weaknesses of LEC's. For DEA beginners, (Scherman & Zhu, 2006) provided an excellent introductory material. The more comprehensive DEA expositions can be found in the recent publication by (Cooper, Seiford, & Tone, 2006).

Basic DEA Methodology

DEA compares units considering all resources used and outputs generated, and identifies the most efficient units or best practice units (branches, departments, individuals). This is achieved by comparing the mix and volume of outputs generated and the resources used by each unit compared with those of all the other units. In DEA, the organisation under study is called a DMU (Decision Making Unit). In short, DEA is a very powerful benchmarking technique (Scherman & Zhu, 2006).

The linear programming technique is used to find the set of coefficients (u's and v's) that will give the highest possible efficiency ratio of outputs to inputs for the unit being evaluated. The classical model of DEA is presented in the figure below.

$$\max h_0 = \sum_{r=1}^{s} u_r y_{rj0}$$

$$\sum_{i=1}^{m} v_i x_{ij0} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij0} \leq 0$$

$$u_r, v_i \geq 0$$

Figure 1: Classical DEA model, source (Cooper, Seiford, & Tone, 2006)

Where j is the DMU index; r the output index; i the input index; x_{ij} the value of the j_{th}DMU; $y_{rj}$the value of the r_{th}output of the j_{th}DMU; u_r the weight given to the r_{th}output; v_i the weight given to the i_{th} input; and h_0 the relative efficiency of DMU_0, the DMU under evaluation. In this model, DMU is efficient if and only if h_0 = 1.

DEA applications in Energy and Environmental studies

The application of decision analysis in E&E studies has been reviewed by Zhou et al. (2008). Among the wide spectrum of E&E modelling techniques, DEA, a relatively new non-parametric approach to efficiency evaluation, has also attracted much attention. DEA has been accepted as a major technique for benchmarking the energy sector in many countries, particularly in the electricity industry. The first DEA application in the electricity generation sector was the work of Färe et al. (1983), who measured the efficiency of electric plants in Illinois (USA) between 1975 and 1979, in order to relate the scores obtained to the regulation of the sector. Particularly, the analysis made by Pollitt (1996) on the productive efficiency of nuclear power stations using DEA is of relevance to understand this study approach. The general structure of a DEA model as well as the most widely used efficiency measures in E&E studies (Zhou, Ang, & Poh, 2008).

There are also specific studies linked to the efficiency in the renewable energy sector, for example the DEA application of Barros and Peypoch (2007), (San Cristobal, 2011) and (Iglesias, 2010). In the paper of Iglesias et al. (2010) the productive efficiency of a group of wind farms during the period 2001-2004 is measured using the frontier methods DEA and SFA. In that research an extensive definition of the productive process of wind electricity as their starting point is taken. A production relationship is established, which is similar to any traditional electricity generation technology and the researcher could define micro-economic production functions, given by the general formula:

E= $\int(K, L, F)$ Where E is the electrical energy, K the capital, L the labour and F the fuel.

In the study of (San Cristobal, 2011), the (Multi Criteria) DEA model is applied for evaluating the efficiency of 13 Renewable Energy Technologies. The input and output data used to perform the measurement is also discussed during determination of the parameters in this research. These are just two examples of DEA applications in the renewable energy sector, there can be more found on the existing scientific database.

DEA models applied in the research

The executed DEA models in this research are the basic CRR and Allocation models, giving extensive results on efficiency score. The different models are explained in detail below;

CCR-I

CCR is one of the most basic DEA models, which was initially proposed by Charnes, Cooper and Rhodes in 1978 (Cooper, Seiford, & Tone, 2006). The optimal weights of the input and outputs may vary from on DMU to another DMU. Thus, the "weights" are derived from the data instead of being fixed in advance. The weights are chosen in a manner that assigns a best set of weights to each DMU. The term "best" is used here to mean that the resulting input-to-output ratio for each DMU is maximized and relative to all other DMU when these weights are assigned to these inputs and outputs for every DMU. CCR input orientated aim at minimizing the inputs while satisfying at least the given output level. CRR-efficiency exists of two parts Radial and Technical efficiency. Radial efficiency is when the score of the DMU is one but there are nonzero slacks, which are excesses and shortfalls of inputs or outputs. Technical efficiency is when the score of the DMU is one and has zero-slacks, and then the DMU is also called CCR –efficient.

