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A WINNING AGROBUSINESS MODEL IN THE VEENKOLONIËN

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A Winning Agrobusiness Model in the Veenkoloniën

Synthesizing past work on water storage in the area, biofuel production, and greenhouse agriculture, VFD Consulting explores the possibility of developing a novel approach to agrobusiness in the Veenkoloniën, the Netherlands.

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VFD Consulting

VFD Consulting is a multidisciplinary team encompassing the fields of horticulture, water management, forestry, and aquaculture. The expertise of the VFD Consulting team is combined to present an interdisciplinary approach under a unified vision.

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Summary

The purpose of this report is to explore the development of economic activities in conjunction with water storage in the Veenkoloniën, Netherlands. In pursuit of this goal, a simple feasibility study has been conducted in order to assess the possibility of joining energy production from biomass, greenhouse agriculture, and water storage into one comprehensive plan. Specifically, VFD consultants have compiled information regarding producing biogas from crops, and then converting the biogas to electricity. The byproducts of this conversion, heat and CO_2, can then be used to support greenhouse agriculture. Changes in crop distribution will necessarily have an effect on the water demand of the area *on top* of the projected future demand increase due to climate change.

Water

The current water demand of the Veenkoloniën for agricultural use in the area is expected to increase by approximately 56 Mm^3 over the next few decades. This is the base amount of water that is planned for storage in this report. While water shortage is a real threat in the area, we consider the *additional* water requirement in the future to be more uncertain. This is primarily due to the fact that the current water supply (approximately 100 Mm^3) is guaranteed through legal arrangements between the Hunze and Aa's water board, the Friesland water board, and the Rijkswaterstaat, which controls the water management of the Ijsselmeer (van Slobbe 2012). Because of the strong legal precedence of inter-water agency agreements in the Netherlands, the Veenkoloniën's right to this water is relatively secure. However, due to increasing uncertainty over how the IJsselmeer will be managed in the upcoming decades, any additional demand, while planned for by the water board, may not be met due to resistance from IJsselmeer interests.

Water shortage during the summer is contrasted by occasional extreme water excess during the wet season. In the last year there has been the threat of significant inundation in the Veenkoloniën area due to the current system's inability to absorb and regulate sudden influxes of water. As such, the second criteria of the water aspect of the report is to increase the robustness and flexibility of the system to handle flood conditions. As such, we are focusing on the use of farm-level storage ponds that double as flood retention ponds if managed as such. The ponds were planned using the future increase in demand as the base level of storage, but are capable of storing additional water given changes to the current management of the system in order to compensate for the other items of the plan.

Energy

Due to local resistance to increasing wind power in the Veenkoloniën area, and to give added value to work already in progress regarding exploring solar and algae production, VFD Consulting explores the feasibility of producing biogas from biomass. This line of investigation revealed several strong points. First, there is the will in the area to develop the "brand" or "image" of the Veenkoloniën area as an energy producer. Secondly, traditional crops (potatoes, sugar beets, and corn) grown in the area show a high biogas potential. Finally, developing energy production pursues local governmental goals of expanding the economic profile of the area.

The technology of converting crops to biogas is well researched, and well established in the Netherlands and around the world. A review of the available options and combinations of fuel and digesters is included. Furthermore, the non-crop options (industry residue, manure content, and

“sludge”) are briefly examined. All of this is to search for the amount of energy crop that would be needed to produce a viable amount of gas for electricity production (or direct input into the national gas grid). This gives rise to three scenarios. In scenario 1, 3,3% of the currently cropped area is dedicated to producing crops for energy production. Scenario 2 is 6,6% of the area, while Scenario 3 is 9,9% of the area. According to local experts, approximately 67% of the croppable area is already dedicated to growing possible energy crops (potatoes and sugar beets), which means the water requirement does not need to be redressed.

Greenhouse Agriculture

The final aspect of the report involves critically examining the conditions under which greenhouse agriculture is viable in combination with the previous two aspects. Greenhouse agriculture is beneficial in this plan because it can utilize two of the “waste products” of converting biogas to electricity, and does not necessarily result in an increase in water demand when designed to be water-neutral. The area that must be dedicated to greenhouse agriculture in order to be economically viable under the three crop-area scenarios is described in conjuncture while taking the area required for water storage into account. Furthermore, greenhouse agriculture supports the previously mentioned local goal of expanding the economic profile of the Veenkoloniën without straying too far from the area’s agricultural roots.

The Common Link

This report addresses the social, economic, and technical feasibility of the three aspects described above. While this allows for the “whole picture” to be considered, VFD Consulting as nevertheless needed to delineate and define the criteria against which the value of each scenario is judged. In this case, the base amount of water storage is set and, for simplicity, is considered in terms of surface area. The production of energy crops is expressed in terms of hectares, as biogas and electricity conversion is expressed in terms of energy/hectare. Finally, greenhouses are delineated primarily by the space they occupy, as the design calls for them to be water neutral. All three of these plan aspects have costs and benefits that can be expressed in terms of euro/hectare, while the *current* uses have value in the same form. Therefore, the common link between the components of this plan is the effective use of *area*, which serves as our base evaluation criteria.

An additional level of complexity is added by considering the interests of the stakeholders of the Veenkoloniën. This report briefly explores the impact the proposed actions will have on stakeholders, as well as the role these stakeholders might play in putting the plan into action. This adds a second common link of creating a socially effective plan that does not irreparably alienate any of the identified key stakeholders.

Contents

Figures and Tables

Introduction

The original concept behind this report was to develop a "winning agribusiness model" based around water storage in the region of the northern Netherlands known as the Veenkoloniën (see Figure 1). The VFD Consulting team was tasked by Tauw to explore novel options that combine agribusiness and water storage in an integrated manner, and to perform a feasibility study regarding the implementation of such options. These novel agribusiness options were not rigidly defined, and as such were open to interpretation by the VFD team. The agribusiness model explored in this report, therefore, represents a combination of Tauw's goal of developing a model around novel agribusiness solutions and water storage, and local perspectives on what the area needs and wants.

In order to develop a well-rounded and complete feasibility study, this report is divided into three general sections. The first section presents the "baseline" information of the Veenkoloniën. It is a compilation of data that has already been gathered and synthesized, as well as first-hand information gathered from interactions with representatives of interests in the Veenkoloniën. The first section also includes the problem definition as it arises from the information and perspectives from the Veenkoloniën, and the specific measures whose feasibility the VFD team will explore as a possible solution for the problem. The second section contains the basic information regarding those specific measures delineated in the first section. This represents mostly technical specifications in order to provide transparency regarding the initial decisions for what is to be included in the final feasibility assessment. The third and final section of this report includes combining the measures of the plan, based on the common term of area (be it hectares or price/hectare, for example), in order to determine what combination of measures, if any, are feasible in the area based on three possible scenarios which will be discussed in more detail later. The final component of the report will be recommendations regarding how to move forward with implementation of Tauw's original goal to combine water storage with economic development.

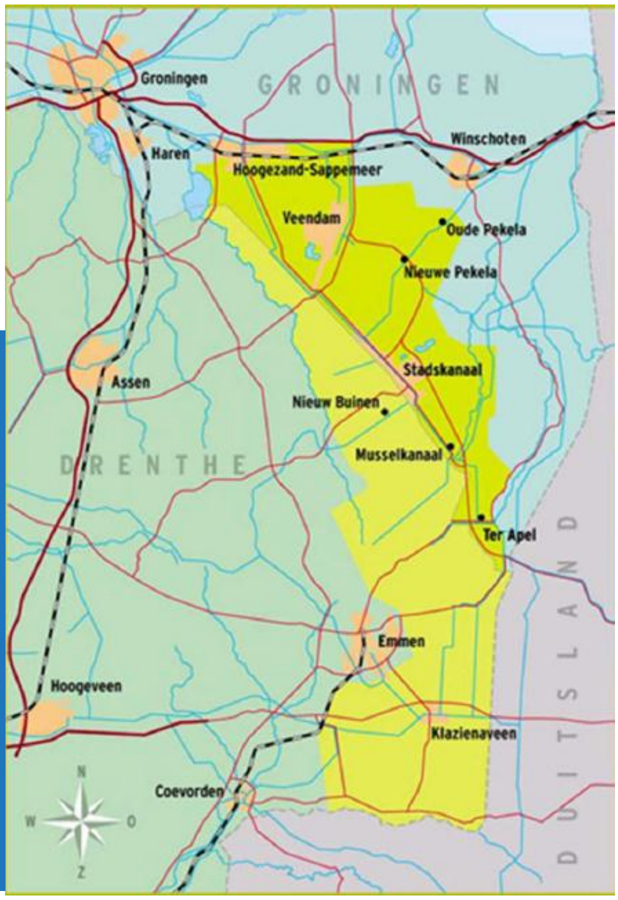


Figure 1. Map and inset of the Veenkoloniën (area in yellow).

The Veenkoloniën

Located in the northeast of the Netherlands, the Veenkoloniën is a loosely defined area of approximately 85.000 ha that straddles the border between the provinces of Drenthe and Gronginen, with the German border to the south and east. The Veenkoloniën is dominated by sandy soils throughout much of the area, although the soil has a "high" level of organic content. There is some localized peat soils, concentrated primarily in the south, near Germany. The elevation of the area varies between 1and 20 meters above NAP, and is predominately characterized by arable farm land (Durenkamp, de Wit and Zoetendal 2009). The climate of the Veenkoloniën is characteristic of the northern Netherlands and of the North Sea, with summer temperatures peaking around 25 ^{o}C and winter low temperatures between -5 and -15 ^{o}C (Royal Netherlands Meteorological Institute 2012). Precipitation in the area varies between approximately 45 mm/month to nearly 80 mm/month (*ibid.*). The landscape of the Veenkoloniën is heavily "rationalized", having been altered by humans over the course of several hundred years. A complex network of canals dominates the landscape, now utilized for agricultural purposes.

This combination of physical characteristics of the Veenkoloniën leads to certain problematic physical issues. First, the amount of intensive agriculture on such sandy soil makes the area particularly susceptible to the negative impacts of drought (Durenkamp, de Wit and Zoetendal 2009), as sandy soils lack the retention capacity of clayey soils and do not maintain soil structure well under water stressed conditions. Secondly, the channelized nature of the waterways in the Veenkoloniën (combine with agricultural and urban restrains on the waterways) leads the area to be threatened by occasional flood conditions (*ibid*.). The impacts and importance of drought and flood conditions in the Veenkoloniën will be discussed in more detail later in this section. Finally, the combination of "poor" soil conditions and variable climatic conditions makes the area not ideally suited for the kind of intensive agriculture that is practiced in the area (*ibid.*). While the physical characteristics of the area determine the initial starting conditions of our understanding, the actions of those individuals and organisations that inhabit the Veenkoloniën colour the analysis by bringing their own constraints and perspectives to the area. Therefore, we will begin to examine the uses of land in the area in terms of use-groups (stakeholders will be analysis in greater depth later in the report).

Farming

Approximately 90% of the Veenkoloniën's area is dedicated to arable agriculture (not animal husbandry) (Durenkamp, de Wit and Zoetendal 2009, de Putter 2012). This 76.500 ha is further broken down into approximately 50% starch potato production, 28% cereals, 17% sugar beets, and 5% other various crops (K. Wijnholds 2012). On a global scale, the goal of privatized agriculture, as is present in the Netherlands, is to maximize the profit of the individual farmer and to propagate the continuation of agriculture through time. In opposition to these goals, farmers in the Veenkoloniën face occasional drought and flood conditions exacerbated by the physical characteristics of the area, and made worse by increasing water demand during water-scarce times, uncertainty regarding future water supply, and changing markets. Most notably regarding the latter, European Union Common Agricultural Policy which is now supporting the starch industry with a premium system is expected to change, reducing or eliminating the starch subsidy. As a consequence, the industry and farmer's activities are threatened (Strijker 2008).

Water demand for agriculture in the Veenkoloniën is expected to rise in the future due to a combination of factors. Global Climate Change (GCC) models indicate that the average temperature of the Veenkoloniën area could increase by as much as 2 ^{o}C with rainfall dropping during the summer by approximately 100 mm (den Besten, Waterschap Hunze en Aa's Water System 2012), resulting in a growing deficit between potential crop evapotranspiration and available water. Furthermore, precipitation could rise during the winter by approximately 75 mm (*ibid.*) further straining the capacity of the agricultural drainage system. As it is, crop yield loss during the summer may be as high as 30% in extremely water poor years (Durenkamp, de Wit and Zoetendal 2009), while there has been recent local concern about flood events in the winter (*ibid.*).

The absolute number of farmers or farm enterprises in the Veenkoloniën is not well established, but several estimations have been made regarding farm size. One estimation places the average farm size at approximately 47 ha, with the average full time farming operation being 77 ha (Aquarius n.d.). Another estimation indicates the average farm size to be closer to the 100 ha mark (de Putter 2012). These figures do not accurately reflect the variability of land distribution per farming operation. Figure 2 illustrates the fact that some agricultural operations may include more than 300 ha, while others consist of less than 25 ha. As such, the VFD team has estimated 100 ha to be a more representative size for commercial, full-time agricultural operations for the purpose of this report.

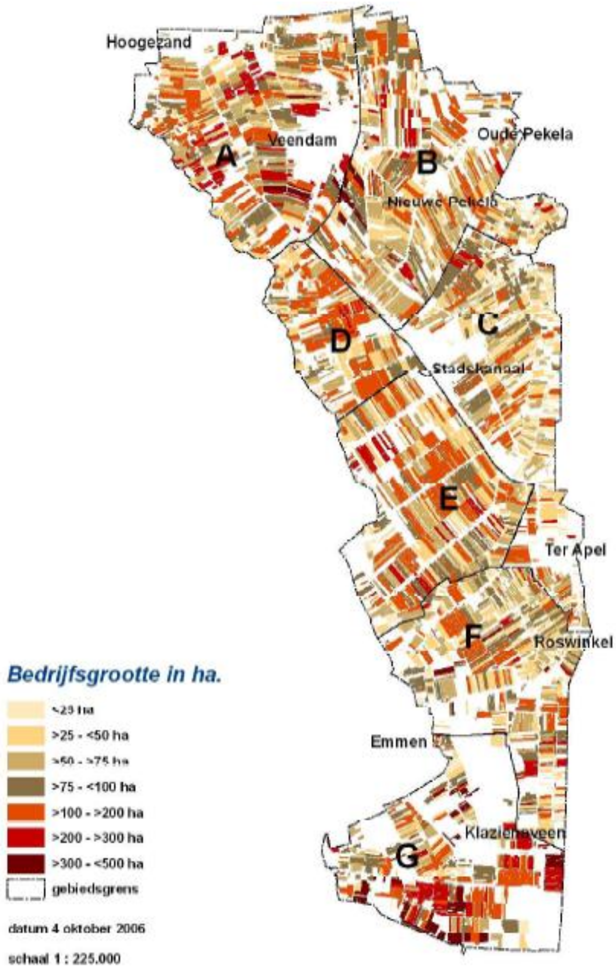


Figure 2. A map of the area demonstrating ha/farm

While the farming presence in the Veenkoloniën is large and important, agriculture is nevertheless subject to and partnered with several other social categories.

Water Management

The Veenkoloniën falls under the Hunze and Aa's water board. It is this organisations task to manage the water levels in the canals throughout the area in such a way as to maximise safety and ensure a water supply (den Besten 2012). Summer canal levels are typically set at 0,9 m below ground level while winter levels are approximately 1,3 m below ground level to prevent flood conditions. The main distribution canals have been designed with a discharge capacity of approximately 1,0 liter/sec/ha, with a supply or design capacity of approximately 0,3 l/sec/ha (*ibid.*). Furthermore, while each farmer is expected to make irrigation decisions on their own, the water board is charged with the long-term planning of the area.

In this respect, the water board is becoming increasingly concerned about their dependence on the IJsselmeer (van Slobbe 2012). Of the 100 million m^3 (Mm^3) of water that the water board supplies (de Putter 2012), approximately 50 Mm^3 is imported from the IJsselmeer for summer time use (Durenkamp, de Wit and Zoetendal 2009). This water is pumped approximately 100 km laterally and 15 to 20 meters vertically under the control of the water board. While these actions might be considered “business as usual” since the current water amount is legally guaranteed to the Hunze and Aa’s water board, increasing uncertainty over future management of the IJsselmeer means that any *additional* water demand in the area may not necessarily be met through “usual” means.

Unfortunately, the water board expects the gross amount of water they will need to supply to the area to increase from 100 Mm^3 to approximately 175 Mm^3 (de Putter 2012). If further water supply from *outside* the area were to be considered, for the perspective of the water board, the limiting factor is the capacity of the pumps that transport the water from the IJsselmeer (den Besten 2012). This implies that the pumps already operate at maximum capacity during some times of the year, and explains why the water board is exploring options regarding water storage within the area on the Veenkoloniën-wide scale.

The Hunze and Aa’s water board crosses the border of Drenthe and Groningen provinces, and is defined not as a political unit, but as a hydrological unit. Therefore, its stated goals are not political but rather strictly limited to water management.

Political Entities

The provincial and municipal governments of the Veenkoloniën express concern regarding the propagation of agriculture, economic expansion, and improving the landscape (Durenkamp, de Wit and Zoetendal 2009). The first goal relates to the relative influence and importance of agriculture in the area. As discussed previously, agricultural enterprises occupy the majority of the area, and therefore represent the major political body of the area. The second goal of economic expansion belies a more obscure issue. Common belief holds that the north of the Netherlands is socially “backwards”, and this idea is supported by a continual exodus of the younger generation from the agricultural areas to the urban centres. As such, the local governments wish to stimulate interest in the area by reinvigorating the economic image of the Veenkoloniën through novel businesses. By expanding the economic profile of the region, it is conceivable that the region might experience an influx of wealth and a reversal of population decline coupled with an improved image. This final point regarding image of the area is closely related to the third concern of the local governments. Improving the landscape is directly related to the desire to reinvent the image of the Veenkoloniën as a nice place to live and do business. However, economic expansion *and* landscape improvement is not achieved solely through governmental decree. It is instead reliant on the marriage between government policy and the local industrial goals.

