



## **Community Investment, an 'option' to consider.**

**A System Dynamics Model for a Local Energy Community Coalition**

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# **Community Investment, an 'option' to consider.**

A System Dynamic Model for a Local Energy Community Coalition.

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***“You can’t solve a problem with the same mind that created it.”***  
-Albert Einstein-





## PREFACE

This research is the final chapter of my master course Construction Management & Engineering at the University of Technology in Eindhoven. This research has been executed under the authority of the KENWIB foundation, which performs research for the municipality of Eindhoven to help create an energy neutral Eindhoven.

Finishing this thesis does not only mean finishing my master, but also my life as a student. Such a moment is a great time to reflect on the time at the university and the career which I am about to begin.

This thesis thought me best of both worlds; the conceptual thinking of the university and the realistic side of the practical world.

The people I have to thank the most are my parents. They never stopped believing in me, unless other people thought differently. Also, I want to thank some other people; my brothers, friends, guys from the rugby club. They all helped me to recharge my batteries when they were empty when it was needed.

Of course, I also want to thank my supervisors. I want to thank Bauke and Erik for providing me the opportunity and space necessary during this project. On the other hand providing me direction and focus in times, whenever I was desperate for it.

Also I want to thank Ron for his enthusiasm, positive criticism and helping me to understand the reality of my research.

Finally, I hope that whoever reads this article, he or she will read it while keeping the quote of Albert Einstein of the previous page, in their minds. I do not say this research is going to change the current system, but you have to think more radical to improve the problem.

Mark Looije

Eindhoven, 11<sup>th</sup> of July 2011



## MANAGEMENT SUMMARY

In the quest for more sustainable investment in the build environment, this report tries to provide a model that could be a solution for the split-incentive in the investment decision. The context of this split-incentive, the value created by current investors, is not captured in the current energy system. The stakeholders, which capture this value, are the end-users. This report researches a model where the end-users act as investors in their district. The goal is to provide these new investors with a financial model to decide if such a project is feasible for them.

In the research the model of an Energy Autarky District (Müller et al., 2010) is used as a framework to start from. Autarky district strictly means that the defined district is totally independent from its environment. That is on this moment probably not feasible. However, the goal is to generate energy in the district by using only what is available in the district. Selling this energy generates profit and this profit is used to increase the energy efficiency of the buildings in the district. This investment is done to decrease the total demand of the district. At a certain moment, there is a surplus of energy capacity, it then is feasible to sell the energy to a contiguous district. This benefits the district, because the profit of the sold energy can be turned dividend to the users of the original district.

The method to research this concept is done with using System Dynamics and scenario-driven planning. Georgantzas (2010) has combined these two methods, both developed in the 60s of last century. System Dynamics is a method to show feedback loops of a system and calculates stocks and flows using qualitative and quantitative data. In this research, the qualitative data are the results of a scenario driven planning model.

To value the concept real options are developed. Normally the Net Present Value (NPV) is used to decide if a project should be started. The NPV has the options of; start or reject the project. However, the option wait is not included. The real option theory searches for the optimal moment to invest in a project.

A general model for the concept of an energy autarky district is developed with the LECC as developer. This concept is modeled in SD and scenarios are used as data input. This model for heat and electricity generation is implemented in the district of Prinsjagt in the city of Eindhoven. With a dataset of the municipality of Eindhoven, the district use is implemented in the SD model. The SD model calculates when this case study can make profit on using geothermal heat and solar panels.

To conclude, there are three factors for feasibility; using environmental opportunities, creative search for capital and social spin-offs. The Community Collation Action Theory (Butterfoss & Kegler, 2002) could be a great organization structure for a LECC. This organization starts with a group of early adopters, which can make use of our financial model. Finally, the research shows the result of using the NPV and real option theory in the case of the Prinsjagt. It concludes, that the NPV suggests the project is feasible. However, the Real Option Theory suggests that the optimal value is not reached. Waiting for two years offers the best value. This option to wait can be seen as a call option and is worth 37.000,- euro. With this conclusion, the LECC can decide what to do and start developing a business plan.



## GLOSSARY

The following letters and abbreviations are used in this article. The content is explained in the document. However, the most important and difficult letters and abbreviations are recited here.

### Letters

$\alpha$	drift parameter, growth rate parameter of the Brownian motion
$\rho$	exogenous discount rate
$\sigma$	variance parameter, in Brownian motion
F	Value of opportunity to invest.
I	Cost of Capital
r	riskless interest rate

### Abbreviations

GJ	Giga Joule
LECC	Local Energy Community Coalition
NPV	Net Present value
PJ	Peta Joule
SD	System Dynamics
SdP	scenario-driven planning



# 1. INTRODUCTION

This chapter introduces the theme, problem and purpose of this report. It starts with introducing the context of the subject. This context is a mixture of my personal view and the views of others on the subject. From this context, the problem statement will be derived. From this problem statement, the goal and research questions will be derived. Furthermore, focus and boundaries of the research will be introduced. After that, the relevance of this research will be shown. Finally, a reader's guide will be structured to have a good view on the structure of this report.

## 1.1 CONTEXT

*Today, being a good corporate citizen requires more than business as usual – it requires investments in society and the environment. Short-term thinking got us into the financial mess, and long-term investments that also benefit the world around us can lead us out of it. Any large-scale efforts to solve the great global challenges that do not include the private sector will fall short. We are all shareholders in our children's future and the future of our planet, and by working together we can build an economy in which everyone can benefit from free markets.*

*Former President Bill Clinton, Harvard Business review September 2009*

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Many prominent leaders and scientists have spoken about the change of the energy system and our living patterns to save our planet. However, the 'Green revolution' hasn't taken place. According to many scientists the technologies are available to produce renewable energies (Kajikawa et al, 2008). The problem is that there has not been created a real market for radical green innovations (Hockerts & Wüstenhagen, 2009). Incumbent firms use all their power to only create incremental innovations, which keep them in control. Until now there have only been green innovations. A 'revolution' may only occur when all facades of our energy issues have been bundled. The question is, which actor will stand up and stir 'the revolution'. In the quote of Bill Clinton an important issue is stated; in a sustainable society, the people should act and start developing their own sustainable world.

A renewable energy community has long been advocated, particularly by alternative technology activities, as a way to implementing renewable energy technologies, emphasising themes of self-sufficiency local determination, engagement and empowerment (Dunn, 1978) (Hoffman, High-Pippert, 2005). These communities can start redeveloping their own districts into energy neutral districts.

The path to energy neutral cities can be followed by using the pillars of energy autarky (Müller et al., 2010). The theory of energy autarky rests on three closely related principles;

- The use of endogenous potentials for renewable energy resources rather than energy imports.
- The decentralization of the energy system.
- The increase of the energy-efficiency in the supply side as well as the demand side.

According to the Compact Oxford English Dictionary, the term autarky is derived from the Greek word autarkes and means *economic independence or self-sufficiency*. According to Muller et al. (2010) autarky is, compared with autonomy, a suited word, because it refers to

an open system instead of a closed system. Müller et al. (2010) defines energy autarky as “a situation, in which a region does not import energy resources from other regions, but rather relies on its own resources to satisfy its need for energy services. This strong definition of energy autarky is unlikely to be fully achieved, because exchanges with other regions in reality probably always lead to a certain amount of import of energy resources. Therefore, energy autarky should be understood to be a vision to which to move to”.

In current practice creating renewable energy or sustainable houses is often separated very strictly. Furthermore, the value creation of the investment is not very solid. For two reasons.

1. The investor does not profit from its investment. The end-user receives value of the efficiency of the investment. This phenomenon is called a split incentive.
2. There is no real value received of synergy between the efficiency of the houses and the generation of renewable energy.

A possible solution to solve this split incentive is that the community needs to cooperate together. If they really want to change into a sustainable environment, they can make it themselves. They could be the actors to start the 'green revolution'.

*The main problems of such communities are the uncertainties they face when starting such a community.*

## 1.2 PROBLEM STATEMENT

In the previous chapter some problems are shown. The main problem is that changing into an energy autarky district, the community needs to get involved. Investment in; efficiency, generation of renewable energy, and better distribution channels are value creations projects in favour of the users. To receive these values the community needs to cooperate in the initial investment. Now there is no real view on what this means for these stakeholders.

***Problem statement; the value of a sustainable investment is not captured by current investors; this development stops them investing in sustainable districts. On this moment there are no real investors who act as an energy developer on a large scale. Could a community coalition act as a new developer?***

In this research the stakeholder who should be the new energy developer is already defined. The local energy community coalition is appointed as the stakeholder who should invest in the sustainable district. They will receive the most value of these projects, so they should create it. This research will show the possibilities for starting sustainable communities and support people to start a sustainable community

## 1.3 PURPOSE

The purpose of this research is defined by its goal, focus and research questions. Also clear boundaries are defined.

### 1.3.1 GOAL

To define our research questions, first the goal of this research has to be defined.

This research has the goal to create a tool for energy sustainable communities, who can start redeveloping their district into energy sustainable ones. This should be done by providing them different options of investment in their district.



***The goal is to design a financial decision model to help a community start the redevelopment of their district into one which is energy self-sufficient.***

The main focus in this goal is to show what the financial possibilities are for a community to start a local energy community. This means showing what the current situation is and how energy autarky could financially profit them. Scenarios will be used to help communities understand which different uncertainties there are starting such a company.

### 1.3.2 RESEARCH QUESTIONS

The following research questions are defined.

***RQ 1: What are the factors for financial feasibility of energy autarky for a community?***

- I. Are there feasible examples of autarky projects and what are the lessons to be learned?
- II. What are the most important factors of a change from the current system to an autarky system?
- III. What is the exploitation model for a long term investment in an energy autarky district?

***RQ 2: How can a community energy coalition be organised?***

- I. How can a community be organised and what is the distribution of responsibilities and profit?
- II. In what fields have community coalitions already been implemented?
- III. What are the factors of the decision-making process for investing in a sustainable community?

***RQ3: What are the scenarios for the community as energy developer?***

- I. What are the financial scenarios for the organisation structures?
- II. What is the framework for implementing a community energy coalition?

### 1.3.3 RESEARCH BOUNDARIES

To ensure the research questions are kept in the context of this research, some boundaries are drawn. These boundaries ensure the focus remains in the field of the problem statement and will add something to the stated goal of the research.

- The technological feasibility is assumed proven; the focus is on showing the financial feasibility.
- The focus during this whole project is merely on new technology, because only new technology can be implemented more easily into new projects. However, a real change can be made if the current real estate is changed. That's why only urban redevelopment is being considered.
- The Energy autarky concept in this report is one only developed for communities. This research will not provide a framework for a business plan. Of course this report features aspects which may also become part of a potential business plan, but the end result must be the starting point for elaborating a business plan.
- The scenarios will be general scenarios for the concept of energy autarky; the options will be focussed on the case study.
- The model is focussed on the annual feasibility; data will be used on an annual base. The issues of seasons- and day cyclic is to be included.
- The concept does not include the distribution network for the district heating system. The cost for this network is assumed market conform.

## 1.4 RELEVANCE

The relevance of this research is divided into three parts; scientific, social and personal.

### 1.4.1 SCIENTIFIC RELEVANCE

The information of the scenarios can be valuable for communities which are considering a redevelopment of their district. The model shows structures of financing and organizing possibilities in a community which has been subject to the energetic changes. Knowing your uncertainty can be useful in this process of decision making. The scientific value is the System dynamics model which can be used in other communities. In the future it can be further elaborated due to more social behaviours.

### 1.4.2 SOCIAL RELEVANCE

The consumer demands products (including energy) which are labelled sustainable. However, nobody wants to spend more as possible. Hence, as long as sustainable energy is more expensive than regular energy, this status quo will hardly change. The consumer doesn't see that a sustainable environment is a change in generating and consuming energy. If a consumer is partially owner of an energy company, perhaps he will understand the combination between price(differences) and usage. Only if consumers realize how this impasse works, they might change its current patterns.

### 1.4.3 PERSONAL RELEVANCE

In the debate of creating a more sustainable society, most people are pointing towards the government. They should be the ones more involved into the development of sustainable projects. These speculations are unjust though. Consumers should start doing something themselves. They expect that the government take care of projects, while individuals do not mind these issues, and do not even take effort to understand how the current system works or how to change into a more sustainable household himself or herself and save energy. A construction where local individuals start cooperating could be the incentive needed to start the green revolution. I hope that this research shows that this way of dealing with energy is very possible. Communities throughout the countries can no longer argue they have no other options than the current system. If people really do want to change energy usage and control a sustainable society, I would like to show them that they do have an option.

## 1.5 READERS GUIDE

For a good understanding of the structure of this research, an overview of this document is given. It provides the structure and the relations between the chapters.

First, a literature study will be presented; this desk research has the goal to elaborate the concept of an energy autarky district and the local energy community coalition. Secondly, the research model will be presented. After the concept is introduced in chapter two, the process and methods are elaborated. Thirdly, a general model will be introduced and presented, followed by the parameters which will be explained and underpinned. Fourthly, the general model will be implemented in a real case study in the Eindhoven district Prinsejagt. After the results of this case, a conclusion of the research is underpinned. The concluding results will be discussed and recommendations for further research shall be introduced.

## 2. LITERATURE STUDY

In this literature study the two major theoretical aspects of this research will be analysed; the feasibility of an energy autarky district and the community coalition organisational forms. Firstly, the feasibility of the concept of an energy autarky district will be elaborated. The change to a new system will be analysed and the important factors for this transformation will be created. Secondly, the way to organise an energy autarky district by creating a local energy community coalition shall be explored. This part discusses the most-fitted organisational structure for such a coalition.

### 2.1 AN ENERGY AUTARKY DISTRICT

In this paragraph the definition of an energy autarky district is further elaborated. The theory behind the concept is analysed. Examples of this concept will be analysed and learning points are defined. The method of financial feasibility of the concept is theoretically analysed by looking to transformation of the current system to the autarky system. The system change factors will be shown, which will be important for the modelling process. I shall end this chapter with the conclusions of the feasibility of an energy autarky district.

#### 2.1.1 THE CONCEPT OF AN ENERGY AUTARKY DISTRICT

The concept of an energy autarky district is developed following two major events. It started with the definition of 'sustainable development' by the Brundlandt report in 1987. There, the definition of a sustainable development is defined as; "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1985). The second event was the United Nations conference in Rio de Janeiro in 1992. There the Brundlandt report was called the leading idea for the 21<sup>st</sup> century, which resulted in the creation of the Local Agenda 21 (LA21). The main goal of LA21 is to involve the societal actors on the local level into decision-making regarding sustainability issues by way of collaborative target setting and assessments (Owen & Videras, 2008). Within the LA21 the framework of energy autarky was developed.

In this paragraph the framework will be further elaborated and examples of energy Autarky districts are going to be analysed.

##### 2.1.1.1 DEFINITION OF AN ENERGY AUTARKY DISTRICT

According to the Compact Oxford English Dictionary, the term autarky originally comes from the Greek word autarkes and means: economic independence, or self-sufficiency.

This definition suggests that the district is a closed system. This could be, if the research would focus on a gated community. However, the research is focussed on an open market. The district could be defined as the whole system. The boundaries of this system divides everything between the system and the environment.

In the framework of energy autarky Müller et al. (2010) defines four subsystems; social, economic, energy and ecological.

The focus of this research is on the energy autarky; however the other subsystems are sometimes interconnected.

In Figure 1 the model of Müller is shown. In this figure is shown how the sub-system cooperates together.

In the model primary (P) and secondary (S) energy flows are shown. These energy sources are outside the defined region. These sources need to be limited. The regional resources are used to fuel the region. The other sub-systems provide in this need. Economic factors can increase efficiency improvements, so less energy is needed. The sub-systems will now be individually elaborated.

### 2.1.1.2 THE ENERGY SUB-SYSTEM

Müller et al (2010) defines the energy sub-system of energy autarky on three closely related principles;

- The use of endogenous potentials for renewable energy resources rather than energy imports.
- The decentralisation of the energy system.
- The increase of energy-efficiency of the supply as well as the demand side.

Müller explains the relations between the district and its environment by a system approach and through the principles of thermodynamics (Sonntag, Borgnakke & van Wylen, 2002).

The two definitions of thermodynamics are used to explain the use of thermodynamics in a system.

- Exergy is “the maximum work that can be obtained from a system or flow within a reference environment” (Dincer & Rosen, 2007).
- Entropy describes the amount of disorder in a system. The entropy is at its maximum when the thermodynamic system is in equilibrium with its environment.

Müller uses this thermodynamics theory to explain the sustainable energy system. Such a system is characterised by low entropy. Low entropy can only be achieved if the loss of exergy, which occurs during conversion and transport, is kept low over all parts of the energy flow. This is because any loss of exergy has to be replaced on the basis of energy resources.

The three pillars of the subsystem will now be further elaborated.

### ENEDOGENOUS POTENTIALS

Only in the north of the Netherlands fossil fuels are available. In the rest of the Netherlands energy generation has to be done by renewable sources. Many research is done in these techniques, however this is not a total overview for these techniques. Only a short overlook is presented in relation to the use in a district.

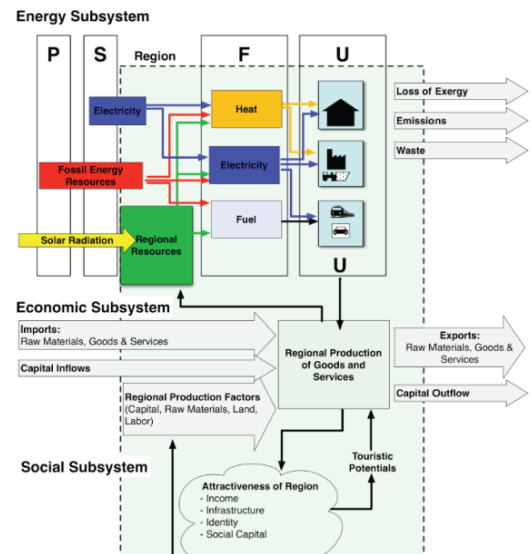


Figure 1 flowchart energy autarky (Müller et al., 2010)

### Rest heat from industry

Before we even start thinking of actually generating the energy, a survey to what is already present should be conducted. For example, abroad a geyser or hot water reservoir could be used as heat source. In the Netherlands there are not such natural chances. However, we have industry plants, which produce a lot of rest heat and waste. Rest heat could be used and waste could be transformed to bio gas. Also we have a lot of greenhouses in the Netherlands whom produces a lot of rest warmth.

### Geothermal energy

Geothermal energy is heat located a few kilometres below the surface. The generation uses heat from the earth to supply us from heat. It can also use a cogeneration unit to also supply electricity. This form of generation has two forms; cold heat combination, and deep geothermal. CHP puts warmth in the ground during summer and uses this in the winter. Deep thermal generation drills in the earth tills it is so heat it can be used in district heating. According research by the Dutch ECN research agency (2011), geothermal energy has large potential in the Netherlands. The price for thermal energy is equal or even less than the current fossil energy prices. And with the probability that prices will rise in the future, it could well be a very good technology to use in our districts.

### Solar energy

A solar panel is the most accessible form of energy generation for the consumers. For a few thousand Euros you can generate warmth or electricity in your home. This is of course a great method, only until now energy cannot be stored on a good way. This means that the reliability of the sun is very high.

### Biomass

The calculations for more use of biomass energy show, that it is possible in the Netherlands. However, the question remains if it should be used in an urban area. In research by Elbersen (2008) the three major suppliers of biomass are; Agriculture, Forrest & Nature, and supplements from the water. The idea of energy autarky means that these resources should fall into the district. However, mostly these resources don't fall in the urban region.

### Wind energy

Wind energy can be divided into onshore and off shore. According Junginer et al. (2004) both methods are financial feasible. However, this research is focussing on an urban district. In an urban area the installation of large windmills is not an option. According to Bahaj (2007) micro-generation wind turbines are close to be financial feasible and market prove in the UK. Like the UK the Netherlands has many wind resources. Despite the relatively low wind intensity in urban terrain, the wind resource is well suited to match domestic electricity demand (Bahaj et al., 2007)

## **DECENTRALISATION OF THE ENERGY SYSTEM**

The concept of energy systems refers to the energy chain, that can be regarded as an entity consisting of energy production, conversion, transmission, distribution and consumption (Energy Information Centre).

A normal assumption would be to define decentralisation the opposite of a central energy system. According Ackermann et al. (2001) and Pepermans et al. (2003) this isn't the case.

Ackermann (2001) state the definition should be based on; the purpose, the location, the power scale, the power delivery, the technology, the environmental impact, the mode of operation, the ownership, and the penetration of distributed generation. The practical definition of the previous one could be that this refers to small-scale (under 200 kWe) energy conversion units that are placed in the same location with an energy consumption point and that are used by a small number of people (Merinova, 2003). According to Dunn (2002) the future of the whole energy chain may be integrated into a building site. For now this is mostly realistic for buildings in the rural areas with no connections to the public network. For the larger areas the 'virtual power plan' can be presented as a solution for the new energy chain. This concept works on a centralized control unit and numerous small local energy conversion units (Hexis, 2003).

Understanding the link between distributed and centralized energy systems and sustainable development requires more extended consideration in terms of political, economic, social and technological issues (Alanne & Saari, 2006). This knowledge is important when developing consulting services for decision support and the implementation and operation of energy systems including new technology, which seems to be an increasing research trend today (DENSYS, 2003).

In research by McDowall (2006) a large literature study has been executed among policy goals to reach the desired end result of a decentralised energy system. The largest policy misconception on all tools of future systems is the lack of theoretical background models, the effects of technology policies in their depiction of a hydrogen transitions, making assumptions about the effects of policies on innovation and diffusion of new technologies, but without making the basis for these assumptions explicit (Geels & Smit, 2000).

What should be important when starting to define decentralise wishes to explicit select the right parameters to focus on. This should start with a system on electricity or heating (or cooling) system.

### **INCREASING ENERGY-EFFICIENCY**

Increasing the energy-efficiency on both the supply and the demand side is of central importance; by increasing the efficiency the amount of primary energy used to provide a given level of energy services to the population can be reduced (Müller et al., 2010).

Before a further elaboration of this theme is made, a short look to the reason why users don't invest in energy-efficiency. It has been shown that the widespread adoption of existing energy-saving technologies could enable a significant reduction in energy use, especially in the short and medium run (Beer, 1998) (IWG, 1997). In research by Mulder et al. (2002) they define four reasons for not investing. The first explanation is that the combination of uncertainty and some degree of irreversibility in investment creates an option-value of waiting (Dixit & Pindyck, 1994). The second explanation stresses strategic issues: in a world characterised by spill over's and limited appropriability, the presence of (expected) rival innovation and imitation creates an incentive for firms to postpone innovation or adoption (Reinganum, 1981). The third explanation highlights the fact that over time the performance of existing technologies improves and their price reduces due to learning-by-doing and spill over effects (OECD/IEA, 2000). A final explanation emphasises the role of vested interests. As switching to new technologies (temporarily) reduces expertise and hence destroys rents associated with working with relatively old technologies



for particular subgroups in the economy, these groups may engage in efforts aimed at keeping the old technologies in place (Canton et al., 1996).

### ***2.1.1.3 THE ECOLOGICAL, ECONOMIC AND SOCIAL SUB-SYSTEMS***

It has to be said that measuring the effects of the ecological autarky is hard and even harder to prove. On the ecological level of energy autarky two levels can be defined; the global and local level. On a global level, the ecological contributions of reducing the amount of fossil fuels reduce the emissions of greenhouse gasses. On a local level the ecological effects can contribute as fuels for the district. Organic waste can be used to generate bio-energy. Further, the demand for local agriculture waste may remain the culture landscape.

Economic effects can be seen as a very large scale of activities; the goal of economic sub-system is an increase of volume of production and employment in the region. Of course is the increase all realised on a sustainable way. All economic activities which were first focussed on the central point of energy generation can now be located on the decentralise point in the district. These activities are input for new economic and innovative activities. The entire value chains can be developed on local level. A critical note to the economic sub-system is that not every district has the opportunity to profit from its local resources.

Like the ecological sub-system the social sub-system is hard to prove and is depended on the entrepreneurial spirit of the district.

### ***2.1.1.4 EXAMPLE OF ENERGY AUTARKY***

The concept of an energy autarky district can be hard to understand. It is a rather different system toward the existing system. That's why an example of a real project is introduced and analysed. This analysis has two purposes. First to show an image of what the results can be of this concept. The second objection is to learn some lessons from good and bad implementation in this example. The choice is fallen to the biggest project in Europe, the town of Güssing in Austria.

#### **Güssing**

Güssing is a small town in south- east Austria. It is located 130 km east of Vienna see Figure 2 and is close to the Hungarian border. With a population of around 4000 people, it is totally reliable on its small-agriculture.

Until 1974 it even hadn't received town status. In 2004, Güssing received the European Solar Prize in recognition for its sustainable regional development process (Euro solar, 2004). In September 2005, its European Centre for Renewable Energies (EEE) was awarded the Global 100 ECO-TECH Award in Japan for the 'Güssing model', winning ¥1 million in prize money. What happened in Güssing?



Figure 2 map of Austria



Figure 3 the town of Güssing with its medieval castle and new biomass installation source [www.bcsd.co.uk](http://www.bcsd.co.uk)

In 1990 the Güssing council voted for a policy which would make Güssing and the surrounding district autarky on fossil fuels. Güssing is the first community in the European Union to produce its entire energy demand (electricity, heating/cooling, transport fuel) out of renewable resources (IEA, 2009).

The first step the town of Güssing made was to decrease the demand of energy. They started reducing the energy of public buildings and old buildings; this saved them 50% of the energy use (Boekel & Neven, 2008). With this data an analysis of possible supply of renewable generation was made to satisfy the demand of energy. The town is located in a forest and agricultural area. There is enough wood and agriculture waste to generate the town's energy. In addition, waste of the parquet-floor company in the neighbourhood supplies the system of extra wood. The district of Güssing has around 300 days of sun a year, which makes it also perfect suited for solar energy.

Overviews of the technology results are enumerated below.

- The biomass plant supplies 23 MW of heating to District Heating network by processing 24000 tons of agricultural and forestry material (IEA, 2009).
- The biogas generates 0.5 MW of electricity and 0.6 MW of heating by using 11.000 tons of silage of 250 hectares of farmland. This installation cost 2,1 million euro (IEA, 2009).
- There are two solar units, which generate 9MW of electricity and 15 MW of heating a year. Also there are many individual panels on private houses.
- The most innovative installation is the biomass gasification plant. With fuel capacity of 8MW, the plant operates 8000 hours a year to produce 2,5 MW of electricity and 4,5 MW of heat for the DH by producing 2300 kg of wood per hour (IEA, 2009).

According to Greenup and Go (2007) 8MWh is fed into the national grid, generating 4.7 million in revenue. According to the municipality (2005) they generate 13 million euro each year, this in comparison to the cost they spent in 1991, which was 6.2 million euro. Next to this profit the investment in an autarky system resulted in; a job creation around 1000 jobs, establishment of 60 new companies, the increase of eco tourism in the region.

### Lessons learned

The purpose of the lessons learned is to receive information on the process and organisation of the current project.



The project of Güssing is a successful project; the investment generates a positive cash flow. Hence, it is the most autarkic town in Europe. So what stops us from copying this framework into our own? In the research framework, the framework is focussed on the urban area. Güssing uses to his environmental resources, it generates energy with; biomass, biogas and solar panels. For the Netherlands urban and rural areas are pretty much separated. So to fit Güssing into the framework of an urban area would have serious influence in the boundaries between cities and towns.