Allocation models

The preceding model focuses on the technical aspects of production. The allocation DEA models can be used to identify types of inefficiency which can emerge for treatment when information on prices and costs are known; this is the case in this research. There are two different situations: one with common unit prices and costs for all DMUs and the other with different prices and costs from DMU to DMU. Since in this research, the prices and costs are expected to be different from DMU to DMU. I will focus on the new cost-efficiency related model. Section 8.3 in the book of (Cooper, Seiford, & Tone, 2006) gives a good explanation of the new cost-efficiency model. The following efficiency models will be executed in the performance measurement of LECs;

$\boldsymbol{\theta}^*$ = CCR technical efficiency

$\overline{\boldsymbol{\theta}}^*$ = CCR New technical efficiency

$\overline{\boldsymbol{\gamma}}^*$= New cost efficiency

$\overline{\boldsymbol{\alpha}}^*$ = New allocation efficiency

DETERMINING THE PARAMETERS

The inputs and outputs for this research are identified in collaboration with companies and combined with recent scientific research. Important to keep in mind is what the practice wants to know about LEC's and thus validate the parameters. In scientific research the five inputs (I) and four outputs (O) are found from the research of (San Cristobal, 2011) and (Iglesias, 2010), see table below. From the researcher's theoretical analysis also a number of parameters are concluded, see table below. Finally, the parameters are presented to the practice and discussed is, which parameters are necessary for comparing and establishing a LEC. All the parameters from different sources are presented in table 8 below.

Source	Inputs	Outputs
Theoretical orientation in LECs	Investment, installation size, O&M	Energy, Revenue, Profit, ROI, Payback time
Recent scientific research	Investment ratio, Capital, Implement period, O&M, Labour, Fuel	Energy, Operating hours, Useful life and Tons of CO2 avoided
Additional from experts		revenue per kWh or GJ, Cost of avoided GJ energy,
Conclusion	Installation size, investment ratio, O&M costs	Energy, Revenue

Table 1: Overview of inputs and outputs from different sources.

For the input parameter, indispensable are installation size, investment ratio and O&M costs. Other identified input parameters shown in table eight are incorporated within the three parameters. For instance Labour is taken into account in the O&M costs parameter. Selecting the output parameter is more complex, because it is important for whom the information is and what they want to know about the performance of LECs. Since this research focuses on business approach, therefore Tons of CO_2 avoided and Cost of avoided GJ energy are not important and excluded. Concluded is that Produced energy and Revenue are important in a business approach. Other for example Profit and Payback time can be derived from these output parameters.

DATA COLLECTION

A Local Energy Company is seen as an autonomous entity, independent of the municipality, with the aim of one or more of the following activities to be implemented locally (SenterNovem, 2010):

- Production, delivery and management of renewable energy in their region.
- Financing and / or participation in the renewable energy projects.
- Energy savings.

Local initiatives are in this research initiative where large established energy companies do not have decision making power and can only be involved in the administrative activities. This means that the large energy companies have not got a say in making decisions and do not have investments activities within these local initiatives. Otherwise, the local community does not profit from the benefits. Other pre-conditions for a LEC in this research;

- Local actors (municipality, citizens, housing association and other private local actors) must have the power to make decisions and profit from the economical or environmental benefits.
- The large established energy companies must not have the power to make decisions nor financial involvement.
- The LEC must produce, deliver and manage renewable energy projects, or at least finance and / or participate in renewable energy projects.
- A Local Energy Company is seen as an autonomous entity.

