BIOMASS BASED ENERGY CONVERSION PARKS: A MULTIDIMENSIONAL APPROACH FOR EFFICIENT USE OF BIOMASS

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ABSTRACT: This paper shows how locally available biomass is used to its full potential as source for renewable energy and bio-based products with a multidimensional integrated approach. The use of locally available biomass streams, which are currently hardly or not optimally used, is the center of the project Energy Conversion Parks (ECP). In this work we show the project results for the municipality of Breda, in the southern part of the Netherlands. The ECP developed for this municipality combines anaerobic digestion of various biomass streams, use of waste heat in biogas installations, and use of biogas output for several purposes (heat, electricity, green gas and liquid bio-methane). Models have been developed to quantify the production of various energy vectors as a function of inputs. Moreover, choices can be made about the inputs and outputs, allowing to vary the quantities produced. The models can also calculate the internal rate of return and influence of subsidies for the different process configurations.
Keywords: anaerobic digestion, bioenergy, biomass, economical aspects, integration, local.

1 INTRODUCTION

The bio-based economy concerns the transition from production of materials, chemicals and energy based on fossil oil and gas towards one that is based on renewable biological resources (biomass). Factors as climate change, depletion of fossil resources, dependence on politically unstable regions, and strong price fluctuations of fossil fuels are the driving forces for this transition. According to the Dutch Green Raw Materials Platform [1], in 2030 30% of the Dutch raw materials and energy needs can and should be supplied by biomass.

The core of the Dutch policy vision on the bio-based economy [2] aims at efficient and intelligent use of biomass. Biomass can be converted in various ways into energy or into raw materials for products. In the bio-based economy policy the objective of achieving the highest added value is pivotal (Fig. 1).

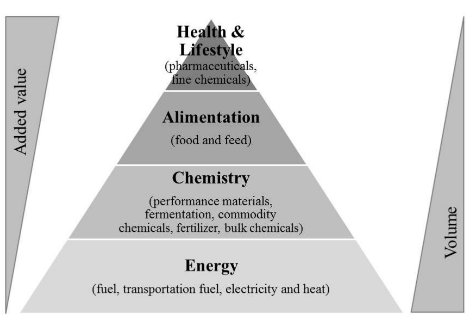

Figure 1: Bio-based value pyramid (Adapted from [3])

This pyramid principle assumes that first of all, biomass is used for the economically most interesting applications, after which the residuals are used, to the greatest extent possible, for other lower value applications (bio-cascading).

In the implementation of this pyramid principle for the use of biomass as source for our daily products (energy, chemicals, materials) we face a practical issue: the development status of the appropriate technology increases from bottom to top. At the energy production level we have “proven” technologies at our disposal (combustion, anaerobic digestion, cogeneration of heat and power (CHP), etc.). For higher value products, the required technologies are still under development. In practice, the bio-economy starts at the energy level.

Current production of bio-energy is strongly driven by policy support and subsidies. In most cases the approach is “one-dimensional”: a specific type of biomass, the most apt technology for that one biomass type and a specific output, commonly electricity and heat. Optimization is done towards the main output only. Examples are biogas from manure and green household waste, and CHP units running on woodchips (small units will be using locally available resources but for larger units the import of woodchips is necessary).

Available biomass energetic and economic potential is not used to its full extent in this manner. Issues that stress the need for better approaches are variability in availability of biomass streams, preferred scale of operations, better profits (which too often still depend on subsidies) and the actual sustainability of one dimensional approaches. Furthermore, at the one hand one sees increasing import of biomass for use in energy and at the other hand large amounts of locally available biomass that are not, or not very efficiently, used.

1.1 Project ‘Energy Conversion Parks’ (ECP)

In the ECP project a consortium of Belgian and Dutch research institutes (VITO, Avans University of Applied Sciences, Wageningen University and Research, University Hasselt, and University of Applied Sciences Zeeland) is analyzing whether an economically viable concept can be achieved to valorize locally available biomass (waste) streams, through the use of synergies between different biomass streams, conversion technologies, and outputs. The idea is to maximize the valorization of intrinsic values of the biomass and thereby improving its business case [4].