Industry

There are four industrial groups that are of particular interest in this analysis. They are the starch industry and associated farmers’ cooperative, agribusiness enterprises, the sugar industry, and finally the energy production industry. As discussed previously, starch potatoes are a major crop in the area of the Veenkoloniën. These crops are grown, harvested, and processed within the Veenkoloniën. With the changing EU subsidies regarding starch and sugar (the other major crop of the area), these starch-related entities will likely suffer “restructuring” due to shifting economic sands. However, they also have goals that are aligned with the provincial and municipal goals of continuing agriculture in the area. Furthermore, the crop processing and farmers’ cooperatives of the area should be interested in exploring novel agriculture-based solutions that include storing water for future uses.

The energy production industry is a mixed group in the Groningen and Drenthe provinces. Wind power, while well established in other areas of the Netherlands, and indeed growing in the Veenkoloniën area, is nevertheless coming under fire from negative public image (van den Berg, et al. 2008). Running counter to this high-profile energy production is a low-profile interest in returning to the roots of the Veenkoloniën in exploiting the energy potential of the sun through solar and biomass. This relates back to the history of the area when large-scale peat harvesting removed up to 3 meters of peat from the area, converting it to the sandy soils it is now. However, instead of exploiting the landscape as in the past, the energy production firms of today are more interested in promoting a “clean” image in an attempt to “rebrand” the area (F. Debets 2012), which is in line with the goals discussed previously. These firms, while ready to develop the Veenkoloniën as an energy production centre, are nevertheless limited by the lack of innovation in the field of energy in the area.

The Problem

Having briefly explored the physical and social setting of the Veenkoloniën, a series of problem statement aspects can be interpreted from the information. All the issues and desires present in the area are, however, subject to the overriding goal of the commissioner which is to analyse the feasibility of an agribusiness model including water storage. Therefore, the VFD Consulting team finds these components of the problem:

1. Water demand is planned to increase in the future
    a. There is a desire to increase water independence, or to limit water dependence
2. Water excess is likely to increase in the winter over the next decades
    a. There is a desire to increase flood retention capabilities
3. The area is suffering economic and image problems
    a. There is a desire to expand the economic profile of the area
        i. Local firms are interested in expanding the energy production infrastructure in the area
    b. There is a desire to improve the image of the area
4. Alternative economic activities are expected to “pay for” water storage

In order to provide full transparency and clarity regarding the process VFD Consulting went through in the process of determining exactly what items to assess the feasibility of, it is necessary to further analyse the problem aspects. Doing so allows the team the freedom to classify the different needs and wants of the area in a meaningful way, and to provide a framework around which the feasibility study may be structured.

The Paradigm

Based on the problem aspects discussed, the VFD Consulting team selected a trifecta of themes that represent the common and related threads that run through the various problem perspectives. The three themes that guide the feasibility study are water storage, energy production from biomass, and economic development through agriculture. After a preliminary assessment of the various options through a basic SWOT analysis, the paradigm facilitated the feasibility analysis to be narrowed down further onto specific components of an agribusiness model that might move towards answering the problems identified previously. This brought farm-level surface water storage basins and groundwater storage, energy crop production for biogas and electricity generation, and greenhouse agriculture in as the components of the feasibility study.

Figure 3 illustrates the paradigm, and demonstrates how each aspect articulates back onto the others. Water stored on the farm can be used to grow energy crops. These crops are then fermented and converted to biogas which may be fed directly into the national gas grid or converted to electricity. Ultimately, the balance of income from the biomass and greenhouses then determines if converting productive land to water storage is immediately profitable. The invisible aspect of the paradigm is the stakeholders. While assessing the physical infrastructure of the plan is important, it requires a social infrastructure to operate as intended. These topics will form the mainstay of the remainder of this report, and will inform the final recommendations of the team.

Combining the components of the paradigm with the problem aspects led to the development of the guiding research topic as defined by the VFD Consulting team: Explore the feasibility of energy production from energy crops in combination with greenhouse agriculture and water storage/retention basins in the Veenkoloniën. In order to make this topic more manageable, it is broken down into smaller, more pragmatic questions.

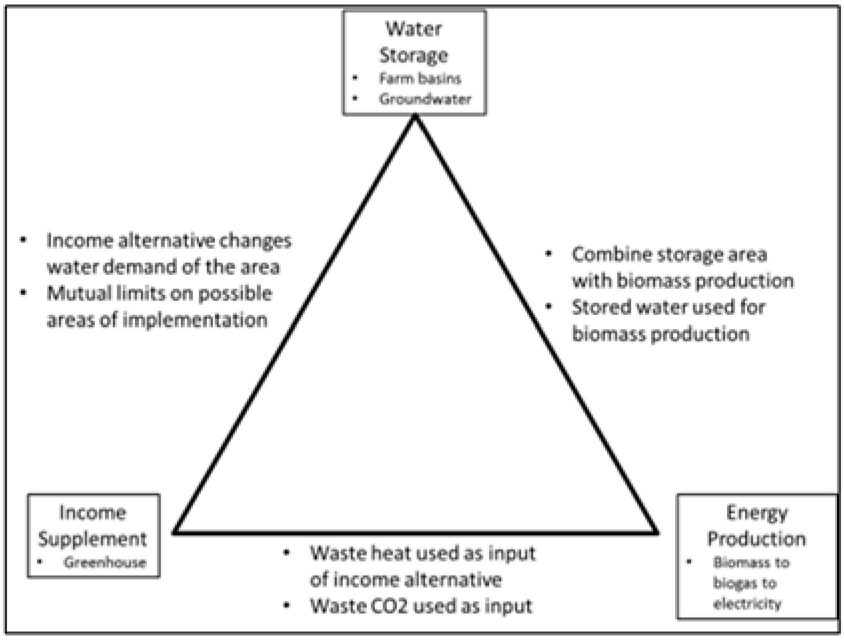


Figure 3. The paradigm, resultant components, and relationships.

Feasibility Questions

- What is the feasibility of combining energy production through biogas to electricity conversion with greenhouse agriculture to support constructing irrigation and flood retention basins under three energy-crop scenarios (3,3% of all crops for energy production, 6,6%, 9,9%)?
  - How much water is required to not increase dependence on the IJsselmeer?
    - How much area is required to store this amount?

            - How much is required per farm?
        - How will the crop scenarios change water demand?
        - How can water storage and water retention be combined?
        - What is the cost of converting productive land to water storage?
    - How can we implement a project of biogas production in the area?
        - Which feedstocks would be the most suitable to produce biogas in terms of methane yield and if relevant crop yield considering the climatic conditions, the soil quality and pathogens as well as current farmers practices?
        - What is the corresponding biogas production process considering the feedstock selected?
        - How much biogas can be produced in the area ?
    - What would be the potential profit of biogas production compared with current profit from agriculture?
    - How can we combine greenhouse industry with the biogas production in the area?
        - How many greenhouses can be supported under the energy production constraints?
        - What is the cost of greenhouse production?
        - What is the possible income from greenhouse industry?
    - What would be the profit gained by greenhouse industry from the energy and side products delivered by the biogas production plant?
        - How much electricity can be converted from this biogas?
        - How much heat and CO2 are produced from this conversion?
        - What is the possible income from electricity sales?

These questions serve to synthesize a great deal of past knowledge, with the input of additional calculation and ideas. However, the importance of these questions compared to previous studies regarding the Veenkoloniën is that they attempt to demonstrate the feasibility of *combining* several novel ideas based on local needs in an a total gross feasibility study. To move forward from the feasibility questions, it is first necessary to explore the basic technical limitations and expectations of the paradigm aspects. These initial conditions will then lead into the final assessment of feasibility in three scenarios.

Stakeholder analysis

Stakeholder analysis is one of the tools to support implementation of the agrobusiness model in the Veenkoloniën. This analysis will be used to support the feasibility analysis of the proposed plan. This analysis is defining who will need to be involved in the development of the agribusiness model. We separate the stakeholders into 3 positions: key stakeholder, stakeholder who has impact on the project, and potential stakeholder. This analysis helps to clarify the stakeholder interest related to this project and its potential benefits, particularly in the water retention, bio-energy and greenhouse. In conclusion, the structured stakeholder is providing the information to who this agrobusiness project is need to involve, thereby anticipate conflicts.

The key stakeholder are placed in the core of the project implementation; then, layered by stakeholder who has impact on the project, and potential stakeholder. A representation of the stakeholder model used, along with stakeholder examples is shown in the Figure 4 (modified from

Ishakanyan 2010). The key stakeholders should be approached to support implementation of the plan (Kitson 2008). Stakeholders who have impact on the project are indirectly related to the implementation. This second layer of stakeholders will influence the decision on the water condition and economy, which affected to the development of the agribusiness model. The potential stakeholders are the people or institution that can be related to the implementation.

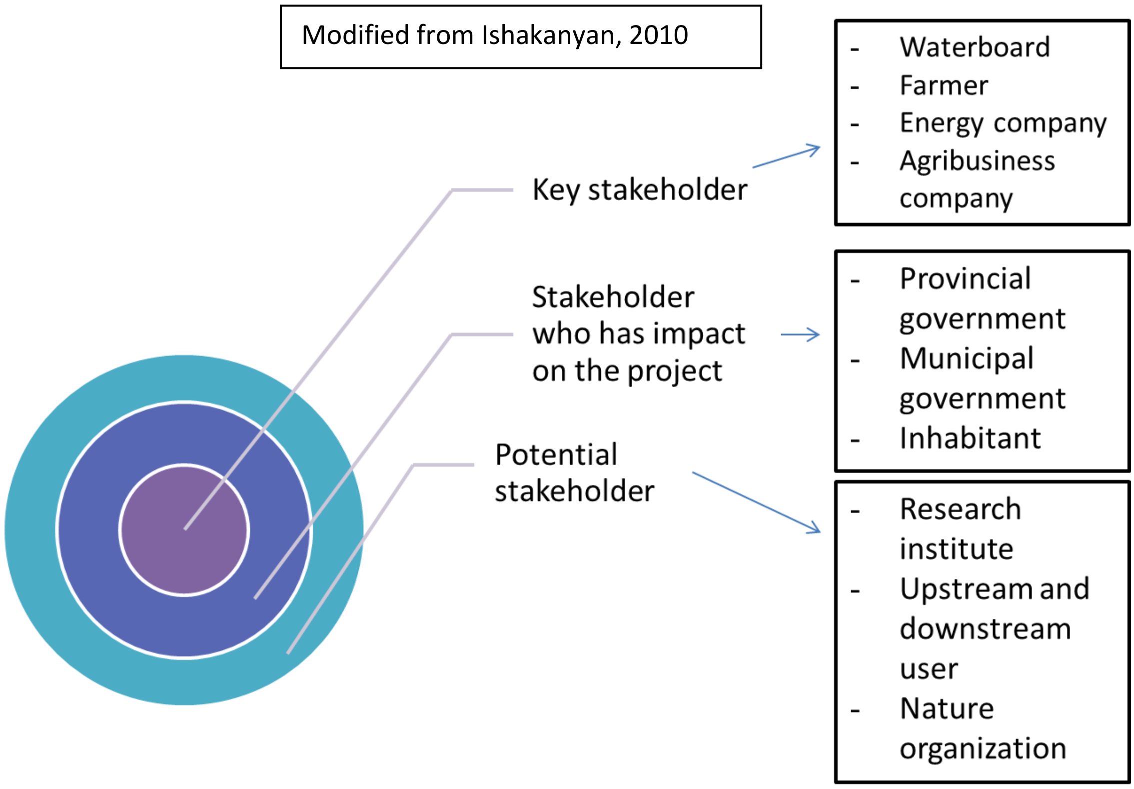


Figure 4. Scheme of stakeholder identification. Modified from Ishakanyan, 2010

Key stakeholder

Water boards, farmers, energy companies, and agribusiness companies are recognized as the key stakeholders. Their goal to achieve the aims and needs put them in the front layer of the influential people for a success project. The effectiveness of an innovation depends on the participation of the key stakeholder (Kitson 2008). The collaboration of all key stakeholders will suit this project. The water manager (waterboard) and water user (farmer, agribusiness and energy company) will deliver a good result in the water retention effort. Furthermore, the partnership of farmer with energy and agribusiness company will result in the successful economic improvement. The collaboration of the key stakeholders is expected to be part of the project implementation.

The background reason to place waterboards in the key stakeholder category is their aim to manage surface water and water quality (Junier and Moster 2011). In the Veenkoloniën, the Hunze and Aa's waterboard has set the goal for 2050 in the rural area policy to retain water in the system; therefore, suitable location and measurement is needed to achieve the goal (Durenkamp, de Wit and Zoetendal 2009). The establishment of the water retention facilities will be interested for the waterboard because it will provide them with the benefit of water regulating. Operation of the water facilities is the responsibility of the waterboard; therefore, the waterboard is one of the lead groups due to the water basis in this project.

Farmer is one of the key stakeholder groups because they are the driver of the economy through their aim to continue agricultural business. To secure their profit, farmers need to guarantee future water supply for crop growth; therefore, the development of the water retention facilities is in line with the farmer aim. In addition, farmers are the occupants of the area and the owners of the land, which is demanded for water retention facilities. If there is no farmer participation in the water retention innovation, the implementation of the project could be failed. The farmers' needs categorises them as one of the most important stakeholders.

Collaboration between the water board and water users, especially farmers, is necessary for successful implementation of an agribusiness model. The mutual benefit will be obtained in the sufficient water supply. In the long term, farmers will gain benefit from the water retention facilities; however, in the short time, the high price of converting the land to water storage will be a high investment for individual farmers. Eric van Slobbe (2012) indicated that farmers will want or expect compensation for taking over part of the responsibility of the waterboard. In short, the collaboration of the waterboard as an investor and farmer is an implementer of the project is necessary.

The second key stakeholder is agribusiness companies; besides farmers, they are working in the area and are a possible investor for greenhouse development. It is predicted that in the Veenkoloniën, agricultural land abandonment will increase and the agribusiness companies will take over (Núñez 2011). While the definition of the "agribusiness company" and "farmer" can be mixed up, farmers tend to local people who work individually and agribusinesses are external companies or cooperatives of local farmers. However, both farmers and agribusiness companies have the same aim of optimising their profit.

On the subject of greenhouses, the companies interested in the integration of bio-energy are the most potential implementation partner. The nearest greenhouse is in the municipality of Emmen is using natural gas for their energy (SREX 2008). For the project implementation, more research will be needed to identify companies with the predilection towards combining greenhouses with bio-energy usage. The interest of the agrobusiness company in the innovation will be benefit for this project. Moreover, the usage of the renewable energy from the near location, and subsidize, will interest the company.

Energy companies are key stakeholders for the purpose of investment and knowledge on bio-energy. The starch and sugar company are the most potential for partnership in the energy subject because they are also developing energy innovation. Moreover, the crops originate in the Veenkoloniën can be used for bio-energy; therefore, to build a plant in the area will appeal for investment. However, conflict between the sugar and starch industry, and energy producers might arise due to the use of the same raw materials. The partnership of the company and farmer will benefit on the security of the input availability. The potato cooperative AVEBE, which is based in Veenkoloniën, is offering the chance for coupling energy production from potato waste (AVEBE 2011). Other example is Suiker Unie, which develop bio-energy from sugar residue (Unie 2010).

Promoting the formation of a farmer's cooperative is one option for ensuring a strong economic base for the plan. The Veenkoloniën has been part of LTO (Land en Tuinbow Organisatie) Noord, an entrepreneur and employers organisation of agriculture and horticulture. The cooperative scheme can be more developed in the various subjects. Moreover, a farmers' cooperative can collaborate with companies in the process of development. Because this is a high-risk venture, individual farmers might not able to invest in suggested activities (water storage, bioenergy production, and greenhouse agriculture). For example, the collaboration of the three farmers' cooperative with Thecogas led to successful implementation of a biogas plant in Onstwedde (Thecogas n.d.). Therefore, collaboration between a farmer cooperative and established companies of bio-energy and greenhouses is an opportunity for this project.

The key stakeholders are closely related to our purposed idea. The position of the key stakeholders in the ideas scheme is intercepting each other as shown in Figure 5. The intercept reflects the collaboration of the key stakeholders. Farmers are the core of the project because they are able to cooperated with the three other stakeholders. The interfaces between farmer and waterboard is the largest extent because as an elected board, the waterboard is the farmer itself; moreover, because the waterboard is the water manager, which water is the primary need for the farmer. The intercept of the farmer with agriculture and energy company is expected to be equal in the future. Farmer will have collaboration to develop greenhouse and electricity from biogas. However, in the short time it is predicted that the extent will be larger in the agriculture company, because some companies have already been there. Furthermore, the energy company involvement is a new idea to this area.

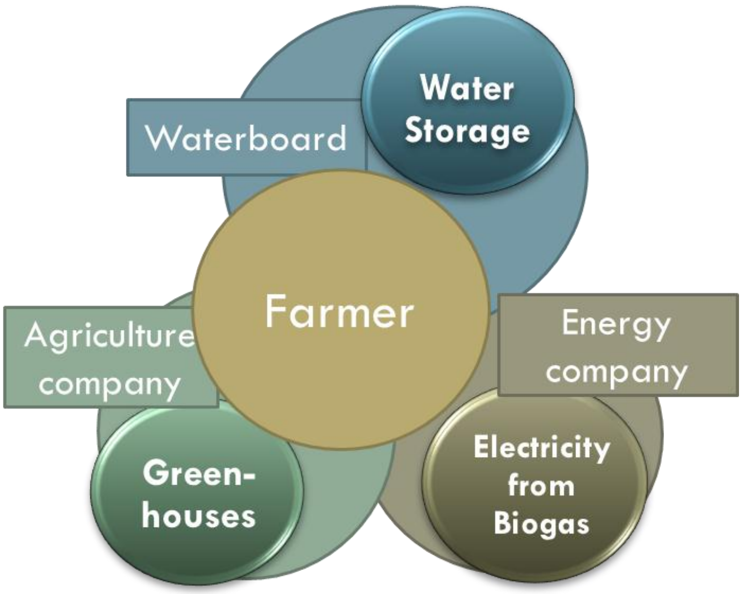


Figure 5. The position of the key stakeholders

Stakeholder who has impact on the project

Provincial governments, municipal governments, and inhabitants are identified as stakeholders who have impact on the project. They were in the second line of the stakeholders because the Veenkoloniën is part of their area and the development of the Veenkoloniën is their aim. There are 2 provincial governments and 8 municipal governments that have set their aims to develop this area (Durenkamp, de Wit and Zoetendal 2009). The inhabitants who have particular living preferences may reject or support the project. In brief, the commitment of provincial governments, municipal governments, and inhabitants of the area will impact the project implementation.