Local Energy Companies in the Netherlands
In total 66 initiatives were found, sorted by Renewable Energy Technique (RET) and also initiators and location of LEC are given. In the figure below the number of LEC per initiator are given. One can see easily that most initiatives are initiated by Residents. Second are the municipalities, which are upcoming actors that started a lot of new initiatives very recently. Within the group of private actors there are mainly waste companies and collective of horticulture and other private companies. The municipalities are already establishing many LECs. However, sometimes these companies are established with other private actors to construct a Public Private Partnership (PPP). Private partners are so far mainly real estate developers and housing associations. In the group others, are research facilities and one nature society represented.

The Decision Making Units
In this paragraph all of the selected businesses are presented. From every DMU the organization, technique and financial structures are analysed. Finally, their inputs and outputs are presented in the parameters table, which will result in the actual performance of these businesses through DEA. The selected DMUs are; Bio energy Eindhoven, Bio energy Fleringen, Patrimonium Energy B.V., Thermo Bello, NDSM N.V., Onze Energie, SVDW Windpark, Windvogel, Meewind, Zonvogel, Zon op Noord, Boer en Buur.

DEA model data sheet
From all the analysed LEC's values per parameter are derived as presented in tables per case above. These values are placed in a prepared data sheet, according to the format of Cooper, Seiford, & Tone (2006). The parameters are the same for each LEC as determined in previous paragraph. Finally there are different kind of data sheet developed, one that includes all DMUs from. This data sheet is presented in the table 2 below.

However, this is the first time energy companies which produce heat or heat and electricity are compared with companies producing solely electricity. Local initiatives in producing heat for use in built environment are still very scarce. Therefore these kinds of companies are outnumbered compared to electricity producing companies. Furthermore, there is more data and knowledge available, for example, at the government about electricity producing LEC. This has led to a second measurement of benchmarking focusing on the LEC that produce renewable electricity locally. In the data sheet the basic amounts determined by AgentschapNL and ECN are also calculated and included in the data sheet, see second table 3 below. In this measurement the in practice operating businesses are compared with theoretical established cases. There are two versions of the second benchmarking, because of the new SDE+ has just been published. The differences are analysed and resulted in a second data sheet for this benchmarking. The differences are mainly found in the financial parameters, the techno-economic have not change with the new SDE subsidy.

DEA RESULTS
The results of the first data sheet as presented in the previous paragraph, are executed in DEA on Technical as well as Allocation and overall efficiency are given in table 4 and 5. From the results, it can be indicated that the best performer is not easily identified because none of the DMUs has all its efficiency scores equal to one. However, a number of results can be derived from this measurement.

Local Energy Company (LEC)	(I)Installation 10^3kW	(C)Installation 10^3Euro/kW	(I)O&M costs 10^3Euro/year	(O)Energy 10^3GJ/year	(O)Revenue 10^3Euro/year
Bio energy Eindhoven	11,500	1,52	880,00	64,19	2.050,00
Bio energy Fleringen	0,416	1,46	66,00	3,24	118,00
Patrimonium Energie	0,400	0,53	29,67	2,28	48,64
Thermo Bello	1,750	0,34	244,37	9,10	258,61
NDSM-Wharf	2,450	0,42	232,44	7,80	282,90
Onze Energie	2,000	2,00	106,00	18,00	480,00
SVDW Windpark	12,600	0,89	611,10	93,60	2.496,00
Windvogel	2,755	0,99	167,79	18,11	448,51
Meewind	165,000	3,72	30.921,00	1.980,00	104.280,00
Zonvogel	0,120	2,13	4,90	0,37	23,46
Zon op Noord	0,015	3,05	1,05	0,05	2,92
Boer En Buur	0,012	2,56	0,31	0,04	2,17

