A COMPLEX MODEL FOR GENERATING SUSTAINABLE LAND USE PLANS

Determining the spatial location allocations of energy sources in urban planning

In partial fulfillment of the requirements for the degree of Master of Science in Construction Management and Engineering

Graduation Report 'A complex model for generating sustainable area plans'
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"Optimisme is een verantwoordelijkheid!"

- Wubbo Ockels

PREFACE

In front of you I present my graduation thesis for the master Construction Management and Urban Development at the Eindhoven University of Technology. This is the completion of my master to graduate. My final research was conducted as part of the KENWIB initiative, a program that has been established to develop and share knowledge on energy neutral living in Brainport. In cooperation with Builddesk, a consultancy that focuses on the energy efficiency and sustainability in the built environment, is the research executed.

From the beginning several challenges were possible but the focus of the research came during the process. With the help and support from my supervisors, family and friends I was able to finish my research. Therefore, I would like to thank some persons for their guidance and help.

First, I would like to thank Pieter Klep, my supervisor at Builddesk, for his time and feedback on my research. During the research, his support and comments gives me help to get new insights for my research. Furthermore, I would like to thank my supervisors Bauke de Vries and Qi Han from the TU/e, for their guidance, advice and critical comments on my research. Also I would like to thank Joran for the critics on the Netlogo model and especially for programming some commands.

During my research, one of my fellow graduation mates died by violence. Besides the fact that we both were graduating, we built a true friendship during the master. Loosing you is hard but missing is much harder. Several times this lost had the upper hand during my research. Therefore, I would like to thank my friends4life for their support, help and good talks about Jack to make it more bearable.

Also thanks to my boyfriend, who helped me with the design of my front despite the strict instructions from the KENWIB organization. My last thanks go to my parents for their support by my research and grief. They gave me the possibility to study and live in Eindhoven for the last two and half years. For this my deep appreciation.

With this research I hope the reader to navigate in the world of sustainable energy. Especially the steps that need to be taking into account to allocate the locations of sustainable energy sources in the built environment.

I hope you enjoy reading my Master's thesis,

Cathelijne Broersen
Arnhem, March 2012

MANAGEMENT SUMMARY

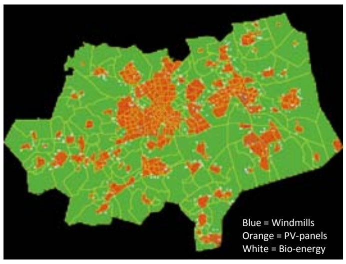
The energy world is changing. The energy demand in the Netherlands will increase until 2020, so also the demand for fossil fuels. According to the European Climate and Energy Package the aim is to have a 20-20-20 reduction in 2020 compared to 1990; 20% less greenhouse gas, 20% more sustainable energy and 20% energy saving. Nowadays a small amount is sustainable but generally fossil fuels are used. It seems to be far away but the preparation of the required innovative energy sources and their infrastructure in the environment is essential.

Different municipalities in the Netherlands have the intention to develop an energy neutral environment. The approach of this integral process encounters different critical developments and need different energy sources to become energy neutral. According to the ministry of economic affairs it is necessary to provide early spatial choices so that sufficient space is available for energy production and to utilize the available space fast and efficient if the market needs it. Each source has their features and so also their own geographic implementation in the spatial environment. Considering the many required measures it affects the entire spatial environment. An integral spatial vision is needed to deal with the spatial consequences of new energy sources in the environment.

Here for, an agent-based model is proposed that individual agent decisions of land use location interact with decisions of other lands use agents. A land-use model is developed to generate land use plan alternatives in an interactive environment of multi agents. Here for the program Netlogo is used that contains of agents that move around in an environment controlled by instructions. The aim of the model is to found the optimal location of energy sources so that a sustainable urban planning map is realized.

The agents are the sustainable energy sources windmills, pv-panels and bio-energy installations. These are controlled by different spatial variables that influence their location in the environment. Depending on where a sustainable energy source locates in the environment, it scores a utility-score based on the variables. Each agent searches for a better location by swapping their location and calculates their utility-score. If the score is higher than the previous score, the agent locates on this location. If not, it goes back to his location where it stands before. The SRE-area serves as case-study where the various agents move around. To compare the different energy sources, various scenarios are composed that achieves the 20 % sustainable energy generation. Because of the subjective approach of the variables, an advice is given based on the case study and the measures with their conditions. The locations of windmills have high spatial influences but financial benefits. PV-panels have the opposite, low spatial influence but high financial investments. For bio-energy installations are suitable to locate in the environment and have financial benefits. The constraint is the dependency of available biomass.

Finally, it is indeed possible to build a model that generates a sustainable urban planning map that determines the allocation of sustainable energy sources in the spatial environment. It is able to provide insights in the spatial planning of sustainable energy sources in the built environment on a large scale level. This model can be used as a communication and decision tool for decision makers in a complex urban planning project.



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FRAMEWORK

1 RESEARCH LAY-OUT

This chapter shows the research approach. The first paragraph describes the context of the research. In the second paragraph the approach of the research is outlined. The third paragraph defines the problem, the questions, the framework and the objective of the research. After the third paragraph the different phases of the research are showed in a research model. In the fifth the research methods are defined. In the last part of this chapter the frame of the research is showed.

1.1 Context

The energy world is changing. The energy demand in the Netherlands will increase until 2020, so also the demand for fossil fuels. This will result in a increasing of the CO_2 emissions due the climate and at the same time the government is realizing to be dependent of foreign countries. According to the European Climate and Energy Package the aim is to have a 20-20-20 reduction in 2020 compared to 1990; 20% less greenhouse gas, 20% more sustainable energy and 20% energy saving. Finally energy zero urban environments want to be achieved in 2050. It seems to be far away but the preparation of the required innovative energy sources and their infrastructure in the environment is essential. This energy transition system will influences the spatial development of the urban area. The implementation of new energy sources occurs on different scale levels, on micro and macro as well. This research provides insight into the development of energy sources in the urban environment. (Ministerie van Economische Zaken, 2011).

Different municipalities in the Netherlands have the intention to develop an energy neutral environment. The implementation of energy sources in the urban environment contributes in the development of energy zero urban environments. These sources shall be applied in new developments areas and the existing spatial environment. It is more likely to succeed in new developments. But only focusing on new projects will lead to not achieving the ambitions. Therefore the biggest challenge lies on the existing spatial environment.

The approach of this integral process encounters different critical developments and need different energy sources to become energy neutral. According to the ministry of economic affairs it is necessary to provide early spatial choices so that sufficient space is available for energy production and to utilize the available space fast and efficient if the market needs it. Each source has their features and so also their own geographic implementation in the spatial environment. Considering the many required measures it affects the entire spatial environment. Various activities are set up, but there is not an integral approach how energy is used in the spatial environment. An integral spatial vision is needed to deal with the spatial consequences of new energy sources in the environment.

1.2 Research approach

1.2.1 Problem

Many municipalities have the ambitious goal of becoming energy neutral. 20 % of the existing energy generation should be realized through sustainable energy measures. A small amount is sustainable but generally fossil fuels are used. Many measures are required but are influenced by different constraints. One of these constraints is the impact on the spatial environment. Applying these measures affects the total spatial environment. Because of the high amount of measures that are needed there is a lack of insights how to allocate a location for these measures. The allocation of each measure in the spatial environment depends on different variables. An integral vision for implementation of energy sources in the built environment is missing. There is a lack of insights in this subject and so research is required.

The problem definition for the research, resulting from the context, introduction and most important problems, can be stated as: "There is not an integral approach for the implementation of sustainable energy sources in the environment, focused on the allocation of locations".

1.2.2 Phrasing of the question

Main question: Is it possible to build a model that determines the location allocations of sustainable energy sources in the spatial environment based on the environmental influences? And which energy sources have potential and where should they be located?

In order to answer the main question the following questions need to be solved. The questions are categorized according to the themes. These questions will be answered in the following chapters of this document. The main question will be answered at the end of this research.

1. What is the current situation of the energy consumption in Noord-Brabant? What is the share of renewable energy in the province of Noord-Brabant and which energy sources have potential for supplying energy in Noord-Brabant?

2. How is the existing spatial planning regulated in the Netherlands? How influences energy sources the spatial environment and which variables represents the spatial requirements?

3. What would be realistic scenarios and what are possible and realistic solutions for the SRE-area? Furthermore, how could Netlogo integrate these turtles?

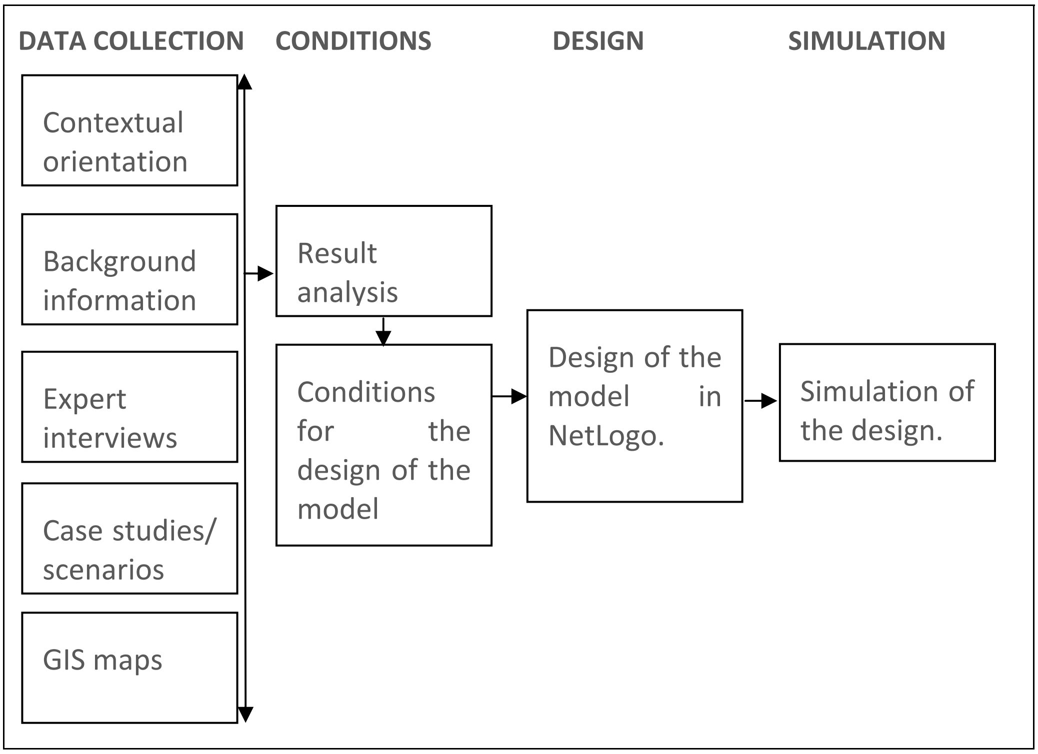
4. What are the affects of the scenarios on the spatial variables of the energy sources?

5. Which conditions of a sustainable energy source have a positive influence to allocate the location in the spatial environment?

1.2.3 Objective

The objective of the research is: "To design a simulation model that can allocate locations for renewable energy sources in the urban environment so that a sustainable urban planning map is realized".

1.3 Research model



This model shows which steps will be taken during the study.

1. The first step is an analysis of the existing data and suitable information. The contextual orientation will critically examine the literature in the field of the Dutch renewable energy development in the spatial environment. Making use of interviews, case studies and GIS maps will also help to determine the conditions of the model.
2. The result analysis will provide conditions for the design of the model.
3. With the determined conditions the design of the model is created. The model will have the shape of an agent based model. In the model scenarios and multi-criteria evaluation will be used.
4. Finally, the model will be tested with various simulations/ scenarios.

1.3.1 Research methods

To gain the expected results the research method will be Agent Based Modeling. Agent based modeling includes the simulation of a problem from the real world, the analysis and optimization of the model and the replacement of the solution back to the real world. A simulation model may be considered as a set of rules that defines how the system, being modeled, will change in the future, given its present state. In general, the simulation model is used in case of complex problems where time dynamics are important.

The system that will be modeled could contain active objects, for example people, vehicles or products, with timing or other kind of individual behavior (Borshchev e.a.). In figure 1 the different types of simulation models and their application is shown.

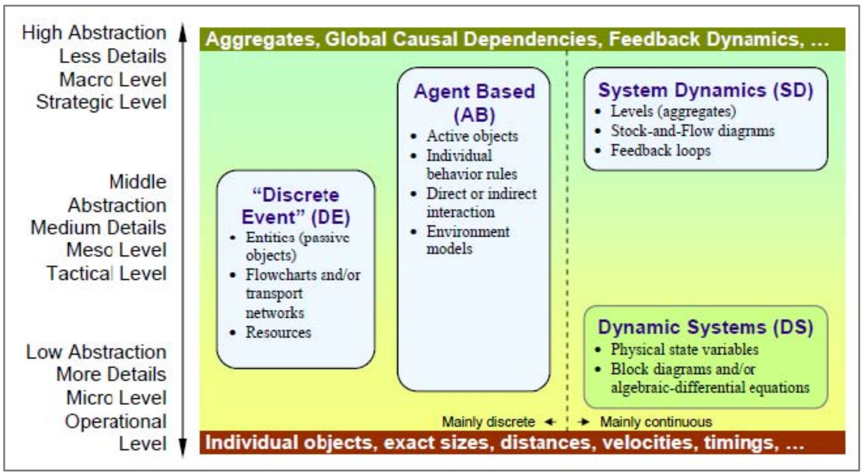


Figure 1 Approaches in simulation modeling on abstraction level scale, Borschev e.a.

According to these findings, Agent Based modeling could be a worthy addition to the research. The model is able to simulate a problem in the environment, so for the research the environment will be a case study. The environment will change over time by a set of rules that defines how the system model will change over time. These rules determine the behavior of the model. These rules can be for example commands how an object behave or how a variable influence the process etc. This method gives the preferences because the others, see Figure 1, aren't able to simulate in the environment. The research approaches the changing environment and so a simulation is useful to the research.

These active objects are in this model sustainable energy concepts that get commands, so than we figure out the behavior of these measures. The settings of the commands are determinative for the behavior of the measures, and so for the environment. The underpinning of these settings is crucial for the model. The information for the underpinning will be gained out of researches. With the use of this method, the influence of energy neutral measures on the spatial environment of the region will be investigated.

For the developing of the model the program Netlogo will be used, what is able to create an agent based model. I will use the Netlogo Manual, published by the Center for Connected Learning and Computer-Based Modeling, Northwestern University (1999). NetLogo is a programmable modeling environment for simulating natural and social phenomena. It's particularly well suited for modeling complex systems developing over time. Instructions are given to hundreds or thousands of "agents" all operating independently. The model makes it possible to explore the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from the interaction of many individuals. NetLogo explores the behavior under various conditions of the simulations. This contains of extensive documentation and tutorials, which can be used and modified (Wilensky U. , 1999).

The approach of the model is based on the research article '*An agent-based heuristic method for generating land-use plans in urban planning*' of Theo A Arentze et al., where a combination of area-type land uses (for example: housing, industry, nature) and facility-type land uses (for example: retailing, schools, medical, services) is made. This research can help by setting up the model because it supports urban planning. The model provides different land-use plan alternatives for a study area, where elements are combined from different approaches. The simulations generate a land-use plan to support decision making for a given study area.

The methodology that is used in the article is also suitable to use in this research. Following these basic steps provides an useful methodology for the model. This article makes use of scenario development and multi-criteria evaluation.

1.3.2 Validation and Verification

Kleijnen (1995) have defined validation as the process of determining whether the conceptual simulation model is an accurate representation of the system under study. For validation different techniques can be discussed like: 'obtaining real-world data', 'simple tests for comparing simulated and real data', 'two new simple statistical procedures for testing whether simulated and real responses are positively correlated and, possibly, have the same means too', 'sensitivity analysis and risk analysis' and 'white and black box simulations'. Verification determines that a simulation computer program performs as intended. So once the simulation model has been programmed, the analysts/ programmers check is the computer code contains any program errors. For verification different techniques can be used, like: 'general good programming practice', 'checking of intermediate simulation outputs trough tracing and statisctical testing per module', 'comparing final simulation outputs with analytical results for simplified simulations models' and 'animation'. (Kleijnen, 1995)

The model will be verified with experts on Netlogo modeling, and validated if the right data has been applied with experts on sustainable energy sources in the built environment. Experts from Builddesk will perform the validation of the model. However, the purpose of the model is not focusing on precise and exact numbers, but it still should represent realistic and possible outcomes.

1.3.3 Reading guide

This research is organized as follows. Chapter 2 contains a literature review of the energy sector. Chapter 3 approaches the spatial planning in the Netherlands briefly. A link between the energy sector and the spatial environment is made, where the spatial consequences of energy sources are explained. The conditions of the model are determined in chapter 4, where in chapter 5 the model is designed. Chapter 6 shows the simulation of the model, which implies the results and findings of the model. Finally the conclusion, discussion and recommendations and further research are presented in chapter 7.

ENERGY

2 BACKGROUND

This chapter approaches the existing energy world. The coming years many changes will take place in this. On different levels various ambitions and visions are proposed to achieve the overall ambition. The focus is on the province of Noord-Brabant where the potential for sustainable energy is described briefly.

2.1 The world of energy

Our society can't live without energy. It is the engine of our welfare and a precondition for our wellbeing. But the world of energy is moving, it's a changeable market. The demand of energy is growing. It's obvious that the fossil fuels will make place for alternatives, because the reserves are decreasing and the use leads to milieu problems. But what is the state of art of the energy market and what are the ambitions to achieve an energy neutral environment?

2.1.1 Energy demand

Worldwide the demand for energy increase, especially trough the growing economic in China and India, see Figure 2. Because of the efficient use of energy in Europe the demand will stabilize. But the demand depends on how the rate of energy saving practically takes place. The expectation will be that the share of electricity increase. This is because the demand for electricity for transport (electric cars) and heat (electric heat pumps) will expectedly increase.

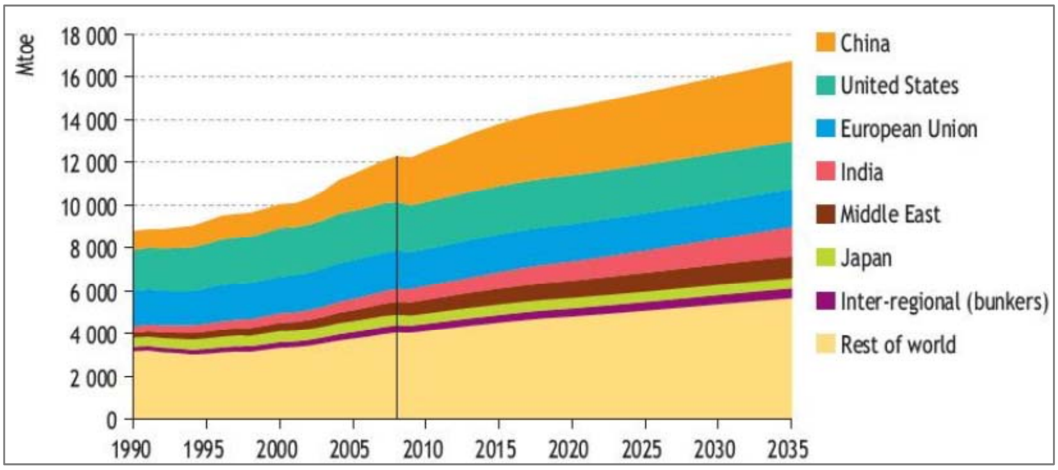


Figure 2 Expected primary demand of energy per region Source: WEO 2010

Global fossil energy sources are sufficient presented in the upcoming decades to meet the energy demand. For example gas, coals and uranium are sufficient available. The availability of conventional oil reserves will decrease and so the price will remain high. Especially, because oil is besides an energy source also used on a bigger scale in other industrial process. The European and the Netherlands will become import dependent in the upcoming decades. The EU has a limit for oil and gas stock. Also the gas reserves in the Netherlands decrease. The Dutch gas production stays until 2030 on the same level, and will decrease after that. The geographical distribution of gas and oil is global limited. The sources are often suited in areas that have political and/ or economical instability.

2.1.2 Main energy consumption

Energy is used by the entire society. The use of energy can divided into four functions; heat, electricity, transport and unused, see Table 1. In Noord-Brabant is the demand for heat 44%, which is the biggest part of the total energy demand. Electricity concerns 16% and unused counts 21%. The unused part is related to conversion losses by the production of electricity. The heat that released by this process remains unused and despite the high demand for heat this percentages of heat will be lost, also called rest heat.

Functions	Energy consumption (PJ)	%
Heat	173	44
Electricity	63	16
Transport	77	19
Unused	85	21
Total	397	100

Table 1 Annual energy consumption divided into main functions, Noord-Brabant (2006)

The end-users can be subdivided into the following categories: residential area, agriculture and horticulture, industry and transport. Each category has their own energy services demand like size, nature (heat/ power), quality (low/high temperature, 'power quality', supply certainty) and dynamics (yes/ no evenly, peak/ dale, influence seasons).

The existing energy-use of each category of Noord-Brabant is showed in Table 2. Industry and transport are dominant users. The total annual net energy consumption of Noord-Brabant is 397 PJs, what represents 16% of the total consumption in the Netherlands (Kasteren, 2008).

Energy consumers	Energy consumption (PJ)	%
Dwellings	67	17
Services	73	18
Agriculture	27	7
Industry	147	37
Transport	83	21
Total	397	100

Table 2 Primary annual energy consumption for end consumers, Noord-Brabant (2006)

The main sources of energy are different fuels like: electricity, gas, heat water and logistic fuels, gasoline, diesel and LPG. Table 3 shows how the energy consumption is divided over the primary energy sources. Energy is generated out of different sources. The use of gas is with 46 % the main source of energy, which is used for the production of heat. In the transport sector is oil the main energy source, which lead to a percentage of 30 %. Coals are used for the electricity production and take 16 % of the total energy consumption. Sustainable energy is extracted out of biomass (4%) and wastes (2%), other energy saving sources are minimal (Kasteren, 2008).

Sources	Energy consumption (PJ)	%
Gas	183	46
Oil	121	30
Coals	64	16
Biomass	15	4
Wastes	8	2
Rest	6	2
Total	397	100

Table 3 Primary annual energy consumption of each source, Noord-Brabant (2006)

2.2 Policy and ambition

The energy market is a global market. Because the energy stock is decreasing, Europe will become dependently on fossil fuels out of unstable regions. Near that the global demand for fossil fuels increases because of upcoming economies, while the costs and risks for especially oil extraction increase. For example the oil disaster by the Gulf of Mexico and the developments in the Middle East. The challenge is to decrease the dependency and the price fluctuations. The government choices for reinforce of the Europe market in combination with directed energy diplomacy. Also nuclear energy is part of the Europe market. This approach will take care for stable prices and reliable energy supplies.

The government signals a number of various developments in the energy world:

- The global demand for energy is increasing. In the VS and Europe the demand will stay equally, especially because of the extra energy savings. Inside the energy demand the share of electricity increases.
- Worldwide there are sufficient energy sources available, but the import dependence for Europe and the Netherlands increase.
- Renewable energy will be a bigger part of the energy mix, however the need for 'gray' energy will be still there in the upcoming decades.
- Renewable energy is still not profitable and is only competitive on long terms with conventional energy sources.
- The costs for energy increase, partly because of the stimulation of renewable energy and required investments in the energy-infrastructure.

Because of these developments in the energy world the Dutch government choice for an economical and international approach with five spearheads. These spearheads are described in the *energierapport 2011, 10 juni 2011*. One of these spearheads is to expand the share of renewable energy. This ambition is divided into a long and short term.

Renewable energy long term. From the EU the ambition is to achieve a reduction of 80 to 95% CO_2 compared to 1990. Divers scenarios give different views of the road to 2050. This is because of the fundamental uncertainty of the developments of new technologies and the future market prices. Inside of these uncertainty a few robust developments can be denied. Worldwide sufficient offer of fossil fuels is available and the global demand for energy increase. On the same time the demand in Europe stays constantly, especially because of the expected energy savings. The part of renewable energy in the European energy mix increase. The required investments in these measures and networks will lead to increasing costs for the customer. The Dutch government encourages the innovation, so that renewable energy can compete with 'gray' energy.

Renewable energy short term. The European goals for the development of energy facilities are:

- Reduction of 20% CO2 in 2020 compared to 1990.
- 20% of the primary energy consumption in the EU must be coming from renewable energy sources. This target is translated to a specific target for each member, for the Netherlands is that 14% in 2020. The most important tool to achieve this target is in the Netherlands the SDE+.
- 20% energy savings in 2020 compared to the 'business as usual'. This goal is indicative and not binding determined. The government sees it as a national concern

and stimulates it through applying tax measures and making appointments with business life.

The part renewable energy consists in 2010 4% of the national energy use. As mentioned before, the European goal for renewable energy is in the Netherlands 14% in 2020. To achieve this goal some significant investments are needed. The government spends from 2015 annually 1.4 milliard euro to stimulate the production of renewable energy.

The costs for renewable energy decrease. Renewable energy will unfortunately be profitable on the longer term. The development of renewable energy depends in particular on four factors:

- The price development of fossil fuels and CO2 emissions.
- Cost reduction of renewable energy technologies.
- Cost reduction in alternatives technologies for example Carbon Capture and Storage.
- The policy approaches and policy incentives.

The European directive of renewable energy requires the Netherlands to produce in 2020 14% of the gross end use of energy by renewable energy sources. The government will stimulate the coming years the production of renewable energy by the following four measures:

- Incentive Sustainable Energy plus (Stimuleringsregeling Duurzame Energie plus SDE+).
- Blending requirement for bio fuel in the transport sector.
- Use of biomassa in power stations.
- Import of renewable energy.

2.2.1 Stimulation of Province Noord-Brabant

The province of Noord-Brabant also takes her responsibilities and wants that Brabant in the future is assured of affordable, reliable and clean energy facilities. The province supports the initiatives for generating energy as many as possible. According to Kasteren (2008) an entire sustainable energy supply is economical feasible and is eventually, in 2040, cheaper and reliable than that the energy is based on conventional sources (Kasteren, 2008). Especially in the period until 2020 substantial extra investments must be made to achieve this transition. Here for Noord-Brabant compose various policies and stimulation programs. One of these documents is the ‘Masterplan Energie Noord-Brabant in perspectief’ where seven spearheads are defined: sun energy, electric driving/ smart grids, biomass, heat, build environment, decentralized grids and wind-energy. Each of these measures has a high potential to implement in the environment and contributes in the ambition. A coherent policy for energy transition also focus to achieve a balance between the stimulation of the introduction of marketable technologies, preparation of options that are almost marketable and stimulation of innovations which have a valuable future perspective. The seven spearheads are divided into three categories, see Figure 3. For the long term the pv-panels, electric driving and some biomass production are interesting, but the implementation of wind, heat, the built environment and some biomass are already feasible for the market (Londo, 2010).

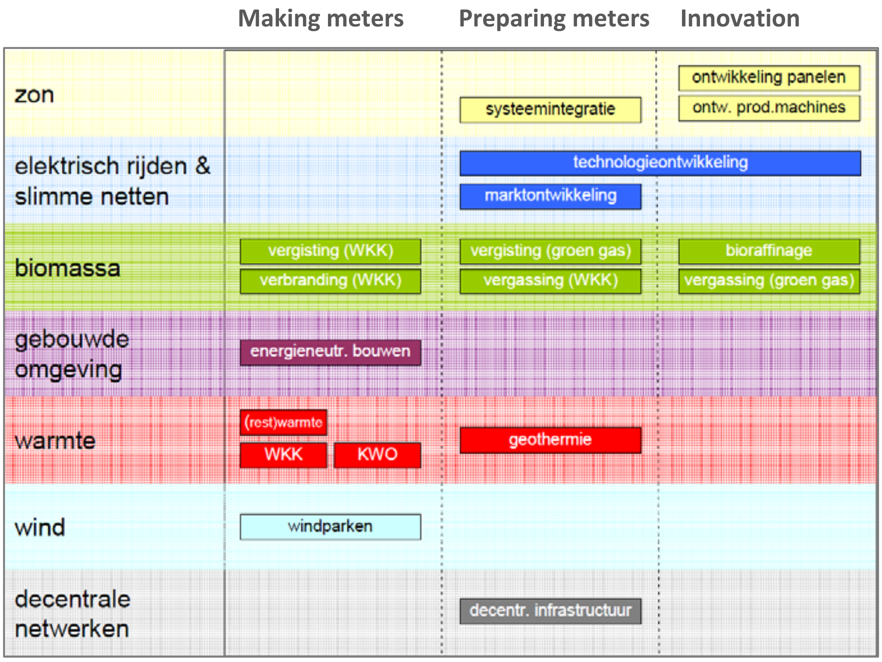


Figure 3 The spearheads of Brabant divided into *making meters, preparing meters and innovation*

2.3 Energy transition

It's a major challenge to develop 'the world of energy' sustainable. As mentioned before the expected demand of energy depends on how the rate of energy savings practically takes place. The use of Trias Energetica can help by the achievement of sustainable energy consumption. Trias Energetica is phased into three steps which approaches the energy problem into simple and logical steps, see Figure 4.