In the water management, provincial governments are assigned with spatial planning, landscape management, supervision of regional water management, and developing soil policy and soil conservation strategies (Junier and Moster 2011). These tasks are in line with the project aim in the water retention development; hence, the support for the water retention faciities is expected. The 2 provincial goverments (Groningen and Drenthe) and 8 municipalities (Hunze en Aa, Burger Odorn, Emmen, Hoogezand-Sappemeer, Menterwolde, Stadskanaal, Veenam, Vlagtwedde) have set development targets for the Veenkoloniën area. The relevant target for our project are improving the landscape and initiating new economic development (Durenkamp, de Wit and Zoetendal 2009). The project will benefit in the term of the raising of the economic activities, in which there are the secure of the water supply, the production of the green energy, the new innovation (the integration of bio-energy and greenhouse), and the new job opportunity. However, the uncertainties in the government policies can be a hindrance for the project continuity.

The inhabitants' position in the second layer of the stakeholder is related to their voting power over the landscape changes, especially regarding building and light. Veenkoloniën has facing an 'image problem' and this project is one of the solutions to improve the image (Durenkamp, de Wit and Zoetendal 2009). Moreover, it is expected that the inhabitant will support the development of the area. Employment opportunity, which is a problem of the area, will increase by initiating this agribusiness model (Thissen, et al. 2010). Because of these efforts, the improvement of the area image will benefit the inhabitant. Therefore, local, non-agricultural inhabitants will need to be convinced of the virtues of implementing the plan.

Potential stakeholder

The potential stakeholders are research institutes, upstream and downstream users, and nature organizations. Research institutes have been helping with the science and knowledge that can be applied; and also support with making 'blue prints' of the area on various subjects, such as energy and landscape. The upstream and downstream users are part of the hydrological system that flows through the Veenkoloniën, and will be affected (positively or negatively) by the plan. The nature organizations environment can have similar objections as the inhabitants discussed previously. They might oppose to the change of the landscape or support it if the area image is improving.

Research institutes have presence in the Veenkoloniën and deliver much knowledge to the area. For example, Praktijkonderzoek Plant & Omgeving (PPO), part of the Plant Science Department of Wageningen University aims to convert science into field applications (PPO 2011). PPO Valthermond has been working in the Veenkoloniën, especially in the subject of agriculture methods. Moreover, the joint collaboration of TU Delf and Wageningen University has work on the potential renewable energy (Broersma, et al. 2011). The partnership of Veenkoloniën locals (farmers, inhabitants, businesses) and research institutes is a potential link between stakeholder groups that can be utilised to make the project more socially accepted.

The upstream and downstream users are not involved directly to the Veenkoloniën development. However, water conditions are related to an area larger than just the Veenkoloniën. The upstream users are in the Friesland area, which are the water supplier to the Veenkoloniën. In the condition of water shortage, upstream user will be stressed to reduce their use. Meanwhile, the activities in the

Veenkoloniën will affected to the downstream user as they are required to deal with flood discharge. The upstream and downstream user will benefit from the water regulation in the Veenkoniën; they will less stressed and absolved from the flood effect. The upstream and downstream users have never been involved in the development of the Veenkoloniën, but their position is potential for collaboration to have integrate project; it is also applies for the nature organization. Indeed, the use of crops might raise some protest due to ethical issues involving converting land from food production to energy production.

It is unknown whether farmer willing to participate on the water basin development, which may result in further conflict between farmers and the water board. Each group may wish to invest or not invest in aspects of the project in their own way. Because of this, collaboration between these two groups will likely need encouragement. Objections from non-agriculture residents and nature organization can trigger a conflict with the parties who agreed with implementing the plan. Provincial and municipal government policy is another factor that creates insecurity in the project, for example, they may not approve of the plan if they do not feel it fully represent their vision of the area.

These stakeholder assessments will be redressed in the final recommendations of the possible scenarios, and can be utilised to *improve* the feasibility by approaching the appropriate stakeholder early in the process.

Water Storage

Reporting base values

The water system in the Veenkoloniën is a complex canal system designed to manage discharge and supply. During the wet season, the system serves only as drainage; the west of the Veenkoloniën discharges to the north collector canals then to the North Sea while in the eastern part discharges to the Winschoterdiep and Zuidlaardermeer (Durenkamp, de Wit and Zoetendal 2009). During summer, water is pumped from the IJsselmeer via two different routes. First supply is derived through Friesland (yellow arrows in Figure 6) to the north and to the south and second supply is pumped via Drenthe (red and blue arrows in Figure 6) to the north (Besten 2012).

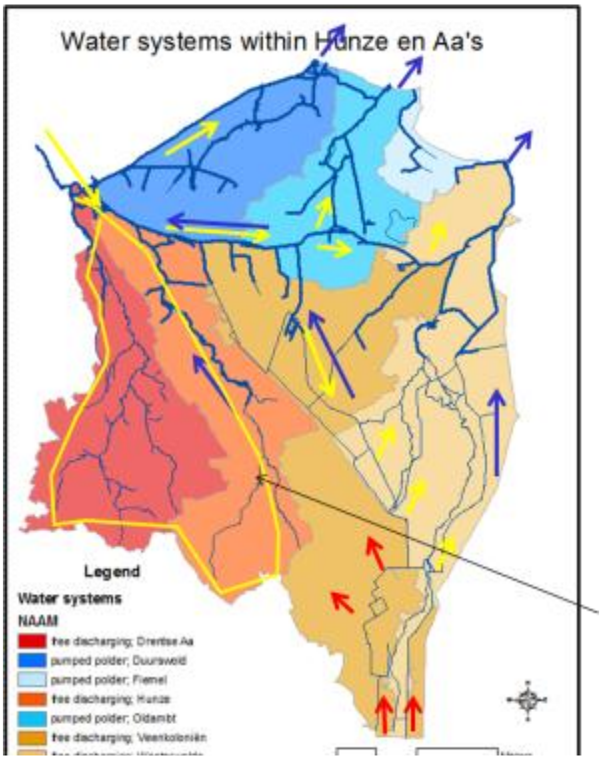


Figure 6. Water system Hunze en Aa's.
Soure: Source spécifiée non valide.

The current infrastructure to serve discharging and supply consists of main water courses (3500 km), pumping stations (135 units), weirs and inlets (325 units), dykes (28 km), regional defences (500 km) and 15 units of wastewater treatment plants (Besten 2012). This existing scheme is considered sufficient to serve the current water demand of 100Mm^3 per year.

However, due to climate change and increasing water uses especially for agricultural purposes, alternative solutions need to be considered in order to minimize increased dependency on the IJsselmeer for water supply during summer. The water board estimates future water demand will increase to 175 Mm^3 per year (56 Mm^3 for agricultural uses).

Here is the baseline water calculations based on values determined by Tauw:

Area of Veenkoloniën

- 85000 ha
- 90% is agriculture
- 85000 ha * 0,90 = 76500 ha

Future Water Supply

- 100 Mm^3 → 175 Mm^3
    - Expected increase in gross supply: 75 Mm^3
- Water supply dedicated to Veenkoloniën: 75%
    - 75Mm^3 * 0,75 = 56,25 Mm^3
- 56.25 Mm^3/76500 ha = 735,29 m = 73.53 mm = 74 mm

This increase in water demand represents the planned future scenario of the Veenkoloniën. As such, and since there is currently "just enough" water, we are considering this increase as the constant factor in our analysis. All other decisions will be based on the desire to store the amount of water required by types of crops for biogas production, so that the Veenkoloniën does not become more dependent on the IJsselmeer during the growing season in the future. Options for water storage will be temporary and permanent storages, and individual water basins on the farm level.

Calculation of storage area

The simple model to calculate roughly area required for water storage is shown in Figure 7 below.

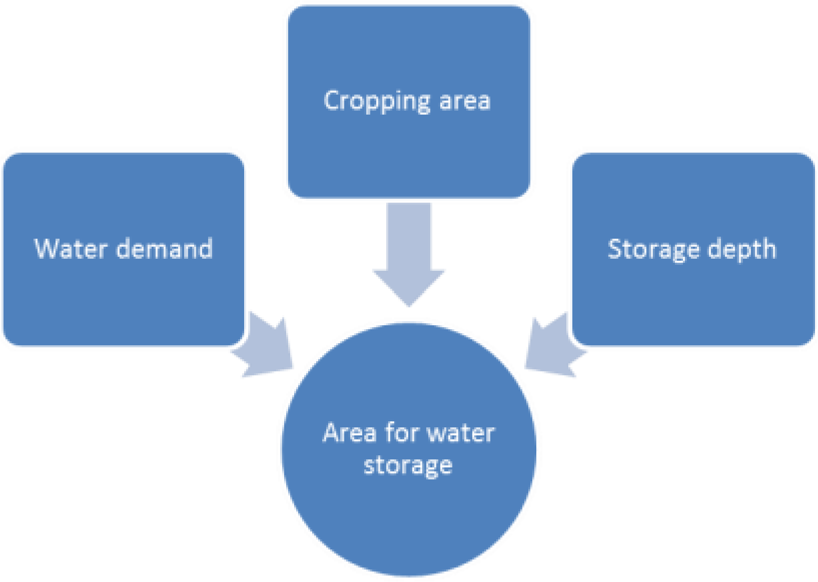


Figure 7. Design scheme of water storage area requirement.

Data required to run this model consists of water demand (m^3/ha), cropping area (ha), and storage depth (m). This groundwater deficit is equal to water demand for irrigation. Finally, the area requirement for water storage (area WS) is defined by the formula:

$$Area\ WS\ (ha) = \frac{Demand\ (m3/ha) \times cropping\ area\ (ha)}{stor.depth\ (m)}$$

Area WS : area required to build water storage (ha)
Demand : amount of water required per hectare (m^3/ha); (1 mm = 10 m^3/ha)
Cropping area : area needed for crop production (ha).
Stor. Depth : reference storage depth = 1.2 m (recommended by water board)
This formula assumes that storage depth is equal in every part of the storage area.

Application of model on the Veenkoloniën

The application of this model uses data of water demand from Tauw. In total future water demand is 175 mm or 1,750 M3/ha. Specifically for agriculture the additional future water demand is 56 mm or 560 M3/ha. Water board recommends storage depth for 1.2 m. The calculation will show two situations. The first situation corresponds to the area required for storing additional water demand (56 mm) and the second is the total future demand (175 mm) which means totally independent from the IJsselmeer.

	Total future water supply (full replacement of water board importation)	Additional water demand to meet agriculture needs only
Water Demand (m^3)	1.750.00	560.00
Area for water storage (ha/ha cropping area)	0,15	0,046

Table 1. Result of calculation for additional water demand for agriculture.

Table 1 presents that in the situation of meeting the total water demand to be totally independent from the IJsselmeer the area required to store water is 0,15 ha per 1 ha cropping area. This indicates a reduction of 15% croppable area.

In case of the other situation, 0,046 ha per 1 ha cropping area would be required to store the additional water demand for irrigation. This means a reduction of 5% farm plot croppable area. The assumption of this calculation is that water supply pumped from Ijsselmeer is not stopped while the new storage is to collect extra water demand.

Application of this result to 100 ha farming plots in combination with a greenhouse will reduce the agricultural area (see Figure 8). One greenhouse requires 10 ha.

Farm water supply

- Farm = 100 ha
- 75% of fields are “irrigated”
- 100 ha * 74 m = 74000 m^3
- 74000 m^3 * 0,75 = 55500 m^3 per farm

Size of surface storage at 1,2 m depth

- $55500\ m^3 / 1,2\ m = 46250\ m^2$ = 4,6 ha per farm

It means 15% and 25% of farm plot reduction for the first and second conditions respectively. Those reduced area of has to be dedicated to water storage and greenhouse.

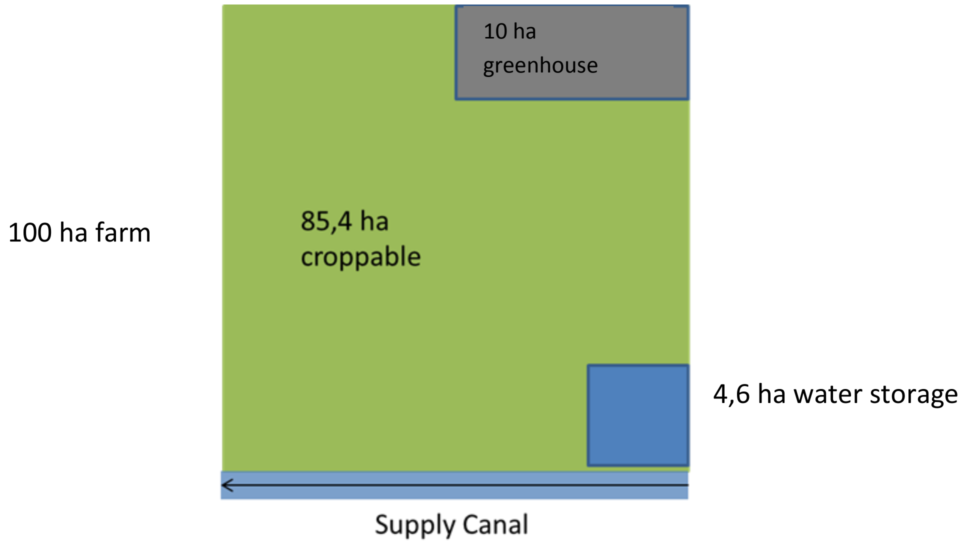


Figure 8. Diagram of idealized farm

Water storage options

Previous ACT group offers two options for water storage, temporary and permanent storage covering more than 11% of the Veenkoloniën area (Behnke, et al. 2009). These options can serve as a retention purpose as well. In the case of a temporary storage area, water can be kept for less than 6 months while for the permanent storage, it is possible to keep it longer. However, a temporary storage solution offers the possibility of using the area during the remaining year for agriculture which is not the case for a permanent storage solution. As shown in figure 8, dykes are built around a temporary storage area and water level is 0.5m. As the water level is above ground-level, to the temporary retention area can be filled only bys using pumps. In the case of permanent storage, soil is excavated 0.8m below ground surface and water level is 0.4 m (see figure 9). The permanent storage area can thus be filled by gravity.

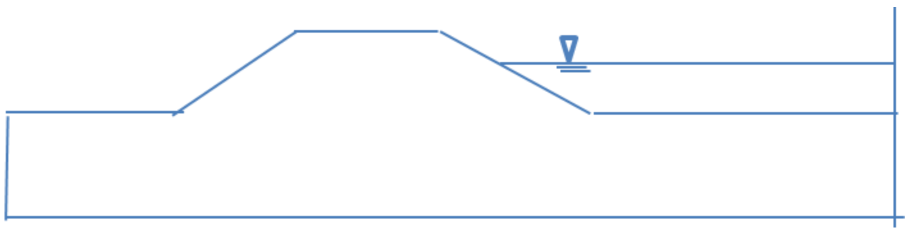


Figure 9. Temporary water storage
Source: (Behnke, et al. 2009, 11)

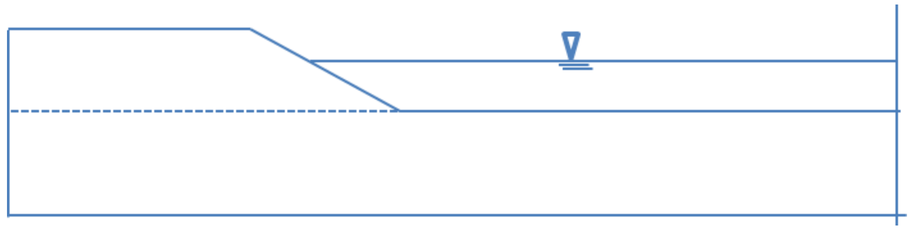


Figure 10. Permanent water storage
Source: (Behnke, et al. 2009, 11)

This previous ACT study concludes that using these two options of water retention area cannot guarantee to totally stop water intake from IJsselmeer (Behnke, et al. 2009).

Soil types in the area present a technical issue for water storage implementation (Núñez 2011). Since the area consists of sandy soil, it is not possible to store the water for long periods of time without aid (pond lining, for example). To cope with this soil type limitation, Núñez (2011) suggests that storage area can be protected by buffer zones such as ditches with high water level in order to reduce water loss. This possibility should be investigated further and in more detail.

Water Storage Strategy

The goals of local stakeholders, as discussed previously, fall into two categories regarding water. The primary goal is to ensure a water supply for irrigation into the future. With the possibility of climate change, and the insecurities regarding management of the IJsselmeer, this means not increasing the water demanded from outside sources. Given this, the goal to increase irrigation water security is to increase in-situ water storage expressly for the purpose of irrigation. The secondary goal, primarily a concern for the water board (in terms of planning, at least), is increasing water retention to prevent flooding. By utilising the concept of a “wet detention pond” (US Environmental Protection Agency 2004), altering it to take the functional use of irrigation storage into account, these problems can be approached in tandem. Furthermore, it is important to keep in mind that developing storage areas necessarily results in a reduction of agriculture area. In this sense approval of the stakholders is of high importance.