However, Güssing is technically making profit, however it has received huge financial supports from the European Union. This said a positive cash flow can be doubted.

To summaries the following points are learned from this projects;

- Definition of a rural or urban area, or a combination
- Every district needs to have it own resources analysis
- Initiator and their interest in the project is needed to start the project

## 2.1.2 THE CHANGE-FACTORS OF AN ENERGY TRANSFORMATION

*Portions of a system cannot be altered or removed without altering the overall system, sometimes to the point of jeopardizing its viability (Blum, 1976).*

Two fundamental trends in society are important drivers in the long –term development of the electrical power system (Botterud, 2003). The first trend is the demand for better cost efficiency. The second trend is the increased public awareness of the influence of our energy use to the world's environment and resources. According to Botterud (2003) these two trends, contribute to change the conditions under which the participants in the electrical power system operate.

The purpose of this paragraph is to analyse the current traditional system and the possibilities of a decentralise system. The goal is to research if there are important issues concerning a change from central to a decentralise system.

### 2.1.2.1 Change factors

Systems are made up of parts, yet the whole is more than the sum of its parts (Ackoff, 1993) (Churchman, 1979).

In their call for contributions to the special issue of the AJCP, Foster-Fishman and Behrens (2007) defined systems change as “efforts that strive to shift the underlying infrastructure within a community or targeted context to support a desired outcome, including shifting existing policies and practices, resource allocations, relational structures, community norms and values, and skills and attitudes”.

What is a system? A system consists of two or more entities, joined by some commonality, to form an organized structure which operates according to rules set out to address a higher order purpose (Battista 1977; van Gigch 1974)

What is systems change? “When the concepts of systems and change are merged, the connotation becomes a process of transformation in the existing structure, function and/or culture of a system. With emphasis on the system as the level of analysis it is essential to

differentiate changes that have broad relevance and implications for the system as a whole from changes occurring only within specific elements (Kelly et al. 2000)". Furthermore, it is important to distinguish whether the systems change is "first-order" or "second-order" (Watzlawick et al. 1974). First-order change represents the natural progression of a system as it adapts to minor and mostly predictable challenges and events over time. The goals and/or impacts of such change do not alter the elemental structures, functions or culture of the system. In contrast and consistent with Foster-Fishman and Behrens' (2007) definition, second-order change intentionally targets the status quo to transform or reframe fundamental system dynamics, structures, resources, rules, norms, and relationships.

### **2.1.2.2 Current system**

The strategy of traditional power generation is to minimise the cost of expansions of generation capacity. The focus was almost entirely on the supply –side of the power system, while demand was simply assumed to follow a forecasted growth rate (Botterud, 2003). Dyner and Larsen (2001) define two technique, which are used to plan their resources; Generation Expansion and Integrated Resource Planning, and Multi-Criteria Trade-off Analysis.

#### **Generation Expansion and Integrated Resource Planning**

The aim of this planning method is to reduce cost of operate as much as possible and expand the generation capacity. This means that the supply side is more important than the demand side. In this planning method the demand side was forecasted on positive growth rate. The principal goal in integrated resource planning is to meet the demand for energy services at least cost (Swisher et al., 1997). The methodology is developed In the USA, but can be applied in different regions on local and national level.

#### **Multi-Criteria Trade-Off Analysis**

Developing a long-term infrastructure installation always encounters protest. Many stakeholders are involved and there are always people with conflicting interests. Methods that use these interests into account are defined as multi-criteria decision making methods. The objective for the multi-criteria methods is to help decision makers evaluate the trade-offs between different system criteria, such as total cost, emissions and reliability (Botterud, 2003).

A short overview of the process will now be given according Hobbs and Meier (2000). It starts with selecting the system criteria by the decision makers. This system will be will be simulated and criteria for technological configuration will be determined. To this system some assumptions will be given. Then the criteria will be assigned with values according decision makers and stakeholders. With the total value an optimal system can be judged.

#### **Overview regulated system**

The methods used; integrated resource planning and multi-criteria analyses are good methods, why don't they fit anymore. In a decentralise system, the decision making process is not carried out anymore by the central energy system. According Botterud (2003) robust power system investment strategies which are identified through these methods cannot be directly implemented, since the degree of centralised planning is low.

### ***2.1.2.3 Decentralise system***

In the decentralise system the goal is to create a better position for the individual stakeholders. In this way they could have a better say in the decision model. Botterud (2003) defines three methods which can be used to create this new systems; system dynamics, multi-agent modelling, and game theory.

System dynamics is a descriptive modelling methodology where the focus is on behavioural simulation of systems at a high level aggregation (Botterud, 2003).

Multi-agent simulation is a tool for analysing the collaboration between agents in a system. In the context of electricity markets multi-agent modelling is well suited for short-term analysis of bidding strategies in the spot market (Ventosa, 2003).

Game theory is another approach which is frequently used for analysis of power markets with a limited number of participant, both in a short term price and long-term investment perspective (Ventosa et al., 2002).

The effect of the change of a system increases the uncertainty in the system. The effect of these uncertainties can still be incorporated into scenario planning techniques, where the purpose is not to identify optimal investment strategies, but rather to gain increased insight into the range of outcomes that the future might bring (Botterud, 2003).

The concept of energy autarky asks for a system which focuses on the decentralise system. In chapter three a research model for the concept is constructed. In this model a system method is used which suite one of the suggested method.

## 2.2 THE LOCAL ENERGY COMMUNITY COALITION ORGANISATION

In this research a financial tool to develop a model of a sustainable community is investigated. In such a research the organisation form structure is very important. The goal in this paragraph is to search for a framework for such an organisation.

Brundtland (1987) defined a sustainable development as “development that meets the needs of present without compromising the ability of future generation to meet their needs. It contains within two key concepts: the concept of needs’, in particular the essential needs of the world’s poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization of the environment’s ability to meet present and future needs.”

The community coalition model is an appealing concept; it expresses the western liberal values of democracy by encouraging citizens to seek solutions to their own problems and by collaborate among multiple stakeholders to jointly tackle intractable problems that could not be addressed by a single stakeholder alone. More importantly, According Kegler & Butterfuss (2002) community coalitions present ripe opportunities for adopting recommended community participatory action research principles, where community members work in partnerships with researchers to collectively define local problems, identify and implement solutions to them, and evaluate their impacts. Initiating and sustaining coalitions is no simple task. However, it is a complex dynamic process that involves multiple coalition-building tasks

First, general organisation forms for a community will be discussed. Secondly, the theory on community coalitions will be introduced. Finally, a short introduction on an investment decision model, for a starting a community, is introduced.

### 2.2.1 COMMUNITY ORGANISATIONS

Projects that involve community ownership can be described as; financial investment or managerial controls by or on behalf of groups of members of the public-- have achieved this to different degrees and in different ways (Stamford, 2004). Projects can be 100% community owned, or may be developed under co-ownership arrangements with the private sector, different legal and financial models of ownership have been adopted (Walker, 2008). These include:

- **Cooperative ownership.** Baywind is a good example. It is setup as the first cooperatively owned wind farm in the UK in the late 1990s, using a model transferred from Scandinavia (Walker, 2008). People in the local community or further afield become members of the cooperative and buy shares to finance the project.
- **Community charities.** These usually take the form of an association with charitable status that provides or runs facilities for the local community, such as village hall associations which use renewable energy to heat or power their buildings. Such charities can also have trading arms or community interest companies to provide local service.
- **Development trusts** These have been particularly used in Scotland to represent communities’ interest in revenue generation enterprises, and in some case this has been extended to include variants of community ownership.

- **Shares owned by a local community organisation** The gifting of shares in a commercial project to a local community organisation such as a trust, has been used as a way of providing a community benefit that is closely tied to the performance of the production unit (CSE et al, 2007)

### **Organisational form**

The four forms introduced by Walker (2008) have the intention of actions by the community. However, the form of an energy autarky can only be developed with the form of an active attitude. The cooperative ownership model is the only form that has this factor. The other three forms don't have the goal and means to achieve an energy autarky district. They depend too much on the commitment of outside stakeholders. The cooperative ownership model is studied by Stamford (2004), in analysing the feasibility of such a model, on a community owned find farm. For this research he analysed this by the community owned models in Denmark and Germany. The result of this research is that Stamford defines three models; community led's- community owned (CLCO); developer led's, community owned (DLCO); investment fund led, community owned (IFLCO). Stamford (2004) defines five success factors for the best structure; feed in tariffs, significant tax advantages, standardised grid connection and interconnection agreements, a domestic sustainable manufacturing base, familiarity with co-operative forms of ownership.

### **2.2.2 THEORY OF COMMUNITY COALITIONS**

The starting point for a community, which wants to develop their district into an energy autarky one, is to organise their selves. This can be done in many ways; the most important one is the right balance in their collaboration. In literature research to the use of community coalitions in energy autarky or energy neutral cities, no results were found. Many researches on the theory of community coalitions are done in health communities. In a recent review, the University of Chicago (2011) presented an overview of the most important community coalition's models.

The NORC (2011) defines three unique functions of community coalitions. First, community coalitions create collaborative capacities among a large group of stakeholders. Secondly, community coalitions build social capital. Thirdly, community coalitions are catalyst of change. Local policy can be changed by the fact that the community has proven that it works.

According to the NORC (2011) there are two theories on community coalitions; Community coalition Action Theory (Butterfoss & kegler, 2002) and the empowerment theory (Fawcett et al., 1995). These theories will now be further elaborated.

### **Community Coalition Action Theory**

A community coalition is defined as a "group of individuals representing diverse organizations, actions, or constituencies within the community who agree to work together to achieve a common goal" (Butterfoss & kegler, 2002).

In Figure 4 the model of Butterfoss & Keggler is modelled. It is divided in three stages of development.

- Coalition Formation
- Maintenance
- Institutionalizing

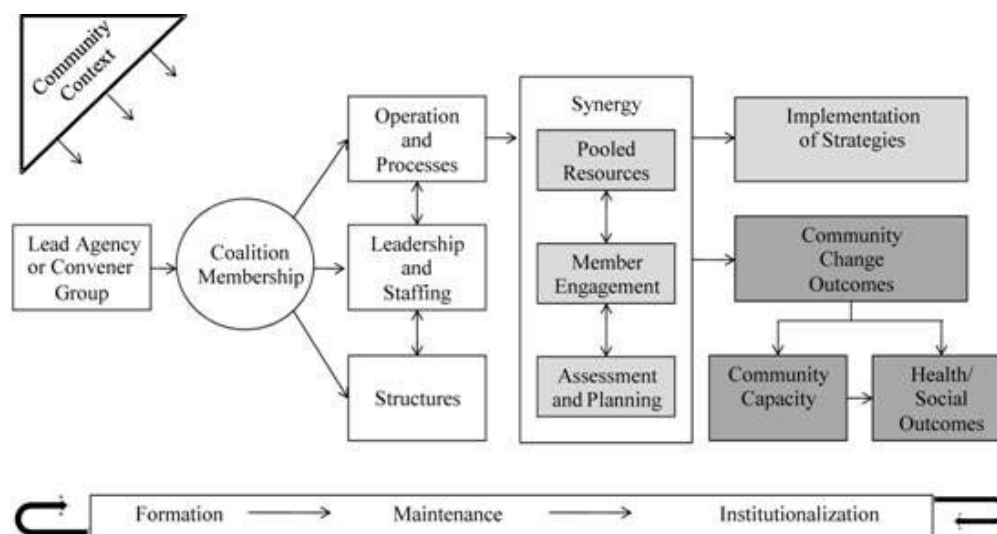


Figure 4 Community Coalition Action Theory (Butterfoss & Kegler, 2002)

### Coalition Formations

During coalition formation, a convener or lead agency brings together a core group of organizations that will then recruit the initial members. Leaders and staff are identified and structural elements such as committees, rules and operating procedures are developed (Butterfoss & Kegler, 2002).

Key factors in the formation stage include resources exchanged by potential members that lead to inter-organizational cooperation; payoffs for coalition members; and adequate size of a core group (Butterfoss & Kegler, 2002).

### Coalition maintenance

In this stage it is important to keep a sort of continuity in the community. This is done by recruiting new members and searching for new and external resources. The key in this process is to prove and identify the positive benefits. For an effective community Kegler, Steckler, McLeroy & Malek (1998) developed twelve factors in the model; leadership, decision-making, communication, conflict, benefits and costs, organizational climate, staffing, capacity building, member profile, recruitment pattern, organizational structure, community capacity.

### Coalition institutionalization

This stage has the purpose to look to the long-term structure of the community. Building community capacity to solve new problems in the future is part of this stage (Butterfoss & Kegler, 2002).

### **Empowerment Theory**

According to Fawcett et al. (1995) Empowerment Theory explores the process of gaining influence over the conditions that matter to people who share communities, experiences, and concerns.

The empowerment Theory consists of three dimensions:

- Person or group
- Environmental
- Empowerment capacity and outcome

Person or group: A vital position in a partnership is the position of its leader. The success of the community depends on, how well they can exploit chances and facilitates their selves.

Environmental factors: external influences can have affect on the change the community wants to achieve. There can be many resistant's; culture values, economic values and policy and laws.

Empowerment and capacity and outcome: The value of a community can change, capacity can change. The success of a community depends on how well they can manage the internal change.

**Collaborative planning** ensures the diversity in the organisation, which ensures a wide platform for changes in the community. **Community action** is the management of the leader to keep the goal of the community as the centre of attention. **Community change** is the result of community action and could encourage new policies and opportunities. **Community capacity and outcome** is the desired state position of the community. **Adaptation, renewal and institutionalization** the community needs to keep an ambidextrous position towards their own goals. They need to have a sharp control on their own goals in the future.

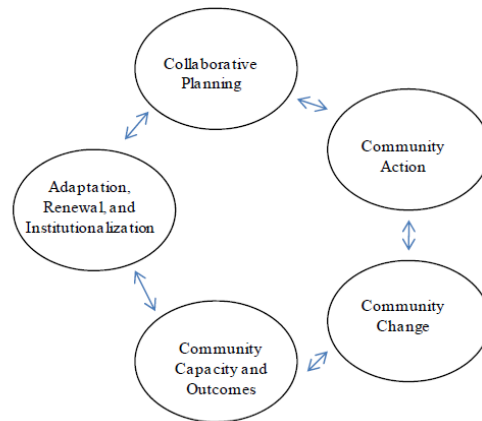


Figure 5 Empowerment theory (Fawcett et al., 1995)

### Programs of Sustainability Communities

In the review of NORC (2011) sustainable communities can be explained on two different ways. First sustaining the community as an organisation and the second definition, the sustainability of the activity of community is observed. In the research only the second definition is relevant.

There are two programs that support the definition; Model for sustainability in Community Health Partnerships by Alexander (2003), and Model for Evaluating the Sustainability of Community Health Initiatives by Berry (2005).

### Model for Sustainability in Community Health Partnerships

According to Alexander (2003) the key emphasis of the model is that there are factors associated with value creation and sustainability. Sustainability is built on the value that collaborative capacity adds to the community and community health and on the collaborative process through which this value is created (Alexander et al., 2003). The five sustainability-enhancing factors are outcomes-based advocacy, vision-focus balance, systems orientation, infrastructure development, and community linkages. It uses four contextual factors that affect the partnership: historical/cultural, political, physical, and economic. Historical/cultural environment is the commitment of adopters and the experience from previous encounters with communities. Political environment is the commitment government policies toward the community with their geographic factors. Physical environment are the geographic factors. Economic environment are economic factors which influence the community.



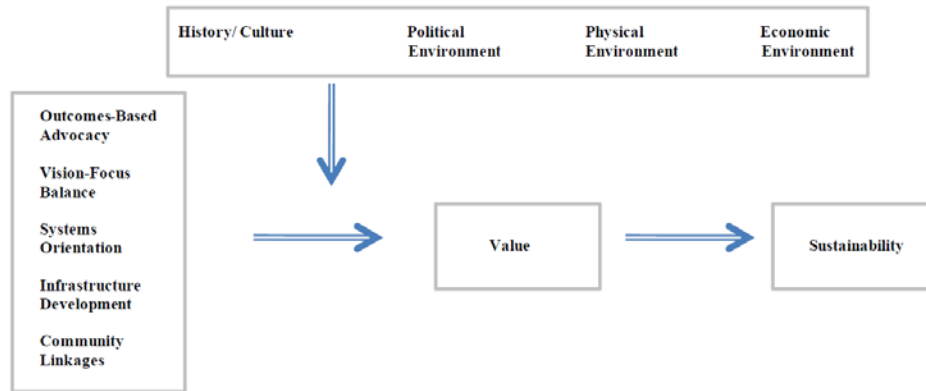
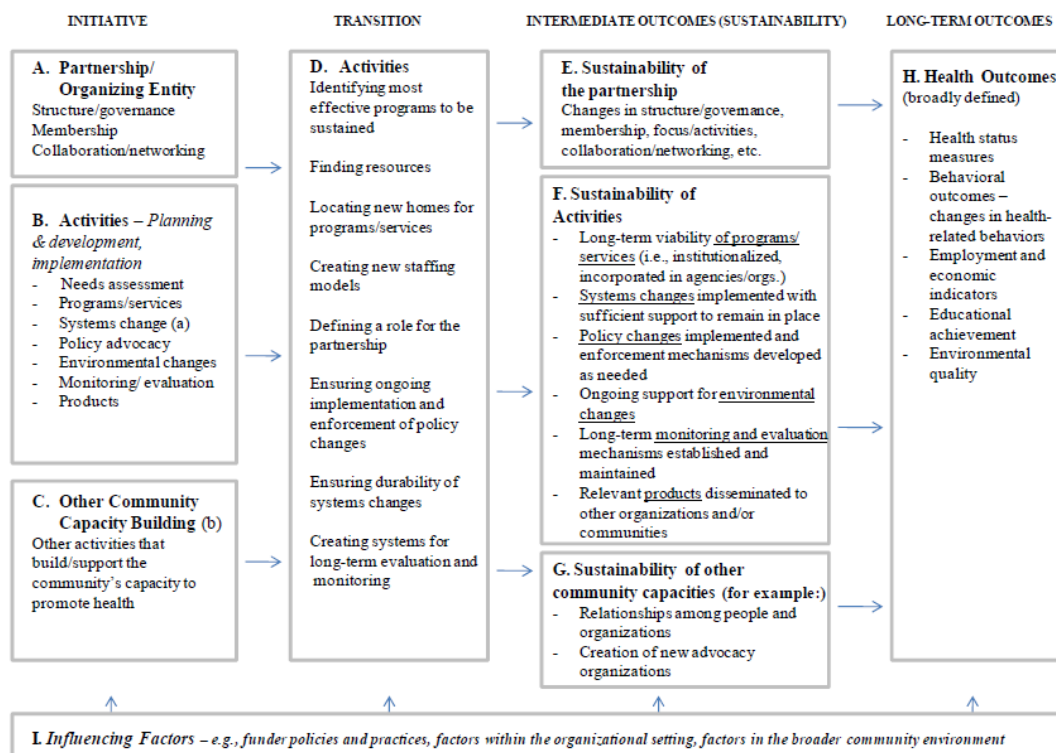


Figure 6 Model for Sustainability in Community Health Partnerships (Alexander et al., 2003)

### Conceptual Model for Evaluating the Sustainability of Community Health Initiatives

Berry et al. (2005) developed a conceptual framework that examines sustainability in a community health initiative led by a community partnership. This model, shown in Figure 7, shows the transition from project initiation to intermediate and long-term outcomes, using a logic model framework (Berry et al., 2005).

The model begins with the column of initiatives. This contains the start of the community with thinking on the structure of the organisation, its memberships, planning and overall capacity. The transition column shows the first activities which support the initiative. This is mainly finding the resources and creating systems for the organisation. The intermediate outcomes show the changes in the environment and their sustainability impacts on the elaboration of community goals. The last column shows the long-term outcome which is the result.



(a) For example, integrated services, data sharing or integrated data systems, results-based budgeting.

(b) For example, health literacy, resident leadership training, organizational development.

Figure 7 Conceptual Model for Evaluating the Sustainability of Community Health (Berry et al., 2005)



This report will not further elaborate the possibilities of the community organisation structure or program. However, for the final modelling actions some assumptions need to be made. This needs to set up the best choice made on the organisation of the community coalition.

In this research the community coalitions is formed by combining the CCAT with the conceptual model evaluating the sustainability of community health. In chapter four a global sketch of such an organisation is developed.

## 2.3 THE INVESTMENT QUESTION

Transforming your district, in a way such as the LECC describes, brings a huge impact for all users of the district. The decision to start such a development process is a very complicated and hard. It should give a good picture of what the investment project brings. In this paragraph the method to validate such an investment is introduced. First a brief overview of how consumers view the decision process is introduced. Secondly, the traditional financial method, the net present value, to validate such questions is introduced. Finally, the real option theory is introduced; this method gives the consumer an extra option to validate the project.

### 2.3.1 INVESTMENT DECISION BEHAVIOUR

The fact that a financial model says an investment is wise doesn't mean a consumer will proceed to start this investment; the adopters of the concept have also other measurement methods.

Consumer decision making can be conceptualized as a series of stages progressing from the recognition of a need to a search for information about alternatives, the formation of a consideration set, a formal evaluation of the considered alternatives, a choice, and finally, post choice processes such as satisfaction or disadaptation (Tuan Pham & Chang, 2010). The person's regulatory focus is a specific strategic and motivational orientation that the person adopts during goal pursuit (Higgins, 1997). Higgins (1997) divides this regulatory focus into a promotion focus, which has the goal to gain extra value, and the prevention focus, which defines the amount of risk which is taken. Recent research by Tuan Pham & Chang (2010) shows the behaviour between promotion-consumers and prevention-consumers. The first finding is, that promotion-focused consumers analyse their problems on a more abstract level, where the prevention-focused consumers want a concrete realistic solution. Secondly, the research shows promotion-focus consumers have larger consideration sets, instead of prevention-focused consumers. These results underpin the following conclusion. Promotion-focused consumers attach relatively greater value to options chosen from hierarchically structured decision environments, prevention focussed consumers attach relatively greater value to options chosen from non-hierarchical structured lists.

The knowledge on this information can be critical for starting a community. Promotion-focused people tend to act very quickly. While prevention-focused people first want more accuracy. This means in a community coalition, that in the early stage promotion consumers need to convince the prevention consumers with the right alternatives. So the SD model, which is this model in the early stage, must convince prevention people. This can be done by many options and accuracy, which means good validation.

### 2.3.2 THE NET PRESENT VALUE

How to assess the opportunity to invest into the energy autarky district concept? The financial tool, which is going to be used, is here introduced. When assessing an investment decision, the normal tool to use is be the Net Present Value (NPV).

Finance literature generally uses the net present value as the tool for deciding to start a new project.

The net present value is the sum of all discounted cash flow from the project, as can be seen in eq. 1-1. In this formula, the sum starts at,  $t$  is zero, and ends at,  $T$ , the end of the project. The,  $V_t$ , is the total cash flow of that specific year,  $t$ . The cash flow is discounted by the discount rate,  $r$ , which is raised to power time,  $t$ . A positive result means a go; a negative result means to abort the project.

$$NPV = \sum_{t=0}^T \frac{V_t}{(1+r)^t} \quad (1.1)$$

#### The pitfall of the NPV

In his journal – Uses, Abuses, and Alternatives to the NPV rule- Ross (1995) shows *the Good, the Bad, and the Ugly* from the NPV. A short overview of this vision is here introduced.

##### The good: Rejecting an investment when it should be rejected

For example, an investment project of 1 million euro generates a profit of 1,1 million at year one. With an interest rate of 10,4% this results in a discounted value of 1,104 million. The NPV-rule tells us to abandon the project because,  $1,1 > 1,104$ , this means a negative NPV. As you can see the interest rate is very important in this calculation and can make or break the result. If the interest is not changed or decreased very soon, the advice of the NPV, to abandon the project, is the correct one.

##### The bad: Rejecting an investment when it should be accepted

Keeping the same example, what to if the increase of decrease of the interest rate cannot be forecasted. What if the interest rate was 10%? The outcome of the NPV would be actually zero. According Ross (1995) the holder profits from declines in one year rate and limited liability if interest rate rise. Such projects can then be compared to a call options on a one-year bounds. The general idea behind this philosophy can be seen as; an option isn't 'in the money', however that doesn't mean the option is worthless.

##### The ugly: accepting an investment when it should be rejected

The subtlest error of all in the application of the NPCV rule is accepting the project, i.e., making the investment, simply because the NPV is positive (Ross, 1995).

Dixit & Pindyck (1994) define the most important failure of the NPV as the; the irreversibility of the investment. Irreversibility and possibility of delay are very important characteristics of most investment in reality (Dixit & Pindyck, 1994). In other words the option to wait for optimal investment decision is not validated in the NPV.

### 2.3.3 THE REAL OPTIONS THEORY

It has become apparent that the traditional static discounted cash flow techniques have severe shortcomings (Dixit & Pindyck, 1994). The NPV gives an outcome for the question, invest yes or no. The investment is made present to the standard of today. However, the method doesn't calculate future changes in the parameters. This means that the decision to abort an investment could be totally different the next day. Real option theory gives a better set of alternatives for such investment decisions.

Real options theory regards new investment as an option, and it is recognised that the value of such a real option comes from three sources (Ross, 1995). Ross defines these three sources;

- The static NPV given that the project is undertaken immediately
- The value of the embedded options built into the project. These embedded options are there of the uncertainty factors in the future.
- The option value which is caused by possible future movements in capital costs

In an investment project many factors can be seen as possible options. The most common options for investment projects are listed by Trigeorgis (2001);

- option to defer an investment
- time to build an option (staged investment)
- option to alter operating scale
- option to abandon a project
- option to switch inputs or outputs from a process
- different forms of growth options.

Trigeorgis (2001) defined the following formula (eq. 1-2) to value an investment option;

$$\text{Total Value of Investment option} = \text{Static NPV} + \text{Value of options from managerial flexibility} \quad (1.2)$$

In Figure 8 the real option theory is modelled. The dotted line is the actually NPV of the project, V-I, as function of the cash flow of the project. To understand this picture, the value, V, of the investment is uncertain and is located on the horizontal axis. The value determines when then NPV is positive. The value where this line crossed the horizontal axis is the minimal value of acceptance for the NPV. The thick line is the value of the option of the investment according equation 1-2. Dixit & Pindyck (1994) refer to this value of the option as the cost of opportunity. The formula for cost of opportunity is discussed in paragraph 4.1.3

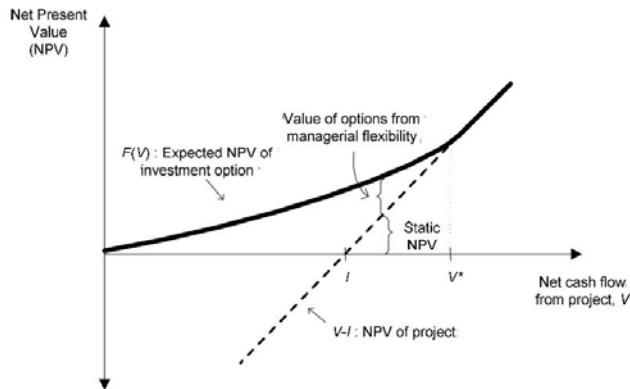


Figure 8 Real Option Theory (Botterud, 2003)

Further in this paragraph the two tools for calculating real option theory according to Dixit & Pindyck (1994) will be introduced; dynamic programming and contingent claims analysis. Before is done one general statistic theory is introduced, the Brownian motion.