A biomass energy conversion park (ECP) is defined as a synergetic multi-dimensional biomass conversion site with a highly integrated set of conversion technologies in which a multitude of regionally available biomass (residue) sources are converted into energy and materials. Important starting point is the presence and availability of biomass streams (types of biomass and availability in the region), other industrial activities that can be linked to or other nearby companies that can exchange energy. Both in biomass resources, conversion technologies and applications, smart combinations and links can be achieved, leading to very efficient and cost effective solutions. Figure 2 shows a schematic representation of an ECP.

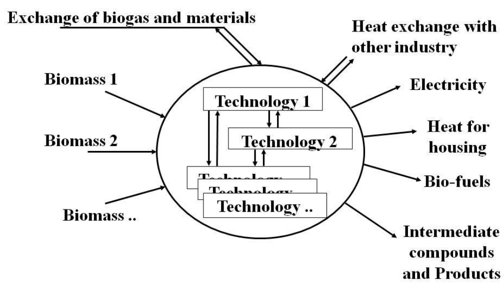

Figure 2: Schematic representation of an ECP

1.2 This paper

The main objective of this paper is to show how locally available biomass is used to its full potential as source for renewable energy and bio-based products with a multidimensional integrated approach. To illustrate that we show the ECP project results for the municipality of Breda, in the southern part of the Netherlands.

The paper is organized as follows. First the inventory of the locally available biomass resources and the current industrial activities and initiatives in the West Brabant region for the production of bio-energy is described. Next, the concept for an ECP pilot in Breda is presented with the evaluation of some technical and environmental aspects. Thirdly, the economic evaluation of two different co-digestion technologies and of different products distributions is discussed. Finally, we present our conclusions in terms of technical feasibility, economic profitability and environmental aspects, such as CO_2 reduction.

2 LOCALLY AVAILABLE BIOMASS RESOURCES

An essential part of an ECP is the availability of biomass. Biomass is generally spread in several locations and has a lower energy density than fossil fuels. Biomass transport is expensive, both in terms of energy as well as in terms of cost.

For the ECP pilot in the municipality of Breda a biomass inventory within a radius of approximately 30 km around the municipality was made [5]. This inventory includes the Northwest Brabant region and some outside municipalities (29 municipalities in total). These municipalities together have a population of 1.2 million inhabitants (7.5% of the Netherlands' population) and cover 6.3% of the country surface.

The biomass inventory focuses on the biomass streams that are currently not used because they are difficult to handle and / or the current processing values in terms of utilization and in terms of thermodynamics, is not optimal. Their processing usually costs money and deliver little or no profit.

An overview of the technical potential of biomass residues in Northwest Brabant, on an energy basis, is given in Figure 3. It is worth to mention that the technical potential of biomass residues is the amount of biomass that is available for bio-energy, taking into account technical capabilities such as harvesting techniques, infrastructure, accessibility, etc. The technical potential on an energy basis per biomass stream is calculated using the key figures found in literature for the appropriate conversion technique (e.g. combustion of wood residues produces 15 GJ per ton biomass [6]).

As figure 3 clearly shows the technical potential of manure is very high (1708 TJ/year). Wood residues, green household waste, and grass from nature reserve have also a relevant energy content of 506, 257 and 229 TJ/year, respectively.

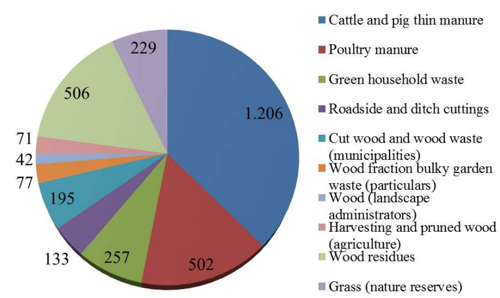

Figure 3: Technical potential of biomass residues in West-Brabant in TJ/year [6]

3 EXISTING FACILITIES AND INITIATIVES

To get a first impression of supply and demand for bio-based products within a radius of 30 km around the municipality of Breda some companies with relevant activities have been visited. Companies are considered relevant if they are involved or intending to, in biomass and/or bio-energy developments in the Breda region. On basis of these interviews, an overview of planned and existing bio-energy plants was obtained.