The three elements of Trias Energetica are:

- Reduce the demand for energy, minimize the consumption:
- Use sustainable sources of energy like wind, the sun, water and the ground:
- Use fossil fuel energy as efficiently as possible.

Figure 4 Trias Energetica

The combination of the three steps makes the development of the energy transition valuable. The emphasis of this research is on step 2 which implements different sustainable sources into a plan area.

During the development of energy transition the terms like *energy neutral, CO2 neutral, climate neutral, energy zero, energy plus, energy supply, C2 emission free* etc. are used generally. These terms doesn't have a uniform definition what leads to uncertainty and confusion of tongues. The uses of these terms are free and there are no legal agreements made. Usually by each development the different parties have agreed their energy ambitions, but what these ambitions define is unclear. Agenstschap NL has established these terms into one definition as a leading definition (Agentschap NL, 2010).

Energy neutral. The term is used for the performance of a building. The primary energy consumption is established by the design and the equipment of the building. It's about the Mega Joules that is divided into gas, electricity and heat. The energy demand is based on the energy consumption that is building- and user-related.

CO2 neutral. The term 'CO2 neutral' is used for the performance of an organization in the broad sense. This term is extracted and covers subjects like energy saving in buildings, CO2-reduction concern mobility, use of energy saving and CO2 compensation.

Climate neutral. In preference, do not use the term 'climate neutral'. Climate is broader than only energy or CO2 neutral, it affects the full scope of sustainability.

These definitions give a good view how to interpret the difference. But which definition is leading for this research? The focus of the research is on the development of an energy neutral environment's plan by implementing energy saving measures. Compared to the definition, the focus of *energy neutral* is on building level but the research focus on an area plan. Looking to the definition of *climate neutral* the focus is on a whole organization what not will be taking in this consideration. For the research the term *energy neutral* is leading but the focus will be on a larger area. Based on the energy consumption of different end-users the energy demand will be divided into gas, electricity and heat. The energy demand will be compensated by implementing different energy saving measures.

2.3.1 Thus far and farther

In the Netherlands the consumption of renewable energy of the total energy consumption decreased from 4,1 % in 2009 to 3,7% in 2010. This can be attributed to two factors; on one hand the total consumption of energy increased and on the other hand the use of biofuels is decreased. As mentioned before, the current energy consumption in Noord-Brabant is mostly based on fossil fuels. Only 6 % of the energy consumption is from renewable energy sources, especially energy from biomass.

Kasteren has defined the potential amount of energy that could be generated out of different sustainable energy sources in the province of Noord-Brabant, see Table 4. Besides the technical potential, the all ready realized consumption is also submitted.

Sustainable energy sources		Technical potential (PJ/ year)	Realized (PJ)
Water		0,1	0,1
Wind		2,3	0,2
Waste		8,4	6,0
Biomass		21,6	11,0
Sun	Heat	154,5	0,1
	Electricity	55,2	0,0001
Total amount		**186,8**	**17,4**

Table 4 Annual amount for technical and realized potential of different sustainable energy sources concerned the province of Noord-Brabant (2006)

The technical potential is based on the technical possibilities and the suitability of locations. The technical possibilities depend of the technical status of a measure, like the efficiency of converting the energy of the source into useable energy. The suitability of a location is influenced by the fact that sustainable measure can't be located everywhere in the environment. The difference with the existing energy facilities is that the renewable sources are diffused in the environment of the province, which influences the adjustment of demand and supply of energy.

The amount of the existing generation is compared to potential amount quite low. To achieve the ambition that 20% of the primary energy consumption comes from renewable energy sources, many things have to be done. The potential amount of sustainable energy sources shows us which measures are interested to implement in the environment.

2.4 Conclusion

Energy is used by the entire society and will increase the upcoming years. The greater part is used for heating and electricity. The residential areas and industry are the biggest consumers of energy, while a small part is represented by agriculture. Approximately 92 % of the energy generation can be addressed to fossil fuels which has a negative influence on the environment. The availability of fossil fuels will decrease and so the import dependency will increase. On European and national level different ambitions are defined (Ministerie van Economische Zaken, 2011).

One of the main ambitions is to generate 20 % of the energy out of sustainable energy sources in 2020. On this moment the use of sustainable energy sources is nil. It is possible to conclude that there is sufficient potential to generate sustainable energy out of different sources. Many of these energy measures have a spatial relevance and discourage to invest in sustainable energy measures. Focusing on providing a vision how energy will be used in the environment is appropriate. In this way, the spatial impact of locating sustainable measures in the environment has to be emphasized. This vision is relevant considering the many required measures, the total spatial impact and the high investments (Kasteren, 2008).

SPATIAL ENVIRONMENT

3 SPATIAL ENVIRONMENT

This research focuses on the spatial impact of sustainable measures in the environment. This chapter briefly describes the regulation of the spatial environment in the Netherlands. Besides that, insights are created how the energy influences the environment and finally how various sustainable measures behave in the spatial environment.

3.1 Spatial planning

The Netherlands is one of the most densely populated areas in the world. The spatial environment is used by living, working, infrastructure and nature. All these functions must find their location. To keep it organized, integral area development is necessary. The government controls the spatial planning by capturing it in the legislation, which is also done by provinces and municipalities.

In the Netherlands the spatial planning has a solid basis, the concern of the government focus on the habitability of the land and the protection and improvement of the environment. This basis is further developed in the legislation on the spatial planning (Wet op de Ruimtelijke Ordening - WRO), but also in many other types of legislation. This all is to organize the development of spatial planning.

The definition of spatial planning is that *Spatial planning involves the search process for the spatial development of a changing society and making of choices how and where functions full their advantage, especially with the view of long term development including the reflection on it* (Spit, 2003).

The planning can take place on different scale levels, like national, provincial, regional, municipal or district level. The structure is characterized as a top-down process, where the plans of the higher governments form the framework for the lower government. At the same time a reverse process takes place, the bottom-up process, whereby the plans of the lower government are controlled by the plans of the higher government (Spit, 2003).

The spatial policy formulates goals for the accessibility, regional economy, landscape, housing and livability. The changeable energy sector will influence the spatial view of the Netherlands (Gordijn, 2003). Like the view of buildings, design of cities, the landscape and the underground will change because of the applying of energy measures. According to van Hoorn (2010) an integral vision of energy is needed so that opportunities are taken with other functions and on one hand to decrease and the other hand to compensate the negative spatial effects. This is relevant because of the many required measures, the total spatial impact and the high investments. A spatial energy vision can be simplify operated by bringing actors on the right moment together, the scale advantages and assembling of the energy goals and the spatial goals for a city (van Hoorn, 2010). Sustainability doesn't stop by the boundaries of a city or it will not be achieved by a city. An intensive collaboration of cities, environment and region, municipalities and province is required.

3.2 Spatial planning of sustainable energy sources

According to Gordijn (2003) the relation between energy and the environment influences three relevant issues: covering of the environment, infrastructure and the value of the experience of the environment. The changeable energy sector has consequence for the amount of space that is needed for sustainable energy measures. The extractions of coal, oil and gas takes mainly place underground and have a minimum influence on the visibility and the over ground level. The comprehensive use of wind energy, biomass and sun energy are sources that take place on ground level, which considerably covers more square kilometers. Besides the high covering, the infrastructure for transporting the energy also needs to be taking into account. The existing infrastructure is insufficient and needs to be extended or new technologies are relevant. The spatial effects are quit unknown and involve new investments. Also the prospective landscape will change over time. For example windmills, which have a positive improvement in some cases. But generally it brings resistance, which lead to delays and stiff collaboration.

The changeable energy sector will lead to implementation of sustainable energy measures in the environment, which effects a changeable environment. These measures has their own features and properties, like demand of surface, energy generation etc.. Each sustainable energy source influences the environment in a different way and on a different way. So also the three relevant issues that show up by relating energy with the environment as mentioned before. This research focus on the allocation of locations of sustainable energy measures, which takes place on area level.

A sustainable energy measure is an energy producer that wants to match an energy consumer. On area level, different variables can be taken into account that influences an optimal match between the producer and the consumer, on both sides (ECN).

- Energy form.
- Amount of energy (expressed in Joules or kWh).
- Power (Watts).
- Temperature level.
- Concurrent of the demand and offer.
- Location of demand and offer.

An optimal match is desirable between the consumer and the producer. Each consumer has different interpretations of their variables, so also the producer. For example the variable *energy form*; the consumers demand is electricity but the measure produce heat, this is a mismatch. So a mix of measures will be implemented in the spatial environment to meet the consumer. A desirable situation is that an optimal mix of measures is implemented in the environment that meet the consumer, and that also an optimal use of the environment is guaranteed. This integration in the environment gives various spatial planning problems. Each of these measures has their own constraints and spatial requirements. This research focuses on the sustainable energy measures windmills, pv-panels and bio-energy installations. These measures have according to Table 4 sufficient potential for generating sustainable energy. Besides that, these techniques are adequately developed for applying in the environment. Below, each measure is defined separately.

3.2.1 Wind turbines

The Netherlands is well suited for generate energy out of wind. Windmills are a sustainable application that contributes in the goal for a sustainable energy system. A difference can be made between offshore and onshore windmills. This research only focuses on the onshore windmills because the case study approach an onshore area (see paragraph 4.4). Wind turbines convert the kinetic energy of wind into electricity. These wind turbines are often part of a larger whole, also called a wind park. The realization of a wind park in the environment takes time and requires a large number of activities of different parties. A wind plan doesn't locate alone but is part of the total urban planning environment. And so the government determined policies on local, national and international level to regulate the application of windmills on Dutch ground.

Wind turbines influence the environment, for example it must be safe, no inconvenience and a minimum damage to animals and plants. So there are detailed requirements established that affects the applicability of windmills in the environment. These conditions must be tested in the context of spatial procedures, permit or even m.e.r.-procedures. For example it involves the aspects like birds, bats, noise, risk, shadow, health, radar, flight safety etc. This research focuses on the spatial consequences of windmills. The involvement of nature, ecology and stakeholders will be extended.

Spatial. Nowadays the new windmills are getting higher and so applying it into the existing structure or hideaway is impossible. So by implementing it into the environment the windmills creates new landscapes. According to Senternovem[1] (2004) the visual influence are less in an environment with a high amount of mass, than open areas where buildings are much further away from the observer (SenterNovem[1], 2004). The distance of the visual nuisance is much longer than noise and shadow nuisance. The boundary of visibility is often underestimated and depends on the brightness of the atmosphere. This is not the same every day and on any location. Figure 5 shows the boundary distance that a windmill is visible by various visibilities of the brightness of the atmosphere. For example, on a bright day the visibility will be high and so the windmill is still visible on 25 kilometers (CBS[3], 2010). According to Möller (2006) the most important factors how windmills influence the visibility of the park are the height of the turbines and the combination of distance and size of the windmill park. Other factors, like color and material are less important. If more than one turbine will be located the preference is that they locate in line or in a grid.

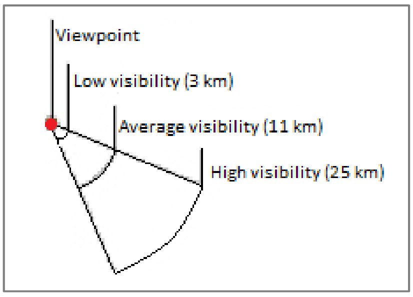


Figure 5 Vision range (CBS[3], PBL, Wageningen UR (2010))

Policy. The province of Noord-Brabant determined the policies that concern the spatial for applying windmills in the area. The policy of windmills depends on the height of a wind turbine. If the shaft height of the windmill is lower than 25 meters the regulation of the municipality is applied. When the shaft height is higher than 25 meter the 'Verordening ruimte Noord-Brabant 2011' is the legislation in force. The province of Noord-Brabant has defined in the 'Verordening ruimte Noord-Brabant 2011' the spatial requirements for implementation of wind turbines in the environment. The regulation is divided into existing areas with a high urban density and areas outside these densities. For the areas outside the high urban density the province designates direct areas for the development of windmills. A minimal of 8 wind turbines must be applied. For the development in the high urban density a windmill can only be allocated on an area with the destination industrial area. The windmills are clustered with a minimum of 3 turbines. The turbines can also not be located into the EHS (Ecological Head Structure). This implies for example the Flora and Fauna legislation etc. (Brabant, 2011). This section shall not further take into consideration because it could exclude possible valuable locations that are interesting for windmills.

Nuisance sensitive objects. These objects are sensitive for the implementation of wind turbines. Sensitive objects are for example buildings and schools. They have nuisance of noise, shadow effects, glare and the safety risks. The noises of the wind turbines can't cause impermissible interference. Since 1 January 2011 all the wind turbines are subjected on the 'geluidregelgeving voor windturbines van het Activiteitenbesluit'. Therefore, the annual average of the noise level (Lden) as result of a wind turbine or wind park should not be greater than 47 dB. During the night the average noise level can't be greater than 41 dB. Before 1 January 2011 the policy WindNormCurve (WNC) was appropriated. Practical the distance of four times the shaft center height will not exceed the WNC-40 norm for noise sensitive objects like dwellings. Shadow effects of wind turbines can cause nuisance for the environment. The 'Activiteitenbesluit' describes that the drop shadow and glare of the wind turbines needs to be prevent or limited. The regulation is that the wind turbine stops if shadow effects take place on a sensitive object. This stop is regulated by a standstill provision, which is needed when the distance between the wind turbine and the sensitive objects are less than 12 times the rotor diameter and that an average of more than 17 days a year and more than 20 minutes each day shadow effects can occur. It only stops when shadow effects really occur. Out of practice, this doesn't influence the financial return because the norm for noise has already sufficient distance. Nowadays the glare of wind turbines isn't applicable, because the turbines are edited what blocks the sparkles (AgentschapNL[3], 2011).

Technical. The technique of a wind turbine is getting smarter. The height and length of the rotor blades are increasing which lead to a higher generation of electricity. On this moment a standard wind turbine has a diameter of 90 meters and a height of 100 meters, see Table 5. A turbine is able to generate 3 MW each year. To prevent that a turbine influences another turbines profit, a distance between them is desirable. The average distance is six times the diameter. The technical features of a wind turbine have a high influence on the return on assets (AgentschapNL[3], 2011).

Generate	Amount of windmills	Height (meters)	Diameter (meters)	Wind speed (m/s)	Max. Power (kW)	Average number of operating hours per year (hour)	Expected Yield (kWh/year)
Electricity	1	100	90	6.5	3.000	2.200	6.600.000

Table 5 Standard wind turbine (AgentschapNL[3], 2011)

Efficiency – return. The profitability of a windmill depends on the investment costs, exploitation costs and the revenue. On this moment it's not always possible to make it a profitable project, and so the government offers stimulations regulation. Besides that, the revenue also depends on the amount of electricity a wind turbine generates. The generation is influenced by several factors: the design of the turbine, the height, the length of the rotor blades, the wind speed and location of the wind turbine. Especially the height of the turbine and the wind speed determine the electricity production.

Generate	Amount of windmills	Max. Power (kW)	Average number of operating hours per year (hour)	Expected Yield (kWh/year)	Developments costs (Euro/kW)	Total investment costs	Result (year)
Electricity	5	15.000	2.200	33.000.000	€1.430	€21.450.000	€492.858

Table 6 Profitability of 5 windmills (AgentschapNL[3], 2011)

In Table 7 the net costs and net income for five windmills are defined. The net costs for each year depend mostly of the amount of financing. The net income is divided into the sale of electricity and subsidy of the government. Especially the subsidy is a dependent variable, which could be change over time. This risk needs be considered (AgentschapNL[3], 2011).

	Assumptions		Amount / Year
Investment	€ 1.430	kW	€ 21.450.000
Financing	5%	(15 years)	€ 2.066.542
Maintenance	€ 0	kWh/year	€ 363.000
Ground costs	€ 14	kW/year	€ 210.000
Net. costs	€ 11	kW/year	€ 165.000
OZB	€ 18.600	Each year	€ 18.600
Other costs	€ 50.000		€ 50.000
Net costs			**€ 2.873.142**
Electr. Sale	€ 0,07	in 2008	€ 2.310.000
Subsidy	€ 0,032	kWh	€ 1.056.000
Net income			**€ 3.366.000**
Result			**€ 492.858**

Table 7 Assumptions costs and income for 5 windmills for each year (AgentschapNL[3], 2011)

Infrastructure – Network. The Electricity grid in the Netherlands contains of a power grid with distribution networks to regional nets where the end user is connected to. Wind turbines onshore are most of the time connected to the regional nets. Before the electricity gets into the net, the electricity is brought back to the proper voltage and the right quality. On this moment, the capacity of the network is not able to capture such high amounts of electricity. In this case, it's desirable to bring the demand and offer as near as possible, which means that the turbine needs to locate near the consumer with the highest demand (AgentschapNL[3], 2011).

3.2.2 PV-panels

The sun is shining every day. Besides light it also contains energy. Solar energy can be converted into electricity by making use of pv-panels (photo-voltaic panels). The development of pv-panels makes enormously steps recent years. The technology improves constantly which lead to rapidly decreasing of costs and prices. The spatial requirements influence the integration of pv-panels in the environment. Below, these requirements and constraints are explained.

Spatial. Pv-panels contain of cells that convert the sunlight into energy. These cells are light in weight and so easily to apply on various surfaces. Usually the pv-panels are installed on the roof of buildings. Not all the roofs have the potential for pv-panels and so a total surface is calculated that is suitable for pv-panels. For this calculation, the research of Klep et al. (2011) is used. This research has the aim to calculate the potential square meters for locating pv-panels of the city Den Bosch. From the total area of Den Bosch, the total square meters of buildings is defined. Only a part of this surface is suitable for the locating of pv-panels. The determination of this amount is based on three variables: solarisation bigger than 80%, slope of the roof and shadow effect. The orientation and obstacles (shadows, trees, dormers etc.) of the panels are also taking into account (Klep, 2011).

We can assume that the city of Den Bosch has an equal intensity of spatial use as the city of Eindhoven (CBS[2], 2010). So the ratio of Den Bosch can be adopted into the calculation for Eindhoven, and finally for the whole SRE-area, see Table 8.

	Den Bosch (m^2)	%	Eindhoven (m^2)	%	SRE-area (m^2)	%	Patch (m^2)	%
Total surface	91.273.058		88.840.000		1.457.810.000			
Total surface of residential and industry	44.950.000	100	65.950.000	100	285.970.000	100	90.000	100
Surface buildings	7.576.093	16.9	11.115.536	16.9	48.198.783	17	15.300	17
Potential surface roof	2.723.543	35.9	3.995.944	35.9	17.327.065	36	5.508	36

Table 8 Potential surface roof

Industrial areas have more potential for locating pv-panels, because of the large amount of square meters of roofs. Also the consumption of electricity is higher and a minimal distance between producer and consumer is desirable.

Efficiency – return. The return of pv-panels is influenced by several variables. The proportion between the amount of energy generation and investment costs define the final efficiency of a pv-panel.

The amount of energy generation is determined by the following formula:

*Hours of sun * Power * Standard losses * Solarisation percent * Obstacle percent*

The power from a sun hour can range strongly. This is because of the seasonal differences, a sun hour in the winter produce less than in the summer. The amount of sun hours varies from 980 – 1070 in the Netherlands, dependently on the location, see Figure 6.

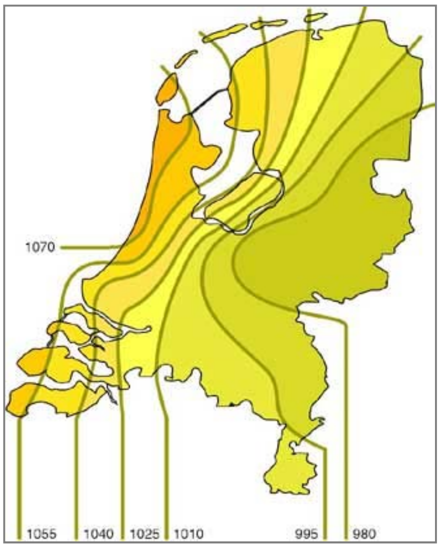


Figure 6 Map with average sun hours each year

The power of an average pv-panel amounted 125 Wp/ m^2, which implies 0.125 kWp/ m^2. Nowadays a modern pv-panel with crystal cells can produce this amount. The standard losses imply variables like converting (8.7 %), loss of cables (0.9 %), pollution (3.6 %) and temperature (3.3 %). This implies a loss of 16.5 % on the production. The total production of a pv-panel calculates 105 kWh/ m^2. Eventually, the total potential square meters times the production of a pv-panel determines the total potential production of energy out of the sun (in kWh/year). This means 105 kWh/year * 17.327.065 m^2 = 1.819.341.872 kWh/ year. This potential generation has good opportunity of success to contribute in the ambitions.

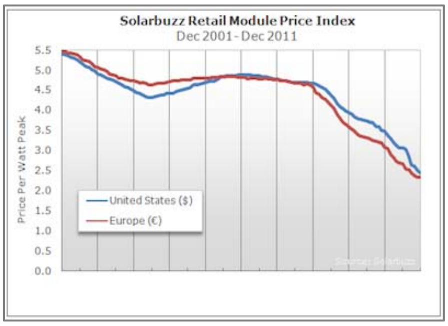


Figure 7 Price per Watt Peak (Solarbuzz)

The investment costs for a pv-panel are calculated by the price per Watt peak. According to (Solarbuzz) the price for each Wp is on this moment 2,33 (see Figure 7). The investments costs are 2,33 times 125 Wp/ m^2, which implies 291,25 Euro/ m^2. The total investment costs will be the square meters times the price/ m^2.

3.2.3 Bio-energy

Bio energy is energy that is generated out of organic materials (biomass). The energy that comes out of biomass can be used for heating or electricity. There are different processes that convert biomass into energy, like fermentation, combustion and gassing. This research focuses on the fermentation process. The use of bio-energy installations has a double bondage location. Even the transport of the organic materials to the biomass station as the transport of heat is strong committed to their location.

To allocate a potential location an inventory of the following variables is required:

- Are their sufficient available square meters?
- Which locations are possible according the land use plan?
- Is integration in the existing developments possible?
- Where are the possible consumers of heat, or connection on the electricity grid?
- Where are possible suppliers of biomass?
- Are there any environmental constraints?

The available square meters for applying fermentation installations in an existing land use plan is restricted. A municipality or province that wants create available square meters for these installations, have to make their own policy choices and they have to translate this into visions of land use plans. During the preparing or updating of the land use plans, the municipality or province must decide where in the area and on what scale fermentation is spatially appropriated. Licenses are needed to build installations. (NVRD, 2009).

Spatial. A distinguish can be made in the size of installations. These are subdivided into small installations on owner level, large scale installations on agriculture areas and large scale installations on industrial areas. The small installations are generally located by agriculture companies in the outlying areas. These have a processing capability around the 1000 m^3 / year. The larger installations on agriculture locations are bigger installations whereby the manure of their own company or local collaboration is used. The larger industrial installations are appropriate for energy production, are generally located on industrial areas or closed to processors or waste treatment installations. These installations concerns processing capabilities of more than 100.000 m^3 / year. The size of an installation cannot directly be assigned, this differs per situation. So the size of installation is divided into the processing capacity of biomass, see Table 9. (Kool et al, 2005).

Size of installation	Processing capacity of biomass
Agriculture companies	< 10.000 ton
Bigger agriculture companies	> 10.000 ton < 60.000 ton
Industrial installations	> 60.000 ton

Table 9 Size of installation

Biomass. Biomass is organic material that can be divided into two types of biomass. The first is biomass that is special cultivated for the extraction of bio-energy. The second kind of biomass is waste like pruning, waste out of industry, Kitchen and Garden Waste, waste paper and agricultural waste. Firstly the focus is on the existing available waste production in the SRE-area. Because the fermentation of only manure is not profitable, co digestion material is added like corn. Organic material used as co-substrate that are able to be added, are standing on a positive list that is released by the government. The total manure that contains of at least 50 % animal manure with one of the products of the list can be seen as animal manure. (Kasteren, 2008).

The available biomass that is useful for fermentation is liquid manure, solid manure and green waste. Table 10 shows the amount of the selected biomass and the total energy capacity that is available in the area, based on CBS data (Statline[2], 2009).

Biomass	Production (Statline[2], 2009)		Caloric value (Kasteren, 2008)		Energy capacity			
Liquid manure	4.838.034	ton	0.3	GJ/ ton	1.451410	PJ		
Solid manure	247.681	ton	0.8	GJ/ ton	0.1981448	PJ		
Corn (See Appendix 2)	240.810	ton	15.1	GJ/ ton	3.6	PJ		
Total	5.326.525	ton			5.2858	PJ	1.468.274.029	kWh

Table 10 Available biomass in the SRE-Area (Statline[2], 2009)

Nuisance sensitive objects. The guide ‘Bedrijven en milieuzonering van de VNG’ advices a focus distance of 100 meters around installations for fermentation and combustion. This is based on distance of at least 100 meters for the smell and noise, 50 meters for dust and 30 meters for safety. The distances for smell, noise and dust are overestimated, while the safety is slightly underestimated (storage of biogas). The advice is that 50 meters is sufficient for safety. (VNG, 2009).

During the transportation of heat the transport losses are very high (Jablonska, 2011). The distance between consumer and producer prefer a maximum distance of 3 kilometers, so that the losses are minimal.

Efficiency – return. The size of investment (and also the return time) depends not only on the capacity. This is also influence by the following factors (NVRD, 2009):

- The manner of energy production and convert (heat and/ or electricity).
- Distance to heat consumer.
- Applied conversion technique (combustion, gassing, and fermentation).
- Applied installation technique.
- Biomass rate.
- Energy rate.
- Caloric value of the biomass.
- Sales rate and application of residual materials.

The generalizing of assumptions for each variable is difficult because of the many differences between bio energy installations. The costs and benefits diverge extremely because each installation has his specifications. Here for an example installation is choice and used to make assumptions for the calculation. This co-fermentation installation locates in Zuidvelde. The biomass that is used contains of manure and corn, with an amount of 15.000 ton each year. This amount is divided into 12.500 ton liquid manure, 2.000 ton solid manure and 500 ton corn. The power is 980 kWe and 1.7 MWth and produce 3.5 million kWh/ year. The investment costs are € 1.633 /kWe, thus the total investment costs are € 1.6 million. The income for each kW is € 0.06 and this implies a total income of € 215.000,- each year. This installation covers an average total square meters of 100 by 100 meters (SenterNovem[2], 2005).

The application of bio-energy is based on biomass which concerns an extended process. This process contains variables which are sensitive for influences. Like the amount of available biomass influences the final generation of energy. This amount can fluctuate and isn't guaranteed for the future. This sensitivity of variables that influences the final generation of energy must be kept in mind.

3.3 Conclusion

The use of energy plays a role in spatial planning. The changeable energy sector influences the existing spatial environment. The implementing of various sustainable energy measures changes the view of buildings, designs of cities, landscapes and underground. Each measure influences the spatial environment in a different way and therefore contains different constraints and requirements. Generally these conditions are influenced by various fields like political, technical, social, financial etc. This research focuses on the spatial consequences of implementing sustainable energy measures. The constraints and requirements approach the spatial effects and the other influences are expanded.