Table 2: Data sheet of inputs and outputs of all DMU

Local Energy Company (LEC)	(I)Installation 10^3kW	(C)Installation 10^3Euro/kW	(I)O&M costs 10^3Euro/year	(O)Energy 10^3kWh/year	(O)Revenue 10^3Euro/year
Bio energy Eindhoven	11,500	1,520	880,000	6.720,000	2.050,000
Bio energy Fleringen	0,170	3,622	66,000	900,000	118,000
Onze Energie	2,000	2,000	106,000	5.000,000	480,000
SVDW Windpark	12,600	0,890	611,100	26.000,000	2.496,000
Windvogel	2,755	0,990	167,794	5.031,660	448,511
Meewind	165,000	3,720	30.921,000	550.000,000	104.280,000
Zonvogel	0,120	2,130	4,900	102,000	23,460
Zon op Noord	0,015	3,050	1,050	12,700	2,921
Boer En Buur	0,012	2,564	0,310	10,000	2,167
Manure fermentation	1,100	3,100	1.083,500	8.800,000	1.601,600
Solid biomass 0-10 MW	2,000	4,445	1.651,000	16.000,000	3.408,000
Solid biomass 10-50 MW	25,000	3,600	14.350,000	200.000,000	24.400,000
Wind on land < 6 MW	15,000	1,350	750,000	33.000,000	3.168,000
Solar Panels 1-15 kWp	0,004	3,105	0,092	2,975	0,991
Solar Panels 15-100 kWp	0,100	2,145	2,125	85,000	23,800
Solar Panels self supply	0,100	2,145	2,125	85,000	19,550

Table 3: Data sheet of inputs and outputs of only electricity producing DMU with old SDE

Regarding the cost-based measures LEC Thermo Bello received full efficiency marks even though it fell short in its CCR efficiency score. Conversely, although Thermo Bello almost has the worst CCR score (0,476), its lower unit costs are sufficient to move its cost-based performance to the top rank. The obtained CCR score of Thermo Bello shows that this LEC still has room for input reductions compared with other technically efficient DMUs. This means that the operation and management costs are too high compared with other LEC, especially considering the relatively small installation size.

No.	Efficiency DMU	CCR Score	New Technical Score	New Cost Score	New Allocative Score
1	Bio energy Eindhoven	0,586025228	0,562856964	0,269831396	0,479396034
2	Bio energy Fleringen	0,68570392	0,754695463	0,44700859	0,59230327
3	Patrimonium Energie	0,60171778	1	0,702884073	0,702884073
4	Thermo Bello	0,475795132	1	1	1
5	NDSM-Wharf	0,320460148	0,84224051	0,62658653	0,743952022
6	Onze Energie	1	1	0,294101494	0,294101494
7	SVDW Windpark	0,901980036	1	0,545506605	0,545506605
8	Windvogel	0,716502545	0,777255169	0,43405252	0,558442758
9	Meewind	1	0,818801033	0,390889664	0,477392734
10	Zonvogel	0,878678233	0,903527777	0,211177287	0,233725285
11	Zon op Noord	0,64060213	0,557457145	0,146899564	0,263517232
12	Boer En Buur	1	1	0,162046514	0,162046514

Table 4: DEA results of first measurement including all efficiencies

On the other hand, DMU Boer En Buur is rated worst with respect to cost-based measures, although it receives full efficiency marks in terms of CCR scores. This gap is due to its relatively high cost structure. This DMU needs reductions in its unit costs to attain good cost-based scores. Derived from this result is that solar panels are still too expensive compared with the other RETs. This result is amplified by DMU 10 and 11, although the results show when scale of initiative is increased the performance also increases. Overall one can derive that DMUs utilize wind energy score the best.