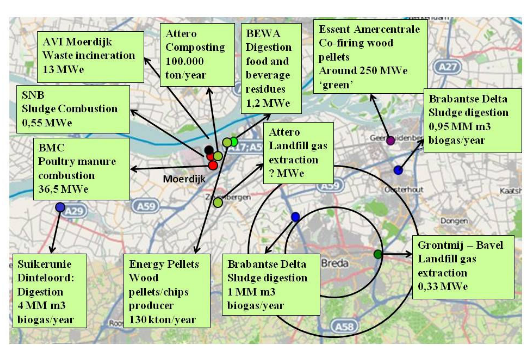

Figure 4: Actual bio-energy installations in West-Brabant

As figure 4 shows there are as yet hardly any digesters in the region but there are considerable bio-energy related activities located in Moerdijk.

Several bio-energy projects are planned. And these only are the known initiatives. New bio-energy initiatives come up nearly daily and are cancelled as easily. Table I shows the present known bio-energy initiatives in West-Brabant.

The inventory had also the aim to get acquainted with the "relevant players" in the region, and their plans and wishes. Besides they might have already specific locations in mind for their initiative which could be suitable for the development of an ECP. Furthermore the inventory was used to examine the possibilities for exchange of heat and/or biomass and/or intermediates between their installations and the ECP complex.

Table I: Bio-energy initiatives in West-Brabant

Company	Location	Type	Capacity
ATM	Moerdijk	heat supply	60 MW
Attero	Moerdijk	green household waste digestion, liquid bio-methane upgrading	70,000 ton/year
Attero	Moerdijk	digestate gasification	30,000 ton/year
BEWA	Moerdijk	digestion food and beverage residues	0.6 MWe
Brabantse Delta	Breda	biogas production	1,200,000 m^3 biogas/year
Brabantse Delta	Oosterhout	utilization CO_2/ heat at Meertens concrete	Not known
Municipality Breda	Breda	biomass combustion	40,000 ton wood/year
Municipality Breda	Breda, Bavel	new industrial zone	57 ha net
Municipality Breda	Breda, Claudius Prinsenlaan	sustainable heat	?
Suikerunie	Dinteloord	digestion	expansion from 4 to 10 million m^3 biogas/year
United gas/C2Circle	NW-Brabant/ Zeeland/ South Holland	liquid bio-methane production	?

4 CONCEPT PILOT ECP BREDA

4.1 Generation of pilot alternatives

For this process it is advisable to have a good overview of the techniques we want to use. Important questions to be answered include:

- Is the focus on existing technologies, or innovative techniques are also considered?
- Are only energy and biomass taken into account, or also bio-based products?
- What region is chosen?

Once the scope is clear, several alternatives may be generated. In this brainstorming phase, the alternatives are not yet (sharply) assessed, because it is important to figure out the largest possible number of options to choose from. When generating alternatives, several approaches are available:

- *Initiative-driven.* In this approach an existing initiative determines the selection of (biomass or energy) flows incoming and outgoing the pilot, and the necessary conversion technologies.
- *Location-driven.* On basis of a current location it is determined which biomass / bio-energy conversion steps can be placed.
- *Technology-driven.* In this approach, on basis of the selection of a technology (e.g. anaerobic digestion), or combination of technologies (e.g., anaerobic digestion in combination with biogas upgrading) the ECP is established. An application should be determined for all inputs and outputs.
- *Product-driven*. Here, on basis of a desired product is, with back reasoning, determined which the most suitable technical configuration is.