To achieve the ambitions of the government a high amount of measures is needed and a mix of measures is desirable to get the total demand of energy. This means that different spatial effects of the various measures encounter each other. Such an integral vision is needed so that opportunities are filled in and to decrease and compensate the negative spatial effects.

Therefore, a model is designed for visualizing an integral vision. The next chapters approach the model further.

THE MODEL

4 CONDITIONS FOR THE MODEL

This chapter approaches the condition of the simulation model. The first paragraph describes the basis features of the model. The second defines the computer program which will be used for simulating the model. After that, in paragraph three, four and five the different conditions of the model are determined.

4.1 Agent Based Model

Agent-based Modeling and Simulation (ABMS) can model complex systems composed of interacting, autonomous ‘agents’. An agent has a behavior that interacts and influences other agents, which influence each other’s behavior. They experience and adapt their behavior so it’s better suitable to their environment. These tools are suitable to approach land cover changes. The ABMS allows crossing levels to understand high-level structures and processes as outcomes of low-level agent interactions. So, ABMS provides a common framework for processes at multiple levels. Agent-based techniques can be used to identify how external information affects the spatial pattern and composition of land cover over time.

A typical agent-based model has three elements:

- A set of agents, their attributes and behaviors.
- A set of agent relationships and methods of interaction: An underlying topology of connectedness defines how and with whom agents interact.
- The agents’ environment; Agents interact with their environment in addition to other agents.

So agents interact with their environment and with other agents. The information that will be implementing in the model is the input datasets, the observed land cover data and the model structure (Macal, 2010).

This research proposes an agent-based approach because individual agent decisions of land-use location interact with decisions of other lands use agents. These decisions need to be coordinated so that a collaborative plan will be generated. The use of agent-based modeling represents the multiple actors of particular land uses. In this research a land-use model will be developed to generate land use plan alternatives in an interactive environment of multi agents. The use of land-use models is a well-established component of planning support systems to support spatial planning. Based on the article of Arentze et al. (2009) the land-use model will be established. This article develops a method whereby a heuristic is introduced for generating land-use plans that combines elements from different approaches in land-use modeling. This integrated model is better able to account for a difference in nature between area-type land uses (for example: housing, industry, agriculture) and facility-type land uses (for example: schools, retail). This is because facility and area agents use different methods to generate a plan for their land use. A combination of suitable heuristics is translated in a single agent-based system. This model can be used for what-if-analysis in a planning support system where assumptions of policy choices, policy values and autonomous developments can specify by users. Finally, the spatial assumptions of these assumptions will be revealed by the model (T A Arentze, 2009).

The difference between the article and this research is the approach of plan area. The article focuses on the accommodation of the growth of an existing area. Such an ‘empty’ area will be developed with new area-type land uses and facility-type land uses. This research approached the existing environment where different facilities will be applied. This is because of the demand for energy facilities on large scale. These facility-type land-uses react on the existing area-type land-uses and try to optimize a network of facilities considering the spatial distribution of demand for the facilities. As mentioned before, the area and facility agents use different methods to develop a plan for their land use. Both types of agents have also in common features; they distinguish between a macro-strategy and a micro-strategy. A macro-strategy contains a specific setting of the parameters of the method used to spatially allocate the land use, the micro-strategy contains this allocation. So a micro-strategy is integrated in a macro-strategy which determines how a macro-strategy is realized in a land use plan. On macro and micro levels, both use different concepts and methods.

According to Arentze et al. (2009) the Teitz and Bart (1968) vertex heuristic will be adapted on micro level, also known as the interchange heuristic. For good reason is this heuristic used as the most widely method for discrete-space problems. In general, the interchange heuristic finds solutions where locations need to be selected out candidate locations. For the algorithm is an initial solution selected, the current solution. The current solution is the set of cells that are currently claimed by the agent for this facility. A candidate cells which is not in the current solution is substituted for each cell in the current solution. If the utility of the next solution has a higher value than the current solution, the next solution becomes the current solution. Otherwise there will be no substitution. The interchange algorithm is able to solve location-allocation problems which imply to find the location of a given number of facilities that improve the objective function. The objective function in the research of Arentze et al. (2009) is defined by the p-mediaan model, the p-centre model and the maximum-covering model. These specifications for defining the objective function might consider dependent on the nature of the facility. Because of the nature of this research, the facility-agents fill in alternative specifications which are described in paragraph 4.3.

The macro-strategy of a facility agent provides the number and size of new facilities, but doesn't define locations. By evaluating possible macro-strategies under best possible location choices and identifying the one that maximizes the objective function, the best macro-strategy could be designate. This is an exhaustive process because if facility sizes can vary on a continuous scale the number of ways in which a task size can be subdivided into parts and the number of possible macro-strategies is virtually infinity. Scenario development is assumed to generate plan alternatives. This will further described in chapter 6.

Based on the article of Arentze et al. (2009) these macro and micro level strategies for facility agents are applied in the model. By making use of this article, the methodology for this research is substantiated.

4.2 Netlogo

For the development of geo-spatial agent-based models the use of Netlogo is a great simulation/modeling system (Crooks, 2008). It provides reliable templates for the design, implementation and visualization of agent-based models, allowing modelers to focus on research (i.e. building models), rather than building fundamental tools necessary to run a computer simulation (Railsback, 2006).

From literature research five software platforms for agent-based models were reviewed. It compares the platforms Swarm, Java Swarm, Repast, Mason and Netlogo. The advantage of

Netlogo includes the highest-level platform, providing simple programming language, built-in graphical interfaces and comprehensive documentation. Primarily it is designed for a grid space where mobile individuals have local interactions (Railsback, 2006). After comparing the software platforms concerning ABMs, the use of Netlogo is highly recommended and will be used for designing the model.

Netlogo is a program that is able to modeling an environment by multi-agents. It is well suited for modeling complex systems over time. To hundreds or thousands of independent “agents” instructions can be given that all operate concurrently. Interactions between micro-level behaviors of individuals and macro-level patterns can be explored. Also the behavior under various conditions can be explored.

The program of Netlogo contains of agents that can follow instructions. There are four types of agents: turtles, patches, links and the observer. Turtles move around in the environment. The environment contains of a grid of patches. Each patch is a part of the ‘ground’ over which turtles can move. The links agents are turtles that stand in connection. The observer is, like the name all ready describes, someone that observes the environment of turtles and patches. The way the world is connected can change by giving commandos to every agent, which is established in the procedure part. For example the turtle, that's moving over the patches, gets commands which lead to changes in the environment. Also agent variables can be implementing so that values (such as numbers) can be stored in an agent. Various agent variables are possible like a global variable, a turtle variable, a patch variable or a link variable. Each turtle has his own value for every variable and each patch has his own value for every patch. These variables could be for example colors or values. All turtles inside the environment can be handled in any conceivable way the user can think of and all agents can interact with each other. In addition, various buttons can be added so that outcomes can be plot (Wilensky U. , 1999).

In spatial systems the uses of agent have a critical issue because it can be applied to any aggregation of objects at any spatial scale and across different time horizons. An agent need not be restricted to human objects but might pertain to any object that contains in space and/or time. The processes that the agents enable, can unwittingly be changed, so also the mobility intrinsic to their location and the scale at which they contain.

The agents are able to be large-scale actors, what consists of multiple individuals, such as an army, a corporation or a terrorist cell. These agents also consider their autonomy and seek to accomplish their own goals, which are may be at least potentially distinct from the goals of the individuals who make up the entity (Crooks, 2008).

To be able to reproduce the model, the turtles, patches and variables agents, which will implement in the model, will be described. The knowledge from chapter 2 and 3 is used for the definition of each agent.

4.3 Turtles: The energy saving measures

The sustainable energy measures are the main turtles in the model. Each turtle has his own constraints and requirements that influence the spatial environment. In paragraph 3.2 an extended description is given of the various turtles, whereby the different spatial requirements that applies to each measure is defined. In this paragraph the description of paragraph 3.2 will be translated into usable data for the model.

The various sustainable energy measures are searching for an optimal localization in the environment. Each turtle will score a value, dependently where it's locating in the environment. The total amount of scores of all turtles defines the objective function. As mentioned before, to improve the objective function the interchange algorithm is used. So if the 'next solution' is having a higher score, the 'next solution' will become 'current solution'. According to the article of Arentze et al. (2009) the score of a turtle is based on the methodology of multi criteria evaluation. This methodology is used because different variables of the turtle influence the score in a different way. By making use of this methodology various criteria and their effects can be considered. For each turtle the different variables (criteria) are put against each other and values are assigned. Each turtle has his own multi-criteria (included values) and so three tables are setup. The subparagraphs 4.3.1, 4.3.2 and 4.3.3 show for each measure the different variables with their values. These values are based on expert knowledge. Experts from Builddesk will perform the validation and credibility. Although, the objective of the model is not focused on precise and exact numbers, it should represent realistic and possible outcomes.

4.3.1 Wind turbines

In Table 11 the features of a windmill are described briefly. These features are the basic for the defining of the variables, which eventually defines the score of the windmill. The column 'requirements' describes the features and the column 'variables' defines the variables.

WINDMILLS							
Features		**Requirements**	**Definition**	**Unit**	**Variables**		**Value**
Spatial		Pattern: turbines locate in a line or grid pattern. Sufficient available square meters	In the surrounding of the turbine are sufficient turbines locating.		1	Yes	0.7
			Mixed area			No	0
Sensitive objects	Agriculture	Distance visual nuisance (Average)	> 11.000	Meters	2	Long	0.7
		Distance shadow nuisance	12 * 90 = 1.080	Meters		Average	0.3
		Distance noise nuisance	4 * 100 = 400	Meters		Short	0.1
	Industry	Distance shadow nuisance	12 * 90 = 1.080	Meters		Average	0.7
		Distance noise nuisance	4 * 100 = 400	Meters		Short	0.3
Energy supply		Demand and offer, minimal distance between demand and offer	The total supply has a short distance to cover the total demand.	Meters	3	Short	0.7
			The total supply has an average distance to cover the total demand.	Meters		Average	0.2
			The total supply has a long distance to cover the total demand.	Meters		Long	0.1
Visual view		Less visual effects by a high amount of mass	A high amount of mass in the surrounding gives less influence on the visual view. Preference industrial area.		4	Low	0.8
			A less amount of mass in the surrounding gives more influences on the visual view. Preference agriculture area.			Average	0.2
			The windmill is (partly) locate in the residential area.			High	0.0

Technical	Diameter turbine	90		Meters
	Distance between turbines	6 * 90 = 540		Meters
Efficiency - return	Wind speed	6,5		M/s
	Full capacity hours	2.200		Hours
	Power generate per turbine	3.000		kW
	Developments costs	1.430		Euro/ kW
	Netto costs/ year/ turbine (15 years)	574.628		Euro
	Netto income / year /turbine	462.000 + 211.200 = 673.200,-		Euro
		Electr. sale	0,07*3000*2200 = 462.000,-	Euro
		Subsidy	0,032*3000*2200 = 211.200,-	Euro

Table 11 Features & variables windmill

The first variable defines if sufficient space is available to locate in line or pattern. A windmill park has the preference to locate in line or grid, this variable calculates the possibility and counts windmills in the surrounding of a windmill. The second variable determines the distance between the windmills and sensitive objects (residential area). Dependently on the distance between these objects the value for this variable will be determined. The third variable preferences a short distance between supply and demand of energy. Here for, how higher the distribution in a short distance how higher the measure will score. The last column defines the influence of a visual view. These influences are lower on industrial areas than in the surrounding of agriculture areas. The technical and return features aren't translated into variables because they are useful for defining the variables. For example, the technical numbers are used for defining the distance between a windmill and sensitive objects (variable 2).

The turtle scores a value for each variable, the sum of these values divided by the amount of variables, determines the windmill-score for that turtle.

4.3.2 PV panels

In Table 12 the features and variables of a pv-panel are determined. According to subparagraph 3.2.2 the features are described briefly. These features are translated into variables and their score-values.

PV-PANELS						
Features	**Requirements**		**Unit**	**Variables**		
Spatial	Potential roof surface	17.327.065	m^2			
	Possibility for locating pv-panels. Available square meters.	100 % of the patches are industrial and residential areas.	m^2	1	Yes	0.3
					No	0
Energy supply	Demand and offer, minimal distance between demand and offer	The total supply has a short distance to cover the total demand.	Meters	2	Short	0.7
		The total supply has an average distance to cover the total demand.	Meters		Average	0.3
		The total supply has a long distance to cover the total demand.	Meters		Long	0.1

Efficiency - return	Hours of sun each year	1.010	Hours
	Power	0,125	kWp/ m^2
	Standard losses	15	%
	Return/ m2	1.010*0,125*0,85 = 107	kWh/ m^2
	Electr. Sale	0,23	Euro/kWh
	Price / Wp	2,33	Euro
	Investment	2,33*125 = 291,25	Euro/ m^2

Table 12 Features & variables PV-panels

Sufficient roof surfaces have the potential for locating pv-panels. Industrial and residential areas have the preference for locating this. Each patch has a surface of 90.000 m^2 but isn't suitable to cover the whole patch with pv-panels. According to Table 8, each residential and industrial area has 5508 m^2 potential to locate pv-panels. And so, variable 1 defines the sufficiency of available square meters for locating pv-panels.

The second variable determines if the distance to the demand is short, average or long. Dependently which distance the turtle has to the demand, it will score 'one' of the three values.

Each pv-panel-turtle will score a value for both variables; the sum will be divided by the amount of variables which defines the pv-panel-score.

4.3.3 Bio-energy

From the description of paragraph 3.2.3 the features for allocating a biomass installation are briefly described in Table 13. These features are translated into variables. The columns on the left describe the various variables textually. The columns on the right assign values to each variable, where each turtle can score a value dependently in which situation it locates.

BIO-ENERGY							
Features	**Requirements**			**Unit**	**Variables**		**Value**
Spatial	Sufficient available square meters	Located on industrial or agriculture area			1	Yes	0.3
						No	0
Sensitive objects	Distance smell & noise nuisance		100	Meters	2	Long	0.7
	Distance dust nuisance		50	Meters		Average	0.5
	Distance safety nuisance		30	Meters		Short	0.3
Energy supply	Demand and offer, minimal distance between demand and offer	The total supply has a short distance to cover the total demand, maximal 3 kilometers.		Km	3	Short	0.8
		The total supply has an average distance to cover the total demand.		Km		Average	0.5
		The total supply has a long distance to cover the total demand.		Km		Long	0.3
Technical	Average square meters	An average of 100 * 100 meters. This means one patch (300 * 300 m).		M^2			
Efficiency - return	Biomass	Liquid manure	0.3	GJ/ton			
		Solid manure	0.8	GJ/ton			
		Corn	15.1	GJ/ton			
	Electric power		980	kWe			
	Netto costs		1.633	€/ kWe			
	Netto Benefit		0.06	€/ kWh			

Table 13 Features & variables Bio-energy

The variable *spatial* defines the available square meters for locating a bio-energy installation. The preference is on an industrial or agriculture area. The variable *sensitive objects* defines the distance between the installation and sensitive objects (residential areas). The *energy* *supply* wants to have a short distance between the demand and offer of energy, how shorter the distance how higher the turtle scores.

Each bio-energy turtle scores for each variable a value, the sum of these values divided by the amount of variables defines the bio-energy-score.

4.4 Study area features (patches)

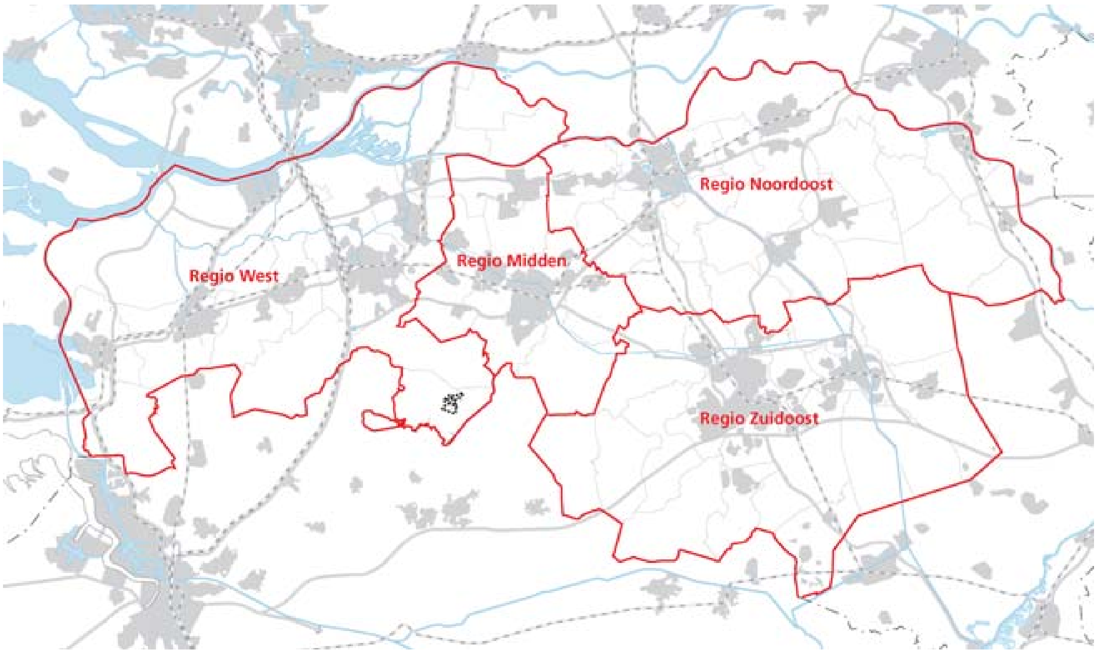


Figure 8 SRE-area

This research will focus on the environment of Southeast Brabant, the SRE-area (Samenwerkings Verband Eindoven), see Figure 8. SRE is a corporation of municipalities and companies that has the aim to utilize the ecological, economical and social opportunities that the process of energy transition in the region offers. The SRE wants to give an impulse to the process of energy transition. The various municipalities have each their own ambitions, for example:

- The municipality of Eindhoven aims to be energyneutral between 2035 – 2045.
- The municipality of Helmond aims for at least 20% CO_2 reduction in 2020 and climate neutral in 2035 – 2045.
- The municipalities in de Kempen – Eersel, Oirschot, Reusel- de Mierden, Bladel en Bergeijk have the aim to be energyneutral in 2025.

Besides the already taken initiatives, there is sufficient potential in the environment to achieve this goal. To achieve profit the various initiatives needs to be placed into a framework, supported and accelerated. By making use of the region, the initiatives have the opportunity to reinforce each other. Because of the large scale and regional potential for energy transition this area is assumed as case study for this research.

4.4.1 Raster of grid cells

The study area is represented by a raster of grid cells. Attribute values that vary continuously over space, are allowed to be recorded at cell location. Commonly the cell states represent land cover and land use, but in fact it can be represent any spatially distributed variable. For example, cell states can represent population density cells (White D, 2000).

For the SRE-area the raster represents the various land uses. The use of land is divided into residential area, industrial area and agriculture area. By making use of GIS (Geographical Information Systems) the different land uses can be represent in a map and finally implement in Netlogo. The map contains the boundaries of the various municipalities of the SRE-area and each municipality is divided into districts. To each of these districts the land uses are allocated, according to an online version of the land use of the Netherlands (CBS[1], 2011). To consider if these assumptions are correctly, the square meters are compared with the square meters of the data of Statline (Statline[1], 2011). As you can see inTable 14, the differences of surfaces of each land use are nil and so the allocation of each land use can be assumed.

Land use of SRE-area	According Statline[1]		According GIS	
Residential area	22.725	ha	26.691	ha
Industry area	5.873	ha	6.158	ha
Agriculture area	117.184	ha	113.199	ha

Table 14 Surface land use according Statline[1] and GIS

The SRE-area has a surface of 153.000 ha, which implies a diameter of 60 kilometers by 45 kilometers. A grid of 300 m x 300 m uniform cells is used. Thus, the study-area contains of 200 cells by 150 cells, in total 30.000 cells. Figure 9 shows the land-use map of the study-area in existing situation.

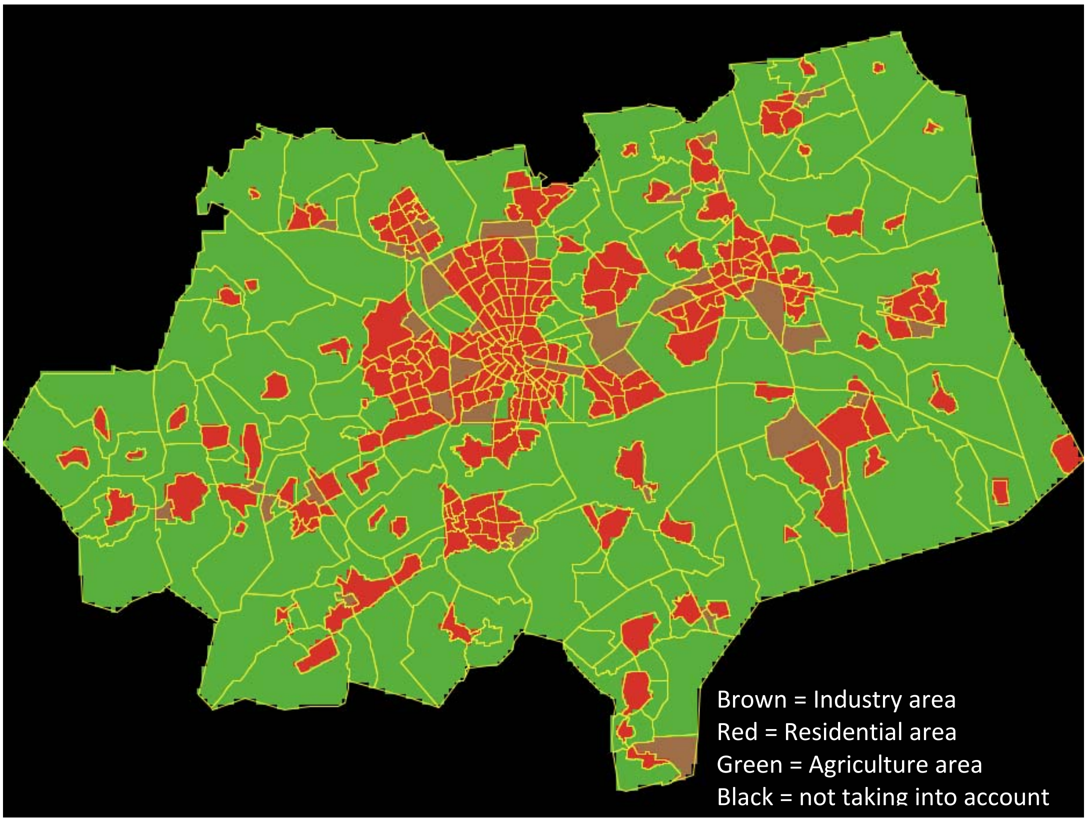


Figure 9 Land-use map SRE-area

4.4.2 Patches

Each grid contains of cells which also called patches. Each patch contains features that influence the utility of a facility agent on that location (patch). The features of the patches are land-use, gas demand and electricity demand, which are explained briefly.

Land-use. According to Statline[1] (2011) the *land use* feature is divided into residential area, semi-build, traffic, recreation, agriculture, forest and inland water (Statline[1], 2011). Because the model focus on residential area, industry area and agriculture area the surfaces of Statline[1] will be allocate into these three land-uses. The residential area includes the surfaces of residential areas (exclusive industry), recreation and parts of semi-build and traffic. The industrial area contains of industry and parts of traffic and semi-build. The land use of agriculture consists of agriculture, forest and inland water. See Table 15.

According Statline[1] Land use	Residential area	[ha]	Industry area	[ha]	Agriculture area	[ha]
Residential area	100 %	14342				
Industrial area			100 %	3810		
Semi-build	50 %	949.5	50 %	949.5		
Traffic	75 %	3339	25 %	1113		
Recreation	100 %	4094				
Agriculture					100 %	77941
Forest					100 %	37453
Inland water					100 %	1790
Total		**22724.5**		**5872.5**		**117184**

Table 15 Land use grouping (Statline[1], 2011)

Gas demand. In the Netherlands the greater part of the energy demand is gas, which generally used for heating. Each function in the built environment has an amount of gas demand. This demand can fluctuate between the functions, for example the function industry has a higher demand than agriculture. The use of gas in the SRE-area is not public and to obtain these data, the energy suppliers must be approached. They're unwilling to collaborate and only the data from the city Eindhoven is known (Endinet). Based on the proportion of gas use of each function in Brabant, the average gas use of the SRE-area of each function is determined, see Table 16. The ratio of gas use between the functions is unknown in Eindhoven. The proportion of Noord-Brabant can't be assumed for the city Eindhoven, but it can for the SRE-area because of the same structure and scale. So the calculation is turned backwards to achieve this proportion. Here for the gas use of Eindhoven is fixed and the proportion between the functions is changeable. The square meters of each function of Eindhoven is compared to the SRE-area. Changing the proportion of gas use in Eindhoven the final proportion of the SRE-area is achieved (same as Noord-Brabant), and so also the total gas use in the SRE-area.

	Proportion energy-use Noord-Brabant (Kasteren, 2008) **(%)**	**Proportion energy-use SRE-area (%)**	**Total gas demand of SRE-area (m3)**	**Total gas demand of SRE-area (kWh)**	**Surface SRE-area (ha) (CBS[1])**	**Surface Eindhoven (ha) (CBS[1])**	**Energy consumption Eindhoven (m3) (Endinet)**	**Proportion energy-use EIndhoven (%)**
Residential area	44	44	491.505.758	5.062.509.304	26.691	5.694	104.853.088	49,7
Agriculture area	8	8	95.622.905	984.915.918	113.199	1.998	1.687.776	0,8
Industry area	48	48	541.775.053	5.580.283.043	6.158	1.187	104.431.144	49,5
Total	100	100	11.627.708.266		146.048	8.879	210.972.009	100

Table 16 Gas demand of each function

Each function has a total amount of gas use and implies an average for each hectare. This is useful to determine the average gas demand of a patch in the model, see Table 17. The last column defines the average amount of gas demand of a patch, divided into functions.

	Total gas demand of SRE-area (kWh)	Surface SRE-area (ha) (CBS[1])	Gas demand per hectare (kWh/ha)	Surface cell (ha)	Gas demand per patch (kWh)
Residential area	5.062.509.304	26.691	189671	9	1.707.039
Agriculture area	984.915.918	113.199	8700,748	9	78.307
Industry area	5.580.283.043	6.158	906184,3	9	8.155.659
Total		146.048			

Table 17 Gas demand per patch

Electricity demand. During the last years the use of electricity becomes more efficient. But besides that, the use of electrical appliances is increasing and so also the demand for electricity. As described under *gas demand,* the electricity use in the SRE-area is not public. Thus, the same approach is used for calculating the electricity demand, see Table 18.

	Proportion energy-use Noord-Brabant (Kasteren, 2008) **(%)**	**Proportion energy-use SRE-area (%)**	**Total electricity demand of SRE-area (kWh)**	**Surface SRE-area (ha) (CBS[1])**	**Surface Eindhoven (ha) (CBS[1])**	**Energy consumption Eindhoven (m3) (Endinet)**	**Proportion energy-use EIndhoven (%)**
Residential area	44	44	2.428.451.494	26.691	5.694	518.062.373	49,7
Agriculture area	8	8	472.457.509	113.199	1.998	8.339.032	0,8
Industry area	48	48	2.676.824.057	6.158	1.187	515.977.615	49,5
Total	100	100	5.577.733.060	146.048	8.879	1.042.379.021	100

Table 18 Electricity demand of each function

Finally the data is used to determine an average amount of electricity demand of each patch, see Table 19.

	Total gas demand of SRE-area (kWh)	Surface SRE-area (ha) (CBS[1]	Gas demand per hectare (kWh/ha)	Surface cell (ha)	Gas demand per patch (kWh)
Residential area	2.428.451.494	26.691	90.984	9	818.855
Agriculture area	472.457.509	113.199	4.174	9	37.563
Industry area	2.676.824.057	6.158	434.690	9	3.912.214
Total	5.577.733.060	146.048			

Table 19 Electricity demand per patch

5 DESIGN MODEL

In chapter 3 and 4 the agents, case study and their scenarios have been identified and thus the programming for the model in Netlogo can be started. This chapter describes how the model is setup. The findings of previous chapters are added into useful settings and formulas. Finally the final Netlogo is finished and shown. Below the workings of the Netlogo model are shown (Figure 10). The flowchart determines the steps which the model takes.