### Brownian motion with drift

Real option uses many statistic and mathematical theories, however for this research is very important. To not make everything too complicated and mathematical, only this theory will be introduced.

A standard Brownian motion has no drift, because it has a mean of zero. The drift creates by the change of  $\alpha$ , and the change of the variance,  $\sigma$ .

$$dx = \alpha x dt + \sigma x dz \quad (1.3)$$

- $\alpha$  is the growth parameter
- $\sigma$  the proportional variance parameter
- $dz$  the increment of the standard Wiener process

### Dynamic programming

Dynamic programming is a tool to investigate the best option to investigate in a project. Dixit & Pindyck (1994) state that dynamic programming central idea uses Bellman's principle of optimality which states;

*"An optimal policy has the property that, whatever the initial action, the remaining choices constitute an optimal policy with the respect to the sub problem starting at the state that results from the initial actions".*

Dynamic programming (DP) is in essence a systematic method of making comparisons for general dynamic decisions. This comparison consists of comparing the present values of immediate investment and from waiting.

DP calculates the present value of an investment opportunity at time zero without the option to abandon the opportunity. The optimal investment of this option is the current option. The second option is the scenario where you can wait with investing. This means the firm is looking to the opportunities in the next period. The outcome of future optimal decisions is called the continuation value. The best decision is the one that brings the

highest net present value. This captures the essence of DP (Dixit & Pindyck, 1994). The DP works backwards; the best choice is the last decision point. This shows the continuations value. This expected continuation value is worked backwards to the current decision point. On the decision point for a 'now or never' call, the termination value is the net payoff for the investment opportunity. The difference between this termination value and the continuation value is called the option to postpone the decision.

In a real world, time is continuous and takes uncertainty as Wiener processes. DP models uses this uncertainty according discrete time Markov processes. The essence of DP is to decompose the investment decision into; the immediate period and the remaining period.

In Figure 8 we have seen the investment needs to reach a specific point, the line where the value of the option troughs the NPV line, this is the optimal investment moment,\*.

### Contingent Claims Analysis

Where Dynamic programming defines, the immediate profit flow and the expected capital gain together provide a rate of return. This discount rate is an exogenous factor, however in practice it could be seen as the opportunity cost of capital. The investor could invest in another project with comparable risk factors. The discount rate should equal this rate for the investor.

The economy has many offers of traded assets with different return and risk characteristics. To assign these assets with a value the market replicates its return and risk through a portfolio of other traded assets.

The aim of Contingent Claims Analysis is to collect assets, which can be traded in the financial market, together in an artificial portfolio. This portfolio can then be assessed on its value by using the Capital Asset Pricing Model (CAPM) model. By using the CAPM model the total financial markets pricing of risk and the market value of the project is brought to a maximum. The value of the investment opportunity can now be expressed without using a specific risk-adjusted interest rate for the project (Botterud, 2003). In equation 1-8 the differential of CCA valuation is shown. It underlines what we mentioned earlier, it uses a risk-neutral validation

$$\frac{1}{2} \sigma^2 \cdot P^2 \cdot \frac{d^2 F}{dP^2} + (r - \delta) \cdot P \cdot \frac{dF}{dP} - r \cdot F = 0 \quad (1.4)$$

Where

r                      the risk-free interest rate  
 δ                      dividend on the replicating portfolio

### Replicating portfolio (CCA)

In CCA the portfolio of options are risk free, to do so, Brownian motion has to count, see equation 1-3.

Investors will not invest in an asset as long there is not a high rate of return. This is divided into; i) the expected price appreciation,  $\alpha$  and ii) in the form of a dividend, direct or indirect,  $\partial$ . Together this brings the total expected rate of return on  $\mu = \alpha + \delta$ .

Assuming the riskless rate of return,  $r$ , is exogenously specified for example as the return on government bonds (Dixit & Pindyck, 1994). The capital asset pricing model (CAPM) can be applied.

$$\mu = r + \emptyset \sigma \rho_{xm} \quad (1.5)$$

$\emptyset$  aggregate market parameter (market price of risk)  
 $\rho_{xm}$  coefficient of correlation between return on the particular asset  $x$  and the whole market portfolio  $m$

### Both methods

Both functions of DP and CCA have many similarities in partial differential equations. The bellman equation of dynamic programming has an interpretation in terms of asset value and the willingness of investors to hold asset (Dixit & Pindyck, 1994). The boundary conditions in the contingent claims approach are based on the idea that investors want to choose the option exercise date optimally to maximize the values of their assets (Dixit & Pindyck, 1994). The most important difference is the assessment of the discount rate. DP defines the discount rate,  $\rho$ , exogenously based. CCA defines a rate of return according equilibrium in the capital market. The risk rate defines the riskless rate of return,  $r$ , defined exogenous. The CCA method only works when the component,  $dz$ , which stands for the Wiener process, can be stated. The DP does not dependent on the quest for equilibrium of processes

An example of the Real Option theory in investment decision is explained below; this example is derived from Botterud (2003).

An investment group is considering building a new energy plant. The investors identify the most important and only problem in the uncertainty of the price electricity, the main question is; at what electricity price is it optimal to develop this energy plant?

In this example only the price uncertainty is presented,  $P$ , see equation 1-7. The expected value  $V(P)$  of the investment is shown in equation 1.8.

$$dP = \alpha \cdot P \cdot dt + \sigma \cdot P \cdot dz \quad (1.6)$$

$$\begin{aligned} V(P) &= E \left[ cf \cdot ic \cdot \int_0^T (e^{-\rho t} \cdot P) dt \right] = cf \cdot ic \cdot \int_0^T (e^{-\rho t} \cdot P \cdot e^{-\alpha t}) dt \\ &= P \cdot k, \quad k = \frac{af \cdot ic}{\rho - \alpha} (1 - e^{-(\rho - \alpha) \cdot T}) \end{aligned} \quad (1.7)$$

Where

$\alpha, \sigma$  expected growth rate and variance rate for price,  $P$   
 $dz$  Stochastic Brownian motion process  
 $af, ic, T$  capacity factor, installed capacity, and lifetime for the new power plant  
 $\rho$  Risk-adjusted discount rate for the new power plant

The following parameters are used by Botterud (2003)

Parameter	Description	Value	Unit
ic	Installed capacity new plant	100	MW
af	Capacity factor	4000	Hours/year
I	Investment cost(Norwegian crowns)	1000	MNOK
T	Life time	30	Years
$\rho$	Risk adjusted discount rate	0.08	Per year
$\alpha$	Expected price growth rate	0 or 0.3	Per year
$\sigma$	Standard deviation in price	0;0.1;0.2	Per year

In Figure 9, two graphics are shown. These graphics show how the optimal price to invest for the given parameter,  $P^*$ , for a Brownian motion. The lines change by changing the uncertainty of the growth rate and price. In the first graph the uncertainty of growth in price is zero ( $\alpha=0$ ). The uncertainty of future price is been drafted for  $\sigma=0; 0.1; 0.2$ . In the second graph the growth rate  $\alpha = 0.3$ . The uncertainty is been modelled again  $\sigma=0; 0.1; 0.2$ .

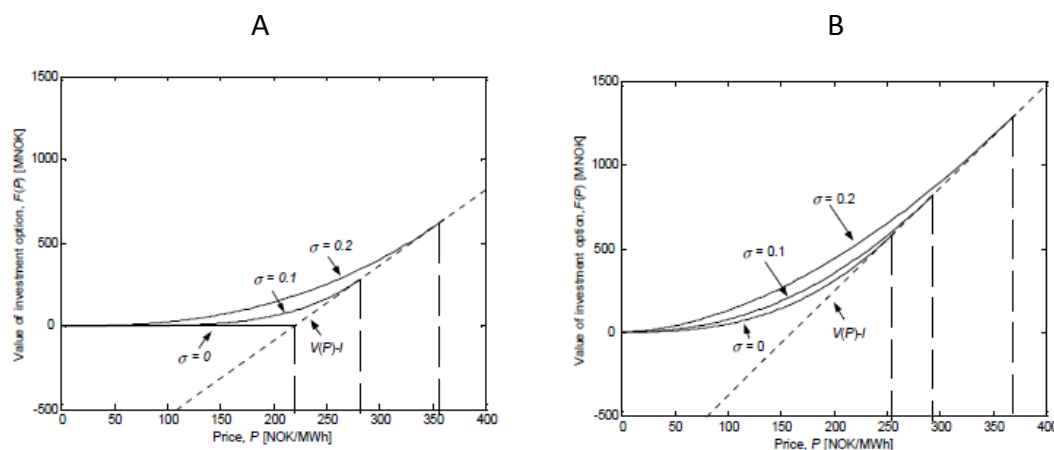


Figure 9 Real options dynamic pricing (Botterud, 2003)

In Figure 9.A the uncertainty of price increase is set at zero. The probability this is happening is modelled by sigma, 0; 0.1; 0.2. As you can when both  $\sigma$  and  $\alpha$  are zero, there is no Brownian motion and the NPV counts. When  $\sigma=0.1$  is derived the result is that the optimal price is around 280 NOK /MWh. The option of the investment is around 400 MNOK. The option value for  $\sigma=0.2$  is around 600 MNOK, with an optimal price of 355 NOK/MWh.

In Figure 9.B the increase of price  $\alpha = 0.3$ . As you can see the angle of the NPV line has increased. Again the variance is set at; 0; 0.1; 0.2. This time the Brownian motion does apply on sigma zero, because the drift parameter is in action. The difference between the two graphs is not the optimal price intersection with the NPV. For the price axis this has no shocking effects. However, the value of the option increases very hard. So does the value of the option for  $\sigma=0.2$  rises from 600 MNOK, in figure 9.A, to 1300 MNOK, in figure 9.B.

So the answer for the investment group is that they have to make a scenario on the future and decide if they want to wait for the optimal price. This process of waiting can be validated by the cost of opportunity on the vertical axis.





## RESEARCH METHODOLOGY: SYSTEM DYNAMICS WITH SCENARIO-DRIVEN PLANNING

*"Twiddle a few numbers and diligently sucker themselves into thinking that they're forecasting the future."*  
- M. Schrage -

Business Leaders in diverse industries and firms, such as Airbus, General Motors, Hewlett-Packard, Intel and Merck, use scenario-driven planning (SdP) with system dynamics (SD) to help them identify, design and apply high-leverage, sustainable solutions to dynamically complex strategic-decision situations (Georgantzias, 2010).

The essence of this research is to show residents what the value of opportunity is, in investing an energy autarkic district. The financial decision is covered with the real option theory. The purpose for using this methodology is to provide a clear picture of uncertainties and its relation.

The SD methodology looks difficult in the beginning. However sometimes a model and its relations say more than a large spreadsheet, with all its formulas linked cluttered. Because this investment reflects on the future, an image of the future needs to be provided. This is why scenario-driven planning is added. The future has too many uncertainties to give a clear picture. It is better to show a few realistic scenarios.

Both methodologies will now be introduced. First SD will be introduced, followed by SdP. Finally the combination of both methods will be discussed.

### 3.1 SYSTEM DYNAMICS

The theory of SD is introduced in fifties and sixties by Jay W. Forrester. Initially it called Industrial Dynamics; when it was developed during his work at the Massachusetts Institute of Technology (MIT). The start of Industrial Dynamics lies on cutting face of engineering and management.

Forrester defines the Industrial Dynamics as: *"the study of the information feedback characteristics of industrial activity to how organizational structure, amplification (in policies), and time delays (in decision and actions) interact to influence the success of the enterprise. It treats the interactions between the flows of information, money, orders, materials, personnel, and capital equipment in a company, an industry or a nation economy"*.

System Dynamics has been used in many fields of industry, the most important issues are here presented; Corporate planning and policy design (Forrester, 1961), economic and business behaviour (Sterman, 2000), Energy and environment (Ford, 1996), dynamic decision making (Sterman, 2000), and supply chain management (Forrester, 1961).

In this research; business, energy and decision making are under discussion. That is why a short look is given to what the experts in these disciplines of SD think.

John D. Sterman is teacher in System Dynamics at MIT. He defines in his article 'all models are wrong'; SD is grounded in control theory and the modern theory of nonlinear dynamics. In his book Business Dynamics (2000) he states, today's solution become tomorrow's problems, which results in policy resistance. With System Dynamics this resistance can be modelled by system thinking.

System Dynamics is much used in the energy industry, in research by Ford (1996) he indicated that recently 33 SD researches have been conducted in the U.S.A. From this research Ford claims there is a trend to use SD for elaboration of privatization of the power

industry and deregulation of the power industry. According to Ford (1996) SD works well because the key feedback loops come to light and the ability to transfer our mental models to computer simulations.

The essence of SD lies in 4 basic building blocks of complex systems; feedback loops, stocks and flows, time delays, and nonlinearities (Sterman, 2000). The feedback loops arise among parts of the system, it finds itself in. These feedbacks can be positive or negative; positive feedback tends to reinforce or amplify whatever is happening in the system, negative feedback loops counteract and oppose change (Sterman, 2000). Feedback loops are modelled as arrows with a plus or a minus, plus minus positive and a minus means negative feedback loop.

Stock and flows state the information of the system (see Figure 11). Here you can see the stock containing the contents. The amount of contents is dependent on the relation between how much flows in and out. Sterman uses the metaphor of a bathtub as a stock and the amount of water in and out as in - and out flows.

A delay is a process in the system that slows the output of the input. This means that as definition a delay is at least one stock. You can have two kinds of delays; a material delay and an information delay.

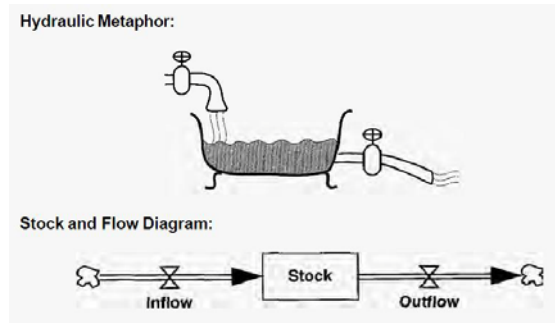


Figure 10 Stock & Flow diagram (Sterman, 2000)

### 3.2 SCENARIO-DRIVEN PLANNING

There are many definitions of scenario planning. Michael Porter (1985) defined scenarios as “an internally consistent view of what the future might turn out to be, not a forecast, but one possible future outcome”. Schoenmaker (1995) defines scenario planning as “a disciplined methodology for imagining possible futures in which organizational decisions may be played out”. According to Georgantzas (2010) scenario-driven planning is; to attain high performance through strategic flexibility, firms use the SdP management technology to create foresight and to anticipate the future with strategic real options, in situations where the business environment accelerates frequently and is highly complex or interdependent, thereby causing uncertainty.

In this paragraph the methodology scenario planning is further elaborated. Firstly, the history of scenario planning is analysed. Secondly the essence of scenario planning is summarised.

#### The origin of scenario planning and its success

The root of scenario planning lays by Herman Kahn, who introduced the name “future-now” thinking (1940) while working at RAND Corporation. Kahn adopted the name ‘scenario’ when Hollywood determined the term outdated and switched to the label ‘screenplay’ (Chermack, Lynham, Ruona, 2001). In cooperation with the Hudson Institute, scenarios were developed to prevent nuclear wars (Kahn 1963). Kahn published the book “the year 2000” (Kahn and Weiner, 1967), this book was the basis for large companies like shell, IBM and General Motors to think about scenario planning.

In 1967 Pierre Wack, the scenario planner of Shell, suggested that the planning six years ahead was not enough (Wack, 1985). Shell started developing scenarios to the year 2000. When the oil prices dropped through the Yom Kippur war, Shell was prepared with a quick strategic reaction. The ability to act quickly has been credited as the primary reason behind the company's lead in the oil industry (Heijden, 2005). This success was not unnoticed by other corporations, many corporations introduced scenario planning in their organisation. It is seemed to be a hype, instead of a new change in strategic planning. Due to the major recession and corporate staffing reductions of the 1980s scenario use was on the decline (Ringland 1998). Shell kept their pace with scenario development and due to their success in two oil crises' the success of scenario planning was proven again.

### Method

The purpose for the research method is to use SD with SdP. This is done according the theory of Georgantzis (2010), this is further elaborated in paragraph three. The scenario planning method underlying this method is the model of Amara & Lipinski (1983). Amara and Lipinski (1983) believe that it is important for scenarios to provide a description of the environment in which a firm competes. The goal of scenario building is for managers to capture and to analyse essential elements of the environment as described in Figure 11 (Amara & Lipinski, 1983). The core of their model

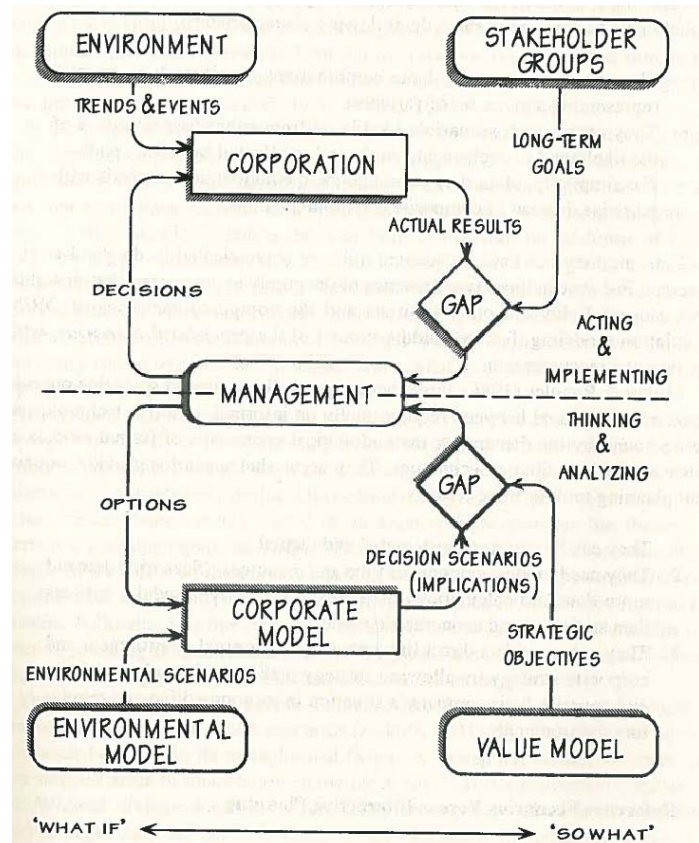


Figure 11 Amara & Lipinski (1983)

is the cooperation between the environmental scenarios and the management choices (Georgantzis and Acar, 1995).

In this model a clear line is cut. The acting and & implementing part and the thinking & analysing part. This research is about the thinking & analyzing part. The decision node shows where everything comes together. The corporate model represents the concept of an Energy autarky district. The environmental model are the scenarios which have influence to the corporate model. And to assess the value of a model we use a value model, in this research a real option theory.

### 3.3 COMBINATION OF SD WITH SdP

According Georgantzis (2010) realizing that a tradeoff-free strategy design requires insight about a firm's environment, both business and socio-political, to provide intelligence at all strategy levels, firms use SdP with SD to design, corporate business and process or functional strategies.

Georgantzis describes three facets for SD with SdP

- The business Environment, the forces behind its texture and futures requisite uncertainty.
- Detailing the framework of SD with SdP.
- Computing the effects on performance of changes in the environment and in strategy.

### The business environment

The method starts with the framework of the business environment. This framework consists of four business environments (Emergy and Trist, 1965).

- 1) Placid or independent- static environment: infrequent changes are independent and randomly distributed.
- 2) Placid-clustered or complex-static environment: patterned changes make forecasting crucial. Comparable to the economist idea of imperfect competition, this environment lets firms develop distinctive competencies to fit limited opportunities that lead to growth and bureaucracy
- 3) Independent-dynamic environment: firms might influence patterned changes. Comparable to oligopoly in economics, this environment makes changes difficult to predict, so firms increase their operational flexibility though decentralization.
- 4) Complex-dynamic environment; most frequent changes are also complex, i.e., interdependent, originating both from autonomous shifts in the environment and from interdependence among firms and conglomerates. Social values accepted by members guide strategic response.

The location of where companies places itself, defines which it can be quantified as active or passive. Active or passive in this situation means scanning its environment. Active companies use for their environment research a process; strategic, assumption, surfacing and testing (SAST). The passive companies do not seek knowledge, they wait until a trend or event shows itself in the environment.

### Detailing the framework of SD with SdP

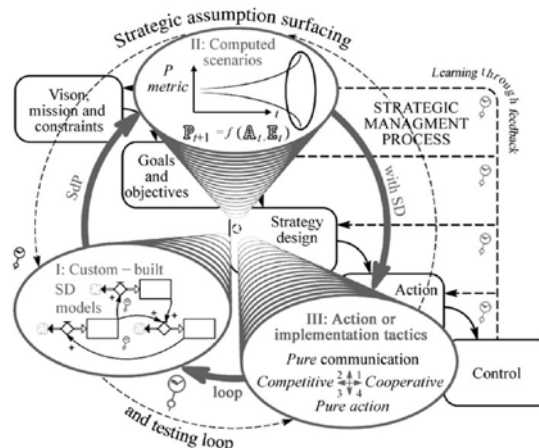


Figure 12 the research loop

SdP with SD begins by modelling a business or social process than a business or social system. It is more productive to identify a social process first and then seek its causes than to slice a chunk of the real world and ask what dynamics it might generate (Georgantzias, 2010). Randers (2005) defines a social system as a set of cause and effect relations. Its structure is causal diagram or map of a real world chunk. A social process is a behaviour pattern of event evolving through time.

Into this SD model, scenarios are implemented in the system. The scenarios are created with a scenario driven planning method. Many authors have described methods for such models. There is not really a wrong or a good model. Importantly, the scenario should have influence on the problem of system. This means the uncertainties of the key variables should be identified. When the scenarios and all other assumptions are implemented into the system, the model running can start. The result of the computed models can be analysed and strategic choices can be made. This result can then be again be implemented into the SD model. By looping back into the model, the results can be checked and forecasted.

### Computing the effects on performance of changes in the environment and in strategy

The essence of detailing the framework of SD with SdP is that you are modelling a social process. The business or social system is perhaps the end result, shown in figure 12. However, the social process of the real world should be format for this model.

This said, when modelling the model it is important to understand the state of this stage in the model. The goal of this stage in model is to implement strategies. So the implementation of the model is the goal. A random picture is not the objective. It should see if a strategy would fail or succeed. To have an ultimate model, this implementations of stage in figure 12 could be implemented in stage 1 to progress in the strategy process.

## 3.4 RESEARCH MODEL

All this information, constructs into the final research method for this research. The research model constructs of seven steps.

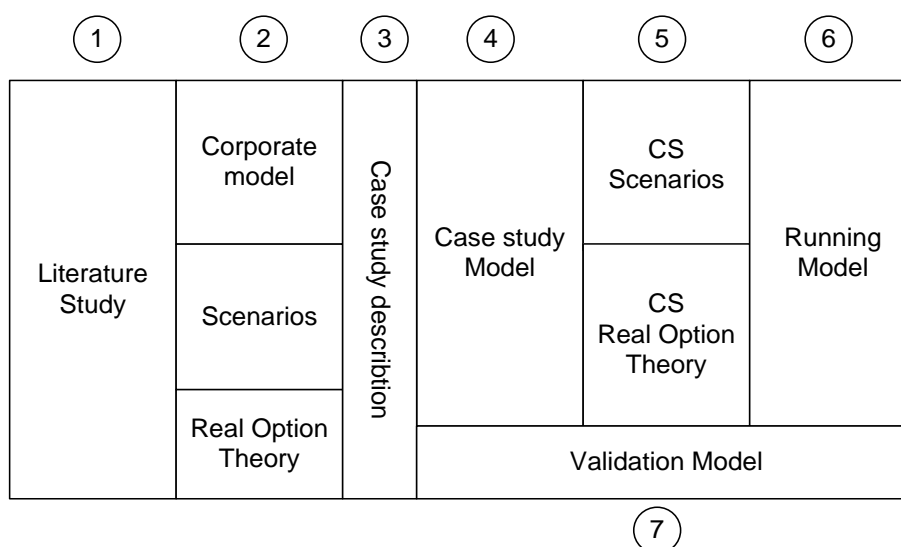


Figure 13 Research model

STEP 1:	Literature study	chapter 2
STEP 2:	Designing the concept model	chapter 4
STEP 3:	Describing case study	chapter 5
STEP 4:	developing scenarios	chapter 4
STEP 5:	Creating real option for corporate model	chapter 5
STEP 6:	Running model	chapter 5
STEP 7:	Validating model	chapter 5

### **LITERATURE STUDY**

The goal of previous literature chapter was to further elaborate the concept of an energy autarkic model. This literature study can be used as roadmap of designing the concept model. In this chapter practical issues are researched, which can be assumed in step 2.

### **DESIGNING CONCEPT MODEL**

In step 2 the concept of energy autarkic district is elaborated into a SD model. This model must work and act as a general model which could be the base for any project. The scenarios and real option theory should be elaborated on a theoretical way, hence could be used into the case study.

The SD model should represent the internal finance system of the LECC. The model is modelled with VENSIM software. The scenarios are defined following external data on the defined problem.

### **CASE STUDY DESCRIPTION**

A case should be selected. The conditions for this case should be; the area should be an existing urban district, there should be a diversity of stakeholders, input required by the SD model, all input requires should be attended.

The inputs from this are; should be; amount of houses, energy use of houses, energy resources input, value of the houses, and income of the residents.

### **CASE STUDY MODEL**

The concept model should be further elaborated according the case study description.

### **CASE STUDY SCENARIOS**

The scenarios should be researched according the concept model and the case study description. These scenarios should be elaborated according the methods used in paragraph 3.2. This means that the scenarios should be validated with a qualitative method.

### **CASE STUDY REAL OPTION THEORY**

After the SD model and the scenarios a final investment decision should be made. This is done according the Real Option theory. The practical method should be Dynamic programming or Contingent Claims analysis.

### **RUNNING MODEL**

The model should be running without any errors. The results of the case study should than be back implemented into the SD model to further create new insights into the case study.



## 4. DEVELOPING THE GENERAL MODEL OF THE LECC

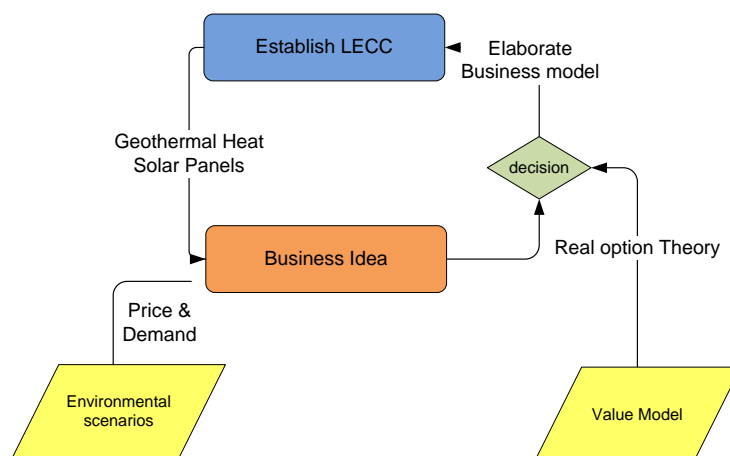
The concept model of the LECC is in this chapter developed. Before this starts, the goal of the model is repeated. This ensures us to focus on the right attributes.