4.2 Pilot concept ECP Breda

We use the product-driven option for the development of this ECP pilot, specifically the delivery of sustainable heat to the city of Breda. This choice is made because there is an existing district heating grid which supplies heat to a large number of buildings in the municipality. Additionally, the pilot should fulfill the following requirements:

- Utilization of multiple, locally available, low-grade biomass.
- At least three different conversion technologies should be present.
- Sufficiently innovative concept compared to the "State of the Art".

The ECP Breda is developed in consultation with the municipality of Breda, which acts as the main external party. Given these starting points, the following ECP concept is established (see figure 5).

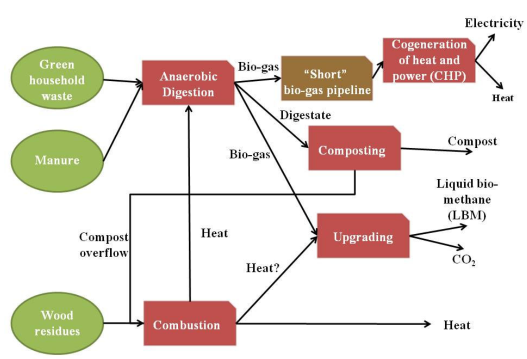

Figure 5: ECP concept Breda

This concept uses three different biomass flows, all of which are to a greater or lesser extent available in and around the municipality of Breda. It is assumed that the heat demand is large; therefore, the limiting factor for the size of the ECP concept is the amount of available biomass.

Innovative aspects of this ECP configuration are the combination of several low-grade biomass streams in an anaerobic digester, use of biogas for heat / electricity, and (if technically possible) liquid bio-methane (LBM), and a combination of anaerobic digestion and combustion so that all raw materials and products are utilized in the best possible way. Final products are electricity, heat, compost, LBM and CO_2.

It is intended to combine the biogas output of various installations in a gas network to be able to switch between using that gas for district heating through locally situated small scale cogeneration units (in winter) and production of LBM (when less district heating is required) for use as fuel in trucks or storage for electricity peak demand.

The placement of the ECP will be in an industrial area, preferably on the outskirts of the city of Breda. Emissions, risks and biomass transport make the placement of an ECP in the city - except perhaps in one existing heavy industry area "De Krochten" - not advisable.

Supply of heat (generated in a CHP from biogas) to users in Breda (e.g. an office buildings area in the city center) can be done in the following ways:

1. Through dedicated heat transport from the ECP to the customers.
2. Through dedicated heat transport from the ECP to the nearest point of the city heating grid.
3. Through a biogas pipeline to customers, where a CHP is placed. The CHP will deliver heat to the users and electricity to the public grid.
4. Through a biogas pipeline to the nearest point of the heating grid, where a CHP is placed to deliver heat to users via the existing city grid and electricity to the public grid.
5. Through a biogas pipeline to a boiler for heat production for the customers.
6. Through a biogas pipeline to a boiler in the heating grid. The generated heat will be an input for the existing district heating grid.

Options 3 and 4 are expected to lead to the best energetic use of biogas (compared to other options). Options 1 and 2 assume the construction of a heat pipe which is expected to have high costs. Option 5 and 6 are expected to have the lowest capital cost. Utilization of the heating network is done in options 2 and 4.

It is expected that utilization of the existing heating network is generally preferable to a direct connection to users. Otherwise multiple networks should be realized in the city of Breda. Given these considerations, and given the good energetic utilization of the biogas in a CHP, is option 4 the best choice.

The ECP requires heat for 1) heating in the anaerobic digestion process, and (perhaps) 2) in the production of LBM. This heat can be generated with the biogas produced in the anaerobic digestion. Because this biogas can be used for high quality applications, it is preferably to burn wood residues and compost overflow for these purposes.

5 TECHNICAL FEASIBILITY ECP BREDA

The development of the selected ECP concept requires further detailing. To what extent are several conversion steps technically feasible? It is important to know whether the technology is proven, on the required scale, and suitable for the available biomass input.

To determine how much biomass is actually available in and around Breda we used our biomass inventory.

In our concept the anaerobic digestion step plays a crucial role. How does the technical implementation of the digestion step looks like? Different biomass streams will be digested (manure and green household waste). Will the digestion take place in separate reactors for the different biomass streams or is it possible to pre-treat the input streams such that they can be fed into one reactor?