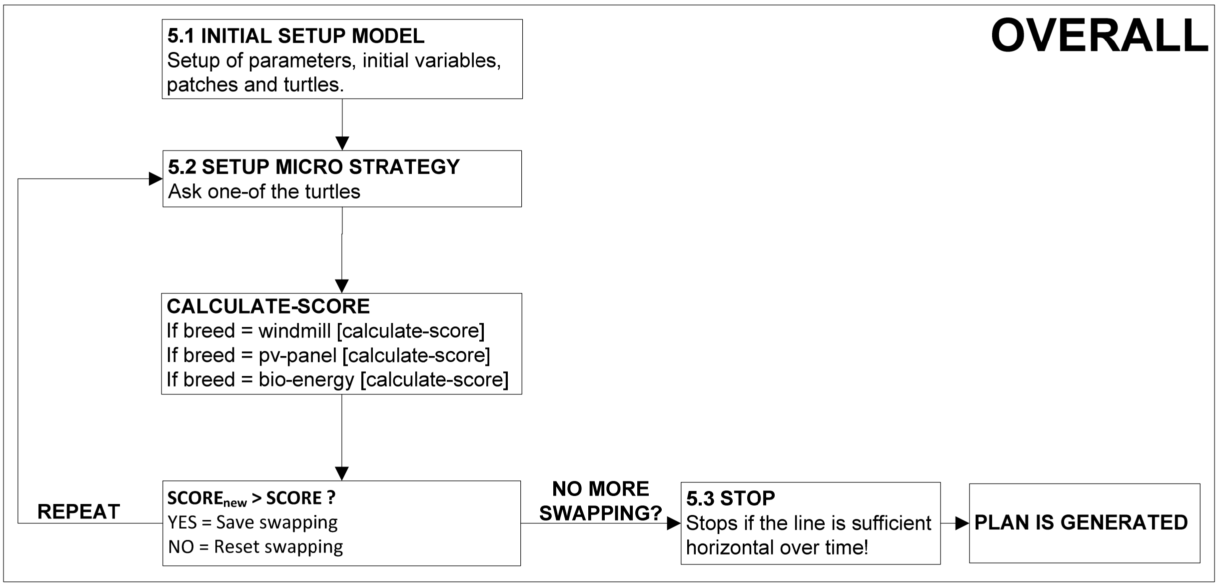
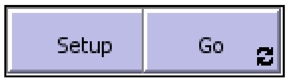


Figure 10 Flowchart Netlogo model

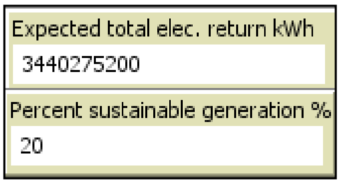
5.1 Initial setup model

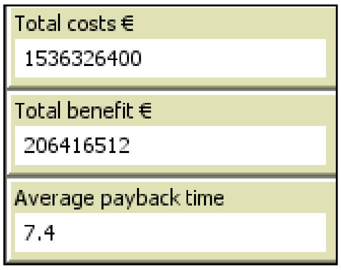


The model is divided into two steps; the *setup* and *go* part. The *setup* button set the model in a state from which it can be run. It starts with clearing all the previous settings followed by the command *random-seed 10*. This command implies that the turtles appear random but are actually generated by a deterministic process. 'Deterministic' defines that the same results appear every time, starting with the same random 'seed'. This is to determine the order in which the agents are chosen to run the commands. It's desirable and important that a scientific model can be reproduced, so the same results are generated. The model can start with a certain seed value that could be any integer. It generates always the same sequence of random numbers. After that the command *display-patches and setup-turtles* are running. These are linked to their own comments which are explained in paragraph 5.1.1 and 5.1.2. The other settings set variables in a state which are useful during the simulation, like the loading of the GIS data into the Netlogo model.

After pushing the *setup* button, the model starts simulating by pushing the *Go* button. The model runs the model by following the command *to go* which is explained in paragraph 5.2. This button includes *forever* in order to repeat the command *to go* forever. The advantage of using this is that the user doesn't have to click each time. To stop the model, again clicking on the *go* bottom will stop the loop.

CODE






```
to setup
        clear-all
        random-seed 10
        display-patches
        setup-turtles
        set total-dataset gis:load-dataset "GIS_DATA/TOTAAL/total.shp"
        gis:set-world-envelope (gis:envelope-union-of (gis:envelope-of total-
      dataset))
        set optimal-score -10000000
        set windmill-score -10000
        set pv-panel-score -10000
        set bio-energy-score -100000
        set total-yield (expected-yield-windmill + expected-yield-pv-panels +
      expected-yield-bio)
        set total-sustainable-generation (total-yield / 17205441326) * 100
        set total-costs (total-costs-windmill + total-costs-pv-panels + total-
      costs-bio-energys)
        set total-benefit (total-benefit-windmill + total-benefit-pv-panels +
      total-benefit-bio-energys)
        set payback-time total-costs / total-benefit
end
```

5.1.1 Display patches

The background environment of the model contains of patches. In this research the background is the SRE-area which implies difference land use functions. In the beginning of the programming the variables that all patches can use are defined under ‘patches-own’. All patches have these variables and are able to use them. In this model the patches contains the variables land-use, gas and electricity. For setting up the patches, the code ‘to display-patches’ is defined.

CODE


```
patches-own [ land-use
              gas
              electricity
             ]
```

CODE

```
to display-patches
 ask patches [
  sprout-dummyturtles 1
  ask dummyturtles [
   foreach gis:feature-list-of total-dataset [
    if gis:intersects? self ? [
     set land-use gis:property-value ? "CONSUMER"
     ifelse land-use = "RESIDENTIAL" [ set pcolor red ] [
     ifelse land-use = "INDUSTRY" [ set pcolor brown ] [
     ifelse land-use = "AGRICULTURE" [ set pcolor green] [
      set pcolor black
     ]]]
    if pcolor = red   [ set gas 1707039 ]
    if pcolor = green [ set gas 78307 ]
    if pcolor = brown [ set gas 8155659 ]
    if pcolor = red   [ set electricity 818855 ]
```

```
        if pcolor = green [ set electricity 37563 ]
        if pcolor = brown [ set electricity 3912214 ]
       ]
     ]
     die
    ]
  ]
  gis:set-drawing-color yellow
  gis:draw total-dataset 1
end
```

The first part of the code describes the land-use of each patch. Herefor the GIS-map is implemented into Netlogo. Out of GIS each patch knows his land-use and so Netlogo gives a color to each land-use. As mentioned before, each function has a different demand for gas and electricity and so each type-patch has a different value for gas and electricity.

5.1.2 Setup Turtles

In the model the different sustainable energy sources are seen as turtles. Under 'turtles-own' the variables belonging to each turtle are defined. The first two variables shows the optimal x and y coordinate of that turtle. After that, the different variables are divided into windmills variables, pv-panels variables and bio-energies variables. Later in this report are these variables used in the formulas. Each variable score a value which contribute in the total score of utility.

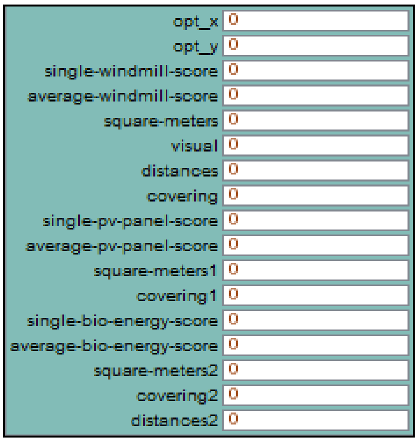
CODE

```
turtles-own [
       opt_x
       opt_y

       single-windmill-score
       average-windmill-score
       square-meters
       visual
       distances
       covering

       single-pv-panel-score
       average-pv-panel-score
       square-meters1
       covering1

       single-bio-energy-score
       average-bio-energy-score
       square-meters2
       covering2
       distances2
]
```

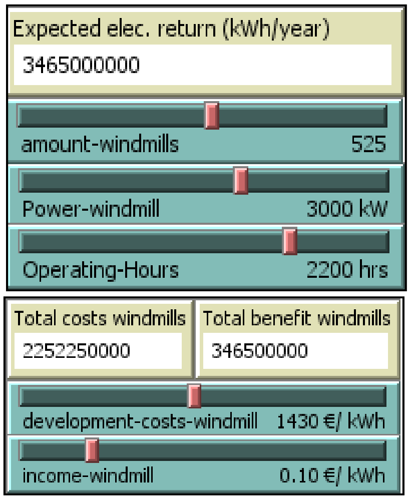


The turtles are setup under the code 'to setup-turtles'. The turtles are divided into windmills, pv-panels and bio-energies. Each turtle contains different settings, variables and constraints. These settings are useful for defining the different formulas.

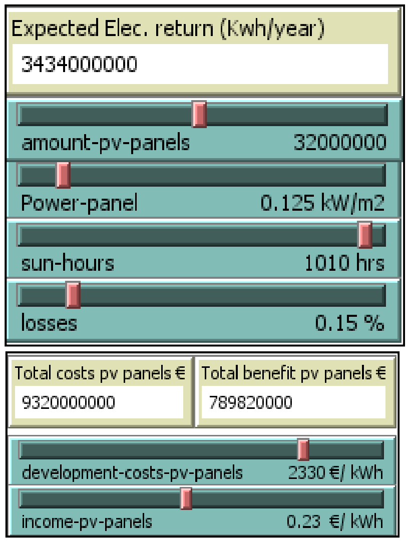
CODE

to setup-turtles

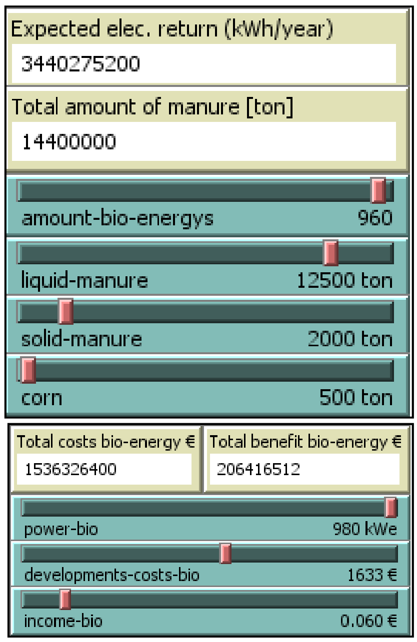
```
set-default-shape windmills "windmill"
create-windmills amount-windmills
 [setxy random-pxcor random-pycor
  set size 1
  set color white
  set expected-yield-windmill (Power-windmill * Operating-Hours * amount-windmills)
  set single-windmill-score 0
  set total-costs-windmill (development-costs-windmill * amount-windmills * Power-windmill)
  set total-benefit-windmill (income-windmill * Operating-hours * Power-windmill * amount-windmills)
  ]
```




```
set-default-shape pv-panels "panels"
create-pv-panels amount-pv-panels / 5508
 [setxy random-pxcor random-pycor
  set size 1
  set color black
  set expected-yield-pv-panels (power-panel * sun-hours * ( 1 - losses ) * amount-pv-panels)
  set single-pv-panel-score 0
  set total-costs-pv-panels (development-costs-pv-panels * amount-pv-panels * Power-panel)
  set total-benefit-pv-panels (income-pv-panels * sun-hours * Power-panel * amount-pv-panels * ( 1 - losses ))
  ]
```




```
set-default-shape bio-energys "bio"
create-bio-energys amount-bio-energys
  [setxy random-pxcor random-pycor
   set size 1
   set color blue
   set amount-manure liquid-manure * amount-bio-energys + solid-manure * amount-bio-energys + corn * amount-bio-energys
   set expected-yield-bio ((liquid-manure * 0.3 * amount-bio-energys) + (solid-manure * 0.8 * amount-bio-energys) + (corn * 15.1 * amount-bio-energys)) * 277.8
   set single-bio-energy-score 0
set total-costs-bio-energys (power-bio * amount-bio-energys * developments-costs-bio)
set total-benefit-bio-energys (income-bio * expected-yield-bio)
]
end
```



5.2 Setup Micro strategy

The objective of the micro-strategy is to found solutions where locations need to be selected out of candidate locations. In the beginning, a current solution is selected which implies the set of cells that are currently claimed by the agent. A candidate cells which is not in the current solution is substituted for each cell in the current solution. If the utility of the next solution has a higher value than the current solution, the next solution becomes the current solution. The micro-strategy is able to find the location of a given number of facilities that improve the utility. In the Netlogo model the micro-strategy, also known as interchange heuristic, swaps the location of a facility and calculates the scores. This process takes place by pushing the *go* button.

The interchange heuristic is the most important part of the model. This part allocates a location for each facility by swapping each location until an optimal score is achieved. Here for each time one of the turtles is randomly approached and calculates his score. The single-score calculates the score on that location and the average-score is the score of the location where the turtle locates before. The command compared these values, if the single-score has a higher value the turtle stays on this location (save-state). If not, it goes back to his location where it locates before (reset-state).

CODE

```
to go
 ask one-of turtles with
  [ setxy random-pxcor random-pycor
    if breed = windmills [
     calculate-score
      ifelse single-windmill-score > average-windmill-score [set average-windmill-score single-windmill-score save-state] [reset-state]
    ]
    if breed = pv-panels [
     calculate-score
      if single-pv-panel-score > average-pv-panel-score [set average-pv-panel-score single-pv-panel-score save-state] [reset-state]
    ]
     if breed = bio-energys [
     calculate-score
      if single-bio-energy-score > average-bio-energy-score  [set average-bio-energy-score single-bio-energy-score save-state] [reset-state]
    ]
  ]
```

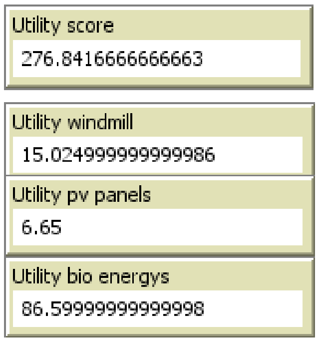
Each turtle remembers his previous location and the location where he is locating on. The code *save-state* and *reset-state* are added so that each turtle remains this.

CODE

```
to save-state
   set opt_x xcor
   set opt_y ycor
end

to reset-state
   setxy opt_x opt_y
en
```

The average-score of the same turtles are summed into one utility value. The total utility score consists of the sum of the utility scores of the turtles. This value will grow until each turtle has their optimal location allocated

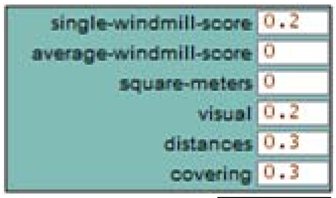


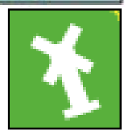
CODE

```
set optimal-score (sum [average-windmill-score + average-pv-panel-score
+ average-bio-energy-score] of turtles)
set windmill-score (sum [average-windmill-score] of windmills)
set pv-panel-score (sum [average-pv-panel-score] of pv-panels)
set bio-energy-score (sum [average-bio-energy-score] of bio-energys)
```

5.2.1 Calculate score

The model consist of three facilities; windmills, pv-panels and bio-energies. The total-utility is determined by the utility of each facility. The utility of each facility is defined by the score of each single facility. This single score shows how this facility scores on that location in the environment. The score is determined by the different variables. Because each facility has their own variables and score allocating, the description for calculating the score is divided into each facility.





Windmills. The windmill facility is able to score on four variables.

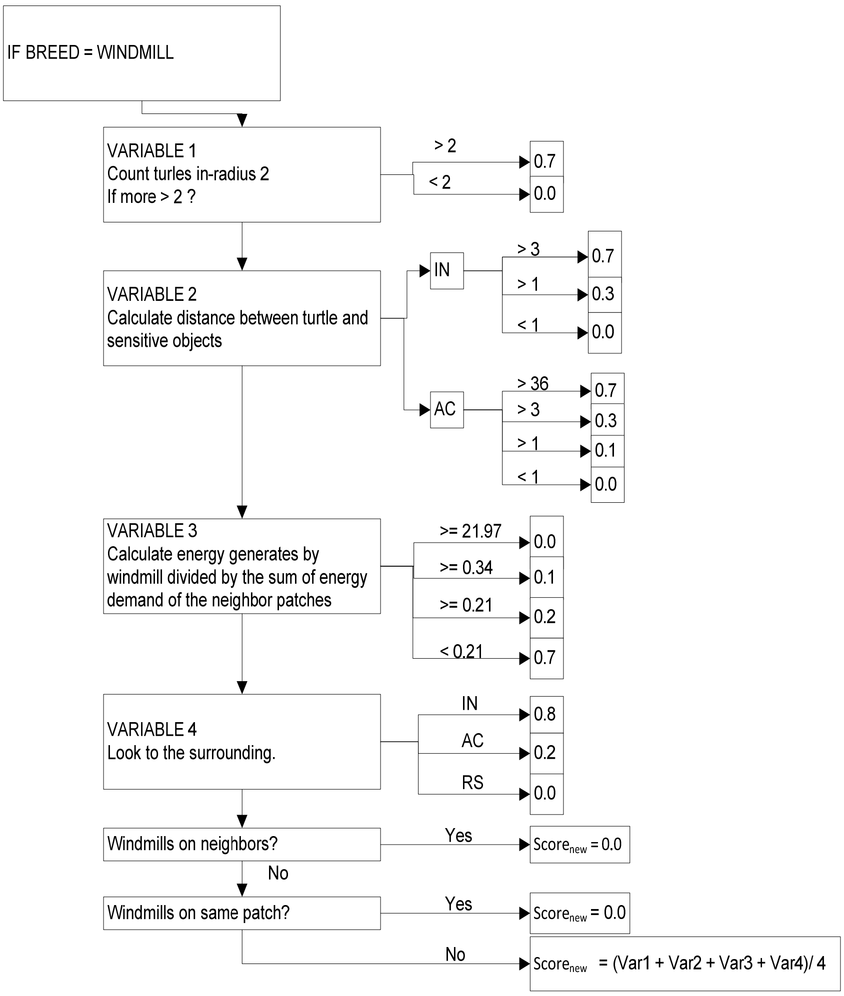


Figure 11 Flowchart windmills

Variable 1. The first variable controls if the windmill is locating in-line or a grid. Here for each windmill counts the amount of windmill that are locating in the radius 2. The neighbor patches do not count because windmills can't locate too close to each other. So in-radius 2 looks only to four patches that lie in the north, south, east and west. If there are more than two windmills in-radius 2, the variable *square meters* is getting the value 0.7, if not 0.

CODE

```
if breed = windmills [
  let pattern count turtles in-radius 2
  ifelse pattern > 2 [set square-meters 0.7] [set square-meters 0]
```

Variable 2. The second variable determines the distance between the windmill and sensitive objects, the distance-RD calculates this distance. Dependently on which patch the windmill is locating and the distance to sensitive objects, the variable *distances* scores a value.

The variable scores 0 if the distance is less than one patch or the patch-here is residential-area. The distance must be at least 480 meter so that there is no noise nuisance, this implies an distance of 1.3 patches. The model only counts with rounded numbers, and sees 1.3 as 2 which imply a distance of 600 meters. Because the windmill is locating in the middle of a patch the half of a patch can also be added, eventually 150 meters can also be added to the distance. This means that the distance is 750 meters and compared to 480 meters has that too much difference. So the distance is set to one patch what means a total distance of 450 meters. This compared to 480 is a minimal difference and because the scale of the model this difference is nil. The other distances are set to 3 (1050 meters) and 36 (10950 meters) patches.

A difference is made between locating on an agriculture area or industrial area. Because if a windmill locates on an industrial area, it doesn't influence the surrounding that much because of the high amount of mass. Compared to the agriculture area this influence is quite high and so a windmill scores higher if it locates far away from the residential area.

CODE

```
let distance-RD distance min-one-of (patches with [pcolor = red]) [distance myself]

if [pcolor] of patch-here = brown [
  ifelse distance-RD >= 3 [set distances 0.7][
  ifelse distance-RD >= 1 [set distances 0.3][
    set distances 0]]
]

if [pcolor] of patch-here = green [
  ifelse distance-RD >= 36 [set distances 0.7] [
  ifelse distance-RD >= 3 [set distances 0.3] [
  ifelse distance-RD >= 1 [set distances 0.1] [
    set distances 0]]]
]

if [pcolor] of patch-here = red [set distances 0]
```

Variable 3. The *covering* variable is a variable that achieve to have a short distance to the energy consumer. The average calculates the total energy that a windmill generates divided by the sum of electricity demand of the neighbor patches. How higher the average how longer the distance that covers the total energy generation.

CODE

```
    let average ((1 * Power-windmill * Operating-Hours) / ((sum [electricity] of neighbors) +  ([electricity]
  of patch-here) + 0.0000000000000001))
    ifelse (average >= 21.97) [ set covering 0] [
    ifelse (average >= 0.34) [set covering 0.1] [
    ifelse (average >= 0.21) [set covering 0.2] [
     set covering 0.7]]]
```

Variable 4. The last variable shows the added value to locate windmills in the surrounding with a high amount of mass. Locating the windmills in a residential area scores 0, despite the high amount of mass. But if a windmill is locating in the surrounding of an industrial area, the windmill scores 0.8. The agriculture area is an open field with a low amount of mass, if a windmill is locating on this function his score for visual is 0.2.

CODE

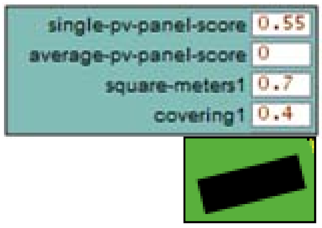
```
    ifelse all? neighbors [pcolor = brown] [set visual 0.8][
    ifelse all? neighbors [pcolor = green] [set visual 0.2][set visual 0 ] ]
```

Total. Finally each windmill scores for each variable a score, depends on where it locates in the environment. It calculates the single-windmill-score only when there aren't any other windmills locating on the same patch or on the neighbors. The single-windmill-score sum the variables scores and divided by the amount of variables, this defines the average score of that windmill.

CODE

```
    ifelse (count turtles-on neighbors) >= 1 [ set single-windmill-score 0] [
    ifelse (count turtles-on self) > 1 [ set single-windmill-score 0] [
     set single-windmill-score (((square-meters + visual + distances + covering)/ 4))]]
   ]
```

Pv-panels. The application of pv-panels consists of two variables. This is because it encounters a minimal influence and nuisance on the spatial environment and it is also easy to apply on building level.



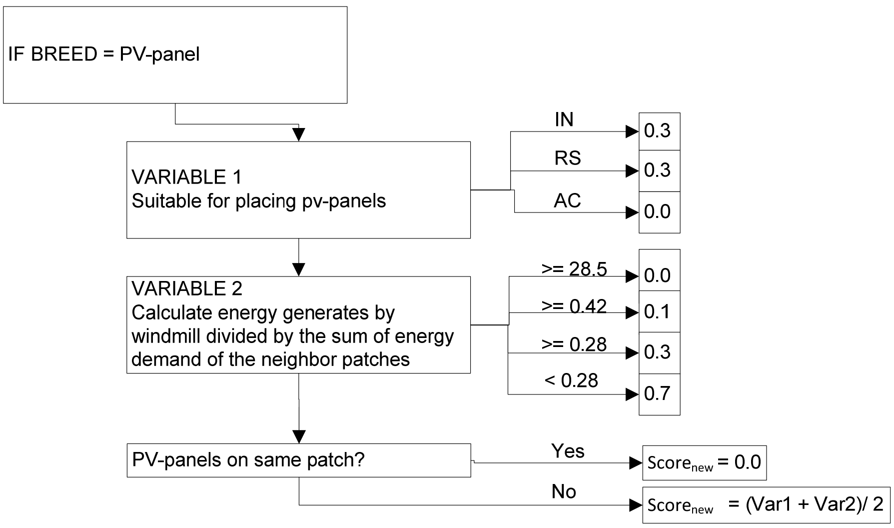


Figure 12 Flowchart pv-panels

Variable 1. The first variable defines the possibility for locating pv-panels on available roofs. Generally sufficient available roofs are in industrial and residential areas. The formula for the first variable achieves to locate on a location where sufficient available roofs are. The pv-panel view on which patch it locates, if this patch is industrial or residential than this variable scores 0.3. If not, it scores 0.

CODE

```
if breed = pv-panels [
   ifelse [pcolor] of patch-here = brown [set square-meters1 0.3] [
   ifelse [pcolor] of patch-here = red   [set square-meters 0.3] [
     set square-meters1 0]]
```

Variable 2. The second and last variable calculates the average distance between the producer and consumer. How shorter the distance how higher the pv-panel scores. The formula calculates the total electricity that a pv-panel generates. This value is divided by the electricity demand on the current patch and of the neighbors. How lower this value, how higher the pv-panel can score.

CODE

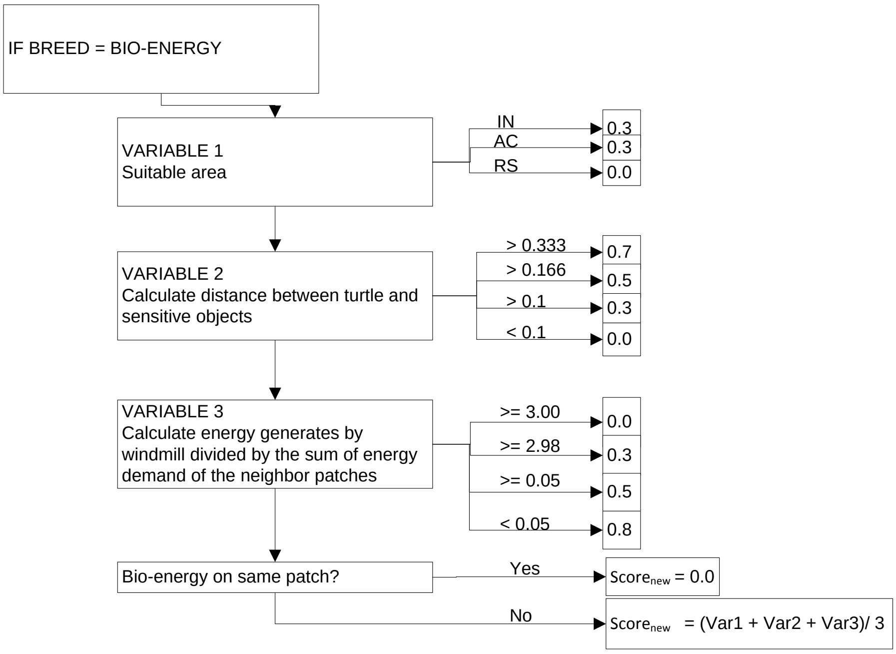
```
  let average1 ((5508 * Power-panel * sun-hours * (1 - losses)) / ((sum [electricity] of neighbors) +
([electricity] of patch-here) + 0.0000000000000001))
   ifelse (average1 >= 28.5) [ set covering1 0] [
   ifelse (average1 >= 0.42) [set covering1 0.1] [
   ifelse (average1 >= 0.28) [set covering1 0.3] [
     set covering1 0.7]]]
```

Total. Eventually the pv-panel calculates his single-pv-panel-score by summing the scores of the variables, and dividing it by the amount of variables. If there is more than one pv-panel on the same patch, this average score is set to 0.

CODE

```
  ifelse ((count turtles-on self) > 1) [ set single-pv-panel-score 0] [
set single-pv-panel-score ((square-meters1 + covering1)/ 2)]
 ]
```

Bio-energy installations. Bio-energy installations generate energy out of biomass. Spatially the score of a bio-energy installation is determined by three variables.



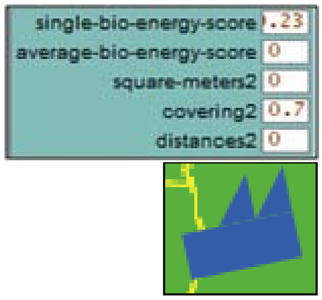


Figure 13 Flowchart bio-energy installations

Variable 1. The first variable checks the available square meters for the installation. The bio-energy scores 0.3 if it locates in the surrounding of industrial or agriculture areas, otherwise it scores 0.