Based on the conditions described by Tauw, approximately 56 Mm^3 would need to be stored in the area in order not become *more* dependent on outside water sources over the course of a year. However, while the size of such storage, divided up amongst the average farm size, can be easily determined, it does not offer the flexibility of acting as a flood attenuation method, nor does it do anything to lessen the *current* water stress. However, by conceptualizing of the water storage as having a *base* amount of storage that should be met all year, or at least met before the beginning of the growing season, and then an additional amount of water that can be stored in times of water excess, the uses can be combined. Annex 2 presents a simple offtake design for farm-scale retention ponds. The design hinges on having two separate offtake culverts. They are designed to allow approximately 30 liters/second through as long as the canals are held at winter level (1,3 meters below surface level) or summer level (0,9 meters below surface level). These values are indicative of current standard operating procedures of the Hunze and Aa’s water board (den Besten, Group Interview 2012).

Managing the Storage

Because the supporting economic activities discussed elsewhere in the report do not require a drastic change in the crop rotation of the Veenkoloniën, the management of the storage basins should have minimal impact on the gross supply. This means that the additional water that is expected in the future should not increase. Furthermore, by filling storage basins in the Veenkoloniën during the fall winter and spring, the temporal distribution of water availability will be shifted. Since the summer is the time when the most water is needed, and therefore when the most water is imported currently, retaining water from the winter would offer relative relief from importing water. While the gross amount of supply remains the same, a portion of that supply is in fact residual water that would otherwise be allowed to flow out of the area during the wet season.

In order to achieve this, there are organizational issues that can be addressed now, and some that will need to be addressed between stakeholders later. First, the water board is in charge of regulating the canal heights (*ibid.*), and therefore the availability of water extraction out of the supply canals into the storage basins will be their responsibility. However, the storage basins will be located on private land and, possibly, privately financed. This in addition to the atomized nature of agricultural management in the Netherlands (van Slobbe 2012) means that operation of the numerous storage basins would either be manually controlled by individual farmers or automatically controlled by the water board. Each of these present certain issues. Manual control allows for a great deal of contextualization. Farmers know how much water they will need in the upcoming season, and also know what the local conditions are in along their stretches of supply canal, allowing them to take advantage of short-term surplus water availability. However, a non-centralised storage system tends to be chaotic, with many individuals making self-serving choices with little insight into the effects on the larger system. Automatic, centrally remote controlled systems, on the other hand, are generally considered more efficient (Cook 2012), and reduce the chances of human error or interference. Nevertheless, such automated systems are also necessarily reactive. Unless extreme care is taken in planning water intake and release rates, the retention ponds may not be utilised to their maximum potential. The third option is to allow for a simple automatic design with flap-gates on the pond-side of the offtake structures, which does not allow for much flexibility, but is at least predictable. Given the fact that there are already manually operated structures in the Veenkoloniën (den Besten, Group Interview 2012), this would be a suitable option for the available social and technical infrastructure.

The second issue to be addressed is examining the water levels needed to maximise water retention. As the design presented in Annex 2 establishes the baseline storage to be always filled as long as the supply canals are at their normal winter levels, the minimal amount of water storage is nearly guaranteed. The additional storage space needs to be dedicated to irrigation storage, flood retention, or combined storage and retention purposes. Because the additional water storage space is only reliably achievable if the canal levels are at their summer levels, if the space were dedicated to water storage, the canals levels would need to be raised, at least for a short period of time. This means a change in the management plan of the water board. While the system is currently managed to “maximise safety” (*ibid.*), the Hunze and Aa’s water board plan will be altered within the next 4 years (*ibid.*), and so it would be possible to consider changing canal water levels in near future. There are associated drainage issues if the canal levels are raise, even for a short time and only in certain locations, but if the filling process is managed in such a way as to minimise impact on farming operations (such as leaving sufficient time for drainage to allow tractor work in the fields), this should be a minimal issue. Alternatively, the remaining storage space in the basins could be dedicated to stormwater retention. If that is the case, the canal levels would not need to be deliberately raised, but could instead rely on natural fluctuations in the canals.

The largest foreseeable sticking points in effectively managing this kind of storage system is establishing a degree of regularity and reliability in the process of storage and use from the ponds, and the overall burden of constructing the storage basins. Regularity and reliability of offtake and release of the stored water depends heavily on interactions between the farmers and the water board. Based on the stakeholder analysis, we can say that these two groups do not have the same immediate goals, and so it will not necessarily be in the farmers' best interests to store water for a hypothetical "worst case scenario". Furthermore, having that amount of water available does incentivize increased use if there are no restrictions. Therefore, while management of the basins may be the responsibility of the landowner, it will necessarily be in close cooperation with the water board. Similarly, the farmers are likely to perceive this type of action as being forced to take over a portion of the water board's responsibility, which the farmers already pay for (van Slobbe 2012). As that is likely the case, it is probably that the water board will need to incentives or support the farmers who are willing to convert productive land to water storage. Linked to this is the total burden of constructing and maintain the storage infrastructure. While it is beneficial to have a reliable water source, the initial cost can be quite high (see Annex 2 for cost estimations). Furthermore, the opportunity cost of permanently converting 4,6 ha per farm could not be estimated in the report, but it should be expected to be quite high. To complicate the matter further, the increase in water demand is not certain, and therefore the need for this water is speculative. In order to manage the very early stages of water storage development, these barriers would need to be overcome or diminished. This is possible through further stakeholder interaction, such as public-private partnership schemes including farmers, the water board, and investors in the energy aspect of the project.

While there are some organisational aspects that would need to be changed for effective management of individual basins, the example design allows for minimal technical alterations to the extant infrastructure. This means that there are negligible external construction costs, but high, undetermined interaction costs in order to operate the system. However, in theory, securing the additional water could reduce the possible 30% yield reduction that is occasionally suffered in the area (Durenkamp, de Wit and Zoetendal 2009). Water storage, while valuable, is not the sole goal of the project. The water stored in the Veenkoloniën is stored for use on crops which, in this project, can be used for energy production. From this point on, we will examine how this water will be put to use, namely by examining the nature of the bio-energy component of our project paradigm.

The Potential of Bioenergy

The potential of biomass as a renewable energy source is large. Biomass energy technology can lead to economic and environmental benefits with regards to energy security and reduction of carbon emissions (Evans, Strezov et Evans 2010). As a result of the rising importance of environmental issues, the Dutch government deployed a new policy programs entitled New Energy for Climate action plan in 2007. The plan includes new climate and energy targets for 2020 with the aim of improving the energy efficiency of the country and reducing its impact on the environment (International Energy Agency (IEA) 2012). These targets are:

- to cut emissions of greenhouse gases by 30% in 2020 compared to 1990 levels;
- to double the rate of yearly energy efficiency improvement from 1 to 2% in the coming years;
- to reach a share of renewable energy of 20% by 2020;

Related to this policy, the Strimulering Duurzame Energie (SDE+) incentives schemes promote the use of renewable energy notably by allocating subsidies.

In the Veenkoloniën area, stakeholders have recently expressed their ambitions to exploit the potential of renewable energies in the region (Costa Due, 2009; Energy Valley, 2009; Agenda voor de Veenkoloniën, 2012). This area is a highly productive area with advanced agricultural management (K. Wijnholds 2012) and thus is presumably suitable for bio-energy production. Currently, potato and sugar beets are produced for the starch and sugar industries. These industries are relying on European Union subsidies which will most likely change in the coming years which will most likely affect the economy of the area (K. Wijnholds 2012). On the other hand, subsidies for bio based energy are increasing in Europe. Hence, farmers have to make decisions in order to maintain their livelihoods. In this sense, the green energy industry seems to be a good alternative for farmers. Two biogas production units exist nearby (J. Debets 2012) supporting the idea that the Veenkoloniën has a potential in bioenergy production.

Biogas: Current State and Perspectives

Biomass is defined by European parliament as “the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as biodegradable fraction of industrial and municipal waste" (European Parliament 2009). Biomass can be converted into various biofuels (bioethanol, biodiesel and biogas), depending on the characteristics of the biomass source (feedstock) and the production technology.

The production of biogas offers considerable advantages over other forms of bioenergy production (Weiland 2010). Contrary to conventional biofuels, biogas can be produced from a large range of organic material including vegetable and animal feedstocks and can be converted into electricity (Rutz D. 2008). Heat, a side-product of power generation from biogas, can be delivered to households or industries (i.e. greenhouses). Biogas can also be refined to natural gas quality and injected in the natural gas pipelines (Farrel et Gopal 2008).

Biogas production is gradually developing in certain countries such as Germany, Austria and Denmark where new types of farm enterprise emerged (Murphy, et al. 2011). The production of biogas energy in the European Union reached 8.3 million tons of oil equivalents in 2009 with a yearly increase of 4.3% (Eurobserv'er 2010).

A drastic change over time from conventional biofuel production (bioethanol, biodiesel) to biogas production is expected (European Environmental Agency 2006). This is the result of the development of this technology and the low yield of conventional biofuel production that makes use of oil or starch only rather than the whole plant (Rutz D. 2008). The total market potential by 2020 has been estimated to be nearly ten times the worldwide energy production from biogas in 2007 of over 90PJ /year (International Energy Agency 2007)

The Potential of Biogas in the Veenkoloniën

The ambition is to develop a biogas or biogas-to-electricity project which is the economically, socially and ecologically sound for the area by maximizing biomass and energy efficiency linked with minimizing the environmental impact within the current social framework. The following factors will be considered to assess the feasibility of the implementation of a project of biogas production in the Veenkoloniën:

- Which feedstocks offer good potential in terms of gas and production yields?
- What are the most suited processes and plant installations for the production of gas from these substrates?

These factors will be assessed in the following sections.

The choice of feedstocks

All types of biomass can be used as substrates for biogas production as long as they contain primarily carbohydrates, proteins, fats, cellulose and hemicellulose (Deublein et Steinhauser 2010)..

There are two main categories o feedstocks: wet and dry feedstocks. Wet feedstocks such as wastewaters, animal wastes and OFMSW (organic fraction of municipal solid waste) are extensively used for anaerobic digestion (Nizami et Murphy 2010). However, they are often co-digested with crops or other wastes (Weiland, Verstraete et van Haandel, Biomass Digestion to Methane in agriculture: a succesful pathway for the energy production and waste treatment worldwide 2009). Recently, the regulations concerning hygiene and nutrient recycling are became more stringent and the legal conditions are much more complicated as well (Weiland, State of the art in the dry fermentation: Future Prospects 2004), which explains why the use of energy crops and their residues as feedstocks have received considerable attention (Zhoua, Löfflerb et Kranert 2011). As shown in figure 6, energy crops and their by-products and residues are the most widely used in Germany. They represent 61.6 % of all substrates used for biogas production, whereas manure and sludge account for 27.7%. However, 83% of biogas plants operate with a mixture of crops and manure, 15% with crops only and 2% with manure only (Murphy, et al. 2011).

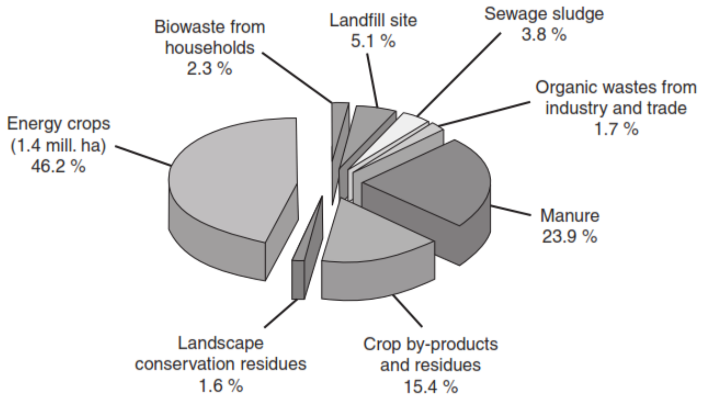


Figure 11 Substrates used for biogas production in Germany
Source: Weiland, et al., 2009

In order to select the most suited feedstocks, it is essential to consider its potential in terms of methane yield and if relevant, the crop yield considering the specific climatic conditions, the soil quality and pathogens as well as current farmers practices, and its availability in the area In the context of the Veenkoloniën area, five different feedstocks can be considered, as shown in Figure 11.

Considering the importance of agriculture in the area, the substitution of traditional crops by dedicated energy crops will be investigated as they are usually fast growing and showed to reach high biogas yield. Although traditional crops are currently produced for food production (starch and sugar), they could also be exploited for their biogas potential. Finally, the area could take benefit from the industrial, domestic and/or animal wastes which potential is currently not exploited.

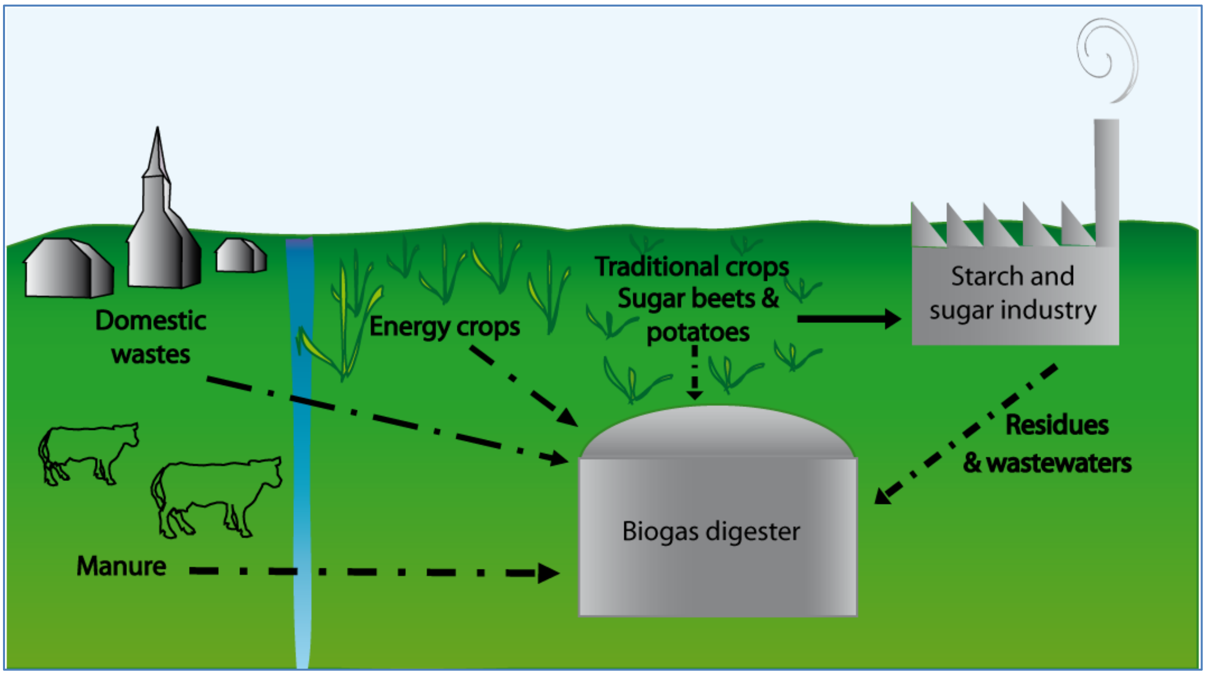


Figure 12 Schematic overview of the potential feedstocks in the area for biogas production

Currently, maize is the preferred crop cultivated in Europe for energy purposes (Heiermann, et al. 2009). This is explained by the knowledge and experience of farmers with this widely produced crop and the availability of machinery. However, a large range of crops had been studied for their methane potential in order to find the most suitable biogas crops in specific areas. Specifically, the potential of certain high biomass yielding and fast growing crops such as *Miscanthus* sp. have been investigated (Angelini, et al. 2009, Murphy, et al. 2011), the methane yield of various crops and plant material is displayed showing the variability among species.

Methane yield (m³ per tonne volatile solids added)			
Maize (whole crop)	205-450	Barley	353-658
Wheat (grain)	384-426	Triticale	337-555
Oats (grain)	250-295	Sorghum	295-372
Rye (grain)	283-492	Peas	390
Grass	298-467	Alfalfa	340-500
Clover grass	290-390	Sudan grass	213-303
Red clover	300-350	Red Canary Grass	340-430
Clover	345-350	Ryegrass	390-410
Hemp	355-409	Nettle	120-420
Flax	212	Miscanthus	179-218
Sunflower	154-400	Rhubarb	320-490
Oilseed rape	240-340	Turnip	314
Jerusalem artichoke	300-370	Kale	240-334
Potatoes	276-400	Chaff	270-316
Sugar beet	236-381	Straw	242-324
Fodder beet	420-500	Leaves	417-453

Table 2. Methane yields from various crops

Source: (Murphy, et al. 2011)

Volatile Solids refers to the portion of solids that are organic and can biodegrade.

However, the methane yield is not the only factor to take into consideration while selecting the most suited feedstock. As crop yields vary largely and their production system too, the net energy yield per hectare should be carefully examined. This factor is assessed from the biomass yield under specific climatic conditions and the energy requirement for plant cultivation, harvesting, storing and processing (Murphy, et al. 2011, Weiland, Verstraete et van Haandel, Biomass Digestion to Methane in agriculture: a succesful pathway for the energy production and waste treatment worldwide 2009).

	Maize	Potatoes	Fodder beet	Grass	Oilseed rape	Rye
Methane yield $m^3 . ha^{-1}$	5,748	9,235	6,624	4,303	1,344	732
$GJ . ha^{-1}$	217	349	250	163	51	28
Process energy demand for digestion $GJ. ha^{-1}$	33	52	38	24	8	4
Energy requirement in cropping $GJ. ha^{-1}$	17	24	20	17	17	17
Total energy requirement $GJ. ha^{-1}$	50	76	58	41	25	21
Net energy yield $GJ.ha^{-1}$	167	273	192	122	26	7
Output ($GJ.ha^{-1}$) Input (tot. Energy)	4.3	4.6	4.3	4.0	2.0	1.3

Table 3. Calculations of net energy yield and output/input ratios for a few crops.
Source: (Murphy, et al. 2011)

The potential of traditional crops, namely sugar beets and potato, barley and maize, gave promising results (Murphy, et al. 2011, Murphy et Power 2008). The main crops of the Veenkoloniën, potato and beets, have a relatively high methane yield which largely compensates their rather high total energy requirement as their output/input ratios are respectively 4.6 and 4.3 (Table 3). As those crops are currently cultivated, it would be an advantage to profit from the cultivation knowledge and the availability of machinery. It would not only facilitate the implementation of this biogas production system but would also comply with the agronomic characteristics briefly discussed in the introduction.