5.1 State of the art conversion steps ECP Breda

5.1.1 Anaerobic digestion of manure and organic (green) household waste

Because the solids content of organic waste is greater than that of manure and co-substrates, the technical implementation of organic digesters is slightly different as compared to standard anaerobic digestion process. Three different technologies are currently used in The Netherlands:

- Mesophile batch anaerobic digestion (Biocel process [7]). In this technology fresh organic waste is mixed with pre-digested organic waste (digestate) and placed in the tunnels by a shovel. The digestion takes place under mesophilic conditions, batch-wise (38 to 40 °C). During the digestion is drainage water re-circulated on the fermenting material. The digestate remains in the digester.
- Thermophilic continuous anaerobic digestion. This is a continuous process under thermophilic conditions (50 to 55 °C). The organic waste is pretreated (reduced and sieved) and then put in contact with re-circulated liquid. This is to ensure that the digestion process starts faster because the re-circulated fluid already contains an optimal amount of bacteria. The liquid mixture is then slowly stirred through the reactors. This type of organic digestion can be performed horizontally (the Kompogas process, [8]), or in a vertical reactor (the DRANCO process, [9]).
- Tunnel percolate digestion [10]. In this technology percolate water is brought repeatedly in contact with organic waste. This water, which is rich in organic material, is then digested in an Upflow Anaerobic Sludge Blanket (UASB) reactor, from which the biogas is obtained. The remaining organic waste is composted.

Of the three methods for organic waste digestion, the Biocel process is discarded because batch digestion of organic waste as technology is no longer used in The Netherlands in the more recent installations. The thermophilic continuous anaerobic digestion (Kompogas, DRANCO) looks like a feasible technology with the following configuration: manure is first mechanically separated in a solid and a liquid fraction, the solid manure fraction and the organic (green) household waste are fed to the digester, and the liquid manure fraction (mainly water) is applied to the land to restore some nutrients to the soil. The other technology, the tunnel percolate digestion, seems to be also an interesting alternative using this schema: the percolate water containing the digestible organics is digested in combination with manure in a stirred tank.

5.1.2 Composting

Composting is a biological process by which, under aerobic conditions in a porous mass, micro-organisms convert biodegradable organic matter to carbon dioxide and water. Advantages of composting are germ killing, drying, material volume reduction and stabilization of organic matter. The process takes several weeks depending on process conditions. Input material should meet the following requirements to be compostable [11]:

- A carbon / nitrogen ratio between 25 and 30.
- Sufficient free water, ideally a moisture content of 50 - 60%.
- Sufficient porosity (approx. 30 - 50% empty space).

5.1.3 Biogas upgrading

Biogas contains, in addition to methane, significant quantities (up to 40% - 50%) of CO_2. In comparison with natural gas, biogas contains in addition various contaminants, such as hydrogen sulfide (H_2S), and ammonia (NH_3). Hydrogen (H_2), nitrogen (N_2), hydrocarbons and oxygen (O_2) are sometimes present in small quantities. Furthermore, biogas is saturated with water and may contain dust particles.

To further process biogas, it is necessary to remove these contaminants to a greater or lesser extent. For use in a CHP unit drying and H_2S removal is usually sufficient. For high quality applications such as injection in the natural gas network or used as fuel, further upgrading is required. The essential and most costly step is the CO_2 removal. For this purpose several proven techniques such as membrane separation, PSA (Pressure Swing Adsorption), and absorption with water (pressurized water wash) are available.

5.1.4 LBM production

Production of LBM (Liquified bio-methane) can be seen as next step in the upgrading of biogas. LBM is compositionally similar to LNG (liquefied natural gas). The main difference is the origin: LBM is produced from biogas and is therefore renewable and sustainable. The LBM production in The Netherlands is currently in its infancy.