CODE

```
if breed = bio-energys [
  ifelse [pcolor] of patch-here = brown [set square-meters2 0.3] [
  ifelse [pcolor] of patch-here = green  [set square-meters2 0.3] [
    set square-meters2 0]]
```

Variable 2. The second variable implies the minimal distance between the bio-energy installation and the residential area. If the distance is more than 0.33 patch (100 meter) the bio-energy scores 0.7. The model counts with round numbers which means that 0.33 is seen as 1, and so this variable counts a distance of 300 meters. Considering the nature of the variables, this distance gives more value to the possible nuisance that may occur. If the turtle is locating on a black patch, the score will also be 0.

CODE

```
let distance-RD1 distance min-one-of (patches with [pcolor = red]) [distance myself]
  ifelse pcolor = black [set distances2 0] [
  ifelse distance-RD1 >= (0.33333 ) [set distances2 0.7][
  ifelse distance-RD1 >= (0.16666 ) [set distances2 0.5][
  ifelse distance-RD1 >= (0.1) [set distances2 0.3][
    set distances2 0]]]
```

Variable 3. The third and last variables determine if the amount of energy that is produced and is used by the consumer locates short to the producer. Here for the total amount of energy that is generated by the bio-energy installation is divided by the sum of gas in a radius of 3. If this value is higher than 1, it means that the distance must be longer to deliver all the energy that is produced. If the average is higher than 1.57 the distance is too long and energy is lost, and the variable scores 0. If this average is between 1 and 1.57, the variable scores 0.3. How lower the average how higher the score.

Out of research the maximum distance is on 3 kilometers only the radius is set to 3 (900 meters). This is because how shorter the distance how lower the lost of energy. So that's why the turtle can still score a value if the average is higher than 1.

CODE

```
let average2 (((liquid-manure * 0.3) + (solid-manure * 0.8) + (corn * 15.1)) * 277.8) / ((sum [gas] of neighbors) + ([gas] of patch-here) + 0.0000000000000001)
ifelse (average2 >= 3.00) [ set covering2 0] [
ifelse (average2 >= 2.98) [set covering2 0.3] [
ifelse (average2 >= 0.05) [set covering2 0.5] [
 set covering2 0.8]]]
```

Total. Finally each bio-energy installation looks if there is any other installation in the neighbor. If it is, the single-bio-energy-score is set 0. Otherwise the single-bio-energy-score calculates his score.

CODE

```
ifelse ((count turtles-on self) > 1) [ set single-bio-energy-score 0] [ set single-bio-energy-score ((square-meters2 + covering2 + distances2)/ 3)]
]
```

5.3 Stop

The model is able to run in eternity but not on a moment the utility score stops increasing. On that moment, all the turtles are locating on an optimal location and aren't able to increase their score. The model will be stopped manually. This is because it's unknown when the optimal score is achieved and therefore it is not possible to program this. The model will be stopped if the total utility-score not longer increases over time. This is when sufficient time passed and the line of the graph is horizontal (Figure 14). The average simulation time is 10 hours.

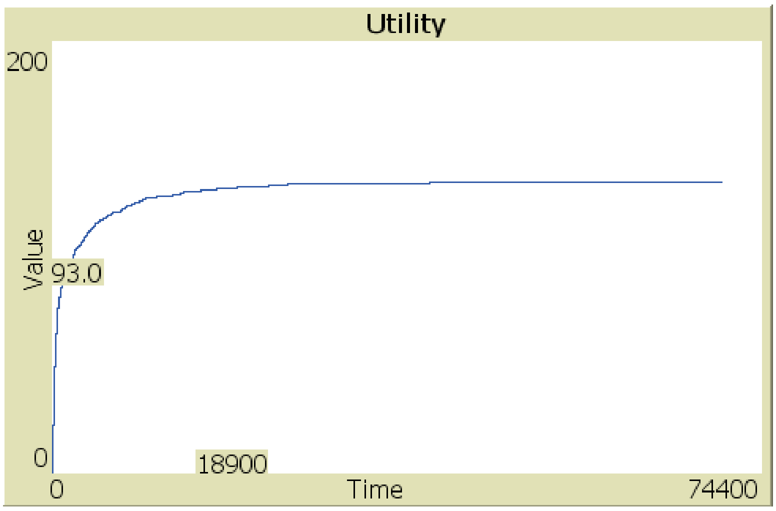
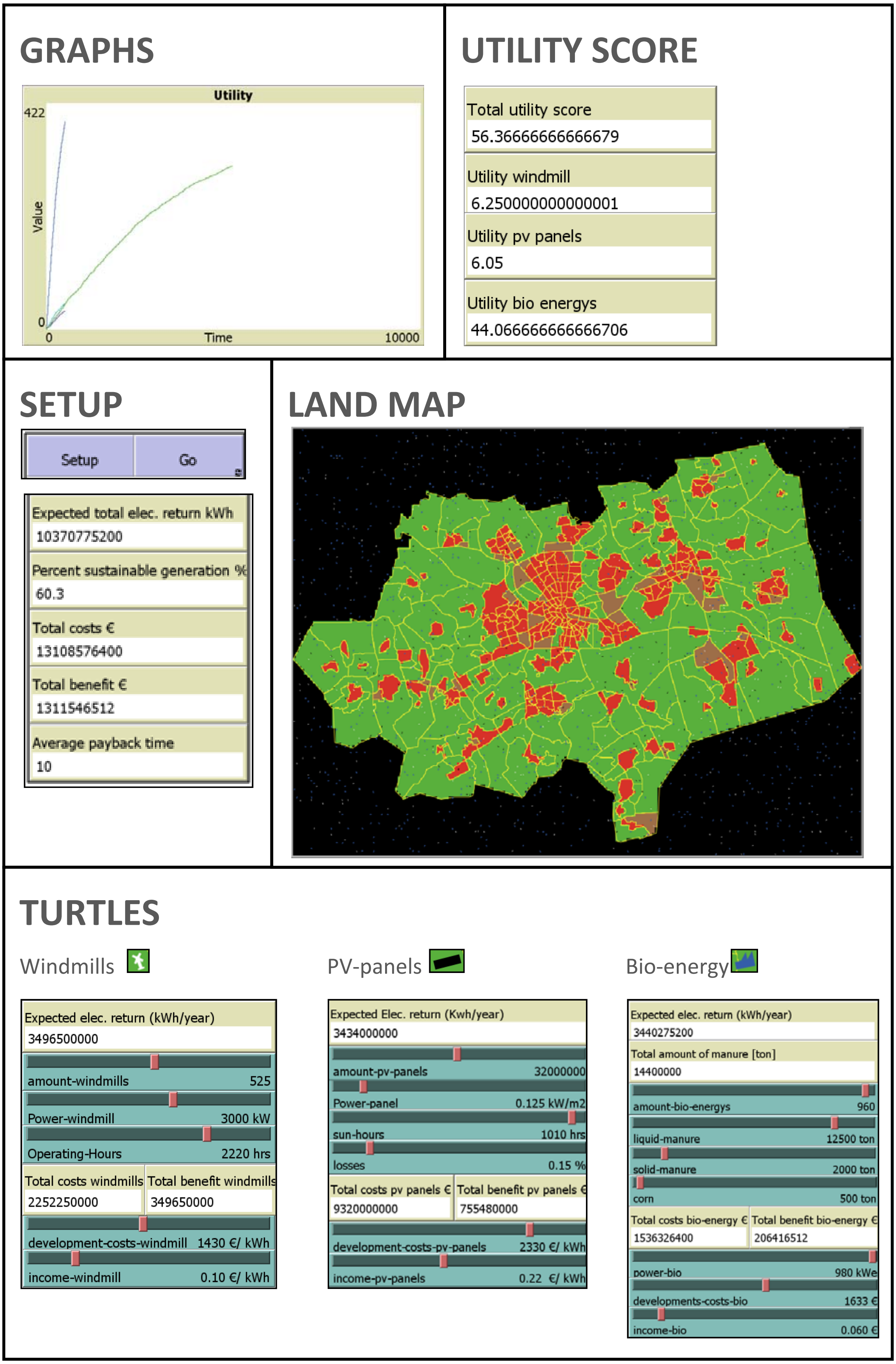


Figure 14 Example stopping the model

5.4 Total model



THE SIMULATION & RESULTS

6 SIMULATION OF SCENARIOS & RESULTS

For representing the larger decision problem, the concept of a macrostrategy is used. The land-use-allocation problem knows the total area that occupied by a facility, but the number of facility locations and facility-size not. In the article of Arentze et al. (2009) the concept of a macrostrategy is introduced. By making use of this, the number of facilities and the size of each facility can be defined but does not specify locations. The best macrostrategy can be found by exhaustively evaluating the possible macrostrategies under various locations to identify the one that maximizes the objective function. The number of possible macrostrategies is infinite if facility sizes and number of ways in which a task size can be subdivided can vary on a continuous scale. The article of Arentze et al. (2009) proposes to do not an exhaustive search procedure and introduces the method macrostrategy. To generate alternatives the development of a macrostrategy is a key component of scenario development. The number and sizes of the facilities are given for a certain macrostrategy, whereby the interchange heuristic defines the optimal location. This research focuses on one macrostrategy and so the size of the facilities is fixed. The numbers of facilities depends on the scenario.

Scenario development is used to simulate different simulation under different conditions. These outcomes are used to compare and finally to make conclusion.

The government has the aim to generate 20 % of the energy use out of sustainable energy sources. This percentage depends on the proportion between the existing amount of energy use and the amount of energy that is generated out sustainable energy sources. The amount of energy generated out sustainable sources depends on the amount of energy measures that implemented in the environment. How higher the number of measures, how higher the amount of sustainable generation. Table 20 shows that 525 windmills, or 32.000.000 m^2 pv-panels, or 14.400.000 ton biomass are needed to generate 20.1 % sustainable. These amounts are the basic assumptions for the scenarios.

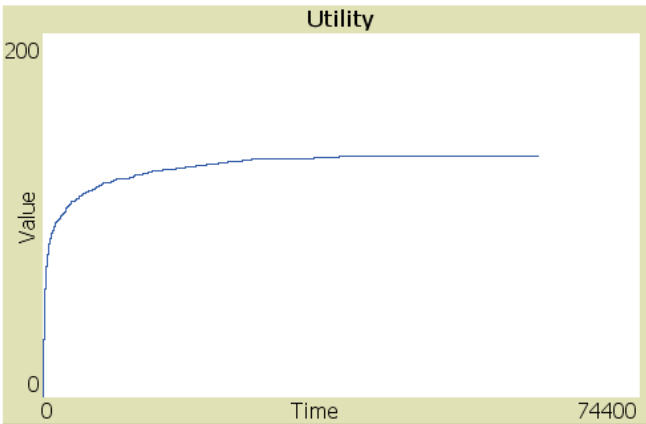
	Windmill		**PV-panel**		**Bio-Energy**				
Biomass					Liquid manure	Solid manure	Corn	Total	
Amount	525	pcs	32.000.000	m2	12.000.000	1.920.000	480.000	14.400.000	Ton
			5809	pcs				960	pcs
Power	3000	kW	0.125	kWp/m2				980	kWe
Hours	2200	hrs	1010	hrs					
Losses			0.15	%					
Caloric value					0.3	0.8	15.1		GJ/ ton
					3.600.000	1.536.000	7.248.000	12,3840	PJ
Sustainable energy generation	3.465.000.000	kWh	3.434.000.000	kWh				3.440.000.003	kWh
Total energy use (See Appendix 1)	17.205.441.326	kWh	17.205.441.326	kWh				17.205.441.326	kWh
Sustainable-generation	20.1	%	20	%				20	%

Table 20 Percentage of sustainable generation

Each scenario implies one of the sources separately. This means that the first scenario only contains of windmills, the second pv-panels, the third bio-energy and finally a mix is made. Each scenario achieves the 20 % sustainable energy generation.

6.1 Windmills

During the first scenario 525 windmills run the model. This amount is equal to the generation of 20 % of sustainable energy. The scenario calculates the total utility score for windmills in the spatial environment. Here for the focus is only on the implementation of windmills that generate 20 % sustainable energy. During running the model the utility score increases and finally achieves a value that stop increasing. Once the model achieves this value the windmills locates on the ‘optimal’ locations. They’re not able to achieve a better score, thus not a better location. It's possible that some windmills doesn't score that well, but aren’t able to increase this score because there is simply no better location. Finally the model stops when the utility score has a constant value over time, see Figure 15 Utility score windmills. The turtles stop swapping and their location is allocated.



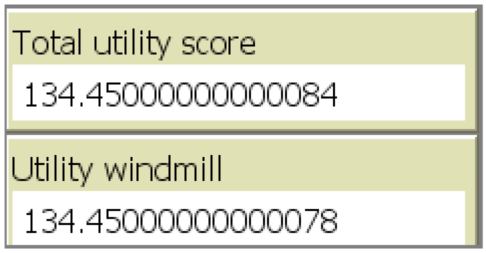


Figure 15 Utility score windmills

During the analysis of the simulation various commandos are established to identify the outcomes (Table 21). The commandos that are used are noted in appendix 3.

		Value-score	Amount of turtles		Proportion	
Turtles on industrial area		Pcolor = brown	88	Pcs	16.8	%
Turtles on residential area		Pcolor = red	0	Pcs	0	%
Turtles on agriculture area		Pcolor = green	437	Pcs	83.2	%
Total amount of turtles			525	Pcs	100	%
Maximum score that can be obtain		380.625				
Total Utility-score		134.45			35.3	%
Average score per turtle (AV = Average score)		0.27				
Turtles with optimal score		0.725	7	Pcs	1.3	%
Turtles with optimal score per variable						
Variable 1	AV	0.38				
	IN	0.7	35	Pcs	39.8	%
		0	53	Pcs	60.2	%
	AC	0.7	252	Pcs	57.7	%
		0	185	Pcs	42.3	%
Variable 2	AV	0.33				
	IN	0.7	51	Pcs	58.0	%
		0.3	37	Pcs	42.0	%
		0	0	Pcs	0	%
	AC	0.7	0	Pcs	0	%
		0.3	425	Pcs	97.3	%
		0.1	12	Pcs	2.7	%
		0	0	Pcs	0	%
Variable 3	AV	0.16				
	IN	0.7	48	Pcs	54.6	%
		0.2	31	Pcs	35.2	%
		0.1	9	Pcs	10.2	%
		0	0	Pcs	0	%
	AC	0.7	0	Pcs	0	%
		0.2	1	Pcs	0.2	%
		0.1	435	Pcs	99.6	%
		0	1	Pcs	0.2	%

Variable 4	AV	0.21				
	IN	0.8	35	Pcs	39.8	%
		0.2	0	Pcs	0	%
		0	53	Pcs	60.2	%
	AC	0.8	0	Pcs	0	%
		0.2	420	Pcs	96.1	%
		0	17	Pcs	3.9	%
Mean amount turtles in-radius 2		2.5				
Mean distance sensitive objects		5.33				
Electricity average value (patch-here + neighbors)		15.8				
Electricity average value (patch-here)		146.5				
Total square meters		525 patches				

Table 21 Outcome analysis windmill locations

6.1.1 Analysis

Map plan. The map of the SRE-area shows the optimal locations for windmills. The first figure shows on which areas the windmills locate (Figure 16). The next figure determines the square meters that will be covered by the windmills (Figure 17).

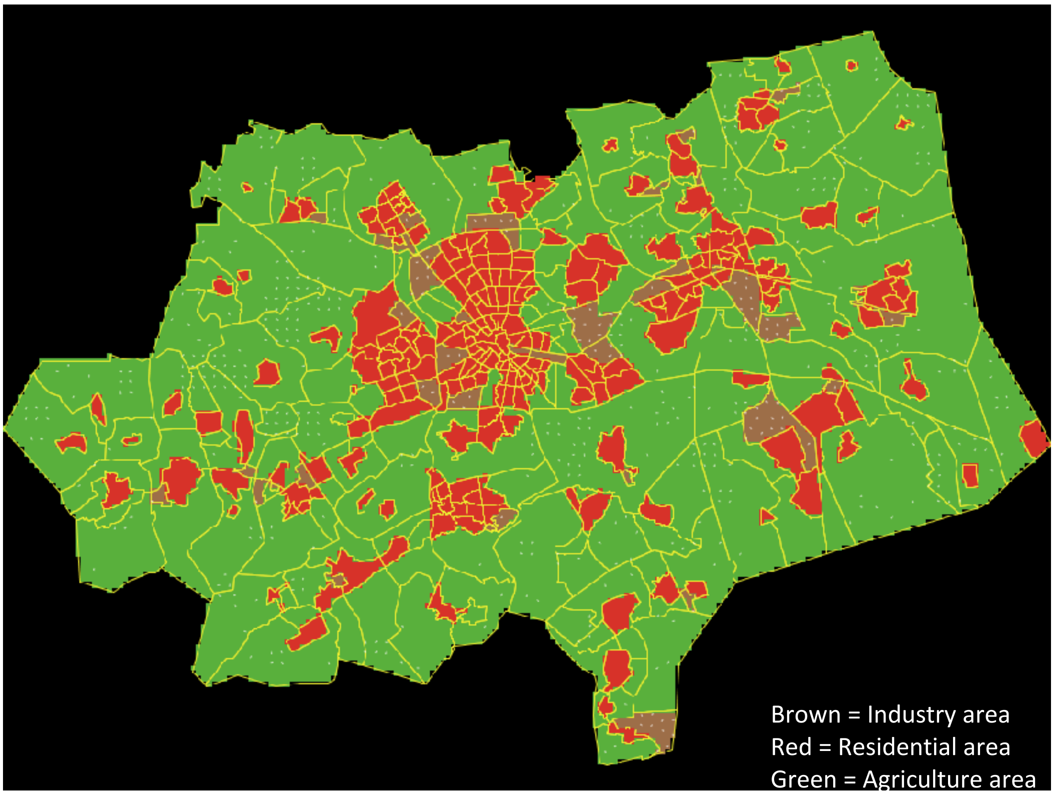


Figure 16 Allocate locations of windmills

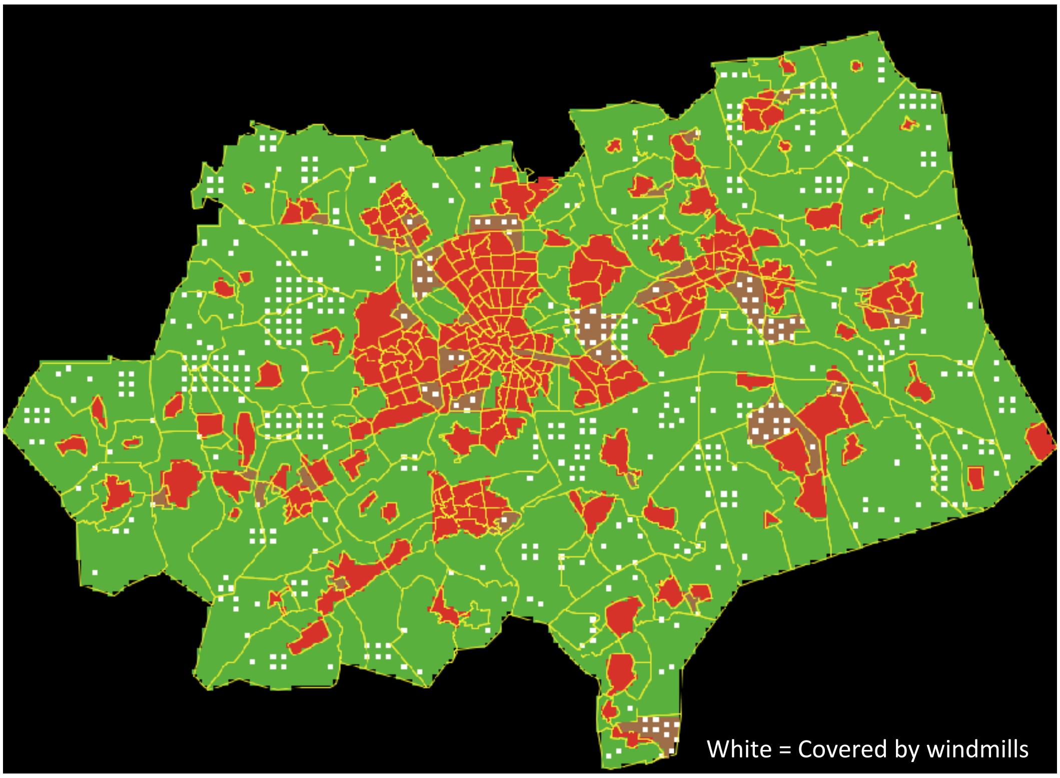


Figure 17 Spatial surface covered by windmills

Overall. Due the amount of windmills the main part allocate on agriculture areas. 88 windmills, as well 16.8 %, are able to locate on industrial areas. The total utility-score is able to score 380.625 but achieve a value of 134.45; this obtains 35.3 % of the total. The average score of all the turtles is 0.27, however the windmills are capable to score 0.725. Only 7 of the 525 windmills were able to achieve this score, see Figure 18.

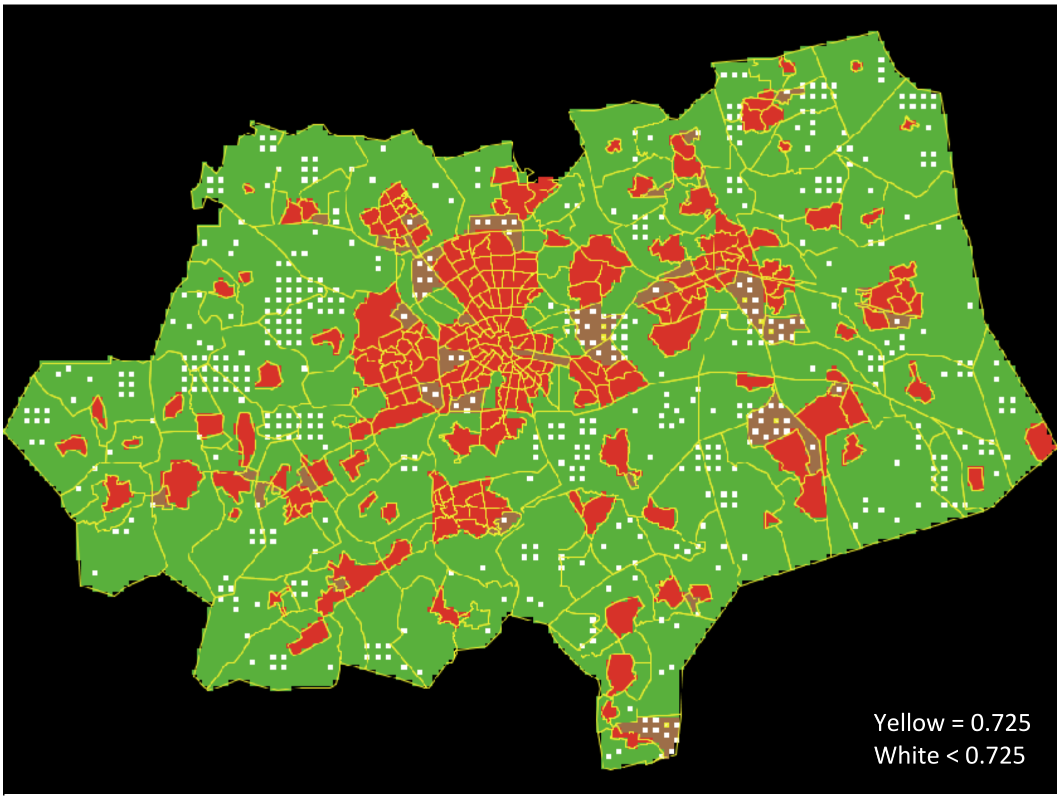


Figure 18 Optimal score by windmills

The windmill scores best on an industrial area, although the major part allocate on agriculture areas. It can be concluded, also from the map, that insufficient locations are available on industrial area for all windmills. Still some industrial areas are available but aren't interesting for windmills. This is because the variables score there lower than locating on agriculture areas. So an industrial area must be of sufficient size to be interesting for windmills. This is also shows on the final map, where the windmills with an optimal score are allocated on industrial areas of a larger size. Comparing the maximum utility score and the final utility score, the windmills aren't able to score that well. From here, it can be concluded that windmills aren't capable to score well and so having a high influence on the spatial environment.

Variable 1. The first variable determines if there are windmills in the surrounding of a windmill. Locating in a grid or line has a positive influence on the location of windmills. Each windmill can score a value of 0 or 0.7. The windmills that locates on industrial area score mainly 0. This includes an amount of 53 (that score 0) against an amount of 35 (that score 0.7) (60.2 – 39.8 %). This proportion also counts for the windmills that locate on agriculture areas. 252 windmills scores 0 and 185 are able to score 0.7, the ratio is (57.7 – 42.3 %). The average amount of windmills that locate in a radius of 2 is 2.5. This includes also the current windmill. The pattern for locating in a grid or line is able for less than half of the windmills. It is possible to conclude that the size of pattern has a maximum because the other half scores higher despite it doesn't locate in a grid or line. From Figure 19, it can be assumed that patterns are only able on designated areas, other locations influence the environment in excess.

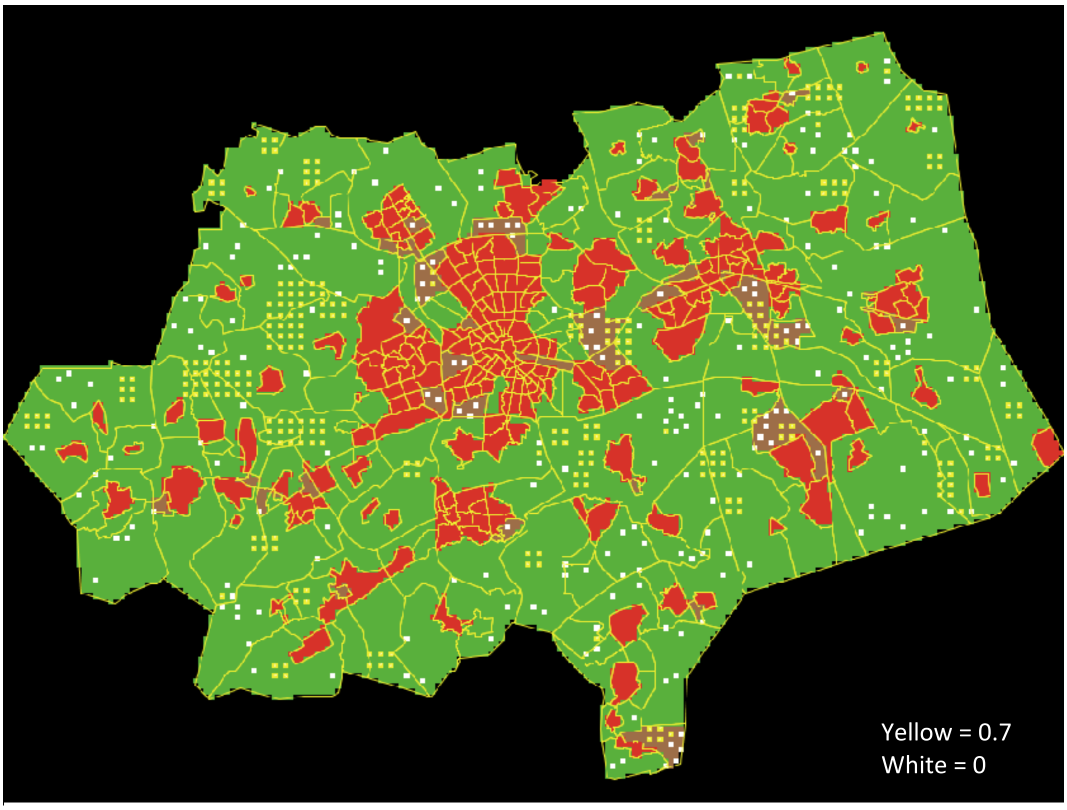


Figure 19 Score variable 1 of windmills

Variable 2. Variable 2 defines if the distance between the windmill and sensitive objects is sufficient. The windmills that locate on industrial area are able to score 0.7 – 0.3 – 0. Slightly more than half of the 88 windmills score a value of 0.7, the other 42.0 % score 0.3. Therefore, half of the windmills have a distance of more than 1080 meters and the other half more than 400 meters. The windmills that locate on agriculture area can score 0.7 – 0.3 – 0.1 – 0. The mainly part can assign to 0.3, as well 97.3 %. This considered an average distance of at least 1080 until 11 kilometers. The other percents obtain the score 0.1 which implies a distance of at least 400 meters. The average distance of all the windmills between sensitive objects is 5.33, which implies a distance of 1599 meters.