Field trials were carried out over three years in order to evaluate the methane potential of dedicated energy crops and traditional crops in the Veenkoloniën (Wijnholds, et al. 2010). All crops tested, that are dedicated to energy production, namely: *Miscanthus*, Jerusalem artichoke, Sudan grass, sorghum, did not reach a methane production as high as maize (7000 m^3/ha). On the other hand, sugar beets showed a high methane yield of about 8500 m^3/ha and their leaves may provide a further 1800 m^3/ha. Nevertheless, a drawback of sugar beets is the difficulty to store them without reducing their quality. Hence, solutions have to be found to preserve beets either by pre-treating them or by finding an efficient way to store them.

Even though the potential of barley in terms of biogas yield was not considered in this study, we were able to estimate its potential. Research indeed showed that it reaches an average biogas yield of 505 m^3/t (Murphy, et al. 2011). Considering an average production yield in The Netherlands of

6t./ha over the 2008-2011 period, it would thus provide 3205 m^3/ ha of biogas. Even though this value is low, barley can be beneficial through other agronomic aspects such as land productivity and landscape diversity discussed further.

An important item in the debate about bioenergy is the soil, both physical (structure, organic matter) and biological (nematodes, diseases). It is indeed of importance to take into consideration the impact of agricultural practices for biogas production on the soil fertility in order to sustain the land productivity. In the Veenkoloniën, the presence of nematodes is a well-known problem which affects productivity. In order to diminish its impact, farmers perform a crop rotation: starch potatoes– sugar beets – cereals. While selecting the most suitable crops for energy production, an emphasis is put to keep a similar rotation to reach maximal yield without reducing future land productivity. Furthermore, the landscape character created notably by traditional types of farming and its cultural value would be difficult to maintain if traditional land management is replaced by an intensive monoculture system with energy dedicated crops in the Veenkoloniën. This might impact negatively the population's perception of the area and actually increase population migration towards other areas. Hence, a switch in crops from traditional to energy dedicated crops has to be carefuly considered.

Industrial wastes and residues from the potato and starch industry (potato juice, beet-pulp, waste water, (peels, leaves) has potential for the biogas production (Fang, Boe et Angelidaki 2011, Parawira, et al. 2004, Alkaya and Demirer 2011). Indeed, wastewater from the potato processing industry is composed of a high concentration of biodegradable components such as starch and proteins which makes this feedstock highly suitable (Monou, et al. 2008). About 3.5 tons of potato-juice is produced per ton potato-starch produced (Data from Karup Kartoffelmelfabrik, 2009 published by, Fang, et al., 2011) which represents a considerable amount that is now only partially exploited. The potato starch producing co-operative AVEBE, based in the Veenkoloniën area, is currently conducting a study to produce biogas from potato wastes in order to reduce its power consumption over ten years (AVEBE U.A. 2011). Currently, the production site, located at Ter Apelkanaal in the Veenkoloniën, has a wastewater purification unit of 400,000 pollution units capacity which represents wastewater quantity from a town of 400,000 inhabitants (AVEBE 2011). From these wastewaters, a substantial amount of organic compounds could be transformed into energy. Many companies in the potato industry already invested in this technology such as Mc Cain Food (GeoTech 2012) and Lamb Weston/Meijer. The latest together with the horticulture and energy companies: Hartman and Econvert created a joint venture Halambco BV that processes residues from potato to produce heat, electricity and CO2 for the greenhouses (Agentschap NL 2011). Another example is the biogas production plant built in Groningen by Suiker Unie. The annual capacity of this plant is expected to be 10 million m^3 of biogas generated from 100,000 tons of sugar beet residues (i.e. leaves) (BioMCN 2011). Hence, the use of these wastes is not hypothetic, it has a real potential which is not completely exploited in the area. However, the investment of the industry in this technology might not benefit directly to farmers as the profitability would remain most likely within the industry.

Animal production wastes such as manure does not have a good methane yield (El-Mashada et Zhangb 2010). However, they can balance the lack of micronutrients in plant feedstocks and by doing so contribute to achieve stable process conditions and high loadings (Weiland, Biogas production:

current state and perspective 2010). Only a few animal husbandries are present in the area. Thus, the quantity of animal production wastes is limited. To benefit from the advantages offered by this feedstock, it would be necessary to purchase manure from nearby areas. However, the transportation cost would consequently increase the production costs of biogas and would also increase the environmental impact. Thus, the use of this feedstock does not seem to be suitable in the area.

Domestic wastes and sludge represent an unlimited feedstock in the area. Currently, municipalities are collecting green wastes (garden and kitchen waste) separately. Thus, it could be easily mixed with the rest of the feedstock instead of being processed into compost, which is often done at external companies. The sludge is already partially exploited by a wastewater treatment plant in the area to produce the electricity necessary for the functioning of the plant (den Besten, Group Interview 2012). Even though domestic wastes and sludge seems to be a good option, it is important to consider the constraints imposed by the regulations concerning the hygiene.

As briefly summarized in table 3, the use of animal production wastes and energy crops do not seem suitable in the area as their supply is limited or they present too many disadvantages. The use of wastewaters and residues from the potato industry appears to be a good option. However, farmers may not benefit from the investment made by the industry. On the other hands, the use of traditional crops and domestic wastes seem to be the most suitable feedstocks considering their methane yields and energy input as well as their contribution to the landscape character and considering the presence of nematodes in the area.

Feedstocks	Energy crops	Traditional crops	Wastewaters and residues from the industry	Animal production wastes	Domestic wastes
Advantages	-Potential high yield (biogas & biomass) -Potential Low energy input	-Benefit from farmer's knowledge and experience -Machinery available -Potential high yield (biogas & biomass) -Do not affect the landscape	-Do not affect food production Exploit wastes	-Do not affect food production -Exploit wastes	-Unlimited supply -Do not affect food production -Exploit wastes
Disadvantages	-Experience and new techniques have to be acquired by farmers -Affect food production -May transform the landscape	-Affect food production	-Benefit mostly to the industry rather than famers	-Limited quantity	-Constraints due to hygiene regulations

Table 4. Summary of the characteristics of the feedstocks available in The Veenkoloniën

Biogas production processes

The biological process of formation of different gases by anaerobic digestion of organic material and the production of energy from one of these gases (methane) is well known (Schön 2010). Through anaerobic digestion (AD), the organic matter is broken down in an oxygen free environment by symbiotic groups of bacteria that break down complex organic materials and convert them into hydrogen, carbon dioxide and acetate which are finally transformed into biogas (Rutz D. 2008).

As mentioned previously, the Veenkoloniën is an agricultural area based on crop production. The quantity of animal waste is limited. We will therefore consider two systems: either a co-digestion system using domestic wastes with crops and their residues/wastes, or a mono-digestion system using only crops and their residues/wastes. In order to have a better idea of the processes that could be suitable for the feedstocks proposed in the previous section, a brief review of each processing system will follow.

A mono-digestion system

Different types of biogas production machinery (digesters) may be used to process dry feedstocks such as crops. Dry digestion systems had been developed to treat feedstocks of high solid content. The two main types are continuous or batch systems. In the former, the feedstock is regularly provided and circulates numerous times through the digester. In a batch system, the feedstock is enclosed in the reactor and the liquor circulates over the feedstock. When digestion is complete, the effluent is removed and the reactor is fed with fresh feedstocks (Schön 2010). Numerous batch reactors can be used and fed successively to ensure a stable gas production over a long term. Precautions have to be taken with this type of material as cellulosic fibres are slow to degrade and can block the pumps, pipes or the mixing equipment. Furthermore, sugar beets and potatoes might introduce contaminated substrates (i.e. sand, soil) which can also get blocked in the equipment.

Concerning wasteweters, the Upflow Anaerobic Sludge Blanket technology (UASB), designed in the Netherlands by Biothane Systems in cooperation with Wageningen University is currently the main digester used to treat wastewater from the sugar and potato industry, and has the capacity to produce biogas (Zoutberg and Eker 1999, Fang, Boe et Angelidaki 2011).

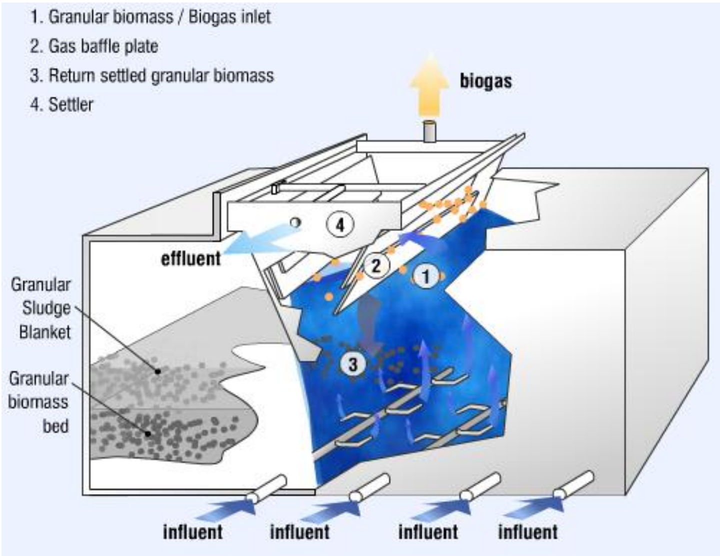


Figure 13. Overview of the UASB technology.
Source: (Biothane 2010)

A co-digestion system

Co–digestion is the digestion of a homogenous mixture of two or more substrates simultaneously (Braun et Wellinger 2003). In this case, the interest is on the digestion of crop materials together with domestic wastes.

In the past, anaerobic digestion was performed on a single substrate, mostly manure or sludge. Nowadays, more information had been collected about the limits and the possibilities of this technology and co-digestion has become more popular (Braun et Wellinger 2003). It promotes homogenous and more stable conditions within the digesters (Murphy, et al. 2011) and circumvents problems resulting from the composition of the feedstock used. For instance, potato and its industrial by-products contain high quantities of soluble organics that may be converted into volatile fatty acids (VFAs) which result in a pH drop (Weiland 2010, Monou, et al. 2008). Furthermore, phenols and proteins that are anaerobically difficult to break down might be present in potato wastewaters resulting in potential toxicity problems (Monou, et al. 2008). The use of co-substrates can improve the efficiency by maintaining a stable pH, helping the degradation of low biodegradable substrates, and accelerating the biogas production (Ma, van Wambeke et Verstraete 2008) .

Final product

Biogas can be either used for power production in combined heat and power engines (CHP) or as a fuel. As roughly 2/3 of the energy contained in biogas is transformed into heat in CHP units, the use of this thermal energy should be assured all year round to profit from all the potential of biogas. The greenhouse industry requires large amount of heat and represents therefore a potential user of the thermal energy produced. This will be discussed in more details in the next section. Alternatively, the purification of biogas to natural gas quality may allow better use of the biogas energy as there is no energy transformation necessary and therefore no loss. For this reason, grid injection is increasingly aimed by biogas plant operators (Braun, Weiland et Wellinger 2010).

Biogas purification

Upgrading or purification of biogas is essential to be able to sell this gas through a gas grid or use it for machinery. The composition of (raw) biogas is ±60% CH_4 (methane) including impurities such as CO_2 (±29%), H_2S and water. If H_2S is not removed, it will corrode vital mechanical components within engines, for example the co generator. Several methods exist to purify biogas. The water scrubber technology is the most common and consists of the incorporation of water in counter-flow, scrubbing the CO_2 and other trace elements. (Rutz D. 2008). This can result in a methane concentration of 98%, guaranteeing a maximum of 2% methane loss in the system. The cost is varies between €0.04/$KWh_{upgraded\ gas}$ and €0.015/$KWh_{upgraded\ gas}$ depending on the capacity of the upgrading plant (Jönsson 2010).

Access to the gas-grid

Several factors have to be taken into consideration to assess whether it is viable to inject biomethane[1] into the natural gas-grid. First, the capacity of the gas-grid may be limited, especially in certain periods of the year (summer) when gas consumption is low *(van Asselt 2012)*. Secondly, the distance of the biogas plant to the gas infrastructure should be evaluated in order to know the investment necessary to reach it. As the location of the biogas plant is unknown for now, no investigation had been done on the gas infrastructures in the area. In this case, it is not of our knowledge where this infrastructure is located. Furthermore, the biomethane should comply with certain standards. It is indeed necessary to bring the biomethane on the right pressure. The degree of compression is dependent on the network in which the biogas will be injected. The Veenkoloniën falls in the Enexis Noord network *(Energie Data Services Nederland 2004)* which uses a pressure of 8 bar *(Enexis 2011).* For safety, a certain smell is also added. All these requirements and the supply should be well monitored.

A possibility to overcome the cost to access the gas-grid is the construction of a biomethane-hub, which is a collective pipeline where multiple biogas producers can supply their biogas. This hub is directed towards a central upgrade station where the biogas is upgraded. By this way investments are shared and can guarantee the delivery of gas to the energy company. As mentioned previously, there are at least two biogas producers present in the close area of the Veenkoloniën. Hence, collaboration could be an interesting option if the project of biogas production is implemented in the Veenkoloniën. For information, a project was initiated in Friesland: Biogasleiding Noordoost Friesland

[1] In the following sections of this report, the term "biogas» refers to the intermediate product after digestion, prior purification. It contains ±60% methane. The term "biomethane" refers to the final gaseous product after digestion of biomass and purification. It contains more than 95% methane.

(BioNoF) which consists of the construction of a hub and a pipeline between Leeuwarden and Dokkum.

It is unsure at this stage of the project whether it is feasible to deliver biomethane through the current gas-grid. More information should indeed be gathered to evaluate the investment necessary.

Legal aspects

The installation of a digester requires an environmental permit under the following category: Ww. This permit is part of the environmental permit. It can be refused if the structure does not fit the zoning (Wabo, Article 2.10) (Wageningen UR 2011). The legal procecedure may take 2 to 3 years as it also involves most stakeholders in the area, among them local residents (van Asselt 2012).

Implementation of a biogas plant Veenkoloniën

There is a general trend towards the production of biogas in Europe as an alternative source of energy which is driven by national policy and incentive. As a source of diversification and development, the potential of biogas was considered in The Veenkoloniën. The potato cooperative AVEBE is currently considering a potential investment in this technology to treat starch potato processing wastewaters and simultaneously producing energy. This technology had been already successfully implemented in other companies such as McCains. As this technology requires a high investment, collaboration with the industry seems to be a good opportunity. On the other hand, farmers need to diversify their sources of income in order to be less dependent to the sugar and starch industries that may face difficulties due to a change of EU subsidies policy. For this purpose, feedstocks other than wastewaters from the starch and sugar industries, and their corresponding processing systems, were examined. The most suited feedstocks, in terms of biogas yield as well as agronomic and ecological aspects, proved to be the current produced crop: sugar beet, potato, maize and barley. Typically, two digestion systems exist: mono-digestion and co-digestion system that processes respectively a single type of substrate or, two or more substrates simultaneously. Co-digestion systems based on crops and manure are the most frequent due to the advantage that both substrates offer. As the Veenkoloniën is a crop production area with only few animal production farms, the supply of manure might be problematic. Hence, replacement of this co-product by domestic wastes or the use of a mono-digestion system might be more suitable in this case. In the last section of this report, the feasibility of biogas production in the Veenkoloniën will be assessed in more details following three different scenarios: 3,3%, 6,6% and 9,9% of agricultural land conversion from current use to energy production in combination with greenhouse industry. Preceding this feasibility study, the potential and requirements of the greenhouse industry in this area will be described in the following section.

Greenhouses - a competitive industry in Veenkoloniën.

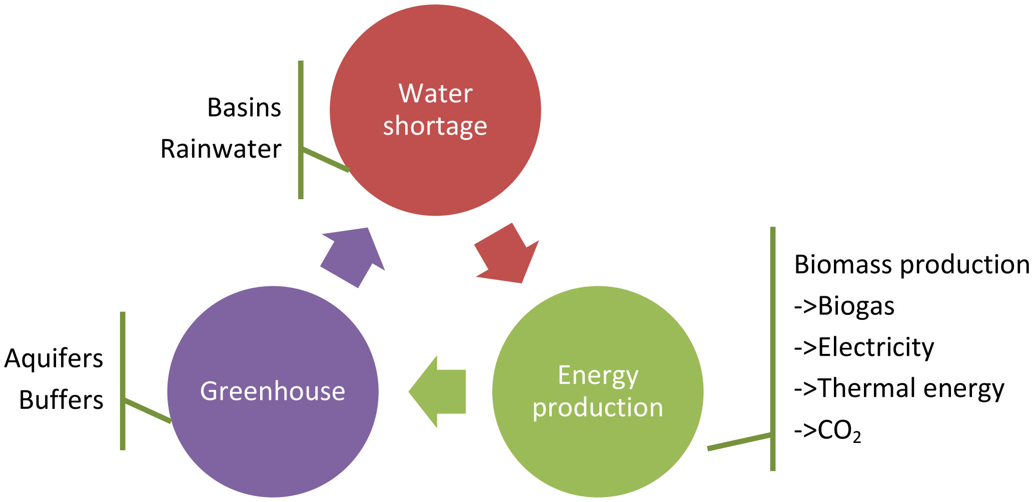


Figure 14. Greenhouse as an alternative income in the agribusiness model linked to the specific needs of the project.