***The goal of this research is to design a financial decision model to help a community start the redevelopment of their district into an energy autarky one.***

The financial decision model is assembled from three sub-systems. First the general model of these sub-systems is introduced. In this general system, the relation between the sub-systems is elaborated. In the following paragraphs these subsystems are further elaborated. The parameters of these subsystems are then introduced and further elaborated.

### 4.1 SYSTEMS ELABORATION

In chapter three, the model of Amara & Lipinski (1983) was introduced see Figure 11. For the development of the LECC model, the model of Amara & Lipinski was converted and adjusted to the model of the LECC. This model is presented in Model 1. The model consists of four sub-systems: Establish LECC, business Idea, environmental scenarios, and value model.



**Model 1 sub-systems of the model converted from Amara & Lipinski (1983)**

In this model the sub-system of the LECC is not further elaborated. The LECC is an organisation and the structure of this organisation is not part of this research. It would probably look like the model of the CCAT of Butterfoss & Keggler (2002).

In the business idea the earning model of the organisation is explained. This internal process is influenced by another sub-system, the environmental scenarios. Together they form the input of the value model of the LECC. However the decision to start this organisation is not part of these two systems. So the value decision model is added to ensure the optimal investment decision is made for the organisation. The decision starts further elaboration of the LECC, into the start-up of the organisation.

The model starts at the establishment of the LECC, which is in this case; the commitment of some early adopters to research the possibility to develop a company with geothermal heat and solar panels. This is constructed in a kind of business idea. Here the opportunity is

developed and implemented in scenarios for the price and demand of that specific area. The value of that specific business idea is valued by using a real option theory method. This model shows some options for the LECC, they decide what to do. If they decide to continue, the business idea is further elaborated into a business model.

#### 4.1.1 BUSINESS MODEL

The focus in this research isn't on the elaboration of the business idea of the LECC. However, it is inevitable to define a general business model for the LECC. The process of how the LECC is going to earn money is important. Also, the question why people want to join the organisation should be asked.

One of the lessons of the literature study was that the energy generation of a Dutch urban LECC would exist of geothermal heat and solar panels. So for both techniques the business models are elaborated. The elaboration uses a visual method, according to the board of innovation (2011), with images to elaborate the flows of products, services, money and credits.

#### GEOHERMAL HEAT

In research by the Dutch research agency ECN (2011,) three possible functions for deep geothermal generation in the Netherlands are developed. The three functions are; horticulture, Greenfield development, and Brownfield development. The horticulture sector can use thermal heat to heat their greenhouses instead of burning gas. In Green- and Brownfield's scenarios, thermal heat is used to heat buildings. The difference is the current network, in a Greenfield there is no heating district infrastructure, in a Brownfield there is already a network available. Geothermal techniques also provide the possibility for cogeneration. However, in study of ECN (2011) this option is called too expensive and doubtful. The heat quest for cogeneration is much higher than for heating, this amount of heat is very deep in the ground, and the cost are very high. So this is not taken in consideration.

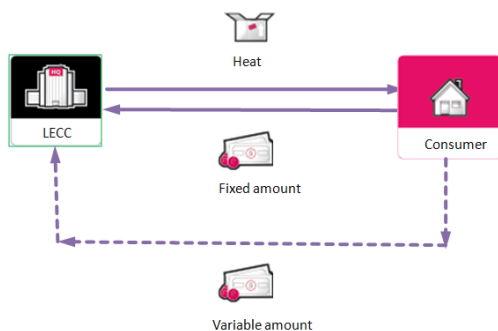


Figure 14 basic gaining model LECC consumer

In Figure 14 the extension of goods is very basic; the LECC delivers heat to the consumer and the consumer pays money for it. In this research an assumption is made, which is created by trial and error.

The consumer pays a fixed amount; two/third of its current energy bill for heat, and the rest in a variable amount. The variable amount is connected to the amount of energy he uses, so this reflects on the user energy behaviour. In this matter the consumer has the incentive to reduce its energy behaviour.



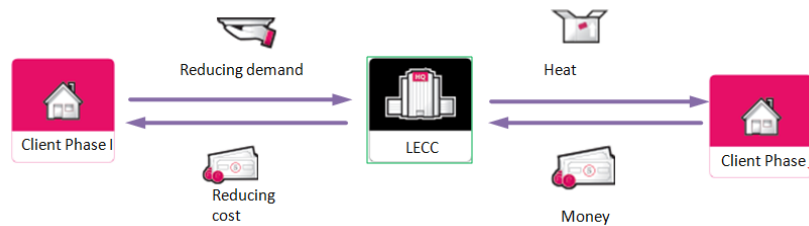


Figure 15 extension users LECC

The reason the LECC prefers this, is that the LECC has an extra incentive. It can sell the saved energy to a phase II district, see Figure 15. Client phase I offers a service by reducing cost, this results in reducing cost. A geothermal installation has one only switch, on or off. So the total amount of energy stays the same. This means the LECC can again sell heat to buyers, without any extra investment. This can be invested in extra efficiency measures or dividend.

### SOLAR PANELS

Solar panels are relative cheap devices to generate electricity, in comparison to a geothermal installation that is. One of the problems is that the effectiveness of solar panels relay on the position of the roof versus the sun. In the district not all roofs are suitable for solar panels. So the LECC invest into solar panels for the entire district. This means that all suitable roofs will be used and the panels will be used optimally.

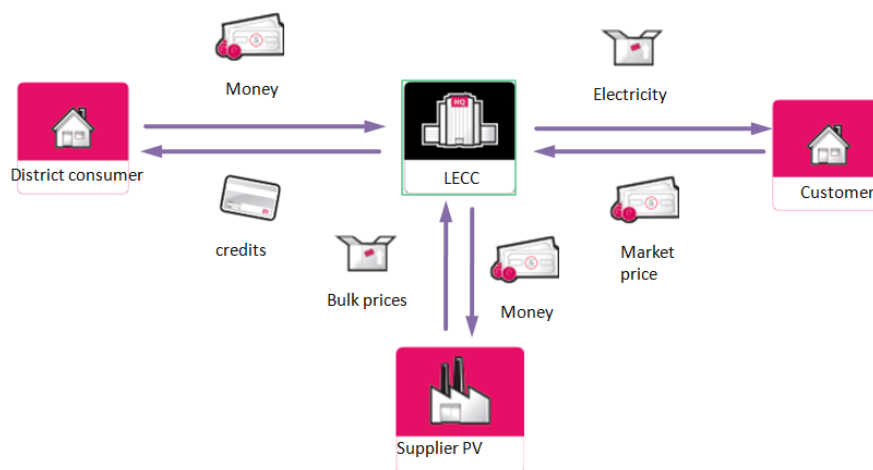


Figure 16 gaining model Solar panels

For the consumer it is better to invest via the LECC, it reduces the investment cost, the LECC can reduce construction and sales cost by constructing in large numbers. Furthermore, there are fewer drawbacks from the environment, which can delay the project. This is because the environment is the LECC.

#### 4.1.2 ENVIRONMENTAL MODEL

The gaining model is an internal process which shows how the LECC is going to earn money. However there are two important environmental variables which can change the outcome of this gaining model. These variables are; the future energy price and the future demand of energy by the consumers. In this analysis of different scenario-driven planning models variables are defined which can be used in the gaining model of the LECC.

#### 4.1.2.1 Data set

In this model we will use scenario-driven models to forecast these two variables. This part of the research will only consist of analysing existing scenarios.

Many companies construct long-term scenarios. However, the demand and price for households is not often maintained in the same scenario.

The data is used from the energy scenarios from Farla et al. (2006). These scenarios are developed on macroeconomic scenarios, namely the model of Huzinga & Smit (2004), see Figure 17.



Figure 17 scenario matrix

Huizenga & Smit define the two largest uncertainties which influence the economies in Europe. The first uncertainty is the commitment to cooperate on an international level. The second uncertainty is the speed of the process of reform in the collective sector in each country.

- The regional communities' (RC) have a strong focus on national power. They block further cooperation among other EU members. Europe divides itself in different business blocks. The national organisation is growing and market processes fall.
- In the transatlantic markets (TM) plot the national power is still high. However collective reform is increased. This will not from an open economy, while individual countries will keep their markets protected.
- Strong Europe (SE) has a high level of attention on international cooperation. European agencies are reformed; the national governments hand over some responsibilities to Europe. The focus of is also on an equal distribution of wealth among the EU.
- The Global Economy (GE) focuses on extension of the EU. However the only real successes are on the economic topics. Reforms on the social and environmental issues will fail. The national government focuses on the individual responsibility.

#### Household electricity demand

According to Hilderink et al (2004) the total demand of electricity of household consumers will rise in all scenarios from 3.300 KWh in 2000 to;

Global Economy	5.300 KWh in 2040
Strong Europe	4.300 KWh in 2040
Transatlantic market	5.000 KWh in 2040
Regional Communities	3.700 KWh in 2040

The historical increase of the electricity increase was forced by; cleaning equipment, freezing equipment and TV's. According Hilderink (2004) the further increase of electricity in household depend on; income, technological developments and increase of luxury products.

### Household electricity price

The largest impact on the electricity price is the implementation of the CO<sub>2</sub> emission system. In Strong Europe the system will be further elaborated en brought to full potential. On the other hand, transatlantic market & global economy will dismiss the system in 2020. Regional Communities doesn't dismiss the system. However, it is used on the wrong way; the CO<sub>2</sub> price/ton is too low. The result of this is that there is no real incentive to do anything with it. The price of electricity is modelled in Figure 18.

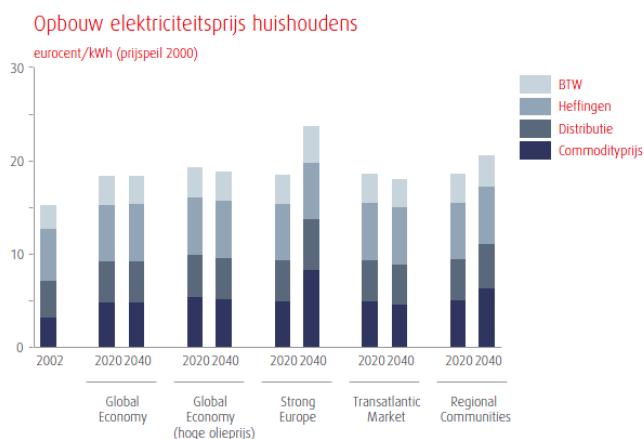


Figure 18 structure electric price (Hilderink et al., 2004)

### Total household heat demand

The demand of natural gas for households will decrease in all scenarios till 2020. The energy use in 2002 was 340 PJ. The values for the scenarios are;

Regional communities	280 PJ in 2020	240 PJ in 2040
Strong Europe	280 PJ in 2020	240 PJ in 2040
Global economy	305 PJ in 2020	320 PJ in 2040
Transatlantic market	305 PJ in 2020	320 PJ in 2040

The community price of gas will increase the next years due to higher foreign production cost and long distance transport. Due to bad trade relations the gas price will rise in the scenario of transatlantic markets and regional communities. Strong Europe has an increase in the first years and then stabilises, due to a decrease of the gas demand. The global economy has a stable increase of price due to the increasing demand. These commodity price scenarios are modelled in Figure 19. As you can see oil price has a high influence in the global economy. In this scenario the oil price is exploding. This has a huge influence in the commodity prices.

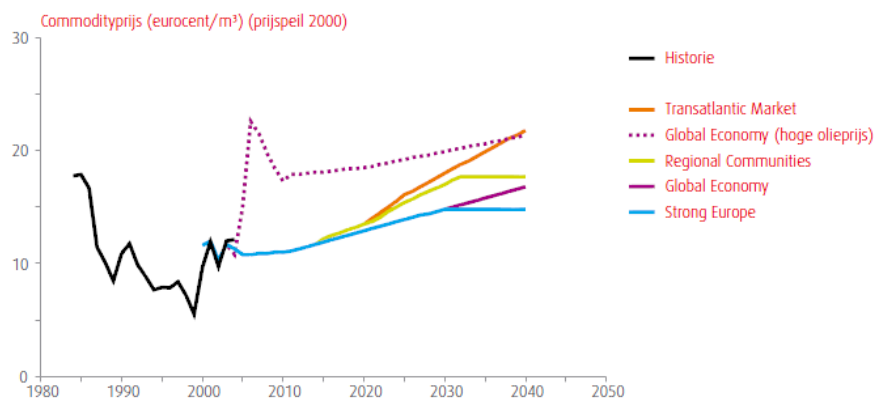


Figure 19 commodity prices scenarios

### Heat price households and large users

The LECC is delivering heat to households and large users. The prices for companies and households are different. The scenarios consider the difference for each buyer. The price-increase is not the same, because other factors play along.

The market price for the consumers is depended on other factors than the commodity prices, like taxes and distribution cost. The prices for the consumers are modelled below, see Figure 20. The prices for the large use consumers are modelled below see Figure 21.

In the model there is only calculated with the commodity prices. This means that increase in taxes, distribution cost is not forecasted.

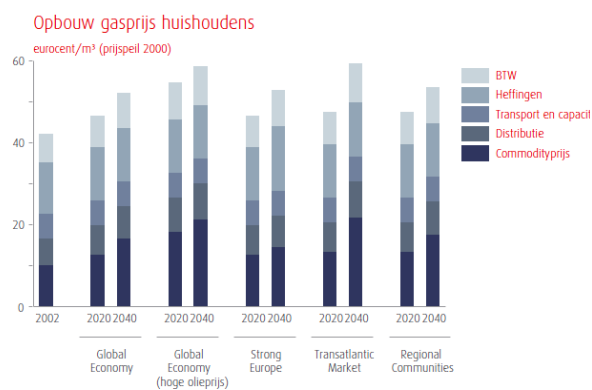


Figure 20 construction gas price

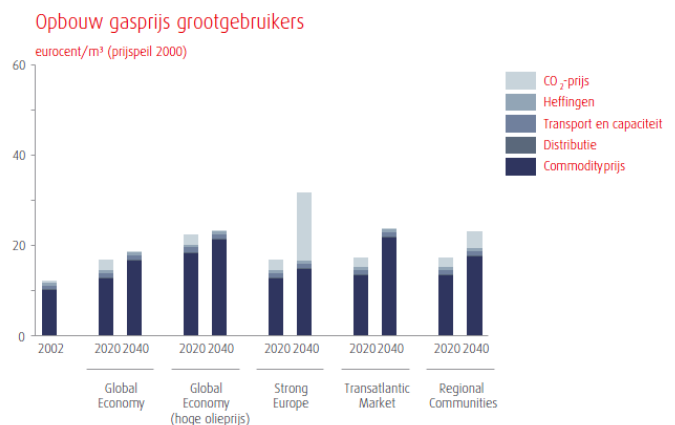


Figure 21 construction gas price large users

#### 4.1.2.2 Implementation data in model

The elaboration of the scenario data (Hilderink et al., 2004) to implemented data for the SD model is described in appendix III. In Figures 23, 24 and 25 the difference between the scenarios is modelled.

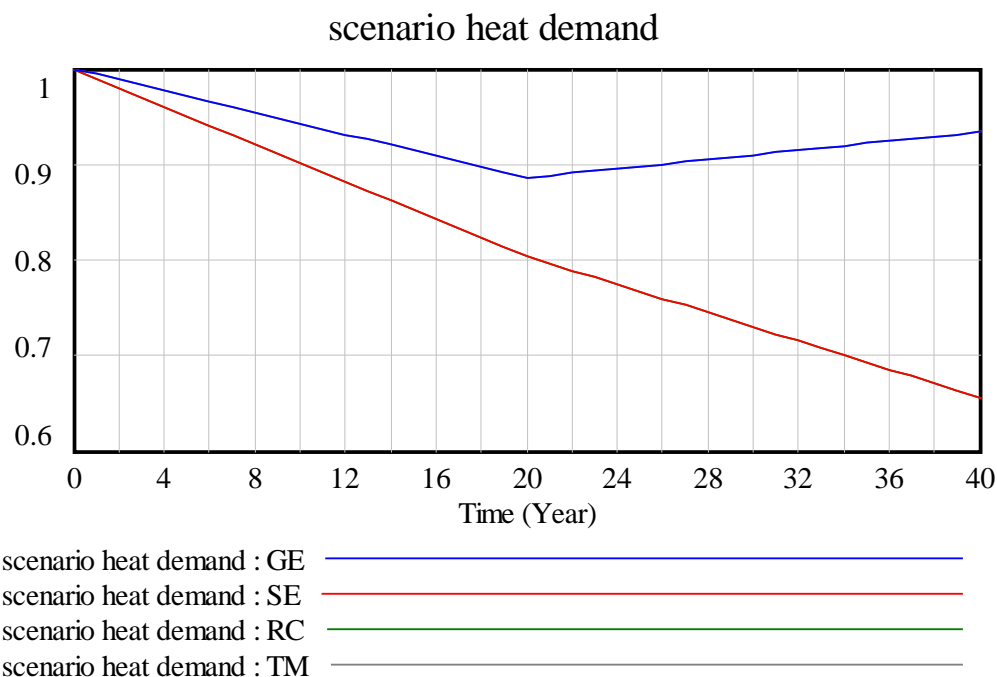


Figure 22 scenario demand Heat to 2040

In Figure 22 there are only two lines, RC=SE and TM=GE. Demand is decreasing in all four scenarios for the first 20 years. This is due to better understanding of energy demand by consumers and better efficient houses. In 2020 the GE and TM scenarios dismiss the EPC code. The design of new building will be less efficient, which will increase the energy demand. For RC and SE the EPN will be further elaborated, which increases the efficiency of buildings. This will reduce demand.

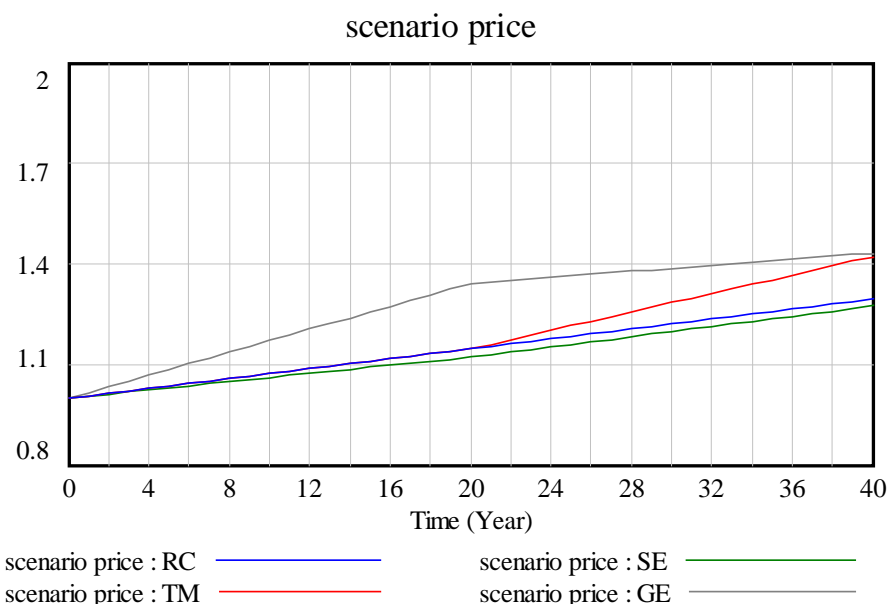


Figure 23 scenario price heat households to 2040

The price for heat for the TM and RC scenarios will increase due to the bad trade relations. The SE scenario is the steadiest scenario. Due to a good climate policy, gas demand will decrease which stables the market. The GE scenario has a high increase of price due to high worldwide demand for gas and a fluctuating supply. After 2020 better alternatives are invented and the independence on gas will be less important for the price.

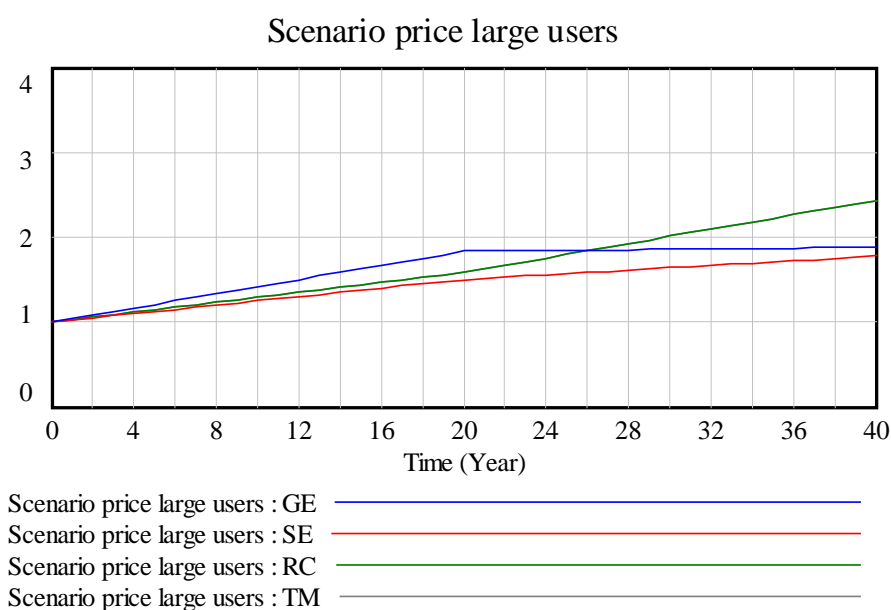


Figure 24 scenario price large users heat to 2040

#### 4.1.3 VALUE MODEL

The corporate model with the SD and implemented scenarios show different stories of the future. For the LECC it is hard to decide which story is correct and when to invest. This is why real option theory is used to judge the NPV. An optimal investment rule with real option theory is introduced.

Dixit and Pindyck (1993) define two important characteristics of investment. First, the expenditures are at least partly irreversible; in other words, sunk costs that cannot be recovered. Second, investments can be delayed, so that the firm has the opportunity to wait for new information to arrive about prices, costs and other market conditions before it commits resources.

This model uses the continuous-time models of irreversible investment by McDonald and Siegel (1986). They had the following problem statement; at what point is it optimal to pay a sunk cost,  $I$ , in return for a project whose value is,  $V$ , given that  $V$  evolves according to the following geometric Brownian motion:

$$dV = \alpha V dt + \sigma V dz \quad (1.8)$$

In this eq. 1-8 the value,  $V$ , at time zero increases lognormal with the variance,  $\sigma$ , with the idea that future is always unknown. The drift parameter,  $\alpha$ , is the proportional growth parameter. When we use the scenario-driven models, the model could be claimed as known. This is with the idea that one of the four scenarios is the truth. In simple words,  $\alpha$  is growth implemented according the scenario data, and  $\sigma$  is zero.

In this 'deterministic' case with no 'uncertainty', the optimal value can be determined. The optimal value rule uses the critical value,  $V^*$ . This rule applies according eq. 1-9.

$$V \geq V^* \quad (1.9)$$

This critical value can be calculated with the following equation. Where,  $\rho$ , is the discount rate and  $\alpha$ , is the drift parameter for the Brownian motion.  $I$ , is the investment cost, this only applies if the answer is larger than the original investment.

$$V^* = \frac{\rho}{\rho - \alpha} I > I \quad (1.10)$$

Part of the process of a higher value in the future is creating a call option to spread the chance of waiting for the critical value. This is called the value of the option to invest,  $F(V)$ . This value model defines the value of the critical value and the value of the opportunity on time zero.

$$F(V) = \begin{cases} \left[ \frac{\alpha I}{(\rho - \alpha)} \right] \left[ \frac{(\rho - \alpha)V}{\rho I} \right]^{\rho/\alpha} & \text{for } V \leq V^* \\ V - I & \text{for } V > V^* \end{cases} \quad (1.11)$$

This offers investors an amount of money they can spend designing a call-option. These calculations will be made for each scenario, because they all have different drift parameters.

## 4.2 ASSUMPTIONS ON THE LECC

The SD model and the environmental models together will form the model for the next paragraph. However, to create this model some assumptions and data will be introduced. The starting point for the final model is the specifications in this paragraph.

There are four types of specifications constructed; location, technical, organisation and investment.

### 4.2.1 LOCATION SPECIFICATIONS

It is not possible to create a LECC everywhere. The choice of the location is the most vital factor in this decision. The success of the concept depends on; the density of the houses, the geothermal specification, and solar specifications. These aspects are further elaborated in this paragraph.

#### NUMBER OF HOUSES

The numbers of houses refers to the amount of users. In the model every house is one unit. The received data on the heat use is in Mega Watt hour (MWh) natural gas. The model converts this from the used gas to fuel the boiler, into the amount of heat in Giga Joule. The reference is that 1 GJ of heat equals 44 MWh of natural gas (milieucentraal, 2011). This reference is used to convert the heat price for Dutch central heating systems.

#### GEO THERMAL SPECIFICATIONS

To determine the amount of geothermal power of the location, the formula of Van den Bosch (2010) is used. This formula is further elaborated in chapter 5, when calculating the case study geothermal power. To calculate this power the following values are needed.

Q	water flow m <sup>3</sup> /hour
$\rho$	density formation water
cv	warmth capacity formation water
$\Delta T$	cooling off water in Kelvin

Q, is the water flow of heat pumped every hour in the system. This is hard to predict, because there is no reference data. In this model the flow is assumed 150 m<sup>3</sup>/hour.  $\rho \times cv$ , is often combined, this is the amount of heat which the water contains.  $\Delta T$ , is the cooling of the heat in the system.

The situation of the plant on the location is very important. This is to optimise the network infrastructure and heat loss. The surface of the geothermal plant can be calculated with the formula of Lund (2007), surface of location plant size is 400 m<sup>2</sup>/GWh.

Further there should be looked to heat production on the location. This could be waste heat from industrial processes in the district.

#### SOLAR SEPCIFICATIONS

The power capacity of the solar panels is calculated by the amount of watt peak (Wp) times the amount of solar days. This data should be known of the location. Also the situation of the houses is important for the angle which the solar beams fall into the panels. So roofs directly situated on the south are available for solar panels. This situates the amount of square meters available on the roofs in the area. A roof is available located with good angle on the south. Per unit 8 m<sup>2</sup> solar panels are calculated.

#### 4.2.2 TECHNICAL SPECIFICATIONS

The data for the technical specifications are vital for the feasibility of the project. There are three aspects which are important; the geothermal installation, the solar panels, and the buildings in the district. Before the project can be made financially feasible, the technical feasibility should be showed.

##### GEOTHERMAL INSTALLATION

In paragraph 4.1.1 the choice for the geothermal installation is already made. The type of installation is here further elaborated. According to the research by the ECN and KEMA (2011), the following parameters belong to the district heating system with geothermal heat in the Netherlands.

The system is called a doublet system; this means there is one production pit and one injection pit. The heat delivering will be on low temperature, of about 75° C. The installation is active for 5000 hours a year.

##### SOLAR PANELS

The lifetime of solar panels in this model is 25 years. The capacity is 160 Wp/panel, which compares to 117 Wp/m<sup>2</sup>. These specifications are used of the solar panel company, Ubbink. They are the most common used solar panel in the Netherlands.