It can be assumed that the windmills on industrial areas have a shorter distance to sensitive objects than on agriculture areas. These windmills have sufficient distance, however 37 windmills have shadow nuisance and this may influence the amount of energy generation. The windmills on agriculture areas are mainly on a distance of more than 1080 meters from sensitive objects. This can be addressed to the fact of the many available square meters of agricultural. It is also possible to conclude that the windmills aren't able to allocate on a distance of at least 11 kilometers. Considering this, the windmills always have a high visibility for the surrounding on agriculture areas (Figure 20).

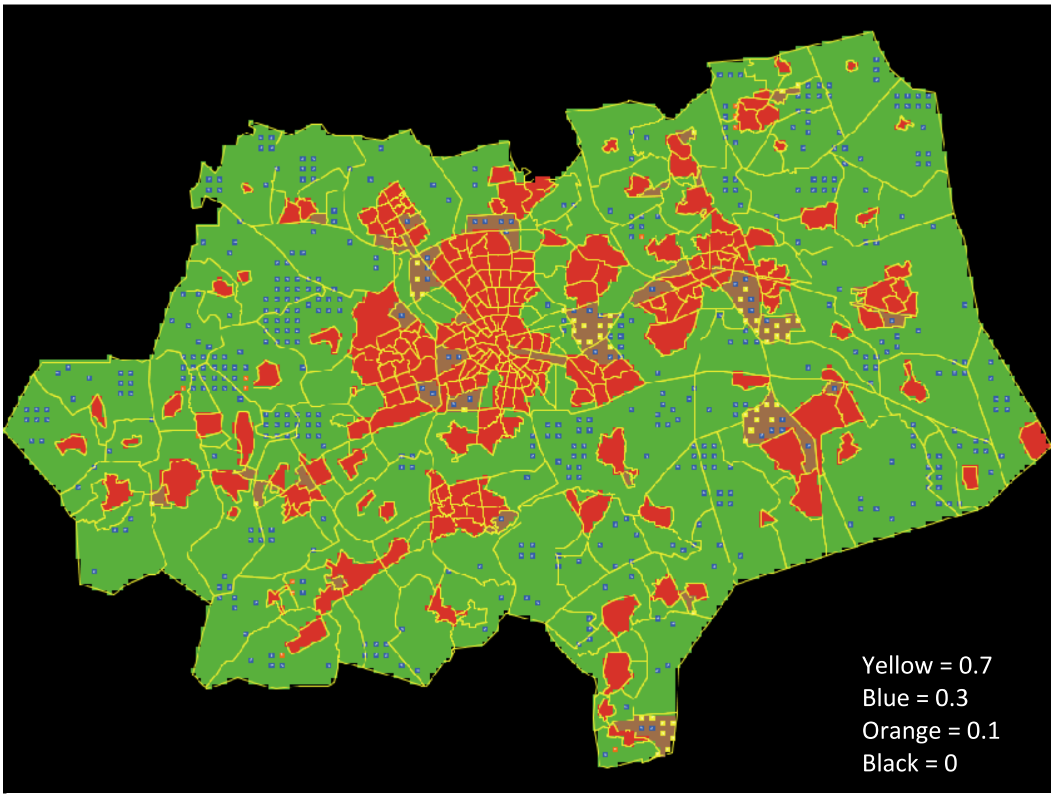


Figure 20 Score variable 2 of windmills

Variable 3. The third variable of the windmills determines if the distance between the consumer and producer is short, average or long. This variable is divided into 0.7 – 0.2 – 0.1 – 0. Around 54.6 % of the windmills that locate on industrial area score a value of 0.7. The 35.2 % can be assign to windmills that score 0.2. The other 10.2 % scores 0.1. The 437 windmills that locate on agriculture area score 0.1. Only 1 windmill gets the value 0.2 and another one 0. This variable divides the total amount of energy generation of the windmills by the total demand of energy on the patch and neighbors of the windmills. How lower this value, how shorter the distance to release all the generated energy. Considering only the patch where the windmill locates on, an average value of 146.5 is determined. If also the neighbor patches are considered, this average value shows 15.8. (Figure 21).

It can be conclude that windmills can release their energy to the consumer the best on industrial area. This can be addressed to the high demand of energy on industrial areas. Therefore, the windmills are able to release their energy to the consumer on a short distance.

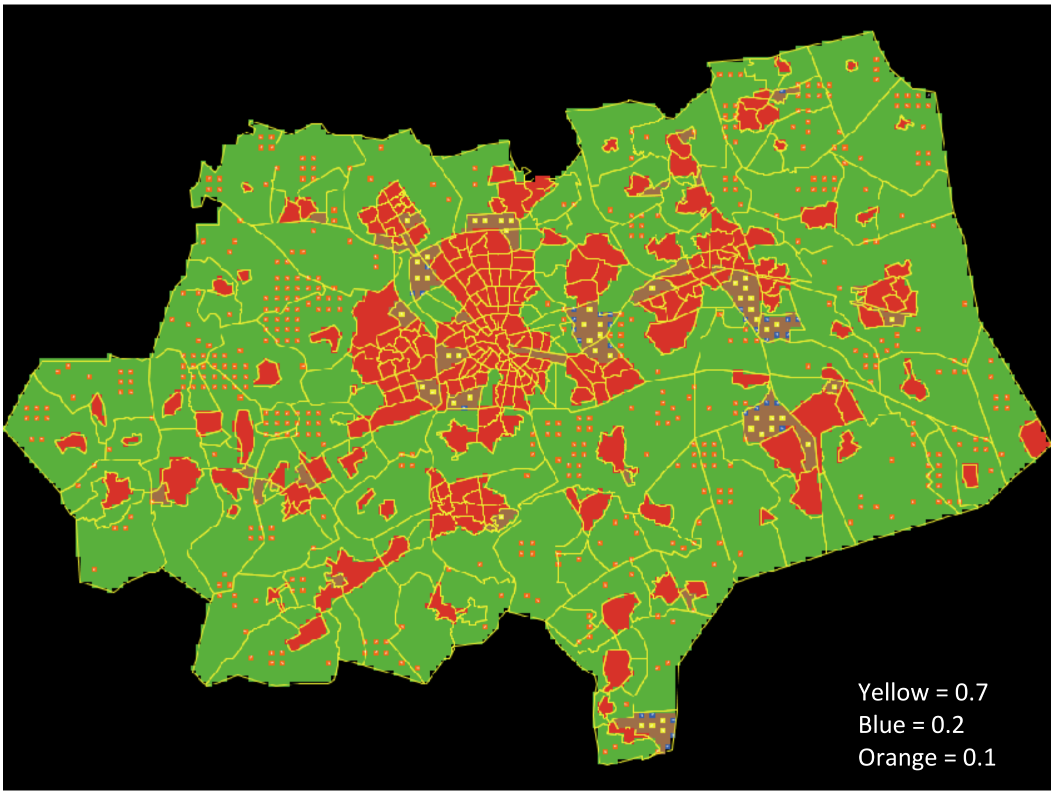


Figure 21 Score variable 3 of windmills

Variable 4. The last variable approaches the windmills if it locates in a surrounding with sufficient mass. This means that each windmill looks if he and his surrounding contain sufficient mass. The windmills that locate on industrial area can score 0.8 or 0. It scores 0.8 when the windmill and his surrounding are assign as industrial area. If not, it scores 0. Only 35 of the 88 windmills that locate on industrial area scores optimal (0.8). The other 60.2 % scores a value 0 for this variable. Due the windmills on agriculture areas the mainly part (96.1 %) are able to locate in the surrounding of the same area. This can be addressed to the high amount of available square meters of agricultural. (Figure 22).

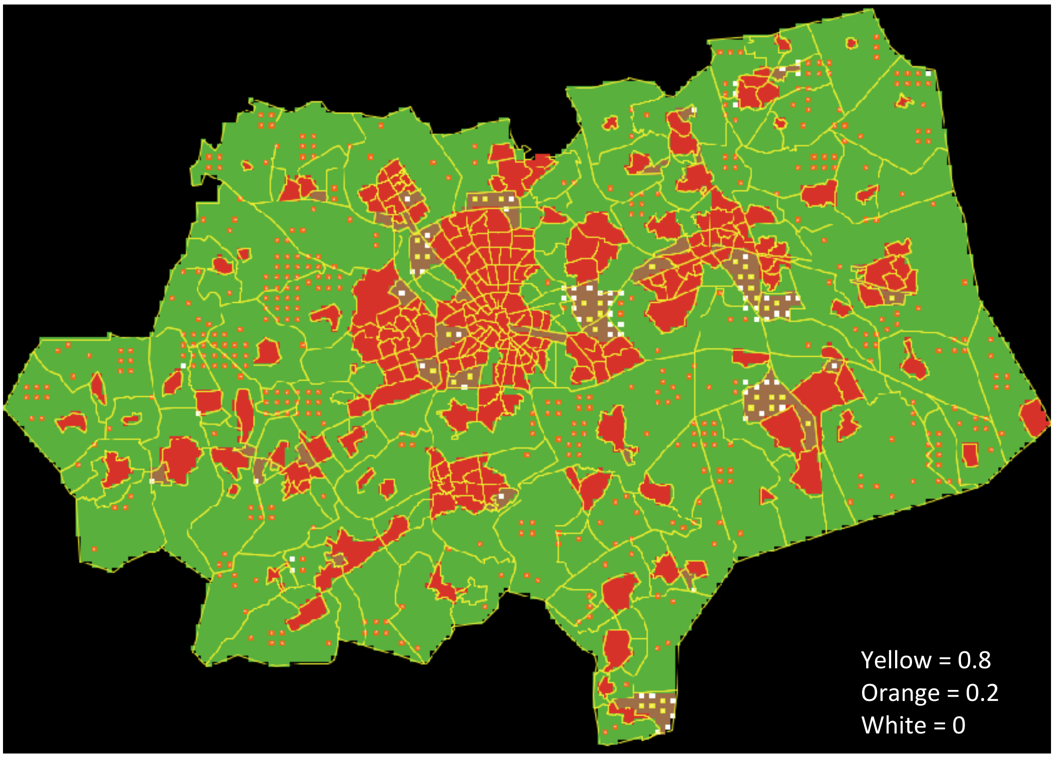
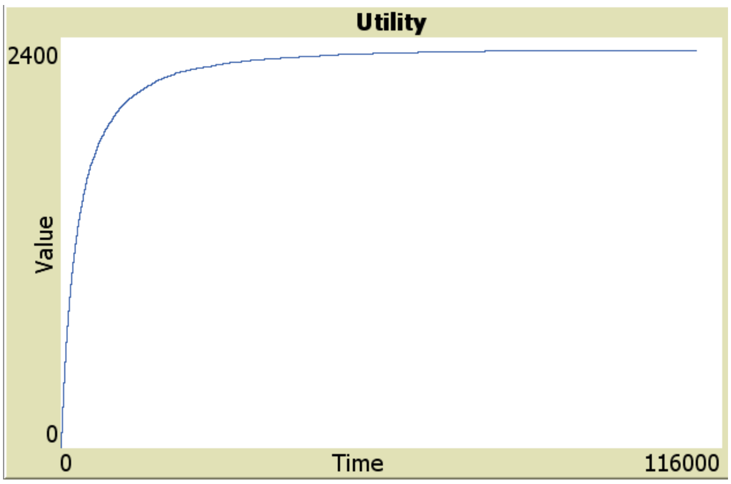


Figure 22 Score variable 4 of windmills

Considering the proportion between scores, windmills have problems to locate in the surrounding of the same mass on industrial areas. However, on agriculture areas is this problem not applicable.

6.2 PV-panels

The scenario *pv-panels* calculates the utility for only implementing pv-panels in the environment to achieve the 20%. During the running of the model the pv-panels search for an optimal location in the environment. The utility-score increases until none of the pv-panels can't found a better location and the utility-score stabilized. The possibility contains that some pv-panels doesn't score that optimal, but aren't able to score better because there is simply no better location.



Total utility score
2328.6499999999714

Utility pv panels
2328.649999999972

During the analysis of this simulation various commandos are setup to identify the outcome, see appendix 3. The outcomes are noted in AV = Average score

Table 22.

		Value-score	Amount of turtles	pcs	Proportion	%
Turtles on industrial area		Pcolor = brown	699	Pcs	12	%
Turtles on residential area		Pcolor = red	2969	Pcs	51.1	%
Turtles on agriculture area		Pcolor = green	2141	Pcs	36.9	%
Total amount of turtles			5809	Pcs	100	
Maximum score that can be obtain		2904.5				
Total Utility-score		2328.7			80.2	%
Average score per turtle		0.4				
Turtles with optimal score		0.5	3655	Pcs	62.9	%
Turtles with optimal score per variable						
Variable 1	AV	0.19				
	IN	0.3	699	Pcs	100	%
		0	0	Pcs	0	%
	AC	0.3	0	Pcs	0	%
		0	2141	Pcs	100	%
	RS	0.3	2969	Pcs	100	%
		0	0	Pcs	0	%
Variable 2	AV	0.61		Pcs		
	IN	0.7	699	Pcs	100	%
		0.3	0	Pcs	0	%
		0.1	0	Pcs	0	%
		0	0	Pcs	0	%
	AC	0.7	1123	Pcs	52.5	%
		0.3	534	Pcs	29.9	%
		0.1	484	Pcs	22.6	%
		0	0	Pcs	0	%
	RS	0.7	2956	Pcs	99.5	%
		0.3	12	Pcs	0.4	%
		0.1	1	Pcs	0.1	%
		0	0	Pcs	0	%
Electricity average value (patch-here + neighbors)		0.25				
Electricity average value (patch-here)		6.2				
Total square meters		5809 patches				

AV = Average score

Table 22 Outcomes analysis pv-panel locations

6.2.1 Analysis

Map plan. The first map shows the allocation of the locations of pv-panels (Figure 23). The mainly part is allocated on industrial areas. The second figure shows the final covering of square meters of the pv-panels (Figure 24).

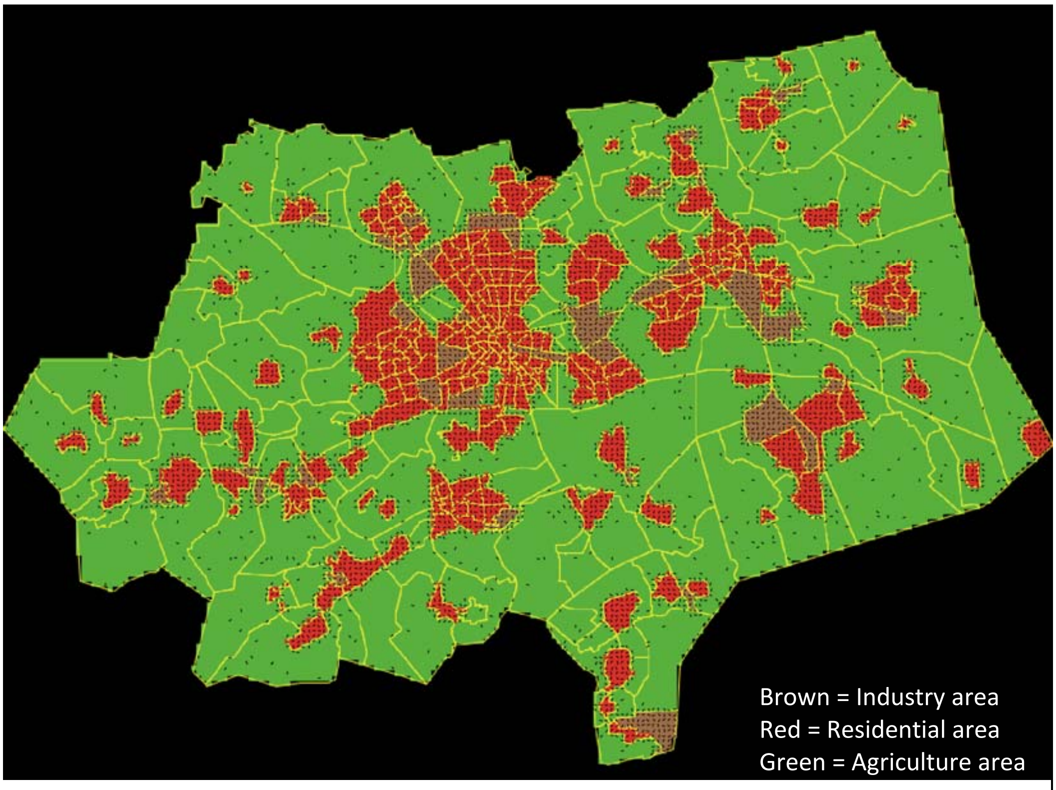


Figure 23 Allocate locations of pv-panels

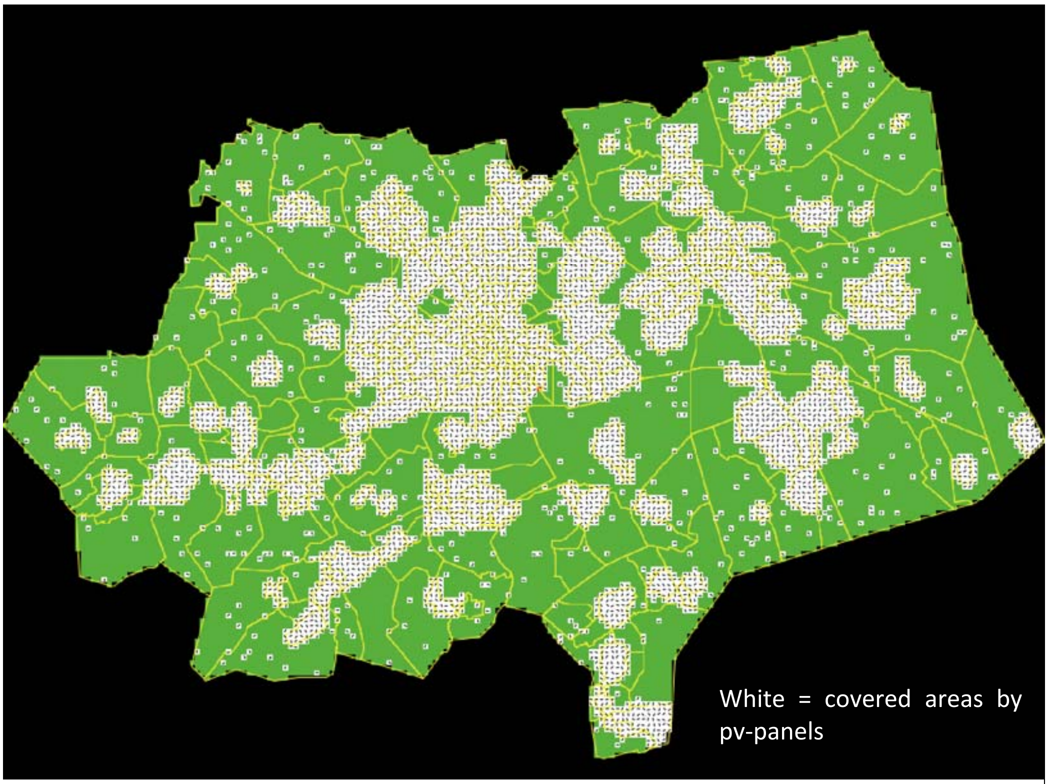
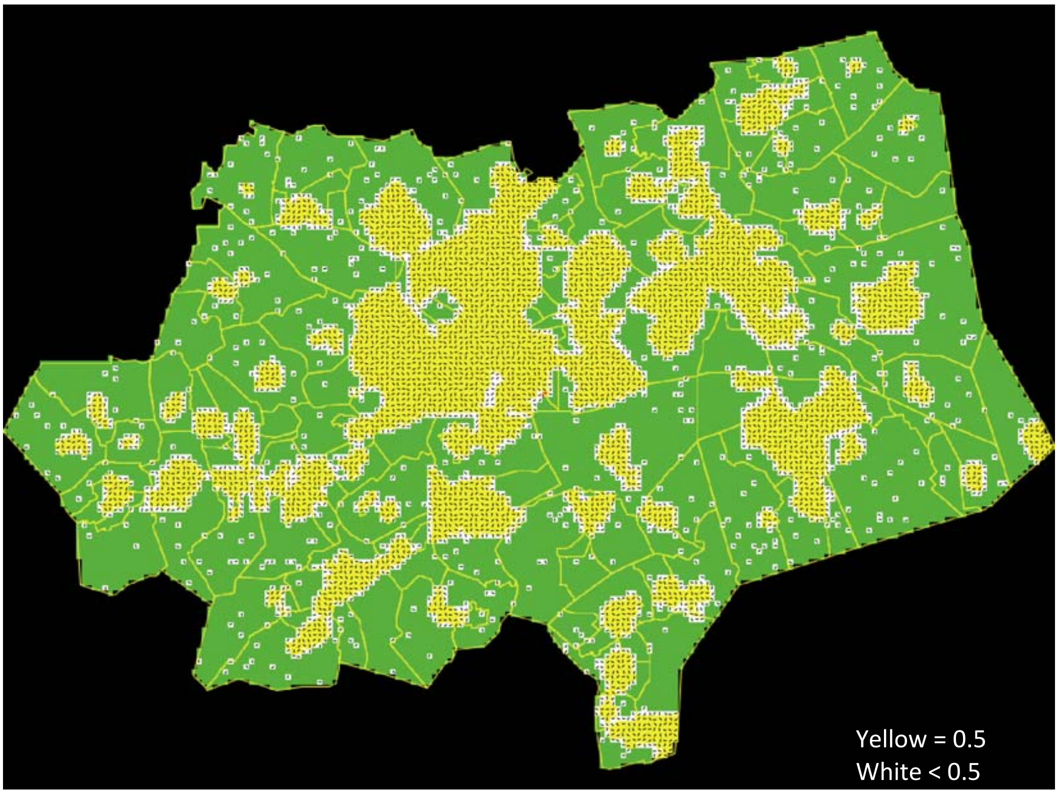


Figure 24 Spatial surface covered by pv-panels

Overall. Half of the amount of pv-panels locates on residential area, 12 % on industrial area and the other 36.9 % on agriculture area. The total maximum score that could be obtained by the pv-panels is 2904,5. The pv-panels didn't come further than a total utility-score of 2328.7, as well 80.2 %. Each pv-panel is able to score a maximum of 0.5, the average score of the pv-panels is 0.4. Although, 3655 pv-panels score this optimal-score, see Figure 25.



Yellow = 0.5
White < 0.5

Figure 25 Optimal score by pv-panels

Considering the locations in the environment, pv-panels prefer to allocate on industrial areas and residential areas. It allows concluding that industrial and residential area has more potential for locating pv-panels, this can be addressed to the potential available roof space. According to the map below, it can be assumed that pv-panels with an optimal score locate centralized on an industrial park. Comparing the possible utility-score that can be obtained and the final utility score, 80.2 % is achieved. It can be assumed that this energy sources has no high influence on the spatial environment.

Variable 1. The first variable defines the possibility for allocating a pv-panel. The preferences are industrial and residential areas because of the available roof space. Not all pv-panels were able to allocate on these areas simply because insufficient areas are available. It depends on the existing available square meters of roof space. Considering this, pv-panels aren't location bounded and are able to locate on top of each roof without having a high spatial influence on the environment. (see Figure 26).

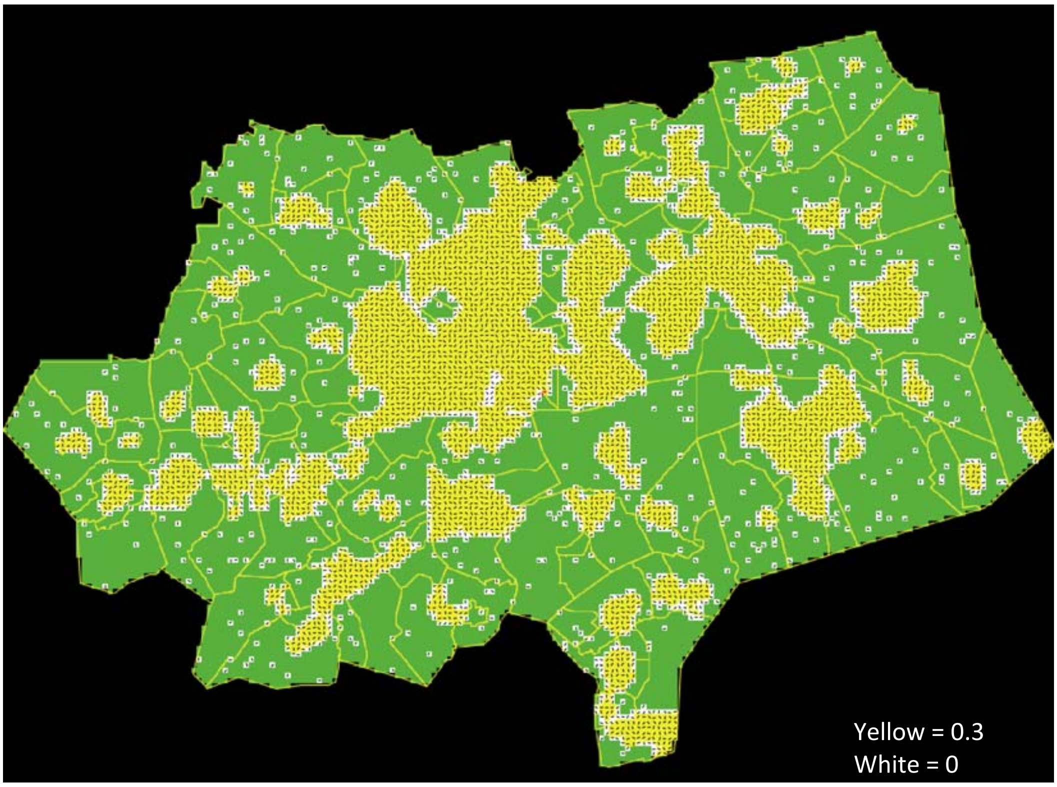


Figure 26 Score variable 1 of pv-panels

Variable 2. The second and last variable defines if the pv-panel is able to release all his energy in the surrounding. Here for, the pv-panel looks to the energy demand on his patch and neighbors. All the pv-panels on industrial areas represent a score of 0.7. The main part on residential area score 0.7 and on agriculture area 0.3, see Figure 27.