5.1.5 Combustion of wood residues

Direct combustion of biomass is one of the oldest and most widely used methods for generating energy from biomass. Combustion involves the reaction of biomass with oxygen from the air. The immediate product of this reaction is hot air, which can be used directly as heat, or for the production of hot water or steam. The steam can subsequently be converted into electricity. Combustion can occur at any scale, from very small (stoves for room heating) to very large scale (power plants).

5.2 Mass and energy balance

Excel models have been developed to determine the product outputs with the DRANCO and the tunnel percolate digestion process. Here, the following technical assumptions were made to keep the models simple and flexible:

- The mass and energy balance are established at the level of individual conversion processes and focus on the most important energy and material flows. Smaller inputs and outputs are neglected at this stage.
- The determination of conversion efficiencies is based on data from literature.
- From each conversion technology, the need for heat and electricity is provided (which is included in the overall calculations).
- The length of the "short" biogas pipeline is set at 3.5 km considering that large-scale digestors cannot be placed in the city of Breda.

The models allow varying i) the amounts and composition of biomass inputs, and ii) choices about the way in which biomass streams are treated. The models outputs are: useful heat, electricity, "green" gas, LBM, CO_2, compost and in some cases residual materials. Besides the actual amounts of products, the models also calculate the energy efficiency of the entire ECP and the specific CO_2 reduction (amount of CO_2 emissions reduced per unit energy input). This makes it possible to evaluate various scenario choices and – in the future – optimize the process towards maximum CO_2 emission reduction and / or energy efficiency.

Because at this stage it was not possible to select one of the two possible anaerobic digestion technologies, the mass and energy balance were made using both. Different combinations of products amounts were also calculated.

Table II shows typical input data for calculating the mass and energy balance for ECP Breda (biomass from Breda and surroundings municipalities). It is assumed that 50% of the technical potential of cattle and pig manure is used. The technical potential from green household waste and wood residues is used in 100%.

Table II: Typical input data for calculating the mass and energy balance for ECP Breda (biomass from Breda and surroundings municipalities)

Parameter	Amount	Units
Green household waste	32,852	ton/year
Cattle manure	506,978	ton/year
Pig manure	179,975	ton/year
Wood residues	19,937	ton/year
% biogas to CHP	50%	
% biogas upgrading to LBM	100%	

Table II shows typical results from the ECP mass and energy balance calculations (biomass from Breda and surroundings). The overall picture from this calculation is that the production of energy and materials using the tunnel percolate digestion is considerably higher than using the DRANCO process. But it should be taken into consideration that in the DRANCO process, a large proportion (more than half) of the manure is not converted into energy (only the manure solid fraction is used). In the tunnel percolate digestion technology all the manure is used. It is also interesting to see that the heat generated in the case of tunnel percolate digestion is lower than in the case of the DRANCO process. This is due to that more energy is required to keep the digester temperature in the appropriate value (larger reactor volume).

Table III: Typical results ECP mass and energy balance calculations (biomass from Breda and surroundings)

Parameter	Amount (DRANCO)	Amount (tunnel percolate digestion)	Units
Net electricity	8,743	17,888	MWh/year
Heat	38,540	53,514	GJ/year
LBM	1,692,799	3,463,570	kg LBM/ year
Green gas	0	0	m^3 green gas/ year
Total energy output	154,654	291,090	GJ/ year
Number of households (heat)	676	939	-
Number of households (electricity)	2,512	5,140	-
Number of trucks (LBM, 100,000 km / year	67	138	-
Number of houses (green gas)	0	0	-
Compost	61,987	65,047	ton/ year
CO_2	3,684	7,526	ton CO_2/ year
manure liquid fraction	571,544	570,527	ton/ year

5.3 Energy efficiency and CO_2 reduction

Some results for the municipality of Breda are shown in figure 6.