Energy

As it is mentioned before there are the possibilities of bio gas production by biomass fermentation. Here is the critical point that shows if greenhouses are applicable or not.

The biomethane produced in the area could be delivered to the greenhouse. Through co-generation, also called combined heat and power (CHP) generators, the biomethane could be converted by a heat engine or a power station in electricity and heat simultaneously. Heat from the engine cooling system and the exhaust gas is extracted by a heat exchanger and then used as a low temperature heat source in greenhouses, a process that also produces CO_2 which can be used by greenhouses to enhance crop production With the use of CHP generators, 50% of energy is converted into thermal energy and 44% into electricity. Considering electricity production, the efficiency appears to be rather low as a larger amount of energy is lost as heat. Still, it is a good alternative for conventional electricity production even without the use of heat, as a coal plant has the same efficiency but a higher CO_2 emission. The tipping point in profitability of a co-generation system occurs when the selling price of electricity exceeds the price paid for biogas by a margin that covers system operating costs (Figure 15). It is advised that co generators operators will only run their cogeneration engines when electricity prices are high and the 'spark spread' is the greatest. In the case that the electricity price is low, it is possible to store heat and operate back up boilers to meet heat demands if necessary. The Netherlands has a liberalized energy market and the government has created substantial feed-in subsidies to support the cogeneration industry and achieve political targets for greenhouse gas reduction and improved energy efficiency. Greenhouse vegetable operations are

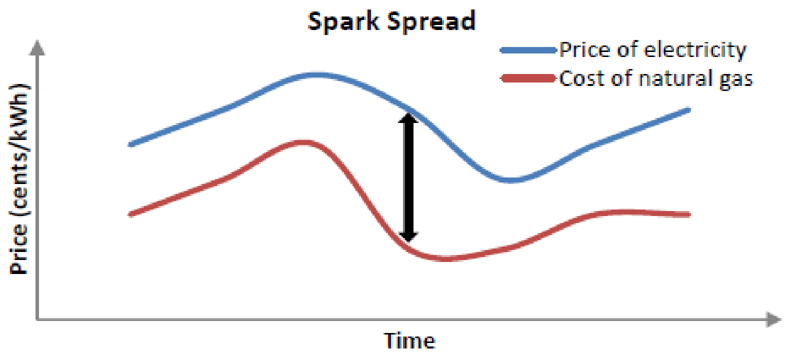


Figure 15. The margin between natural gas purchase price and electricity sale price.

more apt to consider cogeneration than floriculture operations due to the higher heat demand and benefits of CO2 fertilization for vegetable crops.

Figure 16 shows how CHP engines can be connected to existing greenhouse infrastructure to supply heat, electricity and CO2 to the facility. In practice, CHP engines will not completely replace natural gas boilers. A combination of the two systems will be necessary to maximize efficiencies and meet seasonal heat demands of the greenhouse.

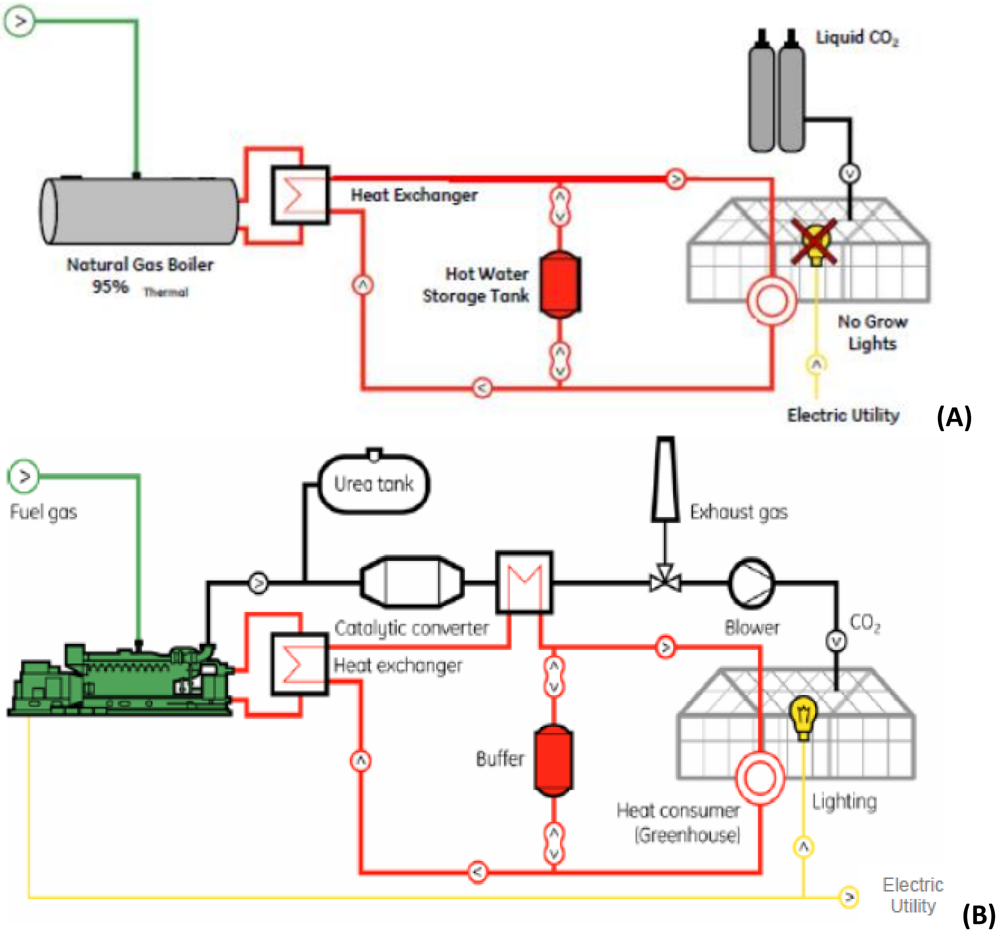


Figure 16. (A) Natural gas Boiler system as source of thermal energy for greenhouse with extra liquid CO2 . (B) CHP Generator for electricity production and thermal energy production for greenhouses.

A small amount of electricity produced will be used in the greenhouse. Compared to heating requirements, electricity requirements are relatively minor in greenhouse operations. The bigger amount of electricity is used for the lighting requirements which can be reduced by efficiency savings oppportunities (using supplemental lighting when partial light is sufficient, or using LED lights between crops in addition to sodium vapor overhead lights) as well as ventilation fans (installing energy efficient fans and variable speed drives on base-load fans).

Thermal energy can be used for heating up a system with greenhouses where it can be used directly (during the winter), or it can be stored in aquifers or basement buffers (during the summer) for later use. Also, the waste CO_2 from the conversion process can be used for the enrichment of the greenhouse air and reduce the emissions. However, CO_2 that is used in greenhouses to increase crop yields must be relatively pure. This can be simply accomplished using emissions from natural gas combustion. While using biomethane, it is important to monitor well the purification before the delivery of biomethane to the greenhouse industry. In the absence of pure CO_2 from natural gas combustion, greenhouse growers would have to purchase liquid CO_2, typically from sources outside of the burn process, or adopt additional technologies to purify CO_2.

Unfortunately, CO_2 demand at greenhouses does not correspond with heat demand. CO_2 demand is the greatest during summer months, when crops are growing rapidly and setting fruit. At this time, CHPs would be idled back because heat demand is lower. The solution will be that CO_2 is stored or sold to the food industry, when CHP operating hours are maximized, meaning that the excess CO_2 will be generated or liquid CO_2 can be imported to meet CO_2 demand during the summer. When CHP operating hours are maximized, CO_2 demand of greenhouse crops is actually the lowest, meaning that excess CO_2 will be generated.

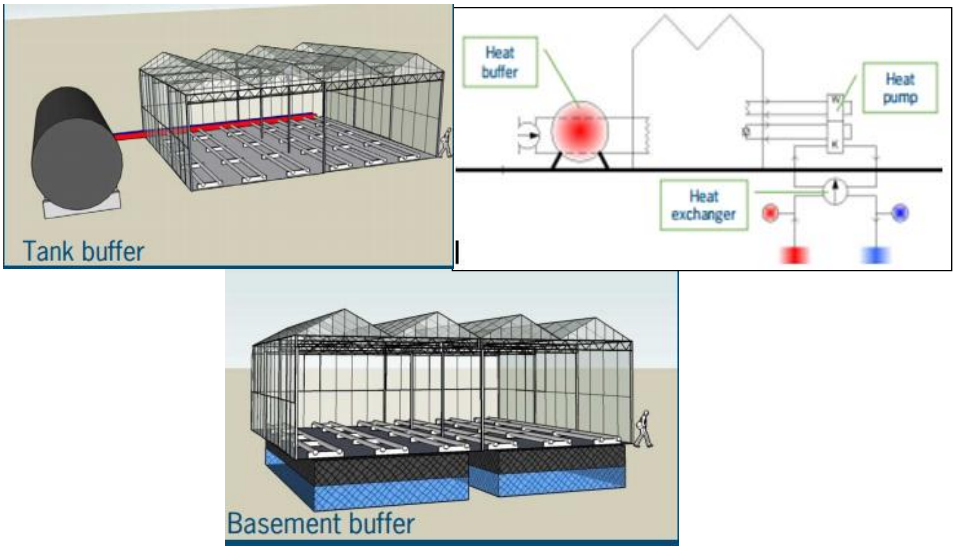


Figure 17. Types of buffers and aquifer system.

Buffer types that are made for short or long term storage of heat water (Figure 17). Tanks buffers are made for short term storage whereas basement buffers or aquifers are made for long term storage. The role of buffers is to handle peak heat demand. Buffers allow lower capacity equipment with lower costs. In coupled production processes of heat and CO_2 (central boiler) or heat, electricity and CO_2 (co – generator) buffers help to partially or fully decouple these processes. In case heat is generated as a result of energy production, generating CO_2 or energy management buffers are needed to store the excess of heat.

In order to meet the needs for thermal energy and CO_2 load it is advised to combine co – generators with normal boilers as it is shown in Figure 18.

Aquifers are not analyzed in this report because it was not possible to reach information about the subsoil levels in the area. It is not clear if the subsoil meets the requirements for using it as aquifer. However, in the implementation sector greenhouse needs are calculated with and without aquifers.

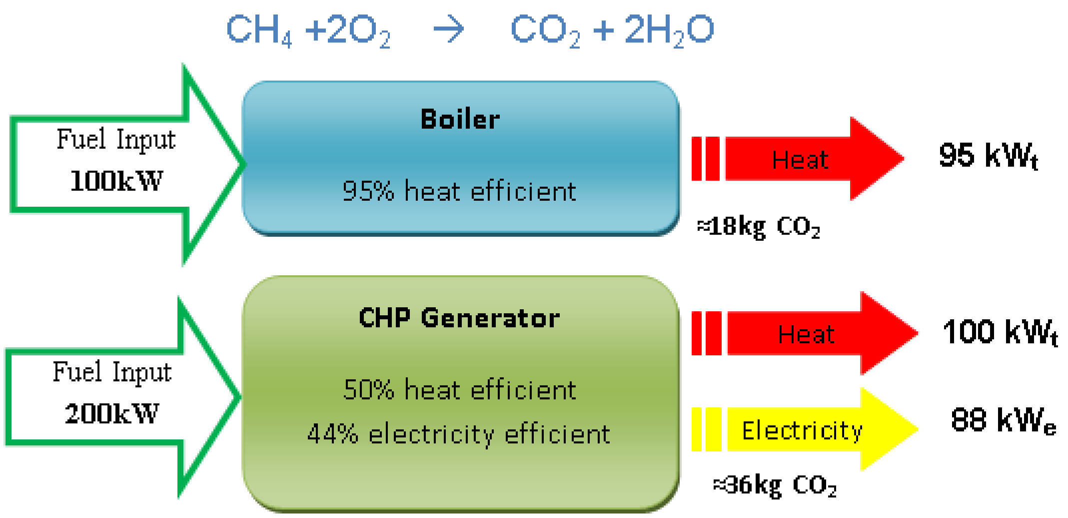


Figure 18. Energy input and output for normal Boiler and CHP Generator with CO2 production.

Water needs

Both availability and quality of water are of high importance. A greenhouse requires approximately 800 - 1000 l/m^2/year. The water that can be used for irrigation can be rain water, well water, drinking water or surface water. In regards to quality and cost, the best choice is rain water and well water. The fluctuation in this amount of water comes from the different irrigation systems and cultivations. Choosing the best combination you can reduce the need to 800 l/m^2/year.

The water requirement for greenhouses increases as insolation increases. There is a rough estimation of about 2,5 ml per J irradiance per m^2. This means the greenhouses have higher water needs during the summer period, and this will need to be addressed in the water storage recommendations. Precipitations in the area (Figure 19) can provide the greenhouse by rain collection up to 770 l/m^2/year and there is an absence of 30 l/m^2/year. This amount of water can be stored from the surface water during the periods that there is excess of water for later use. Rain water harvesting and storage in rain basins with an input of the surface water can make the greenhouse almost water neutral and contribute in the water shortage problem during the summer.

Figure 19. Average monthly precipitations (rain/snow) in Groningen, Netherlands.
Source: (http://www.weather-and-climate.com).

Implementation of greenhouses

Table 5 Calculations for 10 ha greenhouse with and without aquifers.

	Biogas demand (m3)	Electricity produced (kWh_e)	Heat produced (kWh_t)	CO_2 produced (kg)	Area needed to produce the biogas (ha)	Rain water storage m^3	Construction cost (€)	Production profit (€)
Without aquifers	4.500.000	22.037.400	25.042.500	90.153	765	5.000	12.000.000	4.020.000
With aquifers	2.250.000	11.018.700	12.521.250	45.077	382	5.000	12.000.000	4.020.000

The above calculations are based on the heat demand that is needed for heating a normal size greenhouse of 10 ha that produces tomatoes. Knowing the heat demand per m_2 greenhouse and the efficiency of the co-generator it was calculated the amount of biogas that is needed. As it is described in Figure 18 44% of the input energy (bio gas) is converted to electricity, 50 % is converted to thermal energy and 0,36 kg of CO_2 are produced per 200 kWh bio gas. The rain water storage was calculated by the obligation by law for storing rain water which also meets the storage requirements. The construction cost was based on a rough estimation for a Venlo Dutch type greenhouse (€120/m²). The profit of the productions is based on an assumption of trash tomato production of 60kg/m2/year and a price of 0,67€ per kg (LEI Wageningen UR 2012). The use of aquifer reduces the heat demand by 50%.

The water needs of a 10ha greenhouse for annual production is 80.000 m^3. Collecting and storing the rain water in rain basins can provide the greenhouse with 77.000 m^3. The rest 3.000 m^3 will be provided from the surface water. Comparing the greenhouse water needs with the needs of 10ha arable land in Veenkoloniën that needs 13.100 m^3 of water (based on future demand) it is shown that implementing greenhouses can contribute to water shortage in the area.

Feasibility of the 5 Scenarios

Water storage scenario 1: Ignoring future demand increase

Scenario 1 is the baseline of the following four scenarios. During a wet season, excess of water is discharged to lakes in the area and eventually the North Sea. During summer time, water is pumped from the IJsselmeer to the canals in the area, to prevent drought to occur. The current water supply is similar to the demand (100 million m^3) in the area. Existing canals have the capacity of discharging of 1 liter/sec/ha and supply 0,2-0,3 liter/sec/ha. Currently, water supply for agricultural purposes is sufficient.

Water storage scenario 2: Fully meeting future demand increase

Due to climate changes, the future prospective is that there will be an increase of water demand in the Veenkoloniën. At the moment there is a demand of approximately 100-million m3. For the year 2050, this will increase of 75% up to a number of 175 million m^3 water.
As mentioned earlier, the practical expected extra future water demand is 74 mm or 735 m^3/ha. As known, the water supply of the IJsselmeer is already at its maximum, hence the need for extra water storage in the area to continue with the current activities considering the production of crops. To store this extra water demand, there are several options. The most feasible options are groundwater storage and storage on farm-level by basins.

When basins on farm-level scale (100ha) are applied, one farm has to build a water storage system of 4,6 ha (with a basin depth of 1,2m). When all farmers do this, 700 separated basins will be constructed, resulting in a total water storage surface of 3.220ha (for the area of 70.000ha). This 3.220ha of water storage basin can store an amount of 38,6Mm3 water (3.220 ha x 10.000 x1,2m). This number indicates that the supply from the IJsselmeer cannot completely stop. The storage will be filled with rain and surface water during the wet season and can be used during summer time.

The loss of benefit from the crop production due to the construction of a water storage basins will be €1.902,00/ha. An area of 3.220 ha will than give a loss of profit of € 6,122,935.

According to a previous (ACT) study by Behnke, et al (2009) there are two extra options for storing water, temporary and permanent storage that cover more than 11% of the Veenkoloniën area. Following this study, water is kept in temporary storage (less than half a year) and permanent storage (more than six months a year). The area that will be changed into a temporary storage can be used for agriculture during summer. This is not the case for the permanent storage. Dykes are built to surround the temporary storage and give a water depth of 0.5m. It is indicated that the temporary retention area has to be filled by using a pump. In the case of a permanent storage, soil is excavated 0.8m below ground surface and water level is than 0.4m. By gravity this permanent storage will be filled. This water can be used for agriculture during (a dry) summer time.

Biomass crop scenarios

The biomass crop scenarios will make use of Water storage scenario 2: Fully meeting future demand increase as the basis. Additionally, agricultural land will be converted from food production to energy production in order to supply a biogas digester aimed to produce biomethane. Farmers would therefore sell or deliver their products to the biogas operator instead of their current customers (mainly starch and sugar company) at a value based on the average of the market prices (table 6).