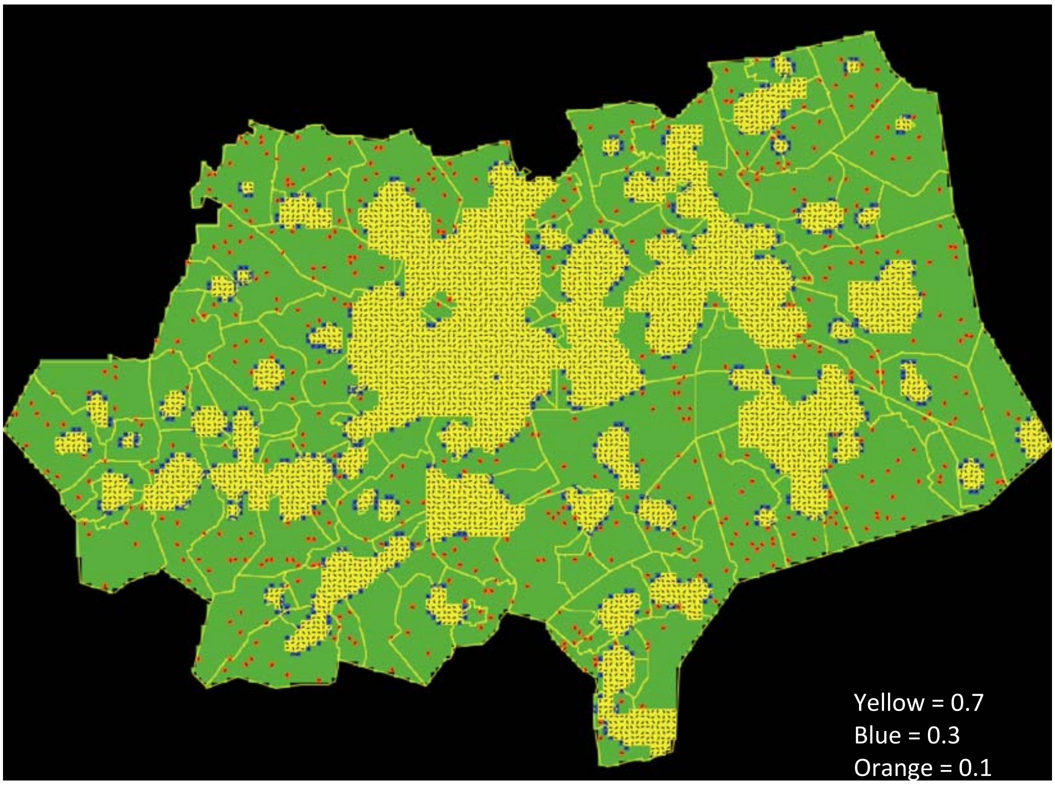


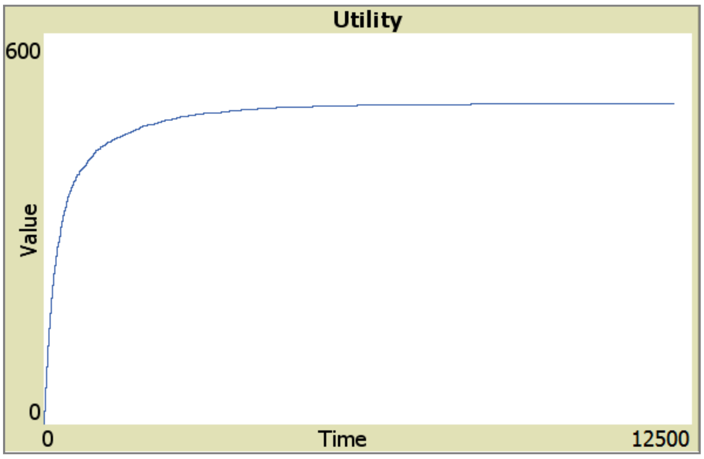
Figure 27 Score variable 2 of pv-panels

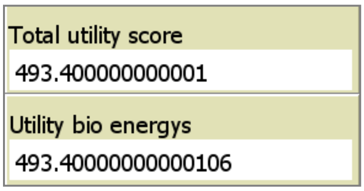
This variable is determined through subdividing the amount of energy a pv-panel generates by the energy demand on their patch and neighbors. This average value of all the pv-panels is set on 0.25. If the pv-panel only counts the energy demand on that patch, the average value is 6.2. However, this considers that the pv-panel can't release all their energy on their location and needs to transport the energy to the neighbors.

The main part of the pv-panels allocate on industrial areas. This can be addressed to the high demand of energy on industrial areas. There for, the pv-panels locate in the middle of an industrial park because it is surrounded by industry.

6.3 Bio-energy installations

This scenario consists of sufficient bio-energy installations that generate 20 % energy of the total energy use in the SRE-area. These installations search for an optimal location in the environment. Each installation scores a value that determines the suitability of that location. The total utility-score defines the score of all the installations. This value increase until none of the installations can't found better locations in the environment. It's possible that an installation doesn't score optimal because there is simply no better location.





During the analysis of this simulation various commandos are setup to identify the outcome, see appendix 3.The outcomes are noted in Table 23.

		Value-score	Amount of turtles	pcs	Proportion	%
Turtles on industrial area		Pcolor = brown	288	Pcs	30	%
Turtles on residential area		Pcolor = red	0	Pcs	0	%
Turtles on agriculture area		Pcolor = green	672	Pcs	70	%
Total amount of turtles			960	Pcs		
Maximum score that can be obtain		576				
Total Utility-score		493.4			85.7	%
Average score per turtle		0.51				
Turtles with optimal score		0.6	134	Pcs	14	%
Turtles with optimal score per variable						
Variable 1	AV	0.3				
	IN	0.3	288	Pcs	100	%
		0	0	Pcs	0	%
	AC	0.3	672	Pcs	100	%
		0	0	Pcs	0	%
	RS	0.3	0	Pcs	0	%
		0	0	Pcs	0	%
Variable 2	AV	0.7		Pcs		
	IN	0.7	288	Pcs	100	%
		0.5	0	Pcs	0	%
		0.3	0	Pcs	0	%
		0	0	Pcs	0	%
	AC	0.7	672	Pcs	100	%

		0.5	0	Pcs	0	%
		0.3	0	Pcs	0	%
		0	0	Pcs	0	%
	RS	0.7	0	Pcs	0	%
		0.5	0	Pcs	0	%
		0.3	0	Pcs	0	%
		0	0	Pcs	0	%
Variable 3	AV	0.54				
	IN	0.8	134	Pcs	46.5	%
		0.5	154	Pcs	53.5	%
		0.3	0	Pcs	0	%
		0	0	Pcs	0	%
	AC	0.8	0	Pcs	0	%
		0.5	672	Pcs	100	%
		0.3	0	Pcs	0	%
		0	0	Pcs	0	%
	RS	0.8	0	Pcs	0	%
		0.5	0	Pcs	0	%
		0.3	0	Pcs	0	%
		0	0	Pcs	0	%
Mean distance		1.76				
Electricity average value (neighbors + patch-here)		0.6				
Electricity average value (patch-here)		32.17				
Total square meters		960 patches				

Table 23 Outcomes analysis bio-energy locations

6.3.1 Analysis

Map plan. The first plan shows where bio-energy installations prefer to locate in the environment. Also the type of land use where the installation allocates is defined, see Figure 28. The second map shows the square meters that will be covered by the installations, see Figure 29.

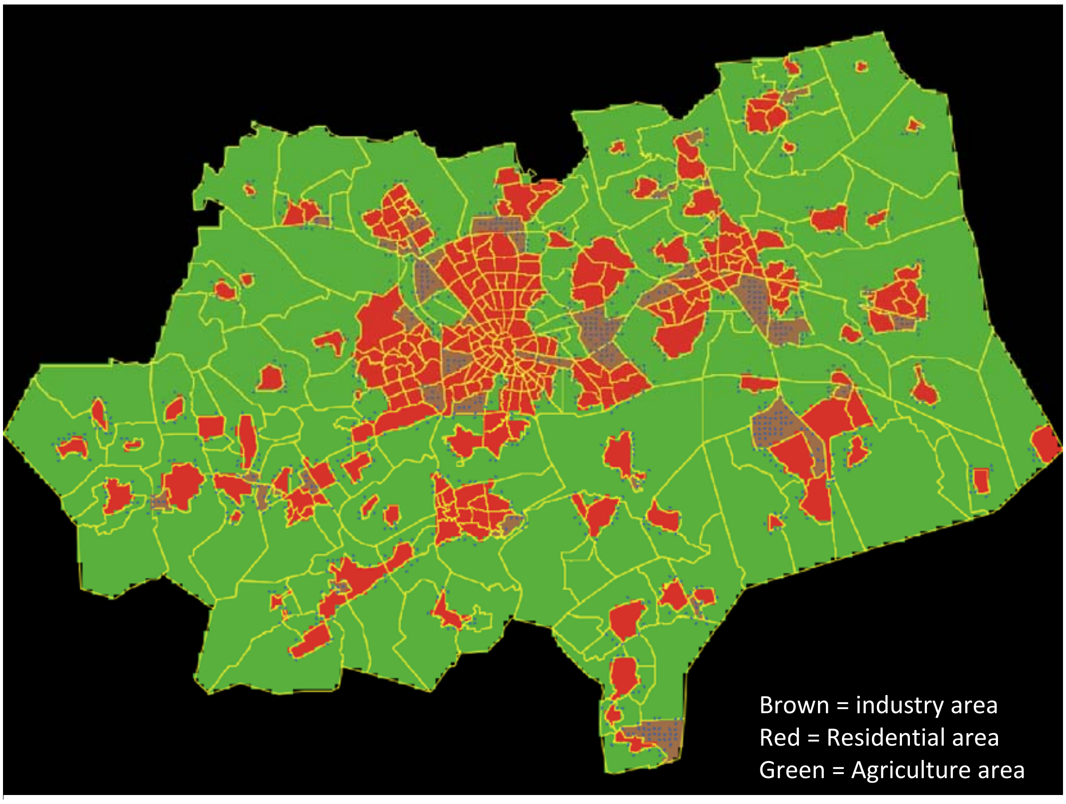


Figure 28 Allocate locations of bio-energy

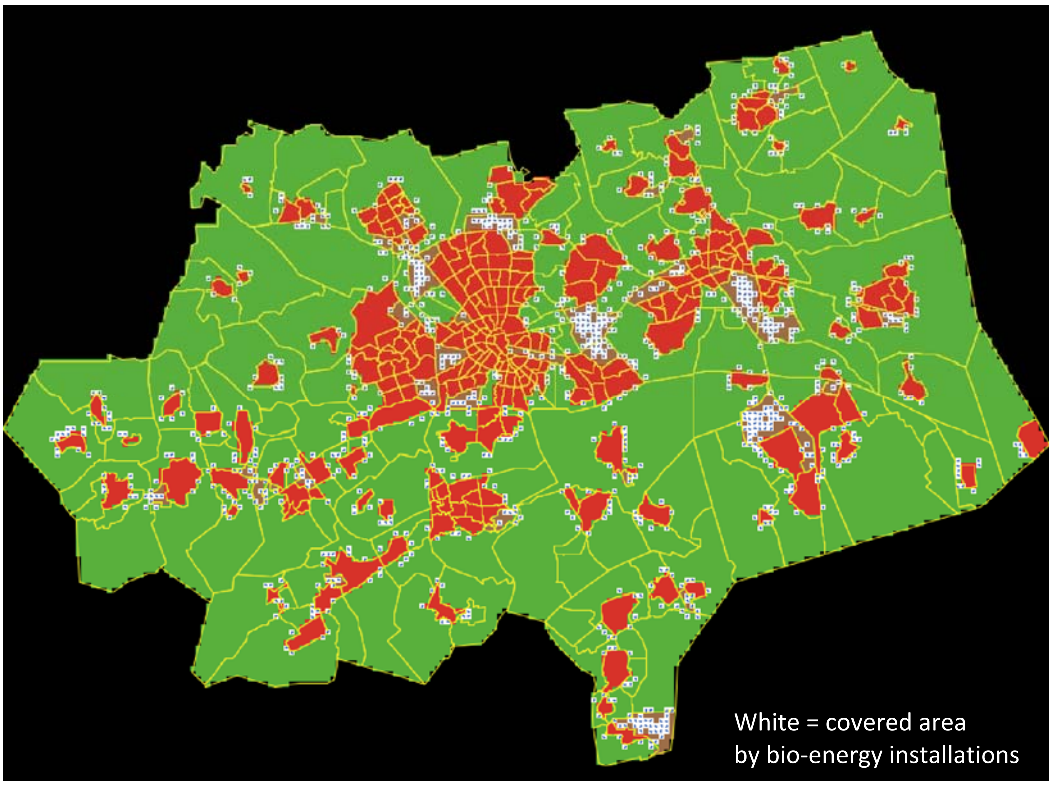


Figure 29 Spatial surface covered by bio-energy

Overall. Of the total amount of 960 bio-energy installations, 30 % percent locates on industrial areas and 70 % on agriculture areas. None of the installations allocate on residential areas because of the nuisance it gives to the surrounding. On agriculture areas the installations allocate around residential areas. It's just a sufficient distance to sensitive objects for having no nuisance of these installations. Compared to installations on industrial areas, on agriculture areas the installations are individuals and locate 'alone' in the environment. Considering the installations on industry it doesn't locate alone but rather in groups.

All the installations could have a total score of 576, but came not further than 493.4. This includes 85.7 % of the total. Considering this, the installations are generally able to score well and thus influence the spatial environment minimal.

The average score of a bio-energy is 0.51. Each bio-energy has the possibility to score a maximum of 0.6 which indicate an optimal location. However, 134 bio-energy installations were able to allocate on an optimal location (14 %). Due the map, the installations with an optimal score allocates centralized on industrial areas, see Figure 30.

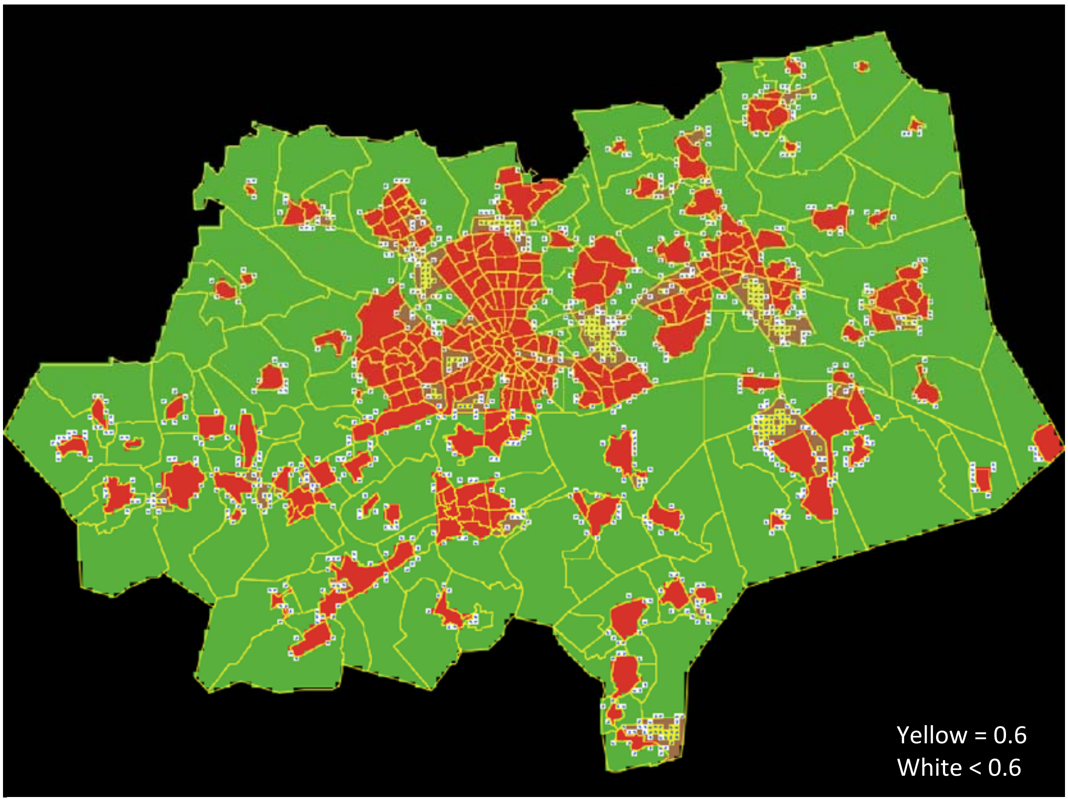


Figure 30 Optimal score by bio-energy

Variable 1. Each bio-energy installation scores for the first variable an optimal score. All the bio-energy installations are able to locate on agriculture or industrial areas. This can be addressed to sufficient available square meters to allocate bio-energy installations. The area is sufficient suitable to locate this amount of installations.

Variable 2. Variable 2 also scores maximal, the bio-energy-installations have a sufficient distance to sensitive objects. It can be assumed that all the installations are able to allocate on a sufficient distance of sensitive objects. The average distance between the bio-energy installations and sensitive objects is 1.76, which is sufficient for having no nuisance.

Variable 3. The last variable determines if the bio-energy installation is able to release all his energy in the surrounding. Here for, the installation looks to the energy demand on his patch and neighbors. The installation are suitable to score 0.8 – 0.5 - 0.3 – 0. On industrial areas, 46.5 % of the installations score 0.8. The other 53.5 scores 0.5. The one on agriculture area all score a value of 0.5. Considering this, it can be assumed that there are sufficient locations for releasing energy to the consumer on a short distance.

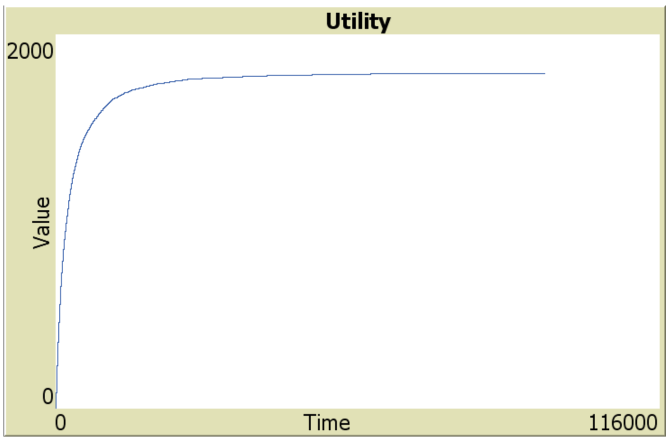
This variable is determined through subdividing the amount of energy a bio-energy installation generates by the energy demand on their patch and neighbors. This average value of all the bio-energy installation is set on 0.6. If the bio-energy installation only counts the energy demand on that patch, the average value is 1.76. It can be assumed that the bio-energy installations must be able to transport his energy to his neighbors. Otherwise it can’t release all his energy to the consumer.

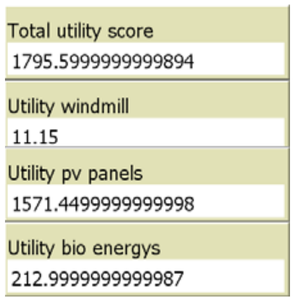
6.4 Mix

This scenario mixed the three different energy sources. Here for a certain amount of windmills, pv-panels and bio-energy installations are add that generate 20% sustainable in total. The previous scenarios assume that the amount of measures is feasible to apply. This scenario adjusts the amount due the possibility of each measure. The amount of bio-energy installations depend on the available amount of biomass in the surrounding. The amount of pv-panels is determined by calculating the available roof space that has a high potential. The amount of windmills is not bounded by conditions, it accomplish the remaining percent. (Table 24).

	Windmill		PV panel		Bio-energy				
					Liquid manure	Solid manure	Maïs	Total	
Amount	20	pcs	17.327.065	m2	4.838.033	247.682	240.810	5.326.525	ton
Power	3000	kW	0,125	kWp/m2				348.000	kWe
Hours	2200	hrs	1010	hrs					
Losses			0,15	%					
Caloric value					0,3	0,8	15,1		
Development costs	1430	€	2330	€ /kWp				1633	€/ kWe
Income-kW	0,1	€	0,23	€ / kWh				0,06	€/ kWh
Netto-costs	85.800.000	€	5.046.507.681	€				568.283.401	€
Netto-benefit	13.200.000	€	427.664.452	€				88.096.442	€
Return-time	6,5	py	11,8	py				6,45	py
					1451410	198146	3636231	5,2858	PJ
Total energy use	17.205.441.326	kWh	17.205.441.326	kWh				17.205.441.326	kWh
Sustainble energy generation	132.000.000	kWh	1.859.410.663	kWh				1.468.274.029	kWh
Sustainable-generation	0,8	%	10,8	%				8,5	%
					Total		20,1 %		

Table 24 Mix scenario





During the analysis of this simulation various commandos are setup to identify the outcome, see appendix 3. The outcomes are noted in Table 25.

		Value-score	Amount of turtles		Proportion	%
Turtles on industrial area	Windmills	Pcolor = brown	19	Pcs	3.35	%
	PV-panels		593	Pcs	33.9	%
	Bio-energy		60	Pcs	14.6	%
Turtles on residential area	Windmills	Pcolor = red	0	Pcs		%
	PV-panels		2545	Pcs		%
	Bio-energy		0	Pcs		%
Turtles on agriculture area	Windmills	Pcolor = green	1	Pcs	0.18	%
	PV-panels		7	Pcs		%
	Bio-energy		295	Pcs	47.97	%
Total amount of turtles			3520	Pcs		

Maximum score that can be obtain		1800					
Total Utility-score	Total		1795.6			99.7	%
	Windmill	14.5	11.15			76.9	%
	PV-panels	1572.5	1571.5			99	%
	Bio-energy	213	213			100	%
Average score per turtle	Windmills		0.56				
	PV-panels		0.49				
	Bio-energy		0.5				
Turtles with optimal score	Windmills			7	Pcs	35	
	PV-panels			3138	Pcs	99.7	%
	Bio-energy			355	Pcs	100	
Mean score of each variable							
Windmills	Variable 1		0.7			100	%
	Variable 2		0.54			77.1	%
	Variable 3		0.54			77.1	%
	Variable 4		0.45			56.25	%
PV-panels	Variable 1		0.29			99	%
	Variable 2		0.7			100	%
Bio-energy	Variable 1		0.3			100	%
	Variable 2		0.7			100	%
	Variable 3		0.8			100	%
Mean distance	Windmills		3.4				
	Bio-energy		1.9				
Energy average value (neighbors + patch-here)							
	Windmills		1.2				
	PV-panels		0.1				
	Bio-energy		2.1				
Energy average value (patch-here)							
	Windmills		10.4				
	PV-panels		0.6				
	Bio-energy		43.9				
Total square meters							
	Windmills		20				
	PV-panels		3145				
	Bio-energy		355				

Table 25 Outcomes analysis mix locations

6.4.1 Analysis

Map plan. The final maps show the final locations of the sustainable energy sources. The first map visualized the locations where the turtles locate on (Figure 31). The second shows the final square meters that each measure covers (Figure 32). The main part is designate by bio energy followed by pv-panels and a minimal part trough windmills.

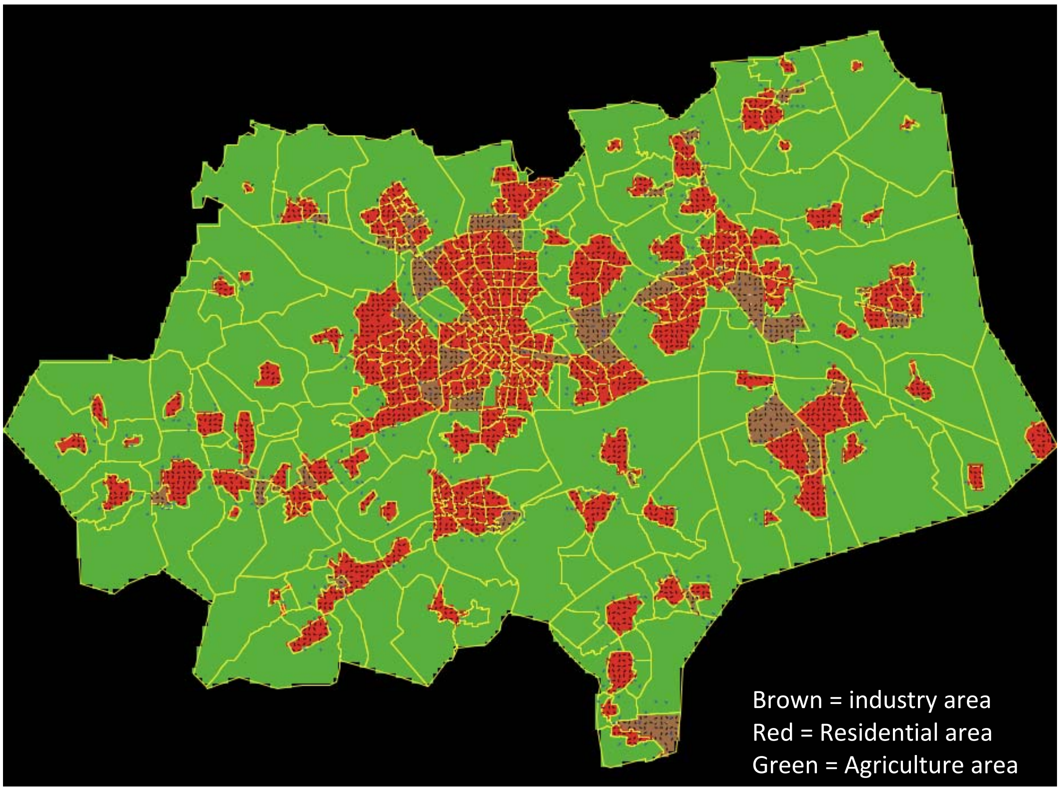


Figure 31 Allocate locations of mix

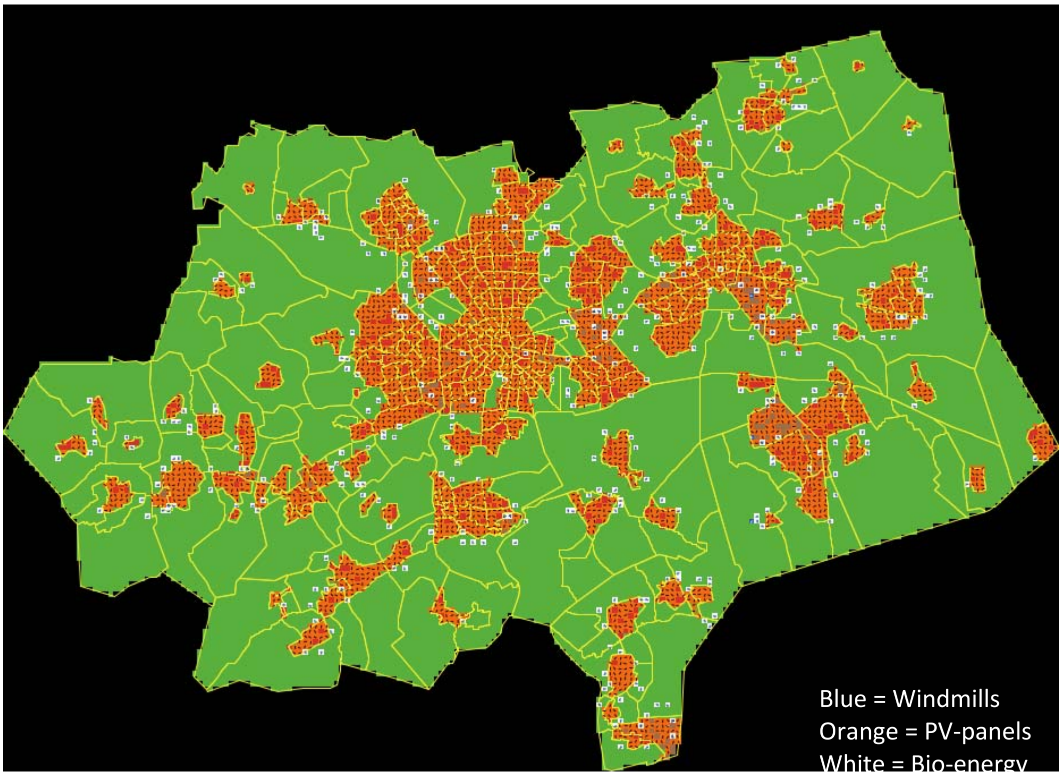


Figure 32 Spatial surface covered by mix

Overall. This scenario approaches a mix of the three measures. Due this mix, the amounts of measures differ. The mainly part are 3145 pv-panels, where 593 locate on industrial areas and 2545 on residential areas. Due the windmills, 19 of the 20 windmills allocate on industrial areas and the last on agriculture area. The maximum score that could be obtained by all the turtles is 1800. Just 99.7 %, as well a value of 1795.6 has finally been scored by the turtles. Especially pv-panels and bio-energy are able to score well. (Figure 33).