In the second measurement only renewable electricity producing LECs are included as explained in previous paragraph. The results show that the best performer is DMU 10 Manure fermentation, with all its efficiency scores being equal to one. Reason is that although with fermentation the investment costs are high, the O&M costs are lower because manure is a waste product of farmers. Furthermore, the SDE subsidy is relatively high, so the returns are high which leads to a high profit. One remark is that it is the theoretical manure fermentation business with the best performance. Nevertheless the DMU 2, with the same RET also has a performance above average. By comparing the in practice operating DMUs with the theoretical DMUs it indicated that the theoretical DMUs scores are better than the scores of the practical DMUs. Looking at the different scores per RET, it shows that DMUs who utilize wind energy perform comparable with the theoretical case. The largest difference is found in the DMUs utilizing bio energy with solid biomass. The theoretical solid biomass DMUs are performing a lot better than the practical ones. Although it is just one case in practice, it seems that this RET can improve performance in practice by far. Again as in the first measurement solar energy have the highest unit costs and therefore is the most expensive RET.

In comparing the differences between the old en the just new published (9^{th} of June) SDE subsidy, not many differences are found. Overall the practical DMUs perform relative slightly better compared to the new theoretical DMUs, than compared to the old theoretical DMUs.

No.	Efficiency DMU	CCR Score	New Technical Score	New Cost Score	New Allocative Score
1	Bio energy Eindhoven	0,483001857	0,552706027	0,249696671	0,45177121
2	Bio energy Fleringen	0,901157532	0,674992832	0,566391659	0,839107664
3	Onze Energie	1	1	0,484375	0,484375
4	SVDW Windpark	0,901980036	1	0,898430533	0,898430533
5	Windvogel	0,706950719	0,793292305	0,714868559	0,901141426
6	Meewind	1	0,80036182	0,361721612	0,45194761
7	Zonvogel	0,698642527	0,684203459	0,195419311	0,285615789
8	Zon op Noord	0,548426797	0,444583029	0,135937969	0,305765088
9	Boer En Buur	0,764281206	0,764281206	0,149954659	0,196203515
10	Manure fermentation	1	1	1	1
11	Solid biomass 0-10 MW	1	1	0,81620292	0,81620292
12	Solid biomass 10-50 MW	1	0,917125778	0,861111111	0,93892368
13	Wind on land <6 MW	0,9328	0,986343381	0,631481481	0,640224787
14	Solar Panels 1-15 kWp	1	0,961762422	0,169883961	0,176638177
15	Solar Panels 15-100 kWp	1	1	0,236238121	0,236238121
16	Solar Panels self supply	0,958695652	0,958695652	0,194052742	0,202413291

Table 5: DEA results of second measurement including all efficiencies

CONCLUSIONS & DISCUSSION

The second part about "best practices" is difficult to conclude. When looking at the results of the DEA test with all LECs from practice. It shows that heating producing companies are performing the highest in especially the cost efficiency measurement. In the basic technical efficiency measurement LECs with wind energy are performing the most efficient. However, not one "best practice" can be concluded but the LEC Thermo Belle is the closest to full efficiency.

In the measurement with only electricity producing LECs a "best practice" can be signalled. With the assumptions of ECN calculated into comparable LECs also included in the measurement. It shows that one of the government LECs based on assumptions is the "best practice" namely, the manure fermentation. The majority of the LECs from ECN perform more efficiently than the LECs from practice. Only the LECs utilizing wind energy is reaching close to their performance level. Thus the conclusion is that assumptions set by the Dutch government are not yet achieved in practice.

For the benchmarking model I have applied DEA, for multiple benchmarking tools. As discussed in chapter three. DEA is applied in many energy sector related research and also in the field of generation of renewable energy. However, another researcher could choose for a different methodology with maybe different results. Also the application of other DEA models or with other parameters is a possibility and one might obtain different results. For the first time in benchmarking heat producing and electricity producing companies are compared. The sector is usually calculating in a different manner. However, for operating a profitable business in utilizing RETs, information on how much CO_2 is saved is not important. This aspect should be further researched and the benchmarking model should be further elaborated with new knowledge and more LECs.

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