Table 6: Average prices, biogas potential of the 4 crops considered for the 3 scenarios

	FEEDSTOCKS				
	crop	**sugar beet**	**potato**	**energy maize**	**barley**
1	yield (t./ha)	76	42,6	75	6
2	price (€/t.)	43	48	12	168
3	price / ha (€/ha)	3.265	2.044,8	900	1.064
4	biogas potential (m3/ha)	10.300	12.780	6.900	3.201,5
5	proportions	17,0%	50,0%	16,5%	16,5%

1 Average yields in the Netherlands : [2008 -2010] : (de Bont, et al. 2010) Except maize : (Agri Holland 2012)

2 Average prices in The Netherlands : [2008-2010] : (de Bont, et al. 2010) Except maize : (Agri Holland 2012)

3 Price / ha = Yield (t,/ha)* Price (€/ha)

4 Based on data from field trials in the Veenkoloniën area (Wijnholds, et al. 2010)

5 (K. Wijnholds 2012)

As mentioned previously, the crops that are currently produced are suitable to use as a raw material for the production of biogas. Hence, the crop rotations and crop proportions remained almost the same as the current situation: 50% potato, 17% sugar beets, 16,5% maize, 16,5% barley (table 6). In these scenarios, we will not take into account the domestic wastes and industrial wastewaters and residues as we do not have enough information to support our calculations. The calculations are therefore based on the surface available for crop production dedicated to energy production (table 7). The biomethane produced would be sold to an energy company or delivered to the nearby industry, such as horticulture at a certain price.

Table 7 Biomethane potential production and costs based on surface available and feedstock characteristics

	6	7	8	9	10
Biomass Crop Scenarios	Surface available (ha)	Biogas potential (m3)	Biomethane (m3)	Cost (feedstocks) (€)	Cost (purification) (€)
1	2.310	22.655.897	13,593,538	4,392,540	2.269.441
2	4.620	45.311.793	27.187.076	8.785.081	4.538.882
3	6.930	67.967.690	40.780.614	13.177.621	6.808.324

6 Respectively: 3.3%, 6.6% and 9.9% of total agricultural area in the Veenkoloniën (70.000 ha)

7 The calculation is based on the current crop rotation and proportions : Surface (17% Sugar beets biogas potential +50% Potato biogas potential + 16,5% energy maize biogas potential + 16,5% Barley biogas potential)

8 Biomethane = 60% of biogas

9 The calculation is based on the current crop rotation, proportions and prices: Surface (17% sugar beet price + 50% potato price + 16,5% energy maize price + 16,5% barley price)

10 Based on a cost of €0,015 / KWh upgraded gas (Jönsson 2010)

Through the use of the co-generation technology, greenhouse industry would convert the biomethane into thermal energy and CO2 to meet their needs and the electricity produced could be sold to the energy company. In return, the greenhouse could provide with waste products from the production of different plants/vegetables. Additionally, when conversion of crops takes place (usually once a year), a large volume of waste material is available to be used in the digester to produce biogas.

The implementation of (extra) greenhouses in the Veenkoloniën area will also have influence on the water demand. With the ability to run a greenhouse water neutral, the water demand will decrease compared to the current arable crops. Taking into account the poor soil quality and the increasing water demand, the implementation of a greenhouse might be very successful (figure 20).

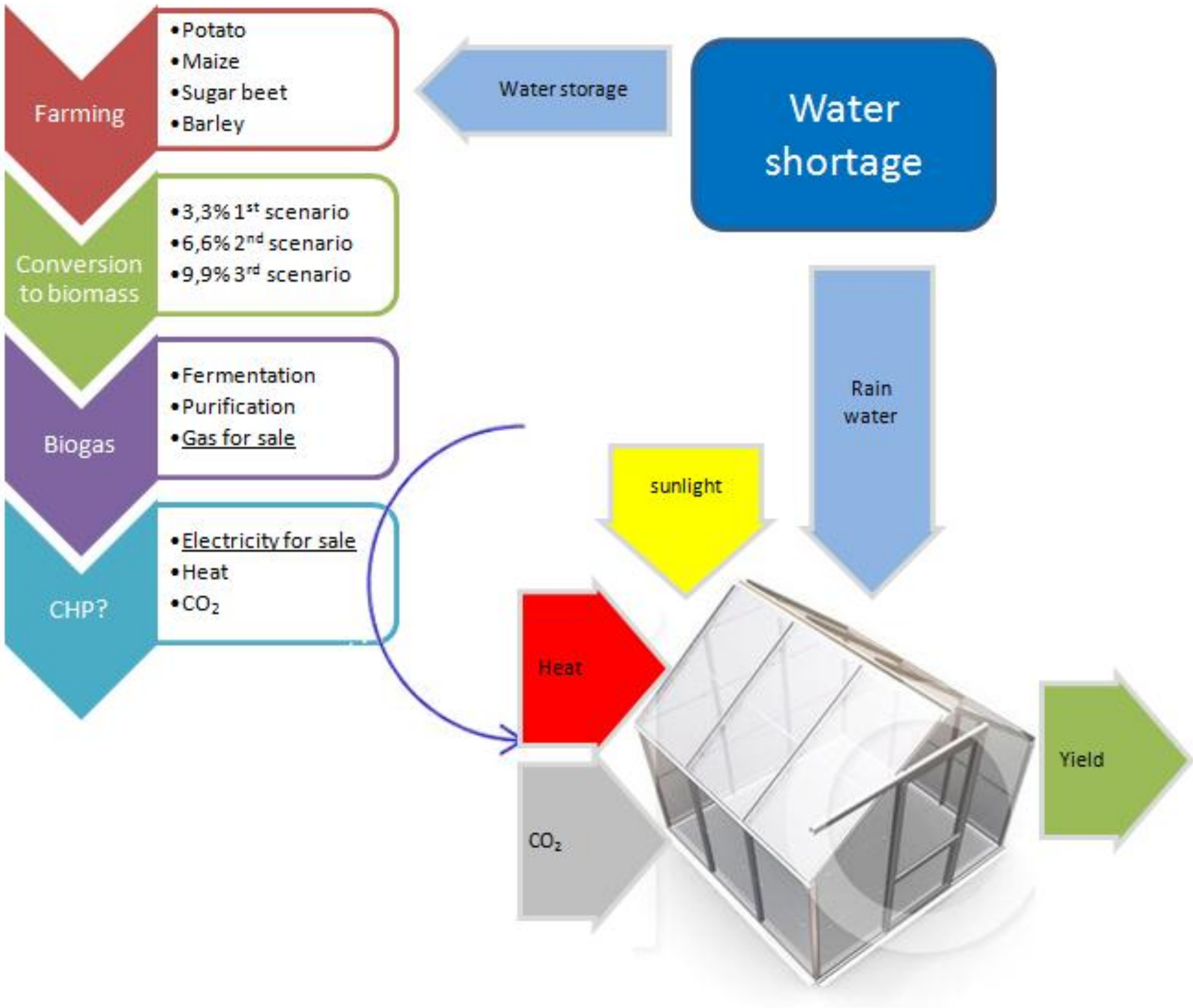


Figure 20 Overview of the combination of biogas production with greenhouse industry

Three scenarios were designed as follow: 3,3%, 6,6% and 9,9% of agricultural land converted from food production to energy production .The outcome from these scenarios will be briefly described. All calculations are performed for one year. Details and reference values are in table 7, 8 and 9.

Biomass crop scenario 1: 3,3% conversion into energy crops

Considering a conversion of 3,3% of the current crop production area (2310ha), the expected biogas produced annually from the crops delivered at the biogas plant would be 22,7Mm3 biogas. After purification, the volume of biomethane recovered would be 13.6 Mm3. Assuming that the crops delivered to the biogas plant would be purchased at their average value over a three years period (2008-2010), this cost would be €4.392.540. Based on an average charge of 0,015€/KWh, the purification operation would cost €2.269.441. The capital and operational costs are unknown. If this biomethane is injected in the grid or delivered to the nearby industry at the grid price, the profit would be €1.385.393 including feedstocks and purification costs but excluding capital and operational costs. This value is based on SDE+ subsidies (€0,592/Nm3) (annex 3).

This volume of biogas could supply a production surface of 30ha of greenhouse. While converting biomethane into electricity through co-generation, an amount of 5,98 GWh of electricity, 6,80 GWh heat and $12{,}2 \times 10^{6}$ kg CO_2 could be produced. Assuming that all the production area is dedicated to tomato production, the profit would be €12.060.000 (excluding capital and operational costs).

Biomass crop scenario 2: 6,6% conversion into energy crops

As previously, the calculations were performed with 6.6% of crop land (4620 ha) used for energy production. An amount of 45,3 Mm3 biogas could be produced annually. The feedstocks and purification would respectively cost €8.785.081 and €4.538.882. A profit of €2.770.786 could be made.

With this volume of biogas, it would be possible to supply a total greenhouse area of 60 ha. Through co-generation, it would produce 12 GWhe of electricity and 13,5 MWht of thermal energy and 24.509.971 kg of CO_2. Assuming that all the production area is dedicated to tomato production, the annual profit would be € 24.120.000.

Biomass crop scenario 3: 9,9% conversion into energy crops

If 9,9% of the current crop production (6930 ha) is dedicated to energy production, an amount of 68Mm3 biogas can be produced on an annual base. The feedstocks and purification would cost €13.177.621 and € 6.808.324.

With this volume of biogas, it would be possible to supply a total greenhouse area of 91ha. It would produce 18GWhe of electricity and 20,4 GWht of thermal energy and 36.764.956,41 kg of CO_2. Assuming that all the production area is dedicated to tomato production, the annual profit will be €36.582.000.

A summary of the output for the three scenarios is visible in table 8 and 9.

Table 8 Biomethane profit and costs in comparison with the current production profit

11	12	13	14
biomethane			current production
Profit (€)	Profit - Cost (€)	Profit - Cost (€/ha)	Profit (€/ha)
8.047.375	1.385.393	600	1.902
16.094.749	2.770.786	600	1.902
24.142.124	4.156.179	600	1.902

10 Based on a cost of €0,015 / KWh upgraded gas (Jönsson 2010)

11 Based on SDE+ subsidies: 0.592€/ Nm3 * Volume of biomethane

12 Profit - (Cost of feedstocks + Cost of purification)

13 Profit - (Cost of feedstocks + Cost of purification) / Surface available

14 Value of crops / ha based on the current crop rotation and proportions and crop prices

Table 9 Output of the calculations for the requirements and profits for the greenhouse industry

	15	16	17	18	19	20	21	22
Biomass Scenario	Biogas used (m3)	Total biogas price (€0,247/m3)	Electricity produced (kWhe)	Heat produced (kWht)	CO2 produced (kg)	Surface (ha)	Profit from electricity (€)	Production profit greenhouse (€)
1	13.593.542	3.357.604,75	5.981.158	6.796.771	12.254.985	30	311.618	12.060.000
2	27.187.083	6.715.209,50	11.962.317	13.593.542	24.509.971	60	623.237	24.120.000
3	40.780.625	10.072.814,25	17.943.475	20.390.312	36.764.956	91	934.855	36.582.000

15 Based on the heat demand (van T'Oosten, 2012)

16 Cost of biogas (Grid cost) (Agentschap NL 2012)

17 Based on conversion of CHP generator (Greenhouse technology MSc. Course, 2010)

18 Based on conversion of CHP generator (Greenhouse technology MSc. Course, 2010)

19 Based on conversion of CHP generator (Greenhouse technology MSc. Course, 2010)

20 Based on the heat production of 100% biogas conversion in electricity

21 Based on grid price (Agentschap NL 2012)

22 Based on real data in 2010 (LEI Wageningen UR 2012)

This feasibility study gives a rough idea about the potential of the combination of biogas production and greenhouse industry. As shown on table 8, the profit of biogas production is estimated at €600/ha (exluding capital and operational costs). We based our calculations on the market prices of the crops which explains a low profit as these feedstocks have a high value. However, it means that the profit is an extra income for farmers by selling energy (€1.902+€600=€2.502).

Recommendations

Water Storage

Based on the content of this report, certain conclusions may be drawn about water storage in the Veenkoloniën, and certain recommendations may be made. First, regarding the technical design of the water storage, individual basins are technically feasible on the farm-level, but they definitely complicate the management scheme. In order to meet the goals of farmers, the water board, and the commissioner, it is recommended that the storage basins be designed with outlets that allow for offtake from multiple canal levels. This increases the flexibility of storage in include stormwater retention. While these basins would be dug into the ground, having multiple levels of offtake allows for the possibility of gravity-filling. This reduces the gross cost of the construction.

The management implication of a variable offtake water storage basin is that the water supply will *also* need to be variable. In order to maximize the storage capabilities of the design discussed above, the water levels in the canals would need to be altered. In the example (LINK TO ANNEX), maintaining summer water levels during the winter would ensure that the basin was completely filled and prepared for irrigation purposes. This change in management has the additional benefit of purposefully planning in the possibility of winter storms that raise the canal levels. This can then serve to smooth out the hydrograph of the supply canals, retaining the water in the area to be released in a controlled way at a later time. According to the estimations of this report, the total possible "stormwater" storage (water storage in addition to the baseline storage for irrigation) per farm is 18.800 m^3 or 18 mm per farm. This extra storage can then go to reducing the *current* water stress.

Each basin results in a minimum cost of approximately €240.000 (€52.000/ha). Farmers are unlikely to be willing to convert productive land to water storage, especially if it requires investing this sum of money on their own. It is therefore advisable to pursue the path of joint cost-sharing between stakeholders. The water board, farmers, and energy production investors are the most likely and suitable stakeholders to approach for initial buy-in to the project, although others such as local industry (potato processing, sugar processing companies) are not out of the question.

Water Storage Management

Managing the water storage so that it does not interfere with normal operation of the already extant system is the only way to ensure the long-term feasibility of the project. Pursuant to this, it is recommended that the Hunze and Aa's water board and the individual land owners or farmers collaborate from the very initial phases of implementation. Farmers can provide valuable insight into the immediate future water requirement changes, so that the water board will not necessarily be forced to operate in a reactive manner. Conversely, if the water board is clear about their timing and flow needs, the farmers will be able to adjust the infrastructure themselves, reducing the need for expensive equipment. Alternatively, in order to ensure consistent operation, the water board can retain full control of the infrastructure via remote control.

Because of the importance of the farmers and the water board, efforts should be made to approach them first. Gaining the support of the water board not only opens access to relatively large amounts of funds, but it also reaches out to the more active farmers who are most likely to be board members themselves.

Since the other aspects of this project were designed with the Veenkoloniën's current agricultural conditions in mind, the overall water demand of the area is not expected to change beyond what was already planned for by the water board. This means, instead of necessitating an uncertain increase to be considered, only the planned supply increase is absolutely needed to be considered. This supports the goal of not increasing the dependence of the area on outside water sources. However, simple design alterations to a standard wet retention pond allows for additional water to be stored either due to intentional changes in supply canals levels or unexpected storm-related pulses. Such storage basins on the farm-level complicate the management landscape of the already existing infrastructure, but these barriers can be overcome, and as such are feasible given sufficient investment incentive. Further research is needed about the social and legal impacts of the water storage methods and cost0sharing strategies recommended.

The potential of bio-energy

There is a potential for the production of biogas in the Veenkoloniën area. Although high expenses are necessary to invest in this technique and the calculated profit in this report might be low, the prospective for the future look promising. There is a large interest in stimulating the development for the production of green energy from the government, hence the providing of the SDE+-subsidies.

A reason why the outcomes of the feasibility study is reasonably low, might be caused by the usage of eatable products (mainly potatoes and sugar beets) which have a high value. An alternative, and ethically a better accepted option, would be the usage of "waste" products. Also there is a probability that the sugar and starch industry will not accept the change of the purpose of the produced crops.

A change of crop production had been also investigated, but it does not appear to be profitable in terms of biogas production. One of the weak points of the area is the poor soil, which only gives room for the growth of a limited number of crops. Most likely this will lead to a reduction of productivity due to the agronomic characteristics of the area and might also affect the landscape.

Waste products in the area can be supplied from the sugar and potato industry, but there also might be other (waste) products available. The main idea is that the raw products do not have a purpose as a food product. Ethically it might be contradicting to use eatable products while famine still occurs worldwide. This might also contradict with the aim of the area which improving their image into "green" and "sustainable". One of the recommendations will be to research on the opportunities to use waste products produced in the area, instead of implementing different types of crops.

More research should be done into the type of digester needed for the conversion of solely crops (mono-digester) and its productivity. It might be the case that a co-digester with manure might give a higher productivity with the crops or waste products from the area. In this case, the lack of manure might become a problem in the Veenkoloniën.

Also more research should be done on the location the digester should be built in regards of the energy/gas grid and the industry. In this report, the infrastructure of these two grids was not researched. In order to be profitable it is better to combine the biogas reactor with a nearby industry to use their waste products and deliver them biogas or heat, CO2 and electricity when biogas is converted with a co-generator/CHP. This would also reduce transport costs of all the material and investment in expensive infrastructure for the gas and electricity grids.

Considering that the use of wastes would be more acceptable and profitable, and the reluctance of the industry to use their raw material, it would be of interest to collaborate with the industry in a way to make it profitable for all (farmers and industry). As AVEBE is an agricultural cooperative, they should be eager to meet farmer's interest as well as their own need.

Greenhouse recommendations

Converting biogas to electricity will make the greenhouse industry in the Veenkoloniën competitive. The tipping point in profitability of a CHP system occurs when the selling price of electricity exceeds the price paid for bio gas by a margin that covers the system operating costs. In the scenarios it is calculated the amount of greenhouses that can be supported with heat if all the biogas is converted to electricity. That gives the option to either invest in the area and install greenhouses or provide nearby greenhouses with bio gas where you get the benefits from the advantages of a CHP system while you get rid of the high investment needed. In case of implementation in Veenkoloniën it is advised that all greenhouses should be placed close to a central area where digesters and CHP units are installed. In this way, the transportation costs and heat loss will be eliminated. Also no extra investment in the construction of new infrastructure for the gas/electricity grid have to be made.