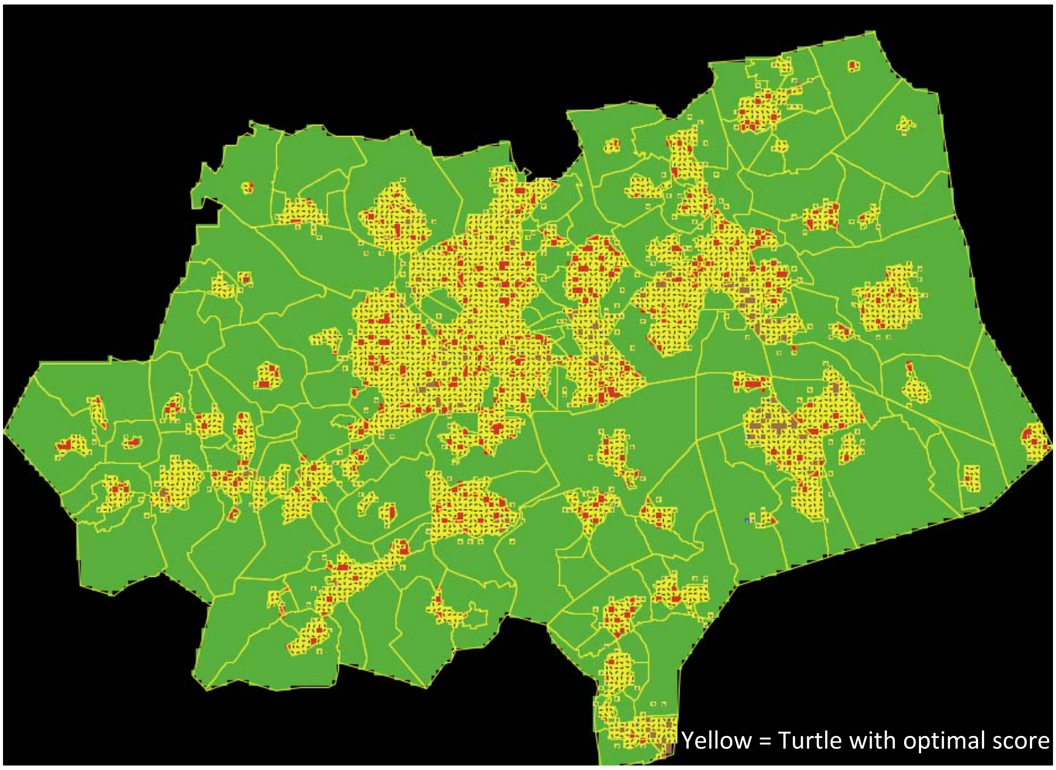


Figure 33 Optimal score by mix

Windmill score. The windmills have an average score for each variable. All of them do score for variable 1, which implies that the windmill were able to locate in a grid or line. Variable 2 scores an average of 0.54 and this defines that the greater part scores average. The windmills have difficulties with founding a location with sufficient distance to sensitive objects and the average distance determines 3.4, as well 1020 meters. The third variable scores also 0.54 and this mean that the windmills have difficulties with releasing their energy on a short distance. The last variable defines an average of 0.45 and this shows that windmills have visual nuisance to the environment.

PV-panel score. A pv-panel is able to score on two variables. The first variable scores for almost all pv-panels optimal and this means that all the pv-panels are able to allocate on areas with roof surface. The second variable defines an average of 0.7 and this determines that sufficient pv-panels can release their energy on a short distance.

Bio-energy score. All the bio-energy installations score for variable 1 optimal which implies that all the installations were able to allocate on a prefer area. The second variable defines the distance between the installation and sensitive objects and scores an average value of 0.7. The average distance shows 1.9 and this means in reality 570 meters. The last variable determines if the installation is able to release his energy in the neighbor to the consumer. The average score is 100 % of the total and this implies that sufficient installations score well.

It is striking to see that all the variables score optimal and therefore all installations locate optimal in the environment.

6.5 Financial

The three sustainable energy sources have different investment costs, return costs and payback time. Each scenario produces the same average amount of energy but differ in costs and benefits. The value assumptions for determining the financial part depend on the amount of energy that a measure produces. This results in the fact that the costs are standing in proportion with the amount of energy production of an energy measure. If the amount of energy production increases; the investment and return costs also increase. This counts for each measure the same. Other influences aren't taken into account, like the financial consequence if the measures are located on several locations.

	Windmill		**PV-panel**		**Bio-Energy**				
Biomass					Liquid manure	Solid manure	Corn	Total	
Amount	525	pcs	32.000.000	m2	12.000.000	1.920.000	480.000	14.400.000	Ton
Power	3000	kW	0.125	kWp/m2				980	kWe
Hours	2200	hrs	1010	hrs					
Losses			0.15	%					
Caloric value					0.3	0.8	15.1		GJ/ ton
Development costs	1430	€	2330	€/kWp				1.633	€/ kWe
Income-kW	0.1	€	0.23	€/ kWh				0.06	€/ kWh
Netto-costs	2.252.250.000	€	9.320.000.000	€				1.536.326.400	€
Netto-benefit	346.500.000	€	789.820.000	€				206.400.000	€
Return-time	6.5	py	11.8	py				7,4	Py
					3.600.000	1.536.000	7.248.000	12,3840	PJ
Sustainable energy generation	3.465.000.000	kWh	3.434.000.000	kWh				3.440.000.003	kWh
Total energy use (See appendix 1)	17.205.441.326	kWh	17.205.441.326	kWh				17.205.441.326	kWh
Sustainable-generation	20.1	%	20	%				20	%

Table 26 Investment costs

As table 26 shows, the highest investment costs can be assigned to pv-panels. Compared to the others, pv-panels also have the highest benefit costs. By generating the same amount of energy, pv-panels has the highest investment costs but also the highest benefit. Although, the proportion between investment and benefit costs defines the return time, this implies for pv-panels 11.8 years. Despite the high benefit, the return time assigns that this measure has the longest time to pay back the investment. Generally, pv-panel projects consist of individuals that assemble pv-panels on their roof, which means individual investments. The total amount of investment costs is split up and so also the risk.

The invest and return costs of bio-energy installations are the lowest, compared to the other measures. The return time includes 7.4 years if there's a sufficient amount of biomass. The installation depends on the available biomass in the area. There should be considered about the available biomass in the future, it should be well substantiated.

The windmills have an average amount of invest and return costs. The advantage is that the proportion between return and investment includes a return time of 6.5 years. This means that a windmill generates in shorter time an equal amount of energy. In general, windmills are located in a line or grid and owned by one investor. This consist a high investment and risks. The advantage is the short return time.

The assumptions are based on values that currently concerns. The prediction is that the price of energy will increase the upcoming years. If this occurs, the return time will be shorter. Also the techniques are getting smarter and efficient which leads to lower investment costs.

6.6 Conclusion

The Netlogo model incorporated three energy measures that simulates four scenarios and finally generates four land-use plans. Each scenario achieves a 20 % sustainable generation of energy. Subsequently, the land-use plans were analyzed on the spatial feasibility. It incorporates a study of the spatial effects of each measure in the built environment.

Based on the scenarios the various energy measures consider their location in the environment, see Table 27. The windmill scenario seems to consider locating on industrial and agriculture areas. Interesting is to see the effect of windmills on the utility-score, it shows that the score that is obtained is a small part of the possible score that could be achieved. This means that windmills influence the spatial environment high. The results from the pv-panel scenario show that the pv-panels are able to score well and this means that it influence the environment minimal. However, the area doesn't provide sufficient available roof space to locate all pv-panels. The bio-energy installations locate on agriculture and industrial areas, it shows that all installations were able to locate on these areas and so sufficient space is available.

Comparing the three measures, windmills provide high influences on the spatial environment, however, bio-energy and pv-panels less. Relative on the amount of measures, less windmills are needed to generate the same energy than pv-panels and bio-energy installations. Pv-panels and bio-energy installations can release all their energy on a short distance, however, windmills have a long distance. This means that pv-panels and bio-energy installations are location bounded and windmills provide the surrounding with sufficient energy.

	WINDMILLS			**PV-PANELS**			**BIO-ENERGY INSTALLATIONS**		
	Value-score	**Proportion**	**%**	**Value-score**	**Proportion**	**%**	**Value-score**	**Proportion**	**%**
Turtles on industrial area	Pcolor = brown	16.8	%		12	%		30	%
Turtles on residential area	Pcolor = red	0	%		51.1	%		0	%
Turtles on agriculture area	Pcolor = green	83.2	%		36.9	%		70	%
Maximum score that can be obtain	380.625			2904.5			576		
Total Utility-score	134.45	35.3	%	2328.7	80.2	%	493.4	85.7	%
Mean distance sensitive objects	5.33						1.76		
Electricity average value (patch-here + neighbors)	15.8			0.25			0.6		
Electricity average value (patch-here)	146.5			6.2			32.17		
Total square meters	525 patches			5809 patches			960 patches		

Table 27 Comparising energy sources

Considering the financial part, windmills have the shortest return time and average investments costs. Despite the high spatial influences, this measure is financially an interesting investment. On the other hand, pv-panels are spatially optimal but have a high investment costs and return time. Bio-energy is spatially and financially an interesting investment. However this measure has a high dependency of biomass that defines the amount of energy generation.

FINAL CONCLUSIONS

7 CONCLUSION, DISCUSSION AND RECOMMENDATION

This chapter presents the conclusion, discussion and recommendation on the findings and results of the research. By executing a literature review, applying a Netlogo model and scenario methodology, knowledge has been gained on the potential and feasibility of spatial energy sources. All this is addressed to the specific research questions and allows reflecting the findings to the problem statement and the main research questions.

The first paragraph comprises the conclusion on the main research question from chapter 1. Answering this question allows a discussion on the importance and influence of the barriers on the spatial feasibility of energy sources. This provides more insight in the problem statement. The second paragraph *discussion and recommendation* reviews the research targets from chapter 1. In response to the results recommendations are given related to the research question.

7.1 Conclusion

The final result of this research for the allocation of sustainable energy sources, is based on the SRE-area (Samenwerkingsverband Regio Eindhoven). The model is realized with the information gathered during the research. The main question will be answered in this section. The main question is divided into 4 questions which are answered in the chapters 2 to 6.

Main question: Is it possible to build a model that determines the location allocations of sustainable energy sources in the spatial environment based on the environmental influences? And which energy sources have potential and where should they be located?

The main question is divided into two main parts: the value of the research model and the outcomes of the model. Below both are answered separately.

7.1.1 Research method

Main question: Is it possible to build a model that determines the location allocations of sustainable energy sources in the spatial environment based on the environmental influences? And which energy sources have potential and where should they be located?

The mainly aboveground sustainable energy measures will, compared to the fossil sources, take more square meters. The changeable energy sector occurs on ground level and results in a changeable environment. By answering the main research question, it is indeed possible to build a model that determines the allocation of sustainable energy sources in the spatial environment. Using the *agent based modeling* approach, a well functioning Netlogo model is provided. The model is able to provide insights in the spatial planning of sustainable energy sources in the built environment on a large scale level. This model can be used as a communication and decision tool by giving insights into the spatial behavior of sustainable energy measures in the built environment.

The model is capable to simulate the spatial planning of energy sources by implementing different measures in the model that is influenced by constraints and requirements. In the model these constraints and requirements are present by variables. Despite that these variables are based on literature still most are subjective. However, decision makers have the possibility to define the variables by their own insights and preferences. This means that the model allows the implementation of the perspective of the involved stakeholders.

The final maps visualize the allocation of the sustainable energy sources in the spatial environment. This spatial insight contributes in the discussion how to handle with the implementation of the energy sources in the spatial environment. The model can easily be extended by adding other spatial measures. By simulating different scenarios the model shows the spatial impacts of each scenario. This gives the model the possibility to compare the spatial influences of each energy measure. Also the technical settings can be change and so the spatial influences of these changes can be compared.

Due the mix scenario, the preference and feasibility of measures can be handled by changing the amount of energy sources. The advantage is the possibility to give priority to the spearheads and availability in an area by changing the amount.

7.1.2 Outcomes model

Main question: Is it possible to build a model that determines the location allocations of sustainable energy sources in the spatial environment based on the environmental influences? And which energy sources have potential and where should they be located?

In this report three sustainable energy measures that influence the spatial environment, are implemented. Windmills, pv-panels and bio-energy installations are compared on their spatial influences. Because of the subjective approach of the variables, an advice is given based on the case study and the measures and their conditions that are used in this report. It describes how to handle and to approach these measures in the spatial environment. This advice is divided into the three measures and will finally compare.

Spatial benefits windmills. In the spatial environment, windmills have a high spatial influence. A well considered spatial plan is needed to decrease this influence. Given the map of Netlogo, windmills prefer to locate on industrial areas with sufficient available surfaces. This is because of the high density of mass, high demand of energy and less visibility. However to achieve the 20 % ambition, the main part of windmills locate on agriculture area. Being on agriculture area has a high visibility and influence on the environment. The windmills aren't able to locate on a sufficient distance for having no spatial influence.

By choosing for windmills the advice is to focus on larger industrial areas. From the model, the SRE-area is suited to provide 88 windmills on industrial areas. Stimulation programs and political views can contribute to achieve this goal. The remaining windmills influence the environment too much and can lead to considerable disagreements and complicated processes. From this, the advice is that these windmills should be left out of the model. This leads to insufficient sustainable generation of energy and therefore other measures should be provided.

Windmills generate a high amount of energy. This leads to a low amount of measures that are needed for the same generation of energy. Because of the average investments costs, the return time is minimal compared to the other measures. Despite the high spatial influences, windmills are financial interesting. Therefore, if there are spatial possibilities to implement windmills it’s interesting to invest.

Spatial benefits pv-panels. Because of the available roof surface, pv-panels prefer to locate on top of residential and industrial areas. A certain amount of available roof is suitable for pv-panels. The advantage is that pv-panels are convenient to apply and have a low influence on the environment. A major part of sustainable generation can be made by covering all suitable roofs. However only applying pv-panels isn't sufficient to achieve the 20 % ambition.

Applying pv-panels is a suitable measure in the spatial environment because of the low spatial influences. Therefore, encouraging this measure doesn't influence the spatial environment but achieves a major part of sustainable generation. Besides the low spatial influence, the investment requires a high financial capital and takes a long return time. Also a high amount of pv-panels is needed to achieve the ambitions. Therefore, setting up stimulation programs and high commitments could make it more interesting to invest in pv-panels.

Spatial benefits bio-energy installations. The bio-energy installations prefer to locate on industrial and agriculture areas. In general, the installations on industrial areas are large installations that process a high amount of biomass. On agriculture areas are the installations small and medium.

Because of the low impact on the environment the main part of the installations are able to locate on a suitable location. The SRE-area has sufficient available square meters and biomass. The application of bio-energy installations is a valuable measure to achieve the ambition. However, this measure has a high dependency of biomass and so very risky. This dependence must be minimized by taking the consequences into account. Like making long-term appointments with biomass suppliers or matching the technique to the available biomass in the future.

Considering the low investment costs and spatial influences makes this measure a valuable energy source.

7.2 Discussion and Recommendation

The aims of this research comprises the potential of a simulation model that generates sustainable land use plans by studying the spatial location allocation of energy sources in urban planning.

Through an extensive literature review and expert knowledge review on the spatial behavior of sustainable energy sources and on spatial modeling, knowledge has been gained and barriers to the spatial location allocations have been identified. The problems regarding allocate locations of sustainable energy sources have been made explicit by designing a Netlogo model. In this, a GIS map and sustainable energy sources and their behavior are translated into a simulated model which incorporated the scenarios and final shows the sustainable urban planning maps.

Simulating the scenarios allows to examining the locations and spatial effects of sustainable energy sources on a large-scale level. The maps show the optimal locations of the measures, however because of the large-scale level there should be zoomed in to show the final location. Expanding the model with a more detailed land use map can contribute in a more specify location in the environment. The black area on the map is unknown and the energy measures next to this area can't see the possible constraints. An important conclusion on this research shows that the final locations need to be customized by zooming in on the map.

The variables that determine the scores, contain indicators on the *spatial constraints*. These variables are subjective and suitable to change and to add new ones. The conclusion, as well advice, is based on the case study and the measures and their conditions that are used in this report. This is too much specified to make a general conclusion of the behavior of these energy measures. The fact that the model shows suitable and realistic maps, allows to assuming that the model is a realistic valuable simulation model.

The research questions are answered and the objective that has been set, is also achieved. However, the research is limited in some way by the research boundaries and new insights and developments can lead to new and interesting subjects to examine. This research focuses on the spatial influences of sustainable measures in the built environment. However, there are still other variables that influence the location allocations, like making the technical and financial variables more dependent variables. Considering the completeness of an optimal location it would be interesting to study the possibility to make these variables locations dependent.

Furthermore, the model consists of a layer that defines the energy demand in the area. Due the spatial constraints, other layers can be added. Because of the difficulty to collect sufficient data these layers aren't add. It will be interesting to collect and to add more spatial layers to make the variables more controllable. For example the existing energy infrastructure, existing sustainable energy sources, detailed land use map, road map for transporting biomass, Ecological Head Structure map. Expanding the model gives more reliable locations. Finally, the model is capable to add more layers and variables.

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APPENDIX

Appendix 1 Total energy use

Gas Consumption

	GAS CONSUMPTION EINDHOVEN				GAS CONSUMPTION PER HECTARE PER SECTOR			
Residential	49,7	%	104.853.088	M3	5694	ha	18415	M3/HA
Agriculture	0,8	%	1.687.776	M3	1998	ha	845	M3/HA
Industry	49,5	%	104.431.144	M3	1187	ha	87979	M3/HA
Total	100		210.972.009	M3	8879	ha		

	CONSUMPTION/HA		SURFACE SRE-AREA		TOTAL GASCONSUMPTION SRE-AREA						
Residential	18415	M3/HA	26691	ha	491.505.758	M3	15,55	5.062.509.304	kWh	18,23	PJ
Agriculture	845	M3/HA	113199	ha	95.622.905	M3	3,03	984.915.918	kWh	3,55	PJ
Industry	87979	M3/HA	6158	ha	541.775.053	M3	17,14	5.580.283.043	kWh	20,09	PJ
Total			146048	ha	1.128.903.715	M3		11.627.708.266	kWh		
				1 PJ =	31.600.000	m3		277.777.778	kWh		
					36	PJ		41,85974972	PJ		

	CONSUMPTION/HA		SURFACE PATCH (300 * 300)		TOTAL GASCONSUMPTION PATCH			
Residential	18415	M3/HA	9	ha	165732	M3	1707039	kWh
Agriculture	845	M3/HA	9	ha	7603	M3	78307	kWh
Industry	87979	M3/HA	9	ha	791812	M3	8155659	kWh

Electricity Consumption

	ELECTRICITY CONSUMPTION EINDHOVEN				ELECTRICITY CONSUMPTION PER HECTARE PER SECTOR			
Residential	49,7	%	518062373,4	kWh	5694	ha	90984	kWh/ha
Agriculture	0,8	%	8339032	kWh	1998	ha	4174	kWh/ha
Industry	49,5	%	515977615,4	kWh	1187	ha	434690,5	kWh/ha
Total	100	%	1.042.379.021	kWh	8879	ha		
		1 PJ =	277.777.778	kwh				
			3,75	PJ				

	CONSUMPTION/HA		SURFACE SRE-AREA		TOTAL ENERGYCONSUMPTION SRE-AREA			
Residential	90984	kWh/ha	26691	ha	2.428.451.494	kWh	8,74	PJ
Agriculture	4174	kWh/ha	113199	ha	472.457.509	kWh	1,70	PJ
Industry	434690	kWh/ha	6158	ha	2.676.824.057	kWh	9,64	PJ
Total			146048	ha	5.577.733.060	kWh		
				1 PJ =	277.777.778	kwh		
					20	PJ		

	CONSUMPTION/HA		SURFACE PATCH (300 * 300)			
Residential	90984	kWh/ha	9	ha	818855	kWh
Agriculture	4174	kWh/ha	9	ha	37563	kWh
Industry	434690	kWh/ha	9	ha	3912214	kWh

Total energy Consumption

TOTAL ENERGY-USE		PROPORTION ACCORDING KASTEREN ET AL. (2008)	
27	PJ	44	%
5	PJ	8	%
30	PJ	48	%
62	PJ	100	%
17.205.441.326	kWh		
62	PJ		

Appendix 2 Available Corn

	Agriculture area (ha) (Statline[1], 2011)	**Corn silage (ha)** (Statline[3], 2012)	**Proportion Corn (%)**	**Return dry matter/ ha (Ton /ha)** (Statline[4], 2009)	**Available corn (ton)**
Noord-Brabant	411.084	56.363	13.7	15,0	845.445
SRE-Area	117.184	16.054	13,7	15,0	240.810

Appendix 3 Commandos

WINDMILLS

count turtles-on patches with [pcolor = brown]
count turtles-on patches with [pcolor = green]
count turtles-on patches with [pcolor = red]
mean [single-windmill-score] of turtles
count turtles with [single-windmill-score >= 0.725]
mean [square-meters] of turtles
count turtles with [pcolor = brown] with [square-meters = 0.7]
count turtles with [pcolor = brown] with [square-meters = 0]
count turtles with [pcolor = green] with [square-meters = 0.7]
count turtles with [pcolor = green] with [square-meters = 0]
count turtles with [pcolor = red] with [square-meters = 0]
mean [distances] of turtles
count turtles with [pcolor = brown] with [distances = 0.7]
count turtles with [pcolor = brown] with [distances = 0.3]
count turtles with [pcolor = brown] with [distances = 0]
count turtles with [pcolor = green] with [distances = 0.7]
count turtles with [pcolor = green] with [distances = 0.3]
count turtles with [pcolor = green] with [distances = 0.1]
count turtles with [pcolor = green] with [distances = 0]
count turtles with [pcolor = red] with [distances = 0]
mean [covering] of turtles
count turtles with [pcolor = brown] with [covering = 0.7]
count turtles with [pcolor = brown] with [covering = 0.2]
count turtles with [pcolor = brown] with [covering = 0.1]
count turtles with [pcolor = brown] with [covering = 0]
count turtles with [pcolor = green] with [covering = 0.7]
count turtles with [pcolor = green] with [covering = 0.2]
count turtles with [pcolor = green] with [covering = 0.1]
count turtles with [pcolor = green] with [covering = 0]
count turtles with [pcolor = red] with [covering = 0.2]
count turtles with [pcolor = red] with [covering = 0.1]
count turtles with [pcolor = red] with [covering = 0]
mean [visual] of turtles
count turtles with [pcolor = brown] with [visual = 0.8]
count turtles with [pcolor = brown] with [visual = 0.2]
count turtles with [pcolor = brown] with [visual = 0]
count turtles with [pcolor = green] with [visual = 0.8]
count turtles with [pcolor = green] with [visual = 0.2]
count turtles with [pcolor = green] with [visual g = 0]
count turtles with [pcolor = red] with [visual = 0]
show mean [count turtles in-radius 2] of turtles
show mean [distance min-one-of (patches with [pcolor = red]) [distance myself]] of turtles
show mean [((Power-windmill * Operating-Hours) / ((sum [electricity] of neighbors) + ([electricity] of patch-here)))] of turtles

PV-PANELS

count turtles-on patches with [pcolor = brown]
count turtles-on patches with [pcolor = green]
count turtles-on patches with [pcolor = red]
mean [single-pv-panel-score] of turtles
count turtles with [single-pv-panel-score >= 0.5]
mean [square-meters1] of turtles

count turtles with [pcolor = brown] with [square-meters1 = 0.3]
count turtles with [pcolor = brown] with [square-meters 1= 0]
count turtles with [pcolor = green] with [square-meters 1= 0.3]
count turtles with [pcolor = green] with [square-meters1 = 0]
count turtles with [pcolor = red] with [square-meters 1= 0.3]
count turtles with [pcolor = red] with [square-meters 1= 0]
mean [covering1] of turtles
count turtles with [pcolor = brown] with [covering1= 0.7]
count turtles with [pcolor = brown] with [covering1= 0.3]
count turtles with [pcolor = brown] with [covering1= 0.1]
count turtles with [pcolor = brown] with [covering1= 0]
count turtles with [pcolor = green] with [covering1= 0.7]
count turtles with [pcolor = green] with [covering1= 0.3]
count turtles with [pcolor = green] with [covering1= 0.1]
count turtles with [pcolor = green] with [covering1= 0]
count turtles with [pcolor = red] with [covering1= 0.7]
count turtles with [pcolor = red] with [covering1= 0.3]
count turtles with [pcolor = red] with [covering1= 0.1]
count turtles with [pcolor = red] with [covering1= 0]
show mean [((90000 * Power-panel * sun-hours * (1 - losses)) / ((sum [electricity] of neighbors) + ([electricity] of patch-here)))] of turtles

BIO-ENERGY INSTALLATIONS

count turtles-on patches with [pcolor = brown]
count turtles-on patches with [pcolor = green]
count turtles-on patches with [pcolor = red]
mean [single-bio-energy-score] of turtles
count turtles with [single-bio-energy-score >= 0.6]
mean [square-meters2] of turtles
count turtles with [pcolor = brown] with [square-meters2 = 0.3]
count turtles with [pcolor = brown] with [square-meters2 = 0]
count turtles with [pcolor = green] with [square-meters2 = 0.3]
count turtles with [pcolor = green] with [square-meters2 = 0]
count turtles with [pcolor = red] with [square-meters2 = 0.3]
count turtles with [pcolor = red] with [square-meters2 = 0]
mean [distances2] of turtles
count turtles with [pcolor = brown] with [distances2 = 0.7]
count turtles with [pcolor = brown] with [distances2= 0.5]
count turtles with [pcolor = brown] with [distances2= 0.3]
count turtles with [pcolor = brown] with [distances2= 0]
count turtles with [pcolor = green] with [distances2= 0.7]
count turtles with [pcolor = green] with [distances2= 0.5]
count turtles with [pcolor = green] with [distances2= 0.3]
count turtles with [pcolor = green] with [distances2 = 0]
count turtles with [pcolor = red] with [distances2= 0.7]
count turtles with [pcolor = red] with [distances2= 0.5]
count turtles with [pcolor = red] with [distances2= 0.3]
count turtles with [pcolor = red] with [distances2= 0]
mean [covering2] of turtles
count turtles with [pcolor = brown] with [covering2= 0.8]
count turtles with [pcolor = brown] with [covering2= 0.5]
count turtles with [pcolor = brown] with [covering2= 0.3]
count turtles with [pcolor = brown] with [covering2= 0]
count turtles with [pcolor = green] with [covering2= 0.8]
count turtles with [pcolor = green] with [covering2= 0.5]
count turtles with [pcolor = green] with [covering2= 0.3]

count turtles with [pcolor = green] with [covering2= 0]
count turtles with [pcolor = red] with [covering2= 0.8]
count turtles with [pcolor = red] with [covering2= 0.5]
count turtles with [pcolor = red] with [covering2= 0.3]
count turtles with [pcolor = red] with [covering2= 0]

show mean [distance min-one-of (patches with [pcolor = red]) [distance myself]] of turtles

show mean [(((liquid-manure * 0.3) + (solid-manure * 0.8) + (corn * 15.1)) * 277.8) / ((sum [gas] of neighbors) + ([gas] of patch-here))] of turtles

MIX

count windmills-on patches with [pcolor = brown]
count pv-panels-on patches with [pcolor = brown]
count bio-energys-on patches with [pcolor = brown]
count windmills-on patches with [pcolor = red]
count pv-panels-on patches with [pcolor = red]
count bio-energys-on patches with [pcolor = red]
count windmills-on patches with [pcolor = green]
count pv-panels-on patches with [pcolor = green]
count bio-energys-on patches with [pcolor = green]

mean [single-windmill-score] of windmills
mean [single-pv-panel-score] of pv-panels
mean [single-bio-energy-score] of bio-energys
count turtles with [single-windmill-score >= 0.725]
count turtles with [single-pv-panel-score >= 0.5]
count turtles with [single-bio-energy-score >= 0.6]

mean [square-meters] of windmills
mean [distances] of windmills
mean [covering] of windmills
mean [visual] of windmills
mean [square-meters1] of pv-panels
mean [covering1] of pv-panels
mean [square-meters2] of bio-energys
mean [distances2] of bio-energys
mean [covering2] of bio-energys

show mean [distance min-one-of (patches with [pcolor = red]) [distance myself]] of windmills
show mean [distance min-one-of (patches with [pcolor = red]) [distance myself]] of bio-energys

show mean [((Power-windmill * Operating-Hours) / ((sum [electricity] of neighbors) + ([electricity] of patch-here)))] of windmills

show mean [((5508 * Power-panel * sun-hours * (1 - losses)) / ((sum [electricity] of neighbors) + ([electricity] of patch-here)))] of pv-panels

show mean [(((liquid-manure * 0.3) + (solid-manure * 0.8) + (corn * 15.1)) * 277.8) / ((sum [gas] of neighbors) + ([gas] of patch-here))] of bio-energys