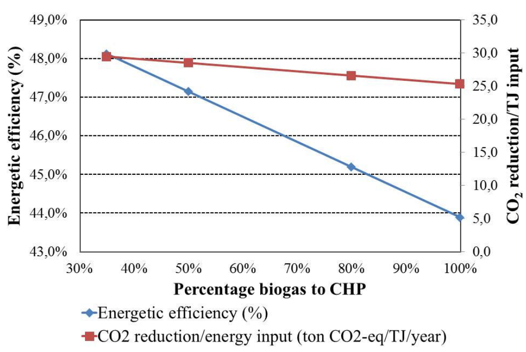

Figure 6: Energetic efficiency and specific CO2-eq. emission reduction as a function of the amount of biogas that is directed to the CHP unit

The energy efficiency drops slightly when more biogas is converted to electricity and heat as opposed to biogas upgrading. The main reason for this result is the energy losses that are incurred when biogas is fired in a CHP unit. The same effect, but stronger, affected the specific CO_2 reduction. Apart from the efficiency effect, another issue is the specific amount of CO_2 reduction which is achieved by replacing heat in Breda. Because the local district heating network utilizes waste heat from a nearby power station, associated CO_2 emission reductions are lower.

6 ECONOMIC EVALUATION ECP BREDA

From the technical perspective both the tunnel percolate digestion and the DRANCO process appear to be suitable technologies for the anaerobic co-digestion of manure and green household waste. In consultation with the municipality of Breda, which acts as "anchor" point for the ECP case Breda, it was decided to make a selection between these two technologies using their economic feasibility as criteria. In theory, other decision criteria can also be used, for example: energy efficiency, reduction CO_2 emission and amount of renewable energy generated.

6.1 Assumptions and results economic evaluation

The economic evaluation of the ECP Breda was conducted using market prices for raw materials and products, with and without subsidy, and the capital and operating costs. The financial parameters are determined using a simple DCF (discount cash flow) model. The following general assumptions were made:

- In all cases, the economic feasibility of a “greenfield” complex is determined. A “greenfield” complex is a complex that is built from the ground, so there is no use of existing infrastructure or facilities, except for the heating net in Breda.
- The capital costs are determined at the level of the whole technology. This is because the concept is still not sufficiently detailed to make a more detailed cost calculation.
- Market prices (positive) and gate fees (negative) are used for raw materials and products.
- The economic feasibility is determined for two situations: i) no subsidy is obtained, and ii) subsidies for the production of renewable energy are obtained by the SDE+ 2012 scheme.
- Other subsidies, such as EIA and VAMIL, are not included.

Figure 7 shows the internal rate of return (IRR) as a function of the manure input when the SDE+ 2012 subsidy is included. In this figure 100% means that all available manure is considered. At 0%, no manure is entering the digester (100% green household waste). The IRR of the DRANCO process is in all cases higher than that of the tunnel percolate digestion. It also appears that the lower the manure input, the higher the IRR. The trend in the internal rate of return as a function of the manure input without subsidy shows the same picture: the DRANCO technology is economically more interesting and more manure input results in a lower IRR.

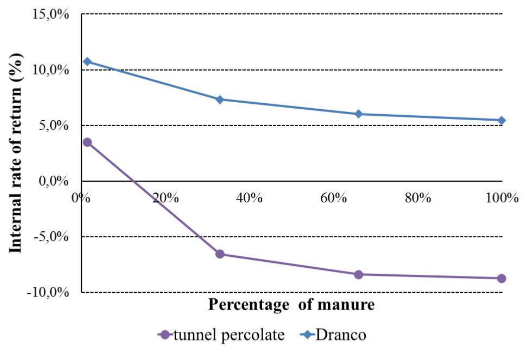

Figure 7: Internal rate of return of the ECP Breda as a function of the manure input with SDE+ 2012 subsidy

Figure 8 shows the internal rate of return as a function of the biogas percentage in the CHP using the SDE+ 2012 subsidy. In this figure 100% means that all the biogas is used in the CHP. 0% means no gas is used in the CHP. In the latter case, 50% of the gas is sold as green gas and the other 50% as LBM. The more biogas in the CHP is used, the better the profitability. Furthermore, the DRANCO process remains in all cases more economically interesting than the tunnel percolate digestion technology.