##### HOUSING EFFICIENCY

The model is a general model and works on general measurements. The secondary goal is to increase the efficiency of the current real estate. The efficiency is gained by investment from the profit of the LECC into the efficiency of the houses. The elaboration of the adjustment should be designed by such a specialist. But the purpose of the efficiency investment is to isolate the building and install smart products, to adjust the saving behaviour of the consumer.

#### 4.2.3 ORGANISATIONAL SPECIFICATIONS

The LECC can only exist if the entire district is willing to cooperate. These stakeholders are the resident, the users, and the entrepreneurs. Also stakeholders with power on the district, like the municipality, have to commit to the project. They have to support the heating district contracts. There will be role for some early adopters to start the process. This early adopters will probably be companies. They are the users of the financial decision model. They want to know when it is optimal to invest.

#### 4.2.4 INVESTMENT SPECIFICATIONS

This paragraph deals with the aspects which determine the investment decision. However, subsidy could be applied; it is not considered in this model. In this time of skimps, the Dutch subsidy system is not reliable to build on.

The following aspect which interfere with the decision to invest are used; cost, income, and finance.

##### COST

The cost can be divided in construction cost and 'maintenance & operation' cost. Which can be further divided into the solar development and the geothermal development.



### Construction cost

The index numbers for the geothermal energy plant are;

- Purchase ground	300.000,-	euro
- Drilling cost	1.500,-	euro / m1
- Development cost	600.000,-	euro/year
- Building cost (plant)	300.000,-	euro/post

The drilling cost are calculated on 1500 €/m1. Because there is a risk involved drilling into the ground and the result of the installation, a lot of extra cost are involved (ECN, 2011).

The development costs are the cost for preparation and insurances, the data is derived from ECN (2011). The physical building of the plant which is also calculated according the data from ECN (2011).

The index numbers for the solar panels are;

- Solar panels, construction and sales,	500,-	€/m2
- House adjustments for solar installation	500,-	€/m2
- Development cost	100.000,-	year

### Operation & Maintenance cost

The geothermal installation is divided into; fixed and variable Operation & Maintenance cost.

- Fixed maintenance cost are operation & maintenance cost. According ENGINE (2007) this cost is 21, - €/kW<sub>th</sub> a year, this contains; insurances, maintenance and operation activities.
- Flexible operation is the cost of energy of using pumps to drain the ground from the ground. This cost is 0.007 €/kW<sub>th</sub> (ENGINE, 2007)

Solar panels

- Maintenance, cost/hour of production 10 €/year

### INCOME

The entire income for the LECC is coming from its members. These members will not tolerate to pay more for their energy then on the free market. However, this only counts for the starting moment. The deal is that the current price is taken and that fixed price adjustment will be made. This means that all price corrections are already made.

In research by the NMa (2009) the average energy bill in Netherlands is € 1961, -. The segmentation in this bill is that the 35% of the bill is energy cost for heat.

From this price we have a fixed amount; this is not the fixed charge for distribution. This amount is for everybody the same, and counts for a fixed amount of heat. When the customer uses more there is variable amount the consumer needs to pay.

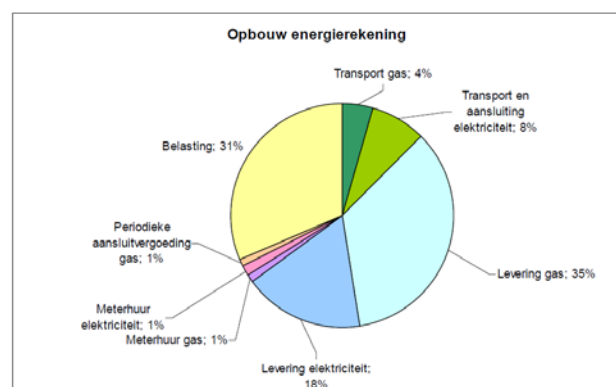


Figure 25 energy bill construction

## INTEREST RATE

The model assumes financing is possible. The construction cost can be loaned at the bank. The loan will contribute 90% of the total investment. The other 10 percentage will be brought together by the shareholders of the LECC. The interest rate for this loan will be 7.5%. The loan will be paid back annually in twenty years.

## 4.3 SD MODEL OF LLEC

In this paragraph the sub-systems programming of the SD model are discussed. All stock and flows of the model will be discussed individually and relations are elaborated.

### *Installed heat capacity*

The installed heat capacity stock determines the amount of installation capacity which is running. The stock determines when the capacity starts production and when it is retired. The stock shows when the geothermal installation is operational and is producing heat.

Construction rate = STEP (max generation area, development time) + STEP (-max generation area, construction time + development time)

Retirement rate = STEP (installed capacity, depreciation)

Installed capacity = Construction rate + retirement (start value = 0)

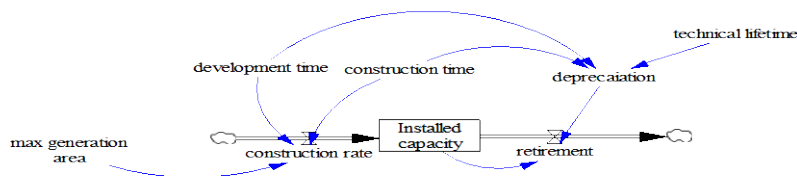


Figure 26 Installed capacity model

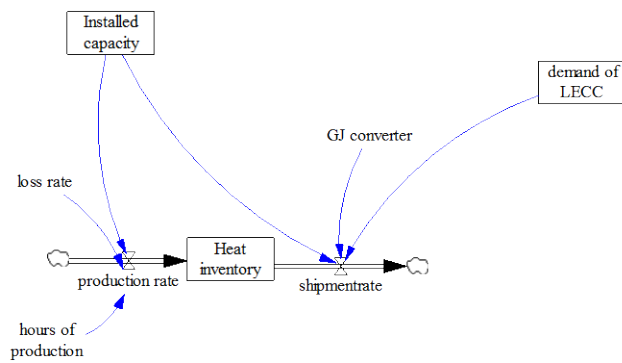
### *Heat inventory*

An important part of the business model of the LECC is to extent their district with the same installation. To determine when to start a second phase, a heat inventory stock is determined. This calculates what the overflow is in the installation.

Production rate = hours of production \* installed capacity \* loss rate

Shipment rate = IF THEN ELSE (installed capacity > 0, demand of LECC/GJ converter, 0)

Heat Inventory = STEP (Production rate - shipment rate, 5)



**Figure 27 Heat inventory**

### *Demand LECC*

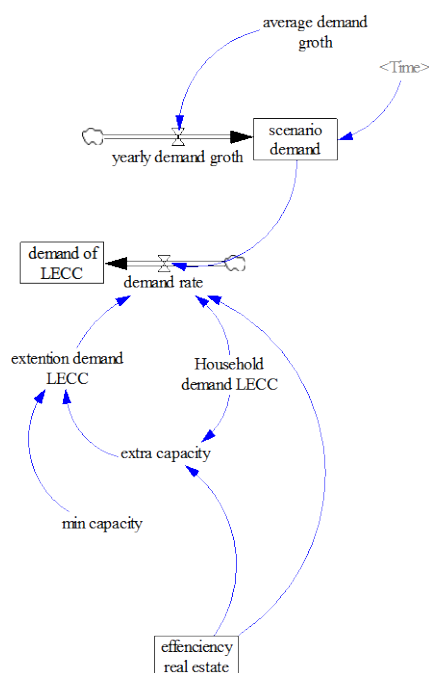
To determine the heat inventory from previous stock the demand of the LECC is needed. This is calculated by the stock demand LECC. This stock is influenced by the start demand, scenario demand and extension of a second district to the installation.

Yearly demand growth = STEP ( $\propto$  year 2000-2020, 0)-STEP ( $\propto$  year 2020-2040, 20)

Scenario demand = IF THEN ELSE (TIME>40, 0, -yearly demand growth)  
(Initial value =1)

Demand rate = (Household demand LECC\* scenario demand \* efficiency real estate) + extension demand LECC + companies demand LECC

Demand of LECC = STEP (demand rate, 5) (start value =0)



**Figure 28 demand of LECC**

### Efficiency

The efficiency is influenced by the rate of efficiency. The efficiency rate is paid from the investment rate. This rate is a reservation of profit to invest back into the district.

Efficiency rate = Investment in real estate

Efficiency real estate = - efficiency rate (start value =1)

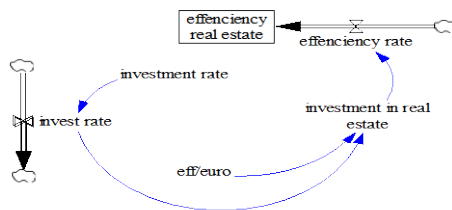


Figure 29 Efficiency real estate

### Profit

The profit of the LECC is the profit before tax. The profit is reserved for investment this means it has no tax obligation. If it is not used for new investment in the LECC, it needs to be taxed. So if there is given dividend to the shareholders, it first needs to be taxed.

Cost rate = Interest+ "Maintenance & operation cost" + yearly amount

Income rate = fixed income + variable income + companies

Investment rate = IF THEN ELSE (profit > min investment rate, investment rate, 0)  
- dividend

Profit = IF THEN ELSE (TIME > 40, 0, income rate - investment rate - cost rate) (initial value = 0)

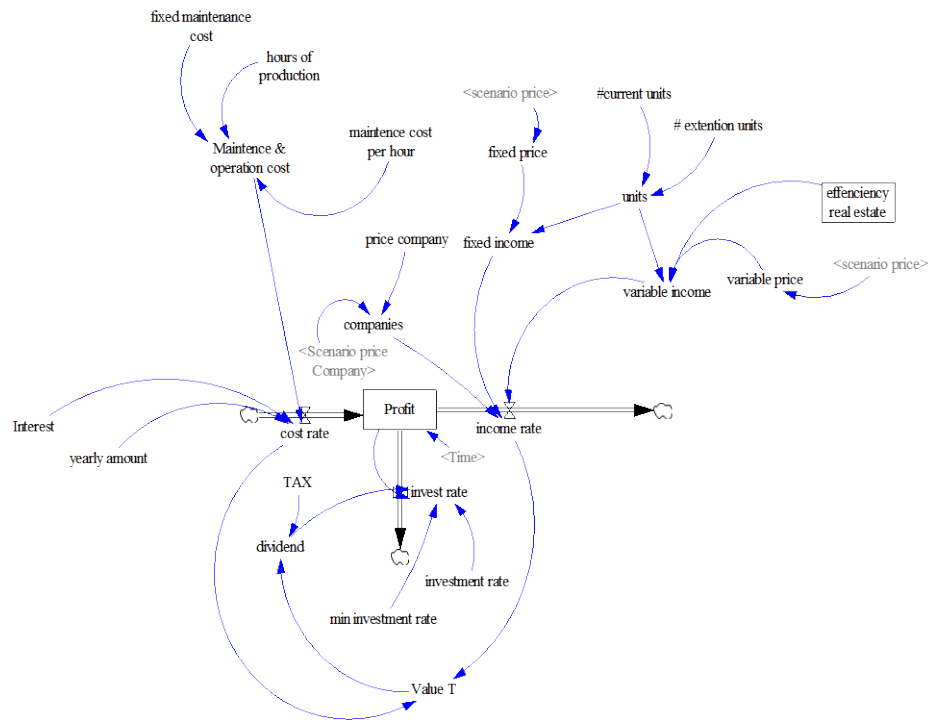


Figure 30 profit flow heat

### Debt

To start the project a loan is needed. In this project 90% of the investment is loaned. The other 10% is equity of the LECC; this is a result of selling the shares of the LECC. The time frame for repayment is 20 years.

Loan = total loan

Repayment = yearly amount

Debt = loan – repayment (initial value = 0)

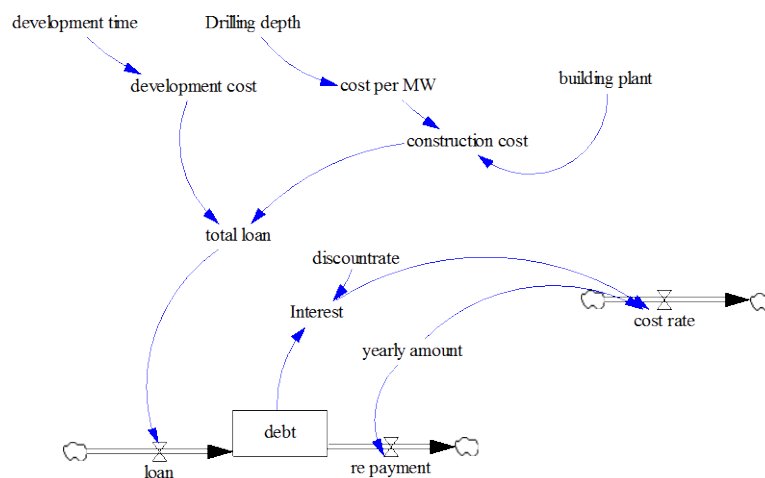


Figure 31 debt flow heat



## 5. CASE STUDY

In the previous chapter the concept model was introduced. This model will now be used in a case study. With the results of this case study the hypothesis can be answered. The case study is in the district of Prinsejagt in Eindhoven. We will fill in real actual variables of this district and run the model. With the result we can draw conclusion about the concept model.

The case study location will first be introduced. Secondly, the concept model for this case study will be developed. Thirdly, the model will be run and the results will be presented.

### 5.1 DESCRIPTION CASE STUDY

For the choice of the case study location, three conditions needs to be fulfilled.

First, this research is part of the KENWIB project, which is a local project in Eindhoven. So for the usefulness of this research, it is relevant to hold the case study in Eindhoven.

Secondly, it should be an urban area, with existing real estate and residents. Also the users should be entrepreneurs and consumers. It is also helpful that this area has room for efficiency growth. In this way there are many improvements which can be made, large and small. The urge for investment is present.

Thirdly, for the use of a geothermal installation it can be helpful to have a large consumer of energy. In literature this mostly is a horticulture building, however these are not located in an urban area. So an alternative is needed.

#### 5.1.1 LOCATION DESCRIPTION

The project consists of two phases; the start-up phase and extension phase. This is later in this paragraph further elaborated.

The first phase location is called 'Prinsejagt 2&3', it is part of the larger district 'Woensel' in the North of the city of Eindhoven. In fig it is indicated as the orange area. The area is enclosed by the; Marathonloop, Estafetelaan, Oude Bosschebaan, 1ste Lieven de Keylaan, and Huizingalaan. From now this area is called phase 1. The extension phase is called 'Prinsejagt 1', indicated with the blue area in fig xx. It is located on the west side of the Oude Bosschebaan and enclosed by the Julierpas, Boschdijk and the 1ste Lieven de Keylaan. In the rest of this report this location is called phase two.

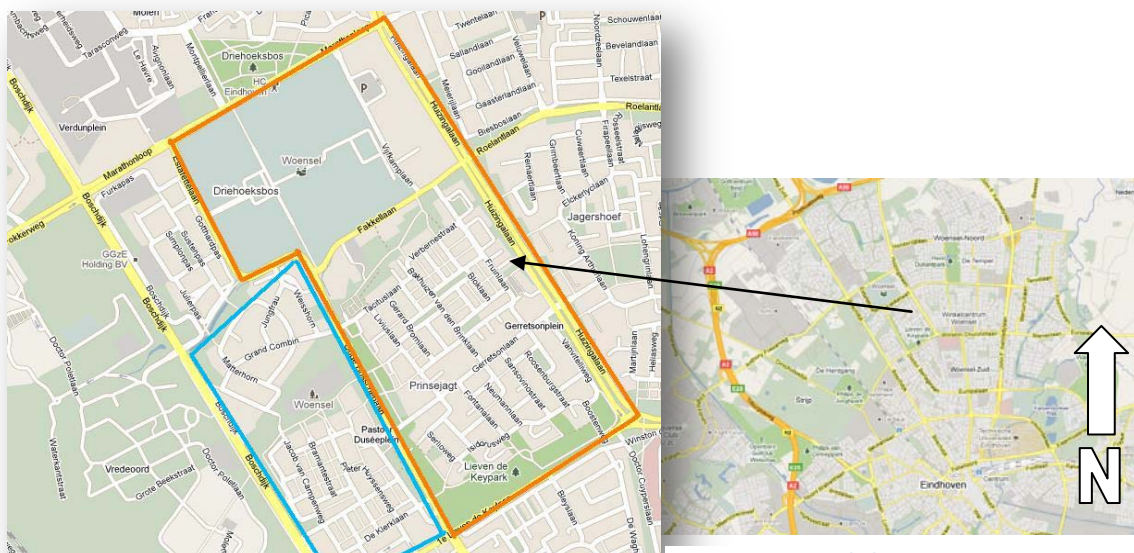


Figure 32 case study location

## GROUND PROPERTIES

Eindhoven doesn't have precious minerals, so there is no database of deep ground properties on the location. This makes it difficult to assess what the ground capability is for the case study location.

Drilling deep in the ground has high investment cost. So investors will not start such activities with a high probability to succeed. Research by TNO (2010) showed a general picture of the probability where the most geothermal chances are in the Netherlands. However, there is no empirical data of the Eindhoven area. In Appendix I charts and the analysis of the probability of geothermal energy in the Eindhoven area is given by TNO. For the case study are rough estimation of the thermal energy capacity is created.

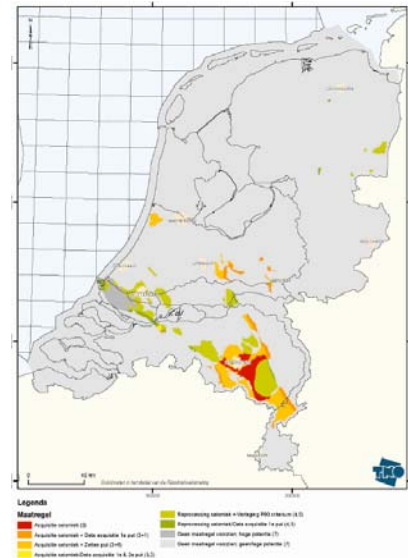


Figure 33 geothermal chart Trias plate

To calculate the doublet of the thermal heat, the formula of Van den Bosch (2010) is used, see eq. 1-12.

$$W_{th} = Q * \rho * cv * \Delta T \quad (1.12)$$

$W_{th}$  Thermal energy capacity  
 $Q$  water flow m<sup>3</sup>/hour  
 $\rho$  density formation water  
 $cv$  warmth capacity formation water  
 $\Delta T$  cooling off water in heat exchanger in Kelvin

For,  $Q$ , a standard flow in the Netherlands is 150 m<sup>3</sup>/hour, however there is no actual data on the case study situation. To be on the save side and to calculate a slower flow, we assume a 100 m<sup>3</sup>/hour.

According ECN (2010) in the Netherlands,  $\rho \times cv$ , can be assumed as 4, 19/3600 MJ/m<sup>3</sup>K.

$\Delta T$ , is the amount of heat in the heat exchanger. In our concept we use low-temperature heating. This means the temperature in will around 70° C and out temperature out will be around 30° C,  $\Delta T$  will be then be 40° C. This equals 40 K.

This resumes in the following calculation (eq. 1-13) for the power of a geothermal installation in Eindhoven.

$$\frac{125 * 4,19 * 40}{3600} = 5.8 MW \quad (1.13)$$

The last information about the ground properties is the drilling depth. From appendix II we can derive that we have to drill 2 km to the Trias plate, which is according TNO (2010) is the right plate for Eindhoven.



## SOLAR CAPACITY

When using solar panels it is important to know the capacity of that location. The two most important factors are the amount of Sundays in that area, and the scope en direction toward the sun.

According to the long term climate atlas of the KMNI (2011) Eindhoven has around 1570 hours of solar a year. A raw calculation on the amount of buildings and the direction towards the south gives an estimation of 50% percent available roof tops in the district to construct solar panels on.

### 5.1.2 ENERGY USE & BUILDINGS

For this case study an energy set of the district was provided by the municipality of Eindhoven. This set present the energy use for heat and electricity for each address. From this set the data was derived for this case study. The general data is introduced in Table 1

	House holds	Companies	unit
<i>Phase I</i>			
# units	2.003	29	unit
use of natural gas	2.210.094	1.952.169	m3
use of electra	4.770.004	3.330.513	KWh
<i>Phase II</i>			
# units	725	25	unit
use of natural gas	1.308.904	205.462	m3
use of electra	2.951.691	1.449.729	KWh

**Table 1 dataset district Prinsejagt**

In table 1 a distinction is made between households and companies. This is later of use when calculating the price for the user.

In phase one 2003 household units are identified. 29 units are identified as companies, this companies are located on the Fakkellaan en de Vijfkamplaan. The most important energy consumers of these companies are the sauna and the swimming pool.

On this moment the swimming pool is under construction to heat the pool with a biomass installation. In this study this installation is not taken into account.

## 5.2 CASE STUDY MODEL

The input parameters are now all introduced, the elaboration of the models is now used in this case study. A starting point is described, so the setting is clear. After that the model will be elaborated and the model will be run and the results will be shown.

### The starting point

The community coalition starts with a lead agency and early adopters. The swimming pool and sauna are highly depended on the price of natural gas in their supply chain. To reduce the risk of high gas prices they search a technology which they are less depended on the market prices of gas. They find a group of households which are interested to create sustainable generation possibilities in their district. They define their goals into the community context.

*Companies: Reduce risk for possible high prices for gas in the future*

*Households: Generating & buying energy, the profit is used to increase the energy saving capabilities of the real estate. The price is market conform.*

The model is separated in heat and electricity generation.

The two models are designed in one model to prevent confusion the electricity parameters are noticed with an 'E', the parameters for heat have no mark.

### 5.2.1 HEAT GENERATION

For the heat generation model the model elaborated in chapter 4 will be used. The following parameters are for these specific case imported into the System Dynamics model. This data is generated from a dataset from the municipality of Eindhoven. The numbers of extension unit's are generated by trial and error in the SD model.

#### INPUT

Household demand LECC	50,230	GJ
Large users demand LECC	44,367	GJ
extentsion demand phase II	29,748	GJ
# Current unit's	2,003	units
# Extension unit's	725	units
Max generation capacity	5.8	MW
Drilling depth (twice)	4,400	meter

A total view of the SD model is shown in Figure 34. on the next page.

When the scenarios are run the results are different for each scenario. There are some general results. These results apply for every scenario, because the parameters for the scenarios have no effect on the rates or flows.

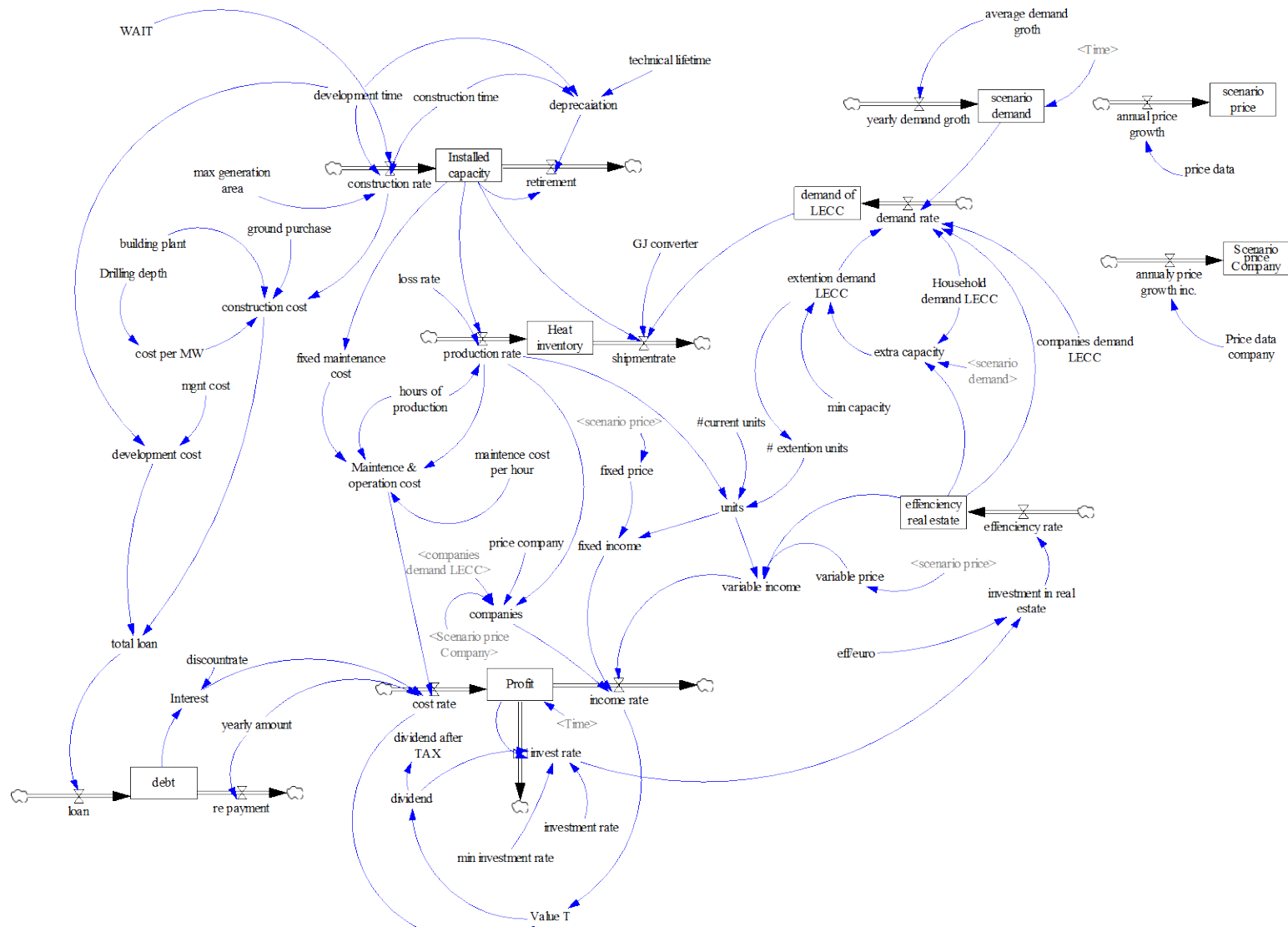


Figure 34 SD model Heat

## Installed capacity

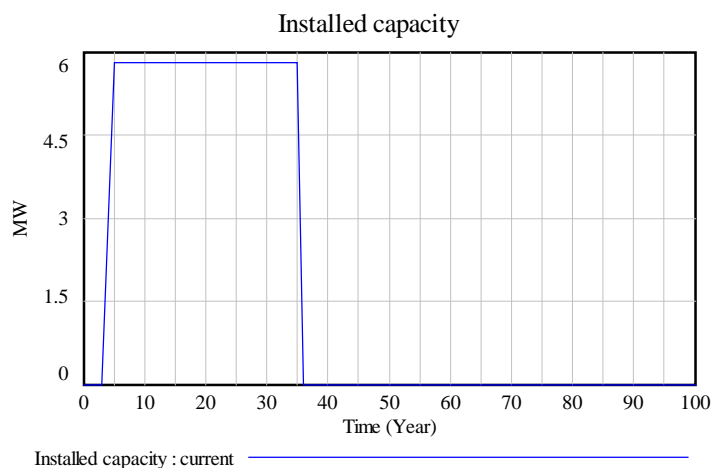


Figure 35 Installed capacity geothermal installation from SD

The calculated 5.8 MW for the geothermal installed is shown in Figure 35. As shown in the picture it takes 5 years to install the plant. After that, the installation will generate heat for 30 years.