Conclusion

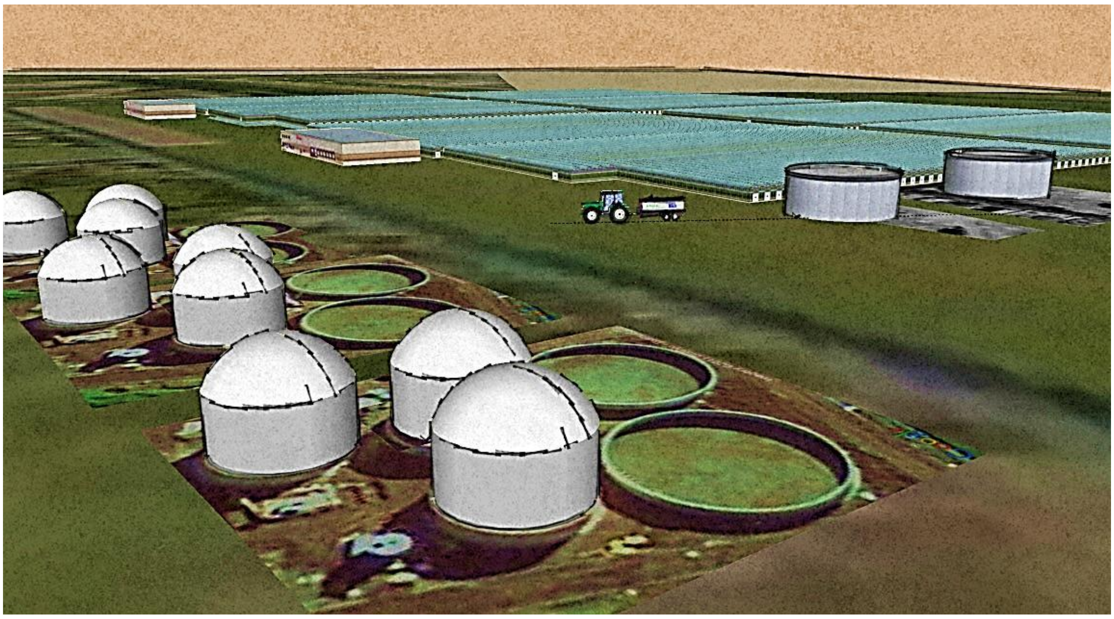
In this report, the VFD Consulting team explored the possibility of developing greenhouse agriculture, bioenergy production, and water storage in the Veenkoloniën. The conclusion is that these three items are feasible under the specific conditions and assumptions delineated in the report. Each component of the project has its own constraints and limitations, and are all subject to the social will of the stakeholders of the area.

Water storage in individual farm-level basins are feasible for both irrigation storage and stormwater retention if the offtake from the supply canals are set for variable canal levels. Similarly, the management of the canals needs to be altered in order to maximize stored water. This water can then be utilized by directly pumping it out onto crops, or by releasing it back into the supply canals when the water levels are low. In either case, the stored water would then go on to support the production of energy crops for biogas.

Energy crop production in the Veenkoloniën has the benefit of not requiring any significant change in cropping patterns, as the area already produces high-energy crops such as potatoes and sugarbeets. This means that the bioenergy production has no negative impact on the water demand of the area. Selling crops for energy benefits both the crop producer and the energy producer. The producer receives the “grey energy” price, and the subsidy still applies to the energy production. The resultant biogas can either be directly sold to the national grid, or it can be converted to electricity, depending on which is more profitable. Converting biogas to electricity has the additional benefit of producing “wastes” that can be used in the final aspect of the project.

Greenhouse agriculture is only feasible in the Veenkoloniën in combination with the above aspects, in addition to sufficient stakeholder investment. However, there are incentives to combining greenhouse production in the plan. Greenhouses expand the local economic profile, and offer a high-grossing crop for income purposes. The combination is especially suited for the plan when the availability of heat and CO_2 from the conversion of biogas to electricity is considered.

The stakeholders of the area will play a very big role in the possibility of implementing the plan. The key stakeholders need to be approached from the earlier phases of implementation in order for the plan to be financially viable. In terms of water, the farmers and water board at the leading stakeholders to convince and bring on board. Bioenergy production is most reliant on the farmers who grow the crops and energy development companies who invest in bioenergy production. Finally, the greenhouse aspect of the plan will be reliant on the farmers and agribusiness companies. The extant cooperatives and industry will play a secondary role to the overall feasibility of the plan components.



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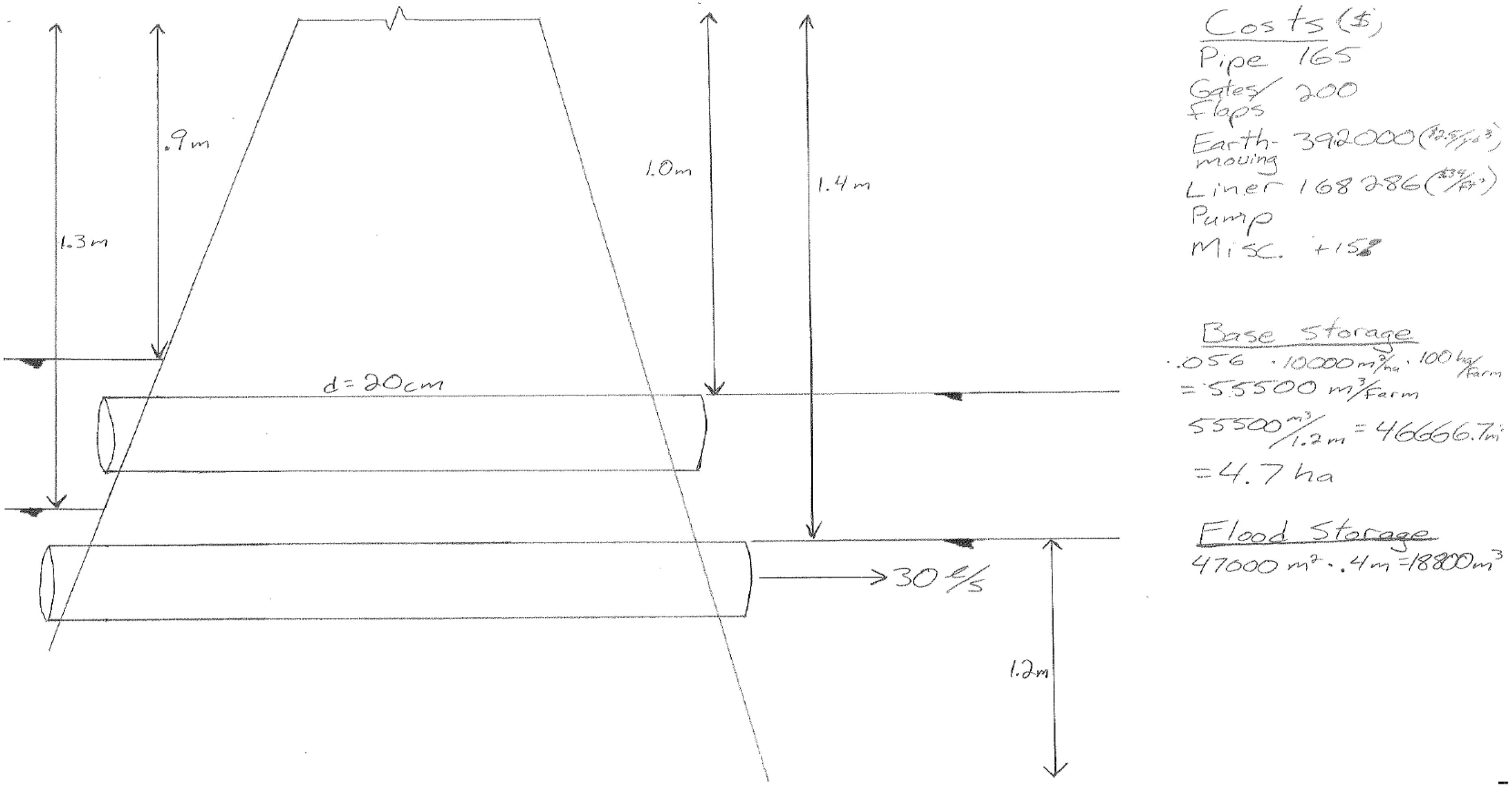
Annex 1. Expected subsidies for 2012 from SDE+ incentive

Source: (Verhagen 2011)

Fase	I	II	III	IV	V
elektriciteit	7 €ct/kWh	9 €ct/kWh	11 €ct/kWh	13 €ct/kWh	15 €ct/kWh
groen gas	48,3 €ct/Nm^3	62,1 €ct/Nm^3	75,9 €ct/Nm^3	89,7 €ct/Nm^3	103,5 €ct/Nm^3
warmte en WKK	19,4 €/GJ	25,0 €/GJ	30,6 €/GJ	36,1 €/GJ	41,7 €/GJ
Datum	di 31 jan	di 3 apr	di 5 jun	di 4 sept	di 6 nov
	Verlengde levensduur allesvergisting (groen gas) (48,2 ct/Nm^3)				
	Uitbreiding van bestaande biomassa thermische conversie en vergisting (warmte) (6,3 €/GJ)				
	Uitbreiding van bestaande AVI (warmte) (6,3 €/GJ)				
	Ketel vaste biomassa ≥ 0,5 MW (warmte) (10,9 €/GJ)				
	Geothermie (warmte) (10,9 €/GJ)				
	Allesvergisting solo en hub (warmte) (14,8 €/GJ)				
	Mestcovergisting solo en hub (warmte) (17,7 €/GJ)				
	Verlengde levensduur biomassa verbranding (WKK) (18,7 €/GJ)				
	Geothermie (WKK) (18,9 €/GJ)				
	Allesvergisting hub (WKK) (19,2 €/GJ)				
	Vrije categorie (7 ct/kWh) (48,3 ct/Nm^3) (19,4 €/GJ)	Waterkracht met verval ≥ 5m (elektriciteit) (7,1 ct/kWh)			
		Verlengde levensduur mestcovergisting (groen gas) (55,1 ct/Nm^3)			
		Allesvergisting solo en hub (groen gas) (59,2 ct/Nm^3)			
		Ketel vloeibare biomassa ≥ 0,5 MW (warmte) (20,8 €/GJ)			
		Thermische conversie biomassa >10 MW en <100 MW (WKK) (22,2 €/GJ)			
		Mestcovergisting hub (WKK) (22,5 €/GJ)			

Fase	I	II	III	IV	V
elektriciteit	7 €ct/kWh	9 €ct/kWh	11 €ct/kWh	13 €ct/kWh	15 €ct/kWh
groen gas	48,3 €ct/Nm^3	62,1 €ct/Nm^3	75,9 €ct/Nm^3	89,7 €ct/Nm^3	103,5 €ct/Nm^3
warmte en WKK	19,4 €/GJ	25,0 €/GJ	30,6 €/GJ	36,1 €/GJ	41,7 €/GJ
Datum	di 31 jan	di 3 apr	di 5 jun	di 4 sept	di 6 nov
		Vrije categorie (9 ct/kWh) (62,1 ct/Nm^3) (25,0 €/GJ)	RWZI/AWZI (elektriciteit) (9,6 ct/kWh)		
			Wind op land (elektriciteit) (9,6 ct/kWh)		
			Mestcovergisting hub (groen gas) (70,8 ct/Nm^3)		
			Mestcovergisting solo (groen gas) (72,9 ct/Nm^3)		
			Verlengde levensduur mestcovergisting (WKK) (25,9 €/GJ)		
			Allesvergisting solo (WKK) (27,3 €/GJ)		
			Vrije categorie (11 ct/kWh) (75,9 ct/Nm^3) (30,6 €/GJ)	Waterkracht met verval ≥ 50 cm en <5m (elektriciteit) (11,8 ct/kWh)	
				Wind in meer (elektriciteit) (12,3 ct/kWh)	
				Mestcovergisting solo (WKK) (30,8 €/GJ)	
				Zonthermie ≥100 m^2 (warmte) (36,1 €/GJ)	
				Vrije categorie (13 ct/kWh) (89,7 ct/Nm^3) (36,1 €/GJ)	Biomassa-vergassing (groen gas) (97,5 ct/Nm^3)
					Biomassa thermische conversie ≤10 MW (WKK) (38,2 €/GJ)
					Vrije categorie (15 ct/kWh) (103,5 ct/Nm^3) (41,7 €/GJ)
	Technologieën die alleen in aanmerking komen in de vrije categorie: wind op zee, energie uit vrije stroming, osmose en zon-pv.				

Annex 2. Basic design of a storage basin offtake from a supply canal



Annex 3.SDE + subsidies

		Fase 1 - 13 maart, 9:00 uur tot 1 mei 2012, 17:00	Fase 2 - 1 mei, 17:00 uur tot 18 juni 2012, 17:00 uur	Fase 3 - 18 juni, 17:00 uur tot 3 september 2012, 17:00 uur	Fase 4 - 3 september, 17:00 uur tot 5 november 2012, 17:00 uur	Fase 5 - 5 november, 17:00 uur tot 27 december 2012, 17:00 uur	Voorlopig correctiebedrag over 2012	Maximale looptijd subsidie (jaar)	Maximaal aantal vollasturen (uur/jaar)	Uiterlijke termijn ingebruikname (jaar)
Hernieuwbaar gas		basisbedrag per fase (€/Nm³)					€/Nm³			
biomassa	allesvergisting solo (groen gas)	0,4827	0,592	0,592	0,592	0,592	0,247	12	8.000	4
	allesvergisting hub (groen gas)	0,4827	0,592	0,592	0,592	0,592	0,247	12	8.000	4
	verlengde levensduur allesvergisting (groen gas)	0,482	0,482	0,482	0,482	0,482	0,247	12	8.000	1,5
	mest(co-)vergisting solo (groen gas)	0,4827	0,6207	0,729	0,729	0,729	0,247	12	8.000	4
	mest(co-)vergisting hub (groen gas)	0,4827	0,6207	0,708	0,708	0,708	0,247	12	8.000	4
	verlengde levensduur mest(co-)vergisting (groen gas)	0,4827	0,551	0,551	0,551	0,551	0,247	12	8.000	1,5
	biomassavergassing	0,4827	0,6207	0,7586	0,8965	0,975	0,247	12	7.500	4

Hier vindt u een beschrijving van de technologieën voor de productie van hernieuwbare warmte en hernieuwbare warmte én elektriciteit (WKK) die in 2012 in aanmerking komen voor SDE-subsidie.

		Fase 1 - 13 maart, 9:00 uur tot 1 mei 2012, 17:00	Fase 2 - 1 mei, 17:00 uur tot 18 juni 2012, 17:00 uur	Fase 3 - 18 juni, 17:00 uur tot 3 september 2012, 17:00 uur	Fase 4 - 3 september, 17:00 uur tot 5 november 2012, 17:00 uur	Fase 5 - 5 november, 17:00 uur tot 27 december 2012, 17:00 uur	voorlopig correctiebedrag over 2012	Maximale looptijd subsidie (jaar)	Maximaal aantal vollasturen (uur/jaar)	Uiterlijke termijn ingebruikname (jaar)
Hernieuwbare warmte en hernieuwbare warmte én elektriciteit		basisbedrag per fase (€/GJ)					€/GJ			
afvalverbranding	afvalverbranding uitbreiding warmte	11,9	11,9	11,9	11,9	11,9	10,4	15	3.710	1,5
biomassa	allesvergisting solo (warmte)	14,8	14,8	14,8	14,8	14,8	9,1	12	7.000	4
	allesvergisting hub (warmte)	14,8	14,8	14,8	14,8	14,8	5,5	12	7.000	4
	allesvergisting solo (WKK)	19,444	25,000	27,3	27,3	27,3	11,0	12	5.739	4
	allesvergisting hub (WKK)	19,2	19,2	19,2	19,2	19,2	11,4	12	5.935	4
	allesvergisting uitbreiding warmte	6,3	6,3	6,3	6,3	6,3	5,5	5	7.000	1,5
	verlengde levensduur allesvergisting (WKK)	19,444	22,5	22,5	22,5	22,5	11,0	12	5.749	1,5
	mest(co-)vergisting solo (warmte)	17,7	17,7	17,7	17,7	17,7	9,1	12	7.000	4
	mest(co-)vergisting hub (warmte)	17,7	17,7	17,7	17,7	17,7	5,5	12	7.000	4
	mest(co-)vergisting solo (WKK)	19,444	25,000	30,556	30,8	30,8	11,0	12	5.732	4
	mest(co-)vergisting hub (WKK)	19,444	22,5	22,5	22,5	22,5	11,4	12	5.935	4
	mest(co-)vergisting uitbreiding warmte	8,2	8,2	8,2	8,2	8,2	0	5	4.000	1,5
	verlengde levensduur mest(co-)vergisting (WKK)	19,444	25,000	25,9	25,9	25,9	11,0	12	5.749	1,5
	ketel vloeibare biomassa ≥ 0,5 MWth (warmte)	19,444	20,8	20,8	20,8	20,8	9,1	12	7.000	4
	ketel vaste biomassa ≥ 0,5 MWth (warmte)	10,9	10,9	10,9	10,9	10,9	9,1	12	7.000	4
	thermische conversie > 10 MWe en ≤ 100 MWe (WKK)	19,444	22,2	22,2	22,2	22,2	7,1	12	6.351	4
	thermische conversie ≤ 10 MWe (WKK)	19,444	25,000	30,556	36,111	38,2	8,1	12	4.241	4
	thermische conversie uitbreiding warmte	6,3	6,3	6,3	6,3	6,3	5,5	5	7.000	1,5
	verlengde levensduur thermische conversie (WKK)	18,7	18,7	18,7	18,7	18,7	8,7	12	4.429	1,5
geothermie	geothermie (warmte)	10,9	10,9	10,9	10,9	10,9	5,5	15	7.000	4
	geothermie (WKK)	18,9	18,9	18,9	18,9	18,9	8,1	15	4.667	4
zonthermie	zonthermie ≥ apertuuroppervlak 100 m² (warmte)	19,444	25,000	30,556	36,1	36,1	13,7	15	700	3