## Cost rate & Debt

The cost rate is used to calculate the yearly cost for supplying the district of heat. It is structured due to the Maintenance & operation cost during the entire lifetime. The peak is a result of the decreasing debt from Figure 37 from the loan. The debt times the discount rate is a yearly cost which we need pay to our financier. Also we have to pay our loan back.

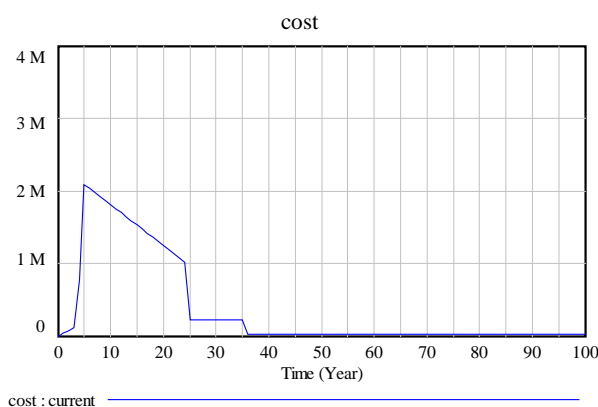


Figure 36 cost rate geothermal installation

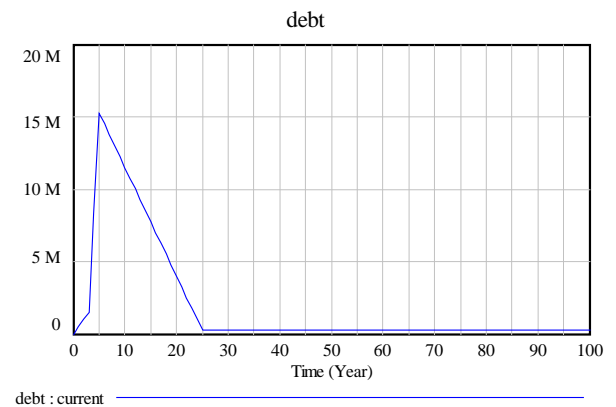


Figure 37 Debt from the investment

Debt is a stock between loan and repayment. In this case the loan is 90% by the bank, we pay a discount rate of 7,5%. The payback time is 20 years. The other 10% is own assets brought into by the shareholders. If there is positive profit, 15% of the profit is divided among the shareholders. The rest of the profit is reserved for further investment.

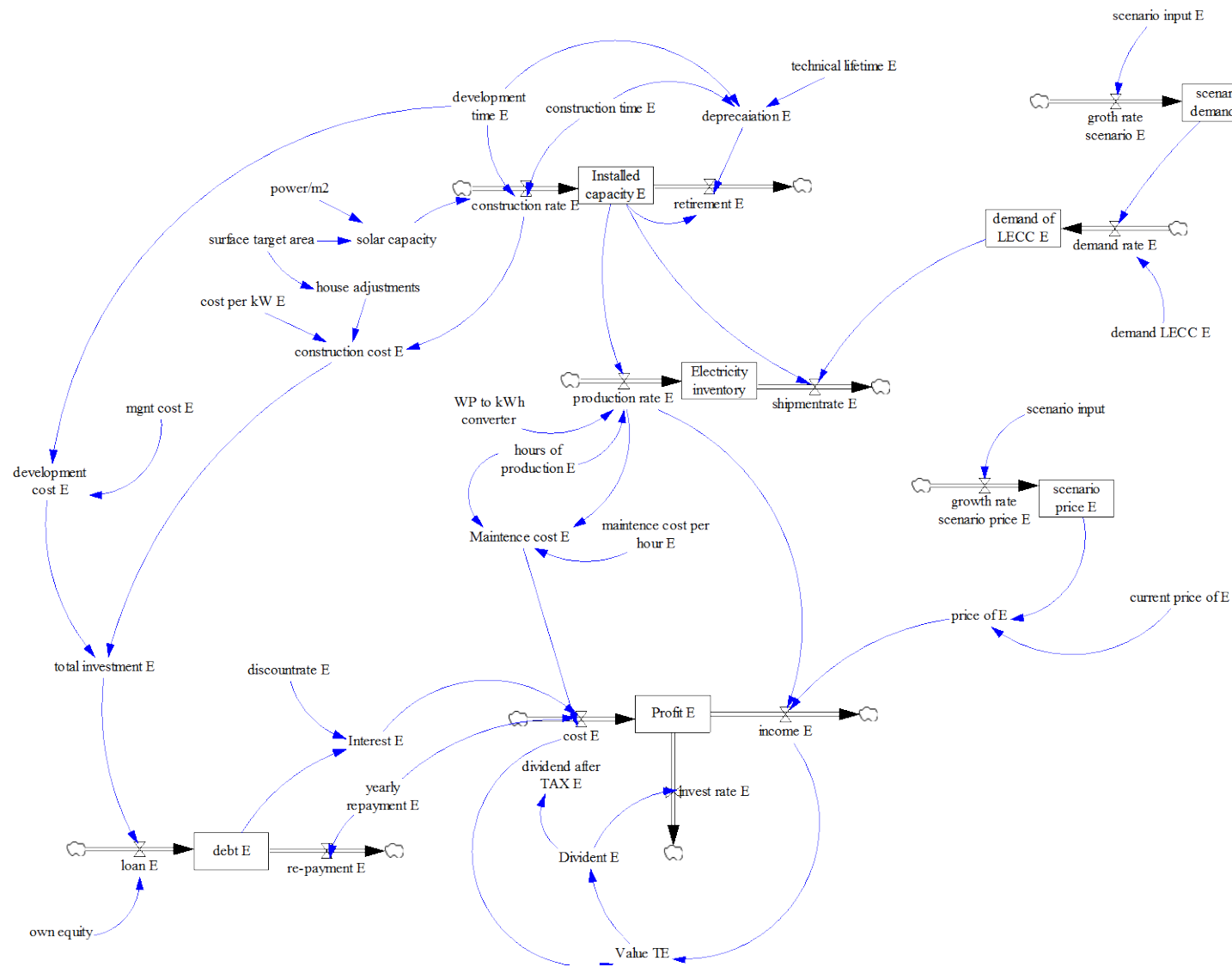


Figure 38 SD model electra

### 5.2.2 ELECTRICITY GENERATION

For the electricity generation model the model elaborated in chapter 4 will be used. The following parameters are for these specific case imported from the dataset from the municipality of Eindhoven. The amount of sun hours is derived from a weather report from the Dutch KNMI (2011).

#### INPUT

Demand LECC E	4.770.004 KWh
Roof surface area E	8000 m <sup>2</sup>
Hours of production E	1570 hours

The total SD model is modelled on the previous page in Figure 39 .

Some general results are shown first. These results count for all scenario, because the parameter for the scenarios have no effect on the rates or flows.

#### Installed capacity E

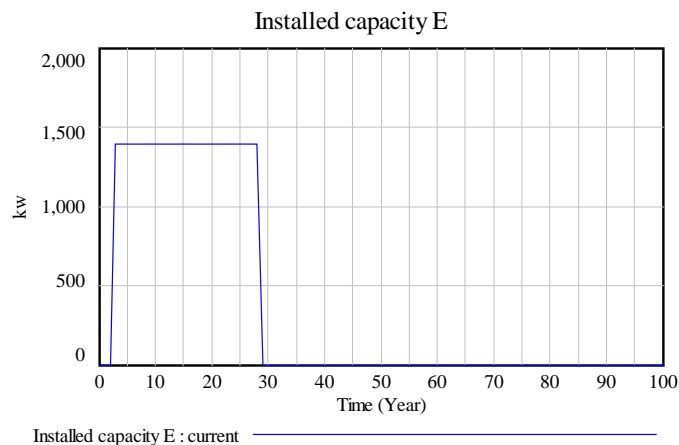


Figure 39 Installed capacity Electricity

The solar panels have a total lifetime of 25 years. The first two years are reserved for designing and making contracts with the LECC. Then the total construction time is six months. Together with the retirement rate makes sure brings the total installed capacity.

### 5.3 RUNNING THE MODEL

The goal of running the different scenarios is too see the difference in each flow or rate in time. After running the four scenarios, elaborated in paragraph 4.1. The most important results of these scenarios will now be showed.

The essence of the geothermal model lays in the profit and in the demand. By decreasing the demand extra participants can join the project which gives more profit.

For the solar panels model o

#### 5.3.1 HEAT DEMAND

The heat demand will start in year 5 after finishing the installation. Because the scenarios for strong Europe (SE) and Regional communities (RC) are the same there is only one line for these scenarios. All scenarios are decreasing. This is under influence of the forecast of less demand and the investment in efficiency of the buildings. This results that in year 34, the second phase can be added to the LECC. This means that the demand increases.

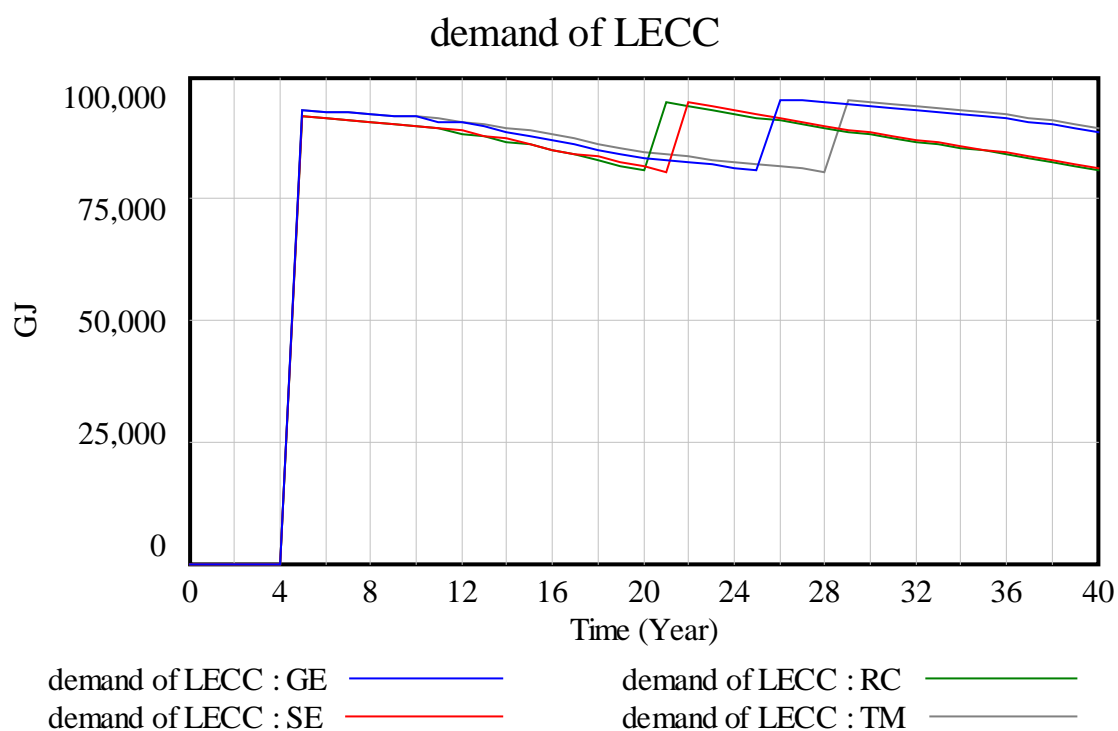


Figure 40 heat demand LECC

#### 5.3.2 HEAT PROFIT

The profit from selling heat is modelled on the next page see figure 41. You might think that the profit for the first few years should be very negative, due to the high investment of the construction of the plant. This investment is left out of this view. The investment is covered by a loan. For this loan we pay every year 10% interest and repay back the loan in 20 years. You can see that after the repayment the profit strongly increases.

A nice result from this model is that very high increase of price not necessary means the highest profit. Due to the high decrease of demand, phase two can quickly be added to the

project which results in higher profits than the high increase of price. We can conclude that a combination of demand decrease and extension of the network offers high results.

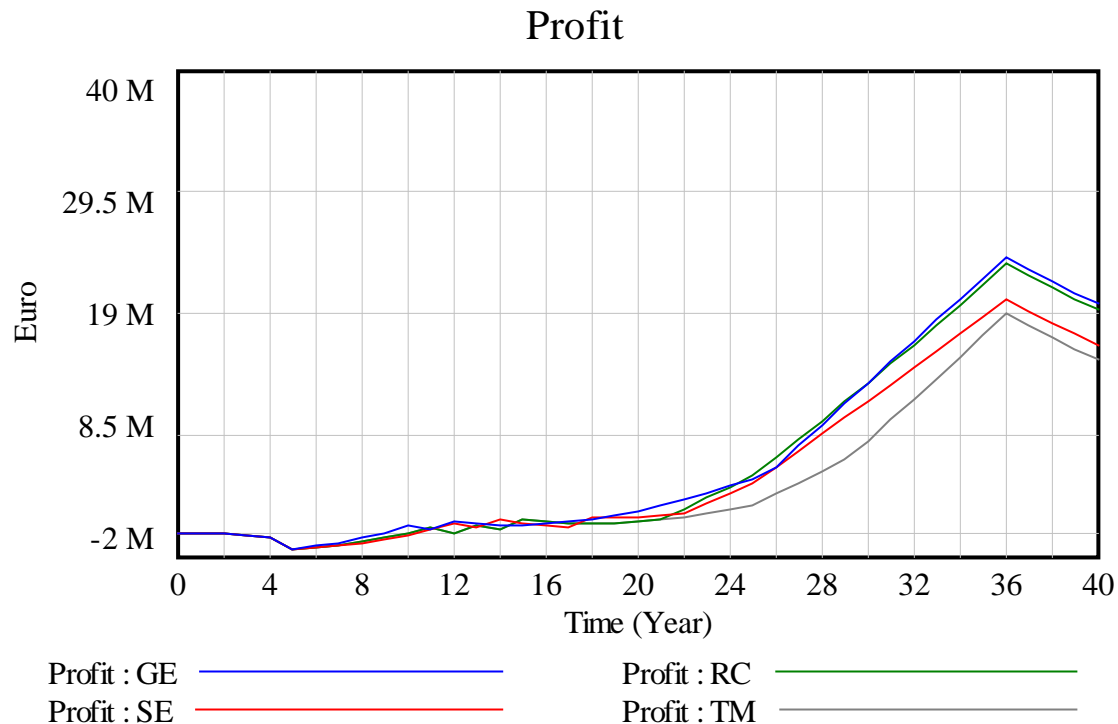


Figure 41 profit heat

### 5.3.3 ELECTRICITY PROFIT

The solar panels project is slightly different organised than the geothermal project. Because some of the participants only have solar panels and can profit from the electricity, the profit is yearly divided due to with paying dividend to all shareholders. All shareholders buy a share of the solar project and receive every year a dividend of this investment.



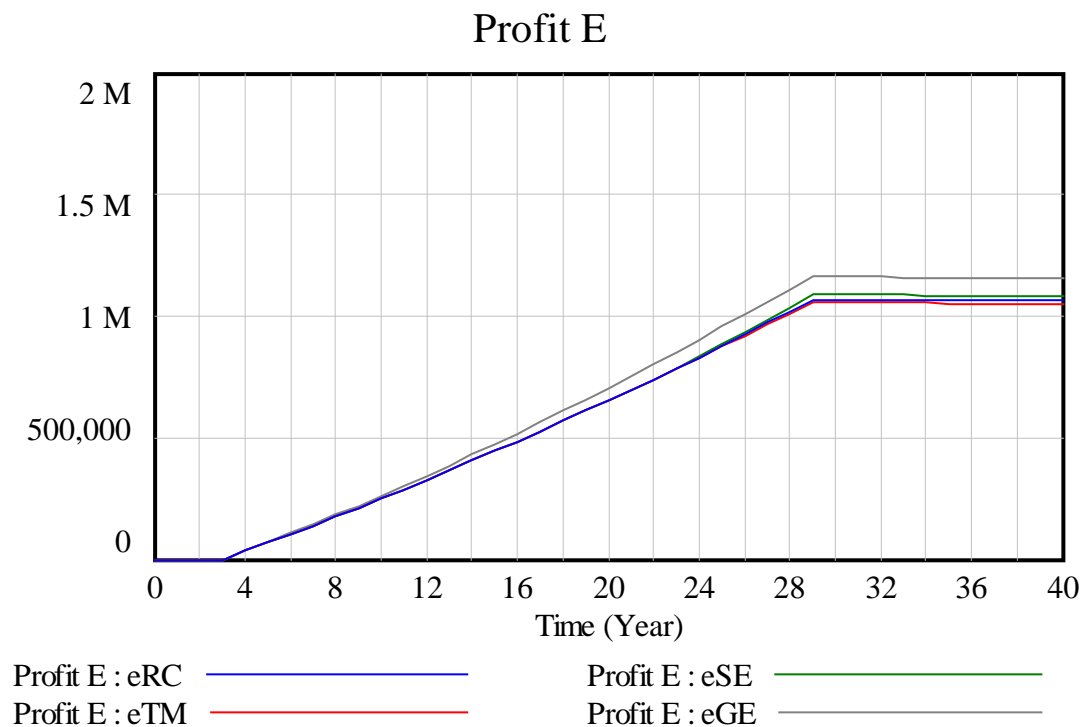


Figure 42 profit Electricity

In Figure 42 the amount of money which is reserved for the dividend is modelled. The dividend is modelled after tax is paid. From the yearly profit of the selling electricity 75% is going to the shareholders in form of dividend. The total amount of dividend a year is sketched in fig xx. For a normal investment project 10% yield is seen as a minimal percentage. As we have a total shares of 2200 units. A quick calculation shows that we cannot fulfil this percentage until the end of the project.

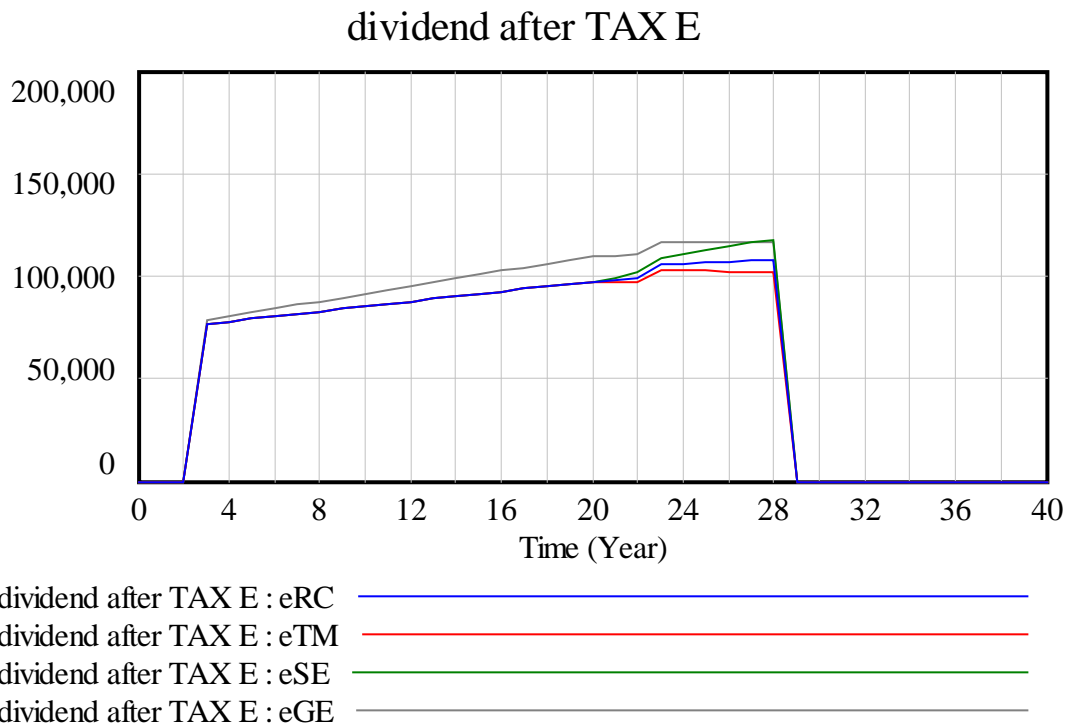


Figure 43 Dividend after tax

## 5.4 CHOOSING AN OPTION

After running the models the investment question remains, should the project be started? Four scenarios are run and the results are presented. These results should now be analysed and compared to make a decision. This decision is for the geothermal investment very hard, due to the high investment. Further elaboration of the investment decision will be threatened for this installation only. The standard method for such question is done with the net present value (NPV). However, as explained in the general model elaboration, after the NPV a real option analysis is made. This is done to value the cost of opportunity.

The NPV formula (eq. 1-1) says that; the discounted values of the project should be larger than the investment. In this case all four scenarios have a positive result see table xx. The data for the NPV can be found in appendix IV.

scenario	Result NPV
GE	510.497
SE	22.859
RC	119.683
TM	32.160

Table 2 NPV results

The NPV is calculated with a discount rate of 17, 5 %. This sounds ridiculously high; however taken in consideration that the project is financed with 90% outside money and it is considered as a highly risk full project. The LECC will be responsible for the entire project which means high risk. This means that finance cost are very high.

The NPV tells us to invest into the project for all four scenarios. This can be seen in table 2. The sum of the discounted values,  $V$ , for each scenario are larger than the investment,  $I$ .

The LECC however wants to know if this is the right time to invest. With the real option theory they try to

scenario	$V^*$	$F(V^*)$
$V^*_{GE}$	1.34	0.013
$V^*_{SE}$	1.38	0.048
$V^*_{TM}$	1.39	0.058
$V^*_{RC}$	1.39	0.058

Table 3 optimal value scenario

determine the optimal investment moment.

In the following table for each scenario the optimal value,  $V^*$ , are determined according eq. 1-12.

In table 2 the value,  $V$ , for each scenario is noted, it is the discounted value of the modeled scenarios from the SD model, for more data see appendix IV.

When,  $V$ , is compared with,  $V^*$ , the conclusion can be taken that scenario GE and RC are optimal situated to invest now. The value of the model is higher than the calculated  $V^*$ . However, the other two scenarios are not close to their optimal decision point.

Now a closer look to the contents of the scenarios is necessary. Does the forecast of the scenario make any sense? The LECC needs to make a strategic decision to validate the scenarios. The logical choice should be that the lowest scenario is the decision point to start the project. This means; wait with the investment, and when the values of all scenarios have a positive result, invest. This option to wait can be valued as,  $F(V)$ , the cost of opportunity.

GE					SE				
$\alpha$	$\rho$	$I$	$V$	$F(V)$	$\alpha$	$\rho$	$I$	$V$	$F(V)$
0.0171	0.175	1.328	1.84	1.401	0.0171	0.175	1.328	1.35	0.060
RC					TM				
$\alpha$	$\rho$	$I$	$V$	$F(V)$	$\alpha$	$\rho$	$I$	$V$	$F(V)$
0.0073	0.175	1.328	1.45	0.165	0.0073	0.175	1.328	1.36	0.037

Table 4 value of opportunity per scenario

The LECC defines two options for the decision.

1. Invest in the project according the NPV. In the case of the Prinsejagt, all scenarios have a positive result. This means that there are financial possibilities for the district to start a process of business plan modelling.
2. Wait with investing in the project. When all scenarios have reached their optimal value, it is time to start the project. The cost of opportunity for such a choice can be developed as a call-option. This call option can be sold to an investor or the companies in the district. When the option is not called, the forecast is not emerged and the reason to develop the option is gone. The cost of this option can be deleted with increase of the price.

The cost of opportunity is the cost of an opportunity when the investment option is "out of money". The investment could be a success in the future, when prices are raised. The value of this opportunity is for the lowest call option, TM, 0, 0037. This means the option for LECC is valued at € 37.000, - .

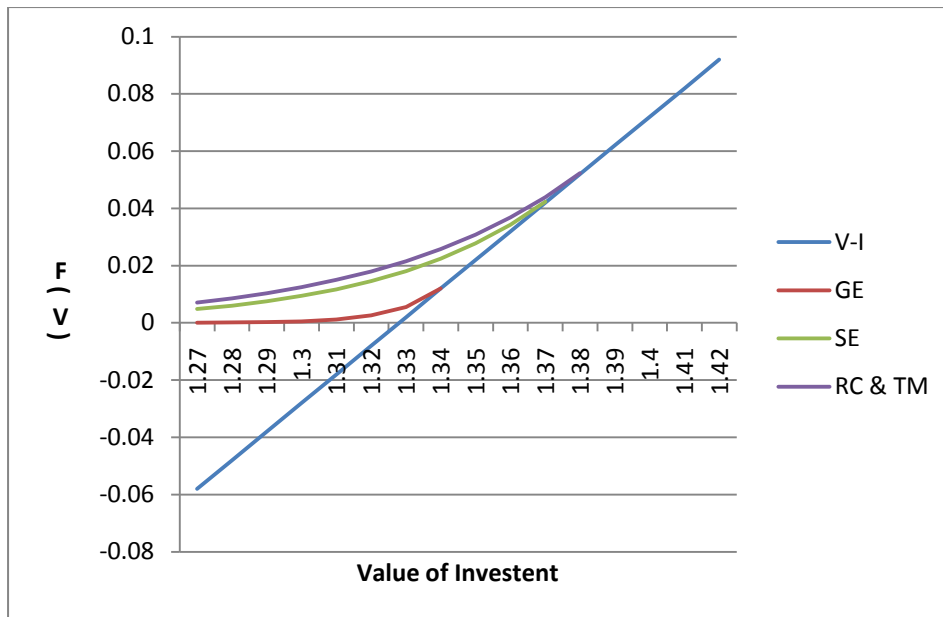


Figure 44 cost of opportunity

Value	V-I	GE	SE	RC&TM
1.23	-0.09802	1.87537E-06	0.001921	0.003312005
1.24	-0.08802	4.29507E-06	0.002423	0.00402154
1.25	-0.07802	9.77153E-06	0.003051	0.004875472
1.26	-0.06802	2.20857E-05	0.003835	0.005901666
1.27	-0.05802	4.95974E-05	0.004811	0.007133075
1.28	-0.04802	0.000110676	0.006025	0.008608618
1.29	-0.03802	0.000245432	0.007533	0.0103742
1.3	-0.02802	0.000540929	0.0094	0.012483895
1.31	-0.01802	0.001185003	0.011712	0.015001324
1.32	-0.00802	0.002580528	0.014567	0.018001237
1.33	0.001978	0.005586589	0.018089	0.021571363
1.34	0.011978	0.012024644	0.022425	0.025814531
1.35	0.021978	0.025734893	0.027757	0.030851129
1.36	0.031978	0.054768868	0.034302	0.036821935
1.37	0.041978	0.115915662	0.042325	0.043891381
1.38	0.051978	0.243995824	0.052144	0.052251309
1.39	0.061978	0.51084457	0.064146	0.062125285
1.4	0.071978	1.063885147	0.078792	0.073773562

Table 5 Value of Real option

The conclusion of this option to wait can be seen as the end result. However, the research model from Georgantzas (2010) Figure 12 shows us that this result can be used to change the SD model and rerun the model.

Furthermore, it would be great to know when scenario TM would reach  $V^*$ . It can be calculated with the real option theory. However, we can see what happens with this scenario, when we create a delay in the SD model. This delay represents, option 2, waiting

instead of investing. When this delay is modeled into the SD model, the following discounted values for  $V^{\text{TM}}$  are presented.

<b>V(1)</b>	<b>V(2)</b>	<b>V(3)</b>	<b>V(4)</b>	<b>V(5)</b>
€ 1,317,142	€ 1,478,143	€ 1,632,245	€ 1,792,174	€ 1,952,741

Table 6 Values of waiting with investment

The conclusion from this data is that two years waiting the  $V^{\text{TM}}$  is larger than  $V^*$ . This means that the all parameters are positive and the project can be started.

For the reliability of this research, validation is vital. The research is validated in two ways; literature and expert validation.

The amount of citations is very high, as one can see in the bibliography. This ensures the theoretical basis for relations, formulas and input data.

Three expert meetings have cleared the relations in SD-model. This said, the validation of the concept is very hard and very subjective. So has a financial expert agreed with the real option model. However, he said, "it is not wrong", but he questioned the switch from financial options to energy demand.

## 6. CONCLUSION

So what can we conclude with the results of this research? To answer this question the given problem statement from chapter one should be answered, which was;

***The value of a sustainable investment is not captured by current investors; this development stops them investing in sustainable districts. On this moment there are no real investors who act as an energy developer on a large scale. Could a community collation act as a new developer?***

This problem statement is divided into three research questions. These questions will be chronological answered. After these conclusions, a discussion on the process, results and conclusion are given. Finally, recommendations for further research are given.

### 6.1 CONCLUSION

The first two research questions give extra weight to the given problem statement. These two questions confirm that the hypothesis is a valid question to ask and provides extra information about the concept. These research questions have also three sub questions; these answers are elaborated in the answer of the research question. For the definition of the sub questions, see paragraph 1.3.

#### ***RQ 1: What are the factors for financial feasibility of energy autarky for a community?***

There are three factors indicated as success factors from the example of Güssing.

##### ***1. Environmental opportunities***

Autarky can only be gained when local opportunities are exploited. These local opportunities are everywhere different. This can be; using natural capabilities, using natural waste from the own district to generate energy, or using industrial waste to produce energy.

##### ***2. Starting capital***

Most of the times there is not enough renewable energy capacities to supply the district with energy. The energy demand is too high. So besides the investment to start a renewable energy generation plant, an investment should be made in decreasing the amount of energy. This cannot really be done in mutual phases. Both investments should be made in the same time. This causes high investment in the start-up phase of the project. An important aspect in this investment decision is the change from short-term into a long-term perspective. The strategic uncertainty of the long-term perspective is in this decision vital. To reduce the risk for the investor of the long-term, commitment of the user is needed. This commitment ensures the investor to invest for the long-term.

##### ***3. Spin-offs***

Becoming autarkies asks a lot of commitment from all stakeholders. Social spin-off in such a project increases the success factor of the project. In the case of Güssing the town was almost dead, there were no jobs and everybody was leaving the town. Since the change in an autarkies district a 1000 jobs were created. This lifted the entire town to higher level.

A returning issue in the conclusion of RQ 1 is the commitment issue. A concept to increase commitment in such developments can also be the starting point for developing community coalitions.

### **RQ 2: How can a community energy coalition be organised?**

In the energy sector there are organisation forms where cooperation's are founded. According to Stamford (2004) the only form which could fit the concept of an energy autarky district redevelopment is the cooperative owned form.

To found such an organisation and satisfy the success factor for an energy autarky district, a more elaborated model is needed. For that reason the format for a community coalition was introduced. Community collations have three big advantages; they bring large group of stakeholders together, create social capital and are catalyst of change.

The best model for a community collation for this model is the community coalition action theory (CCAT) by Butterfoss & Kegler (2002), see Figure 45 . The CCAT has proven itself in the improvement of social security in some suburbs of the USA. It is also used to increase the health care in the some district in the states.

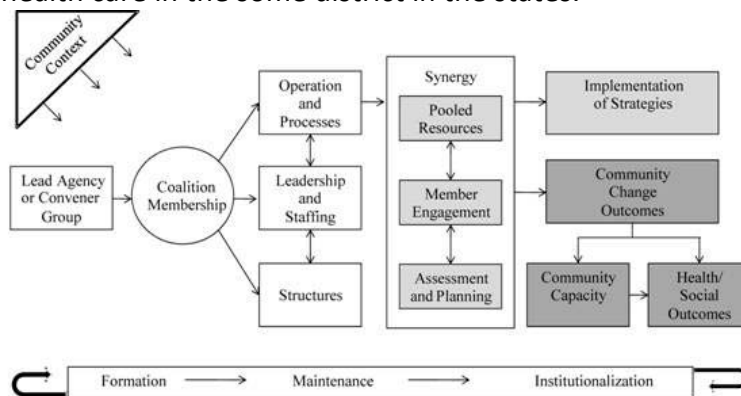


Figure 45 CCAT model (Butterfoss & kegler, 2002)

For this research the start of this process is important. The lead agency or convener group and the community context should be defined very clear and elaborated on the financial level. When that is completed the coalition membership can be determined. The decision to start this is done with the tool of this research.

### **RQ3: What are the options for the community as energy developer?**

In this research a general model is developed for a local energy community coalition. This model uses the techniques of geothermal generation and solar panels to feed the district with heat and electricity. A business idea is used that encourages the participants to reduce energy and expand their district. The business model is supported by four scenarios on demand and price of energy. These four scenarios forecast the future; the events in these scenarios have direct influence on price and demand of the future.

This model was implemented on the district of Prinsejagt in Eindhoven. After running the SD model with the scenarios, the value of the project was calculated. According the NPV in all four scenarios the project was positive, so feasible. The NPV only defines a go- or no go decision. With real option theory, timing of the investment is not taken into consideration. According the optimal value rule, only two of the four scenarios reached the optimal decision point on this moment. The other two, SE and TM, didn't reached the optimal value, but were feasible according NPV. Real option theory suggests to wait until the values emerge. When the future values reach the point of the optimal investment, start the project.

The LECC model defines two options to consider for its stakeholders;

- 1 Invest in the project according the NPV. In the case of the Prinsejagt, all scenarios have a positive result. This means that there are financial possibilities for the district to start a process of business plan modelling. Real option Theory, tells it is not optimal to invest.
- 2 Wait with investing in the project. When all scenarios have reached their optimal value, it is time to start the project. The cost of opportunity for such a choice can be developed as a call-option. This call option can be sold to an investor or the companies in the district. When the option is not called, the forecast is not emerged and the reason to develop the option is gone. The cost of this option can be deleted with increase of the price.

Further running with SD model shows that with the current parameters. The project is calculated an optimal result in two years. This means for case of Prinsejagt option two should be followed and in two years start the project. This option is worth 37.000,- euro.

## 6.2 DISCUSSION

In the research some assumptions are made, these assumptions are not wrong. However, with current knowledge they could be made better.

Firstly, the generation of heat is modelled with the principles of geothermal heat. A geothermal generation plant is a high investment. The question remains if the technique is not too expensive for an organisation like LECC. Furthermore, this high investment asks for a larger area to sell to. This is not a real problem. However, the question remains if such a large area is ready to commit on a voluntary base.

If a smaller district is taken, a commitment issue is easier to tackle. This combined with a technique like the aquifer thermal energy storage could be perhaps given more practical success..

Secondly, this research has the goal to help the consumer to help make an investment choice to redevelop their district into an energy autarky one. In this research the focus lays on the community development. However, the consumer perhaps wants to be convinced that the community investment is the best option. So as a tool for the consumer, an individual investment option could be an addition to the model.

Thirdly, in this research the assumption was that an energy distributor, like Endinet in Eindhoven, would build an infrastructure for this district. The question is if, such companies are fund of these kinds of infrastructures.

Finally, the real option part of the model is correctly constructed according theory from the authors of the theory. However, the theory of real option theory isn't a proven theory in the field of energy. Experts have cleared the result; however they were not really convinced. So, further research on real option theory in the energy sector can be helping the validation of this theory.



### 6.3 RECOMMENDATIONS

This research shows that there can be financial benefit for a district to redevelop their district. However, there needs to be much research before this concept can be realised in real life.

One of the most important issues in a small district heating system is the infrastructure. Due to the opinion of many experts, I have not mentioned it in my research. In the Netherlands, generation and distribution is by law separated. However, it is interesting to know if it feasible to start a small district heating company for like the LECC. Especially the legal and technical problems around such companies can be very interesting.

In the hypothetical case, that there is a small group of people who do what to organise a LECC. What are the behavioural aspects of people to actual join this company. Yes, financially it is feasible, but how do you tackle the problem joining the other people into these LECC.

Finally, a problem with community investment is the long-term investment versus a short term use of the buildings. An average stay in a building is seven years. So if community investment needs to work, a better dividing of shares, risk and profit needs to be taken care of. The question is, what consumer find acceptable in this field?



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## **8. INDEX APPENDIX**

**8.1 Thermal heat chart**

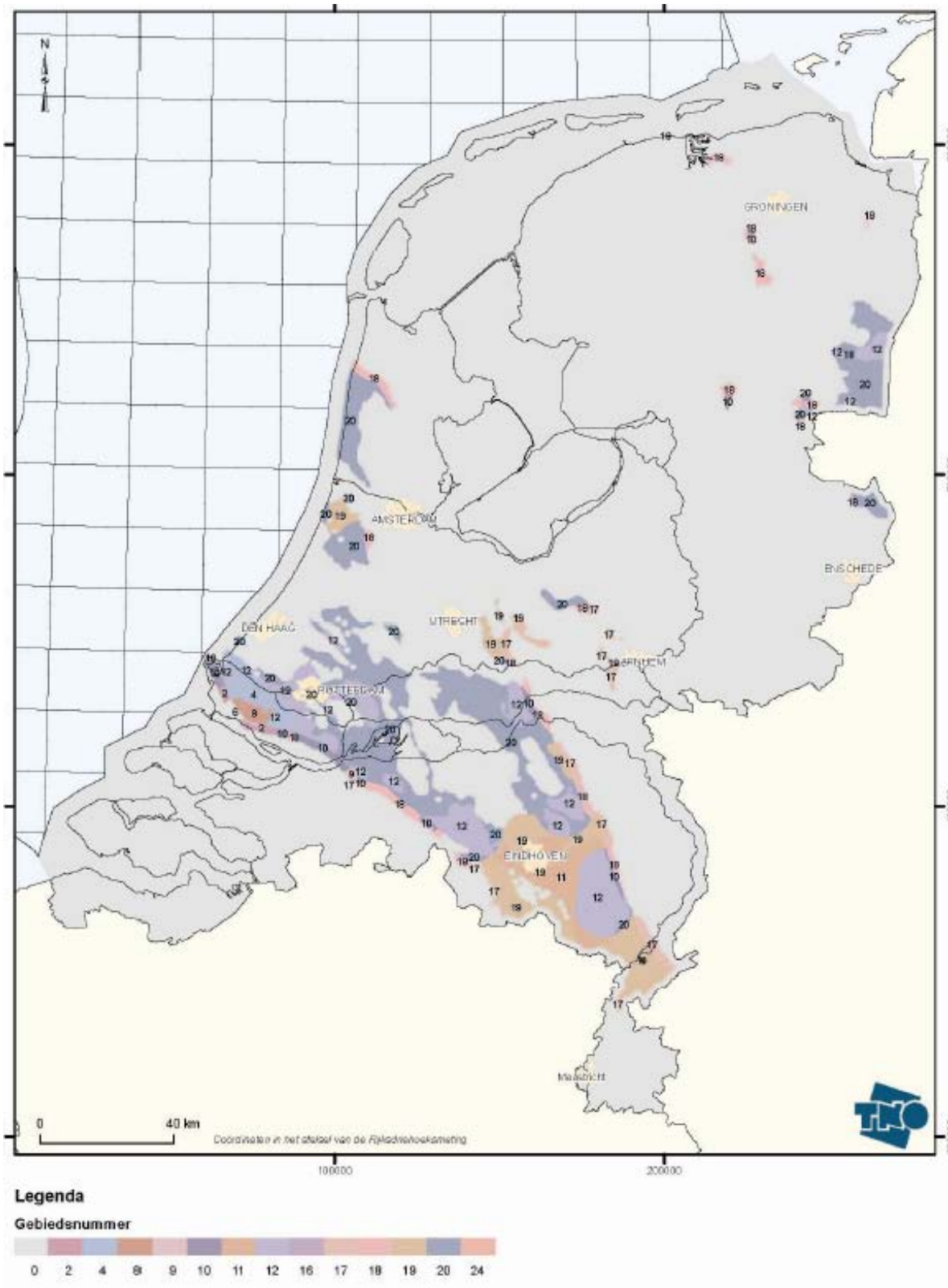
**8.2 Geographical charts**

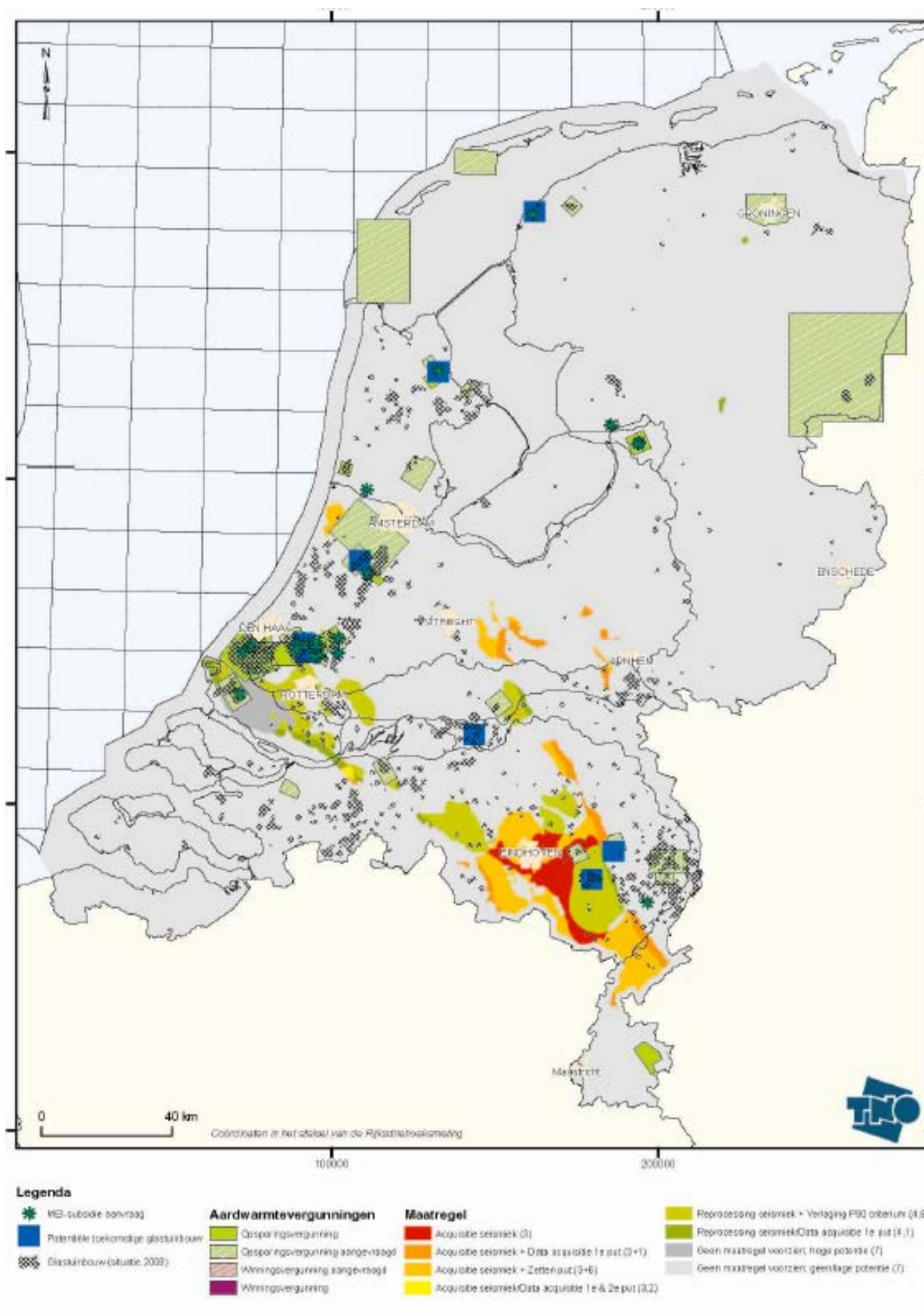
**8.3 Scenario data**

**8.4 value data from the system Dynamics model**

**8.5 Extended summary**

## 8.1 THERMAL HEAT CHARTS





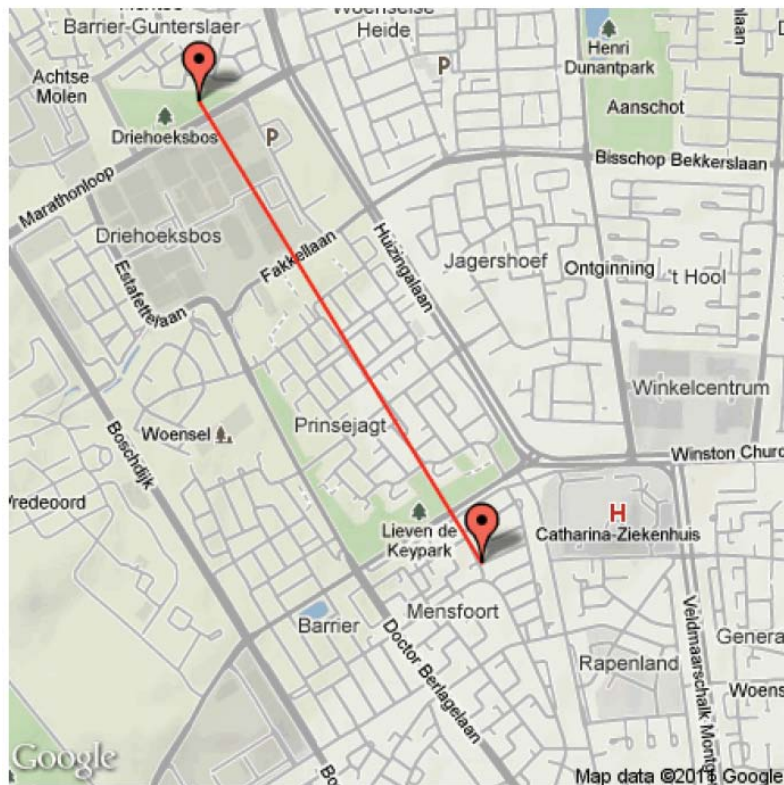
Vermogenskaarten			Aquiferkarakterisatiekaart	Datadichtheidskaart	Onzekerheidsgebied	Maatregel
P10	P90-P50	Onzekerheid	Aard van de ondergrond	Datadichtheid	Gebiedsnummer	
Gebied zonder aardwarmte potentie => P10 < gewenst vermogen (4MW)	n.v.t.	n.v.t.	n.v.t.	n.v.t.	0	Geen*
Gebied met aardwarmte potentie => P10 > gewenst vermogen (4MW)	P90 > gewenst vermogen & P50 > gewenst vermogen	Groot/onzeker	Grillig	Laag	1	1
				Hoog	2	Geen*
			Robuust	Laag	3	1
				Hoog	4	Geen*
		Klein/zeker	Grillig	Laag	5	Geen*
				Hoog	6	Geen*
			Robuust	Laag	7	Geen*
				Hoog	8	Geen*
	P90 < gewenst vermogen & P50 > gewenst vermogen	Groot/onzeker	Grillig	Laag	9	3,2
				Hoog	10	4 of 1
			Robuust	Laag	11	3
				Hoog	12	4 of 5
		Klein/zeker	Grillig	Laag	13	4, of 5 en 2
				Hoog	14	5 en 1
			Robuust	Laag	15	5 en 1
				Hoog	16	5
	P50 < gewenst vermogen & P10 > gewenst vermogen	Groot/onzeker	Grillig	Laag	17	3 en 1
				Hoog	18	Geen*
			Robuust	Laag	19	3 en 6
				Hoog	20	Geen*
		Klein/zeker	Grillig	Laag	21	3
				Hoog	22	4
			Robuust	Laag	23	Geen*
				Hoog	24	Geen*

Nr.	Omschrijving maatregel	Van toepassing op gebied
1	Data-acquisitie in 1ste put	1,3,10,14,15,17,
2	Data-acquisitie in 1ste put en 2e put	9,13
3	Acquisitie seismiek	9,11,17,19,21
4	Reprocessing seismiek	4,12,13,22
5	Verlaging P90 criterium*	12,13,14,15,16
6	Zetten van een put	19
7	Voor verkleinen van spreiding P90-P50 is geen maatregel voorzien	0,2,4,5,6,7,8,18,20,23,24
nr.	Omschrijving algemene maatregel	
8	Mijnwettelijke gegevens die zich nog niet in het publieke domein bevinden vrijgeven	
9	Herbewerkingen van mijnwettelijke gegevens die niet in het publieke domein bevinden vrijgeven	
10	Maatschappij evaluaties die zich niet in het publieke domein bevinden vrij geven	

## 8.2 GEOLOGICALCROSS-SECTION LOCATION

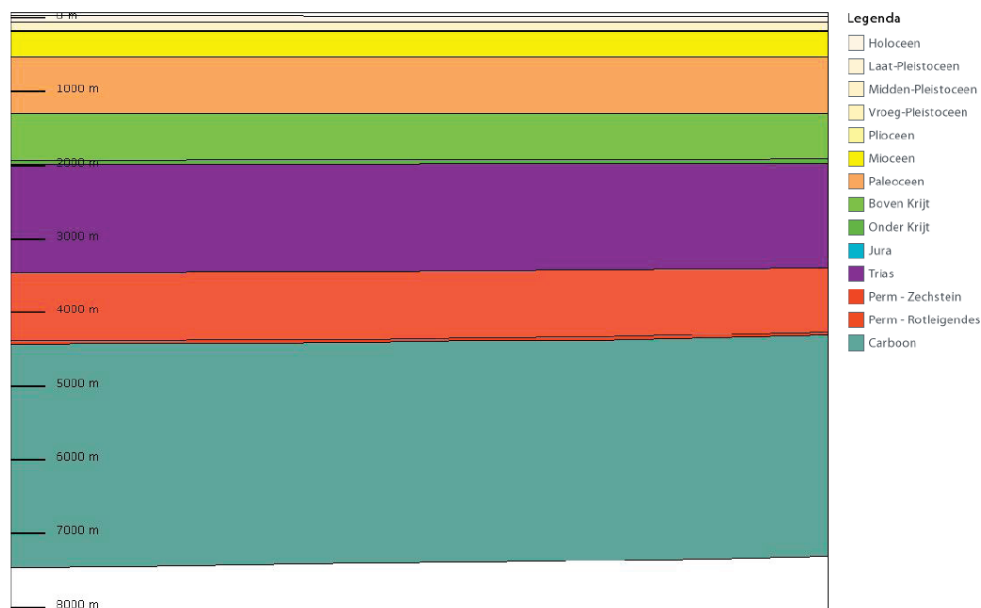
### Geologie van Nederland

een tijdreis van 500 miljoen jaar



### Geologie van Nederland

een tijdreis van 500 miljoen jaar





### 8.3 DATA SCENARIO FUTURE ENERGY DEMAND & PRICES

#### Electricity

electricity use for each household was 3,300 KWH in 2000

	Electricity in 2040	unit	Annual increase
Global Economy	5,300	KWh	1.50%
Strong Europe	4,300	KWh	0.75%
Transatlantic market	5,000	KWh	1.29%
Regional communities	3,700	KWh	0.30%

Price 2000; 15 €ct

	Price in 2020	unit	annual Increase	Price in 2040	unit	annual increase
Global Economy	20	€ct	1.67%	20	€ct	0%
Strong Europe	18	€ct	1.00%	25	€ct	1.90%
Transatlantic market	18	€ct	1.00%	17	€ct	-0.28%
Regional communities	18	€ct	1.00%	20	€ct	0.55%

#### Heat

start value 340 PJ in 2002

	Heat in 2020		annual increase	Heat in 2040		annual increase
Global Economy	305	PJ	-0.57%	320	PJ	0.24%
Strong Europe	280	PJ	-0.98%	240	PJ	-0.74%
Transatlantic market	305	PJ	-0.57%	320	PJ	0.24%
Regional communities	280	PJ	-0.98%	240	PJ	-0.74%

#### Gas price households

price 2000 41 €ct

	Price in 2020	unit	annual Increase	Price in 2040	unit	annual increase
Global Economy	55	€ct	1.71%	60	€ct	0.004545455
Strong Europe	46	€ct	0.61%	53	€ct	0.007608696
Transatlantic market	47	€ct	0.73%	60	€ct	0.013829787
Regional communities	47	€ct	0.73%	54	€ct	0.007446809

#### Gas price companies

price 2000 12 €ct

	Price in 2020	unit	annual Increase	Price in 2040		annual increase
Global Economy	22	€ct	4.17%	23	€ct	0.23%
Strong Europe	18	€ct	2.50%	31	€ct	3.61%
Transatlantic market	19	€ct	2.92%	25	€ct	1.58%
Regional communities	19	€ct	2.92%	25	€ct	1.58%

## 8.4 DATA OF VALUE SCENARIOS FROM SYSTEM DYNAMICS

year	discount	SD GE	GE	SD SE	SE	SD TM	TM	SD RC	RC
5	2.239697334	180564	80620	91905.4	41034.7	106853	47708.7	106853	47708.68
6	2.631644367	258908	98383	152415	57916.3	170368	64738.2	170368	64738.23
7	3.092182132	337344	109096	212989	68879.8	233951	75658.9	233951	75658.87
8	3.633314005	415877	114462	273627	75310.6	297603	81909.5	297603	81909.52
9	4.269143956	494511	115834	334330	78313.1	361325	84636.4	361325	84636.41
10	5.016244148	573250	114279	395100	78764.1	425118	84748.3	425118	84748.27
11	5.894086874	644288	109311	455938	77355.2	488985	82962	488985	82961.96
12	6.925552077	723127	104414	516846	74628.9	545777	78806.3	545777	78806.28
13	8.13752369	794048	97579	570728	70135.3	609739	74929.3	609739	74929.31
14	9.561590336	864855	90451	631730	66069.6	666533	69709.4	666533	69709.43
15	11.23486864	935552	83272	685629	61026.9	730594	65029.2	730594	65029.15
16	13.20097066	1006140	76217	739514	56019.7	787396	59646.8	787396	59646.83
17	15.51114052	1076630	69410	793385	51149.4	844174	54423.7	844174	54423.72
18	18.22559011	1147020	62935	854539	46886.8	900931	49432.2	900931	49432.2
19	21.41506838	1217310	56844	908435	42420.4	957668	44719.4	957668	44719.35
20	25.16270535	1287500	51167	962321	38243.9	1014390	40313.2	1014390	40313.23
21	29.56617879	1363950	46132	1022470	34582.4	1634400	55279.4	1070960	36222.47
22	34.74026008	1440450	41463	1644070	47324.6	1686350	48541.7	1127440	32453.41
23	40.81980559	1473640	36101	1662090	40717.7	1694920	41522	1140480	27939.38
24	47.96327157	1506600	31412	1679780	35022.2	1703150	35509.5	1153150	24042.35
25	56.35684409	1975540	35054	2133390	37855	2147280	38101.5	1601670	28420.15
26	66.21929181	2657780	40136	2151690	32493.4	2156110	32560.1	1614590	24382.47
27	77.80766787	2691330	34590	2169920	27888.3	2164850	27823.1	1627390	20915.55
28	91.42400975	2724910	29805	2188070	23933.2	2173500	23773.8	1640070	17939.16
29	107.4232115	2758500	25679	2206160	20537.1	2182070	20312.8	2250170	20946.78
30	126.2222735	2792100	22121	2224170	17621.1	2190560	17354.8	2266770	17958.56
31	148.3111713	2825730	19053	2242120	15117.7	2198960	14826.7	2283220	15394.79
32	174.2656263	2859370	16408	2259990	12968.7	2207270	12666.1	2299510	13195.43
33	204.7621109	2893030	14129	2277800	11124.1	2215500	10819.9	2315650	11308.98
34	240.5954803	2926710	12164	2295530	9541.04	2223640	9242.24	2331640	9691.121
35	282.6996894	2960410	10472	2313200	8182.53	2231700	7894.24	2347480	8303.794





## 8.5 EXTENDED SUMMARY

### COMMUNITY INVESTMENT, AN 'OPTION' TO CONSIDER.

#### A SYSTEM DYNAMICS MODEL FOR A LOCAL ENERGY COMMUNITY COALITION

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### ABSTRACT

*To develop a more sustainable district; two major systems need to be changed; more renewable energy generation and increasing the efficiency of current real estate. On this moment, no real investment is made due to a split-incentive by both systems.*

*In this research a solution is searched by the developing the concept of a Local Energy Coalition community (LECC). A financial model is developed to determine if a LECC should invest in their own district to become energy autarky. This is done by modeling a geothermal installation in System Dynamics. The System Dynamics model calculates the profit of such investment, due to using a scenario driven planning model. The results of these methods are valued by the Net Present Value and the real option theory. The results are the financial options for a LECC to start developing a business model.*

**Keywords:** System Dynamics, Real Option Theory, Energy Autarky, Community Coalition

### INTRODUCTION

Many prominent leaders and scientists have spoken about the change of the energy system and our living patterns to save our planet. However, the 'Green revolution' hasn't taken place. According to many scientists the technologies are available to produce renewable energies (Kajikawa et al, 2008). Incumbent firms use all their power to only create incremental innovations, which keep them in control. Until now there have only been green innovations. A 'revolution' may only occur when all facades of our energy issues have been bundled. The question is which actor will stand up and stir 'the revolution'(Hockerts & Wüstenhagen, 2009). A renewable energy community has long been advocated, particularly by alternative technology activities, as a way to implementing renewable energy technologies, emphasising themes of self-sufficiency local determination, engagement and empowerment (Dunn, 1978)(Hoffman, High-Pippert, 2005). These communities can start redeveloping their own districts into energy neutral districts.

The path to energy neutral cities can be followed by using the pillars of energy autarky (Müller et al., 2010). The theory of energy autarky rests on three closely related principles;

- The use of endogenous potentials for renewable energy resources rather than energy imports.
- The decentralization of the energy system.
- The increase of the energy-efficiency in the supply side as well as the demand side.

Müller et al. (2010) defines energy autarky as “a situation, in which a region does not import energy resources from other regions, but rather relies on its own resources to satisfy its need for energy services”. This strong definition of energy autarky is unlikely to be fully achieved, because exchanges with other regions in reality probably always lead to a certain amount of import of energy resources. Therefore, energy autarky should be understood to be a vision to which to move to”.

In current practice creating renewable energy or sustainable houses is often separated very strictly. Furthermore, the value creation of the investment has a split-incentive.

The investor does not profit from its investment. The end-user receives value of the efficiency of the investment. This phenomenon is called a split incentive. Secondly, there is no real value received of synergy between the efficiency of the houses and the generation of renewable energy.

A system change to solve this split incentive is that the community needs to cooperate together. If they really want to change into a sustainable environment, they can make it themselves. They could be the actors to start the ‘green revolution’. In this research the problem statement is defined; “the value of a sustainable investment is not captured by current investors; this development stops them investing in sustainable district. On this moment there are no real investors who act as an energy developer on a large scale. Could a community coalition act as a new developer?” The goal of this paper is to develop a financial decision model to help a community start the redevelopment of their district into one which energy-sufficient.

## LITERATURE STUDY

In the framework of energy autarky Müller et al. (2010) defines four subsystems; social, economic, energy and ecological.

The focus of this research is on the energy autarky; however the other subsystems are sometimes interconnected.

In fig 1 the model of Müller is shown. In this figure is shown how the sub-system cooperates together. In the model, primary (P) and secondary (S) energy flows are shown. These energy sources are outside the defined region. These sources need to be limited. The regional resources are used to fuel the region. The other sub-systems provide in this need. Economic factors can increase efficiency improvements, so less energy is needed.

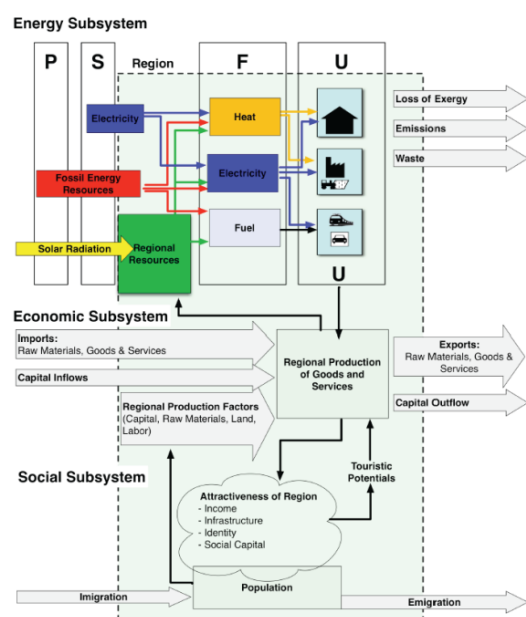


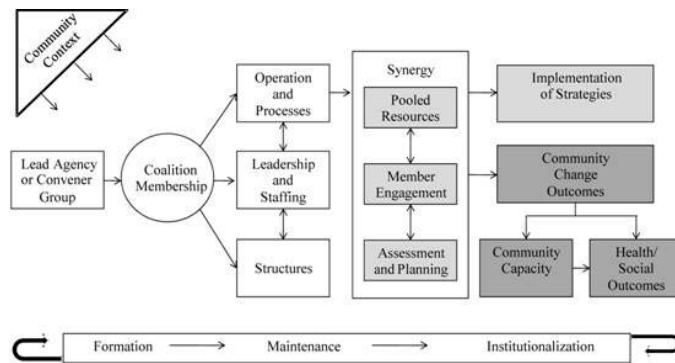
Fig 1 Energy Autarky (Müller, 2010)

Güssing is a small town in south-east Austria. It is located 130 km east of Vienna close to the Hungarian border. With a population of around 4000 people, it is totally reliable on its small-agriculture. The redevelopment of Güssing is a successful energy autarky project; the total investment generates a positive cash flow. Hence, it is the most autarkic town in Europe. So what stops us from copying this framework into our own? In the research framework is focussed on the urban area. Güssing uses his environmental resources, it generates energy with; biomass, biogas and solar panels. In the Netherlands, urban and rural areas are pretty much separated. So to fit Güssing into the framework of an urban area would have serious influence in the boundaries between cities and towns.

However, Güssing teaches us

three important success factors; 1 **Fig 2 CCAT (Butterfuss & Keggler, 2002)**

every district needs to have it own resources analysis, initiator and their interest in the project is needed to start the project



According Butterfuss & Keggler (2002) community coalitions present ripe opportunities for adopting recommended community participatory action research principles, where community members work in partnerships with researchers to collectively define local problems, identify and implement solutions to them, and evaluate their impacts. Initiating and sustaining coalitions is no simple task. However, it is a complex dynamic process that involves multiple coalition-building tasks. This can be done in many ways; the most important one is the right balance in their collaboration. In literature research to the use of community coalitions in energy autarky or energy neutral cities, no results were found. Many researches on the theory of community coalitions are done in health communities. In a recent review, the University of Chicago (2011) presented an overview of the most important community coalition's models. Community Action Theory (CCAT) fitted the most to the energy autarky concept.

CCAT is defined as a "group of individuals representing diverse organizations, actions, or constituencies within the community who agree to work together to achieve a common goal" (Butterfoss & Keggler, 2002). In fig 2 the model of Butterfoss & Keggler is modelled.

To value the concept of Energy Autarky district with the LECC as developer the Net Present Value (NPV) is used. The NPV value is the sum of all discounted cash flow from the project, as can be seen in eq. 1-1. In this formula, the sum starts at,  $t$  is zero, and ends at,  $T$ , the end of the project. The,  $V_t$ , is the total cash flow of that specific year,  $t$ . The cash flow is discounted by the discount rate,  $r$ , which is raised to power time,  $t$ . A positive result means a go; a negative result means to abort the project.

$$NPV = \sum_{t=0}^T \frac{V_t}{(1+r)^t} \quad (1-1)$$

However, the NPV is according Dixit & Pindyck (1993) has some flaws. The option to wait with investment is not taken into account.

Trigeorgis (2001) defined the following formula (eq. 1-2) to value an investment option;

$$\text{Total Value of Investment option} = \text{Static NPV} + \text{Value of options from managerial flexibility} \quad (1-2)$$

In fig 3 the real option theory is modelled. The dotted line is the actually NPV of the project,  $V-I$ , as function of the cash flow of the project. To understand this picture, the value,  $V$ , of the investment is uncertain and is located on the horizontal axis. The value determines when then NPV is positive. The value where this line crossed the horizontal axis is the minimal value of acceptance for the NPV. The thick line is the value of the option of the investment according equation 1-2. Dixit & Pindyck (1994) refer to this value of the option as the cost of opportunity.

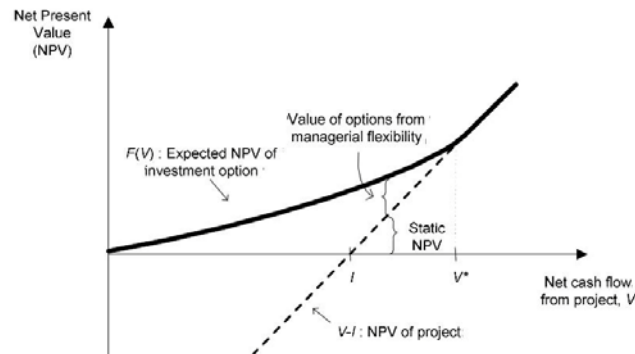


Fig 3 Real option Theory (Botterud, 2003)

## RESEARCH METHOD

According Georgantzias (2010) realizing that a trade-off free strategy design requires insight about a firm's environment, both business and socio-political, to provide intelligence at all strategy levels, firms use SdP with SD to design, corporate business and process or functional strategies. Georgantzias describes three facets for SD with SdP; the business Environment, the forces behind its texture and futures requisite uncertainty, detailing the framework of SD with SdP, computing the effects on performance of changes in the environment and in strategy.

SdP with SD begins by modelling a business or social process than a business or social system. It is more productive to identify a social process first and then seek its causes than to slice a chunk of the real world and ask what dynamics it might generate (Georgantzias, 2010). Into this SD model, scenarios are implemented in the system. The scenarios are created with a scenario driven planning method. Many authors have described methods for such models. There is not really a wrong or a good model. Importantly, the scenario should have influence on the problem of system. This means the uncertainties of the key variables should be identified. When the scenarios and all other assumptions are implemented into the system, the model running can start. The result of the computed models can be analysed and strategic choices can be made. This result can then be again be implemented

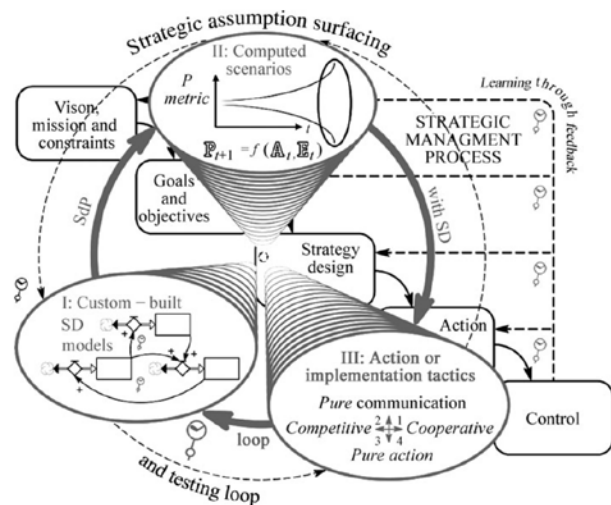


Fig 4 SD with SdP (Georgantzias, 2010)

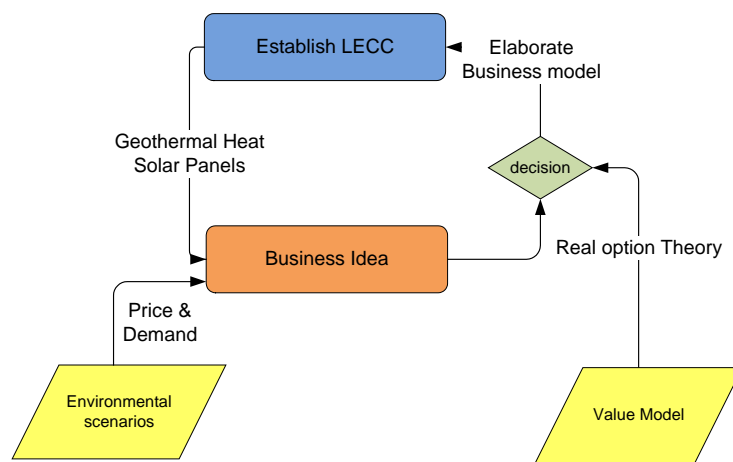
into the SD model. By looping back into the model, the results can be checked and forecasted.

The essence of detailing the framework of SD with SdP is that you are modelling a social process. The business or social system is perhaps the end result, shown in figure 12. However, the social process of the real world should be format for this model.

This said, when modelling the model it is important to understand the state of this stage in the model. The goal of this stage in model is to implement strategies. So the implementation of the model is the goal. A random picture is not the objective. It should see if a strategy would fail or succeed. To have an ultimate model, this implementations of stage in figure 12 could be implemented in stage 1 to progress in the strategy process.

## THE GENERAL MODEL OF A LECC

The general model is converted from the model of Amara & Lipinski (1983). In this model the sub-system of the LECC is not further elaborated. In the business idea the earning model of the organisation is explained. This internal process is influenced by another sub-system, the environmental scenarios. Together they form the input of the value model of the LECC. However the decision to start this organisation is not part of these two systems. So the value decision model is added to ensure the optimal investment decision is made for the organisation. The decision starts further elaboration of the LECC, into the start-up of the organisation. The model starts at the establishment of the LECC, which is in this case; the commitment of some early adopters to research the possibility to develop a company with geothermal heat and solar panels. This is constructed in a kind of business idea. Here the opportunity is developed and implemented in scenarios for the price and demand of that specific area. The value of that specific business idea is valued by using a real option theory method. This model shows some options for the LECC, they decide what to do. If they decide to continue, the business idea is further elaborated into a business model.

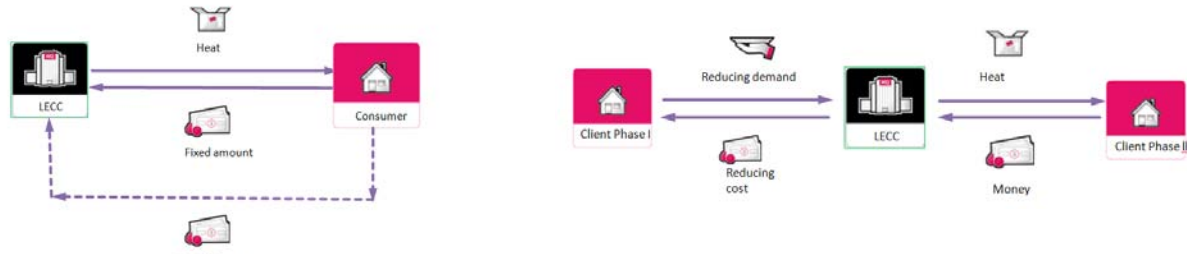


**Fig 5 General model LECC (Amara & Lipinski, 1983)**

## Business idea: geothermal heat

Geothermal energy is heat located a few kilometres below the surface. The generation uses heat from the earth to supply us from heat. It can also use a cogeneration unit to also supply electricity. This form of generation has two forms; cold heat combination, and deep geothermal. CHP puts warmth in the ground during summer and uses this in the winter. Deep thermal generation drills in the earth tills it is so heat it can be used in district heating. According research by the Dutch ECN research agency (2011), geothermal energy has large potential in the Netherlands. The price for thermal energy is equal or even less than the current fossil energy prices. And with the probability that prices will rise in the future, it could well be a very good technology to use in our districts.

In research by the Dutch research agency ECN (2011,) three possible functions for deep geothermal generation in the Netherlands are developed. The three functions are; horticulture, Greenfield development, and Brownfield development. The horticulture sector can use thermal heat to heat their greenhouses instead of burning gas. In Green- and Brownfield's scenarios, thermal heat is used to heat buildings. The difference is the current network, in a Greenfield there is no heating district infrastructure, in a Brownfield there is already a network available.



**Fig 6 earning models of the business idea**

In fig 6 the extension of goods is very basic; the LECC delivers heat to the consumer and the consumer pays money for it. In this research an assumption is made, which is created by trial and error.

The consumer pays a fixed amount; two/third of its current energy bill for heat, and the rest in a variable amount. The variable amount is connected to the amount of energy he uses, so this reflects on the user energy behaviour. In this matter the consumer has the incentive to reduce its energy behaviour.

The reason the LECC prefers this, is that the LECC has an extra incentive. It can sell the saved energy to a phase II district. Client phase I offers a service by reducing cost, this results in reducing cost. A geothermal installation has one only switch, on or off. So the total amount of energy stays the same. This means the LECC can again sell heat to buyers, without any extra investment. This can be invested in extra efficiency measures or dividend.

## Environmental model

In this model we will use scenario-driven models to forecast the most two important variables; demand and price. This part of the research will only consist of analysing existing scenarios.

The data is used from the energy scenarios from Farla et al. (2006). These scenarios are developed on macroeconomic scenarios, namely the model of Huizinga & Smit (2004). Huizinga & Smit define the two largest uncertainties which influence the economies in Europe. The first uncertainty is the commitment to cooperate on an international level. The second uncertainty is the speed of the process of reform in the collective sector in each country. Four scenarios are developed; regional communities, Global Economy, Transatlantic market, and Strong Europe.

The regional communities' (RC) have a strong focus on national power. They block further cooperation among other EU members. Europe divides itself in different business blocks. The national organisation is growing and market processes fall. In the transatlantic markets (TM) plot the national power is still high. However collective reform is increased. This will not from an open economy, while individual countries will keep their markets protected. Strong Europe (SE) has a high level of attention on international cooperation. European agencies are reformed; the national governments hand over some responsibilities to Europe. The focus of is also on an equal distribution of wealth among the EU. The Global



Economy (GE) focuses on extension of the EU. However the only real successes are on the economic topics. Reforms on the social and environmental issues will fail. The national government focuses on the individual responsibility.

## Value Model

The corporate model with the SD and implemented scenarios show different stories of the future. For the LECC it is hard to decide which story is correct and when to invest. Dixit and Pindyck (1993) define two important characteristic of investment. First, the expenditures are at least partly irreversible; in other words, sunk costs that cannot be recovered. Second, investments can be delayed, so that the firm has the opportunity to wait for new information to arrive about prices, costs and other market conditions before it commits resources.

This model uses the continuous-time models of irreversible investment by McDonald and Siegel (1986). They had the following problem statement; at what point is it optimal to pay a sunk cost,  $I$ , in return for a project whose value is,  $V$ , given that  $V$  evolves according to the following geometric Brownian motion:

$$dV = \alpha V dt + \sigma V dz \quad (1-3)$$

In this eq. 1-3 the value,  $V$ , at time zero increases lognormal with the variance,  $\sigma$ , with the idea that future is always unknown. The drift parameter,  $\alpha$ , is the proportional growth parameter. When we use the scenario-driven models, the model could be claimed as known. This is with the idea that one of the four scenarios is the truth. In simple words,  $\alpha$  is growth implemented according the scenario data, and  $\sigma$  is zero.

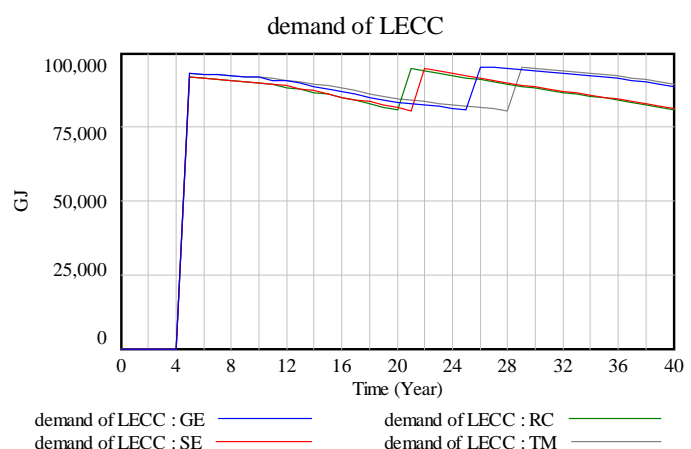
In this 'deterministic' case with no 'uncertainty', the optimal value can be determined. The optimal value rule uses the critical value,  $V^*$ .

## CASE-STUDY

The model of LECC is implemented in a case-study in the city of Eindhoven. A district with 2200 units and a swimming pool was calculated to be connected to a geothermal source in their Neighbourhood. A short summary of the results are presented.

The heat demand will start in year 5 after finishing the installation. Because the scenarios for strong Europe (SE) and Regional communities (RC) are the same there is only one line for these scenarios. All scenarios are decreasing. This is under influence of the forecast of less demand and the investment in efficiency of the buildings. This results that in year 34, the second phase can be added to the LECC. This means that the demand increases.

A nice result from this model is that very high increase of price not necessary means the highest profit.



**Fig 7 Energy demand of LECC, simulation with SD**

Due to the high decrease of demand, phase two can quickly be added to the project which results in higher profits than the high increase of price. We can conclude that a combination of demand decrease and extension of the network offers high results.

After running the models the investment question remains, should the project be started? Four scenarios are run and the results are presented. These results should now be analysed and compared to make a decision. The standard method for such question is done with the net present value (NPV). However, as explained in the general model elaboration, after the NPV a real option analysis is made. This is done to value the cost of opportunity.

The NPV tells us to invest into the project for all four scenarios. The sum of the discounted values,  $V$ , for each scenario are larger than the investment,  $I$ .

The LECC however wants to know if this is the right time to invest. With the real option theory they try to determine the optimal investment moment.

When,  $V$ , is compared with the optimal value,  $V^*$ , the conclusion can be taken that scenario GE and RC are optimal situated to invest now. The value of the model is higher than the calculated  $V^*$ . However, the other two scenarios are not close to their optimal decision point. This means that the project is not optimal to invest on this moment. This optimal moment can be calculated by developing a delay in the system dynamics model.

## CONCLUSION

### ***RQ 1: What are the factors for financial feasibility of energy autarky for a community?***

*Environmental opportunities:* Autarky can only be gained when local opportunities are exploited. These local opportunities are everywhere different. This can be; using natural capabilities, using natural waste from the own district to generate energy, or using industrial waste to produce energy.

*Starting capital:* Most of the times there is not enough renewable energy capacities to supply the district with energy. The energy demand is too high. So besides the investment to start a renewable energy generation plant, an investment should be made in decreasing the amount of energy. This cannot really be done in mutual phases. Both investments should be made in the same time. This causes high investment in the start-up phase of the project. An important aspect in this investment decision is the change from short-term into a long-term perspective. The strategic uncertainty of the long-term perspective is in this decision vital. To reduce the risk for the investor of the long-term, commitment of the user is needed. This commitment ensures the investor to invest for the long-term.

*Spin-offs:* Becoming autarkies asks a lot of commitment from all stakeholders. Social spin-off in such a project increases the success factor of the project. In the case of Güssing the town was almost dead, there were no jobs and everybody was leaving the town. Since the change in an autarkies district a 1000 jobs were created. This lifted the entire town to higher level.

### ***RQ 2: How can a community energy coalition be organised?***

For that reason the format for a community coalition was introduced. Community collations have three big advantages; they bring large group of stakeholders together, create social capital and are catalyst of change.

The best model for a community collation for this model is the community coalition action theory (CCAT) by Butterfoss & Kegler (2002), see fig2. The CCAT has proven itself in the improvement of social security in some suburbs of the USA. It is also used to increase the health care in the some district in the states.



**RQ3: What are the options for the community as energy developer?**

According to the NPV in all four scenarios the project was positive, so feasible. The NPV only defines a go- or no go decision. With real option theory, timing of the investment is not taken into consideration. According to the optimal value rule, only two of the four scenarios reached the optimal decision point on this moment. The other two, SE and TM, didn't reach the optimal value, but were feasible according to NPV. Real option theory suggests to wait until the values emerge. When the future values reach the point of the optimal investment, start the project. The LECC model defines two options to consider for its stakeholders;

Firstly, invest in the project according to the NPV. In the case of the Prinsejagt, all scenarios have a positive result. This means that there are financial possibilities for the district to start a process of business plan modelling. Real option Theory, tells it is not optimal to invest.

Secondly, wait with investing in the project. When all scenarios have reached their optimal value, it is time to start the project. The cost of opportunity for such a choice can be developed as a call-option. This call option can be sold to an investor or the companies in the district. When the option is not called, the forecast is not emerged and the reason to develop the option is gone. The cost of this option can be deleted with increase of the price. Further running with SD model shows that with the current parameters. The project is calculated an optimal result in two years. This means for case of Prinsejagt option two should be followed and in two years start the project. This option is worth 37.000,- euro.

**DISCUSSION**

In the research some assumptions are made, these assumptions are not wrong. However, with current knowledge they could be made better.

Firstly, the generation of heat is modelled with the principles of geothermal heat. A geothermal generation plant is a high investment. The question remains if the technique is not too expensive for an organisation like LECC. Furthermore, this high investment asks for a larger area to sell to. This is not a real problem. However, the question remains if such a large area is ready to commit on a voluntary base.

If a smaller district is taken, a commitment issue is easier to tackle. This combined with a technique like the aquifer thermal energy storage could be perhaps given more practical success. Secondly, this research has the goal to help the consumer to help make an investment choice to redevelop their district into an energy autarky one. In this research the focus lays on the community development. However, the consumer perhaps wants to be convinced that the community investment is the best option. So as a tool for the consumer, an individual investment option could be an addition to the model. Thirdly, in this research the assumption was that an energy distributor, like Endinet in Eindhoven, would build an infrastructure for this district. The question is if, such companies are fond of these kinds of infrastructures. Finally, the real option part of the model is correctly constructed according to theory from the authors of the theory. However, the theory of real option theory isn't a proven theory in the field of energy. Experts have cleared the result; however they were not really convinced. So, further research on real option theory in the energy sector can be helping the validation of this theory.

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Developing a sustainable concept showed me again how difficult it is to implement innovations. So many stakeholders can have an opinion in this process. I really hope that KENWIB can help support people make new steps to a more sustainable society.

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