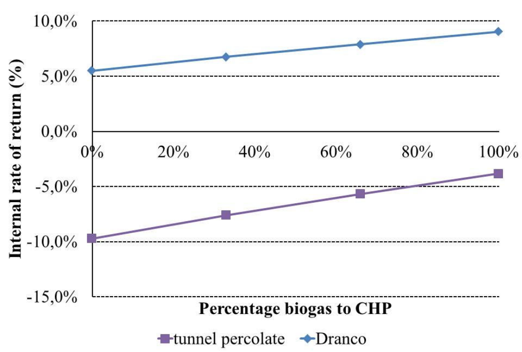

Figure 8: Internal rate of return of the ECP Breda as a function of the biogas percentage in the CHP, with SDE+ 2012 subsidy

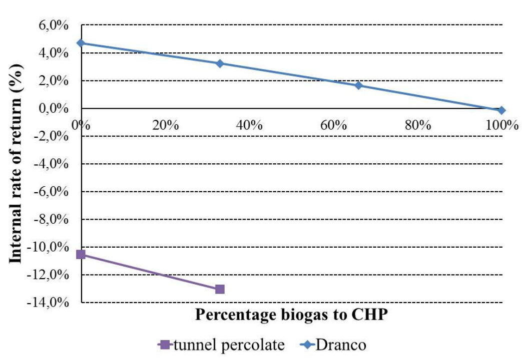

Figure 9: Internal rate of return of the ECP Breda as a function of the biogas percentage in the CHP, without SDE+ 2012 subsidy

Figure 9 also shows that in all cases the DRANCO process is economically more interesting than the tunnel percolate digestion technology. If more than about 35% of the gas is utilized in the CHP, the IRR of the tunnel percolate digestion process cannot be determined, which means that the process is not economically viable. The trend shows that without subsidies, biogas utilization in the CHP is less advantageous than biogas utilization for green gas / LBM.

Figure 10 shows the internal rate of return of the ECP Breda as a function of the ratio of green gas production / LBM production without subsidy. 0 means 100% LBM production, 1.0 represents 100% green gas production. This figure shows again that in all cases the DRANCO process is more economically viable. It also shows that without subsidies the LBM production is economically more profitable than the green gas production.

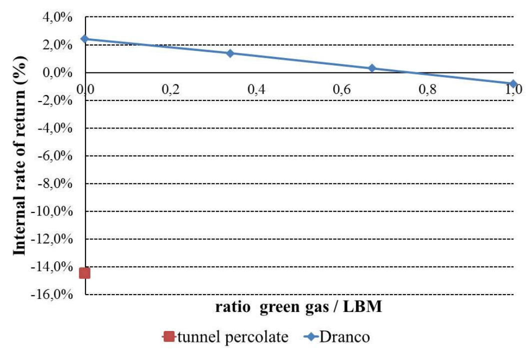

Figure 10: Internal rate of return of the ECP Breda as a function of the ratio of green gas production / LBM production without subsidy

6.2 Sensitivity analysis

Based on the results from the previous section two "semi-optimal" scenarios can be determined (one with and one without SDE+ 2012 subsidy). These scenarios differ in the following points from the optimal scenario:

- 40,000 tons manure / year as input. This is because the ECP Breda concept is built around the idea of combining various biomass streams.
- In the scenario with subsidy still 20% of the available biogas is converted to LBM. This is because in the summer no heat demand is expected

On basis of the scenarios here defined, the sensitivity to variations in the prices of specific products and raw materials was studied.

In figure 11 is the GFT gate fee varied. The leftmost values correspond to a GFT gate fee of 60 Euro / ton. Because this gate fee value may be too high in the future, the IRR for lower gate fees (respectively 50 and 40 Euro / ton) is also provided. As expected, this has a large effect on the IRR of the two scenarios (around 6%).

The variation of the gate fee of manure (25 - 15 euro / ton) has a much smaller effect on the IRR of the scenarios. The main reason for this is that in both scenarios, a significant portion of the manure leaves the process as a liquid fraction. Because this happens at the same price, the effect of the gate fee of manure is less than 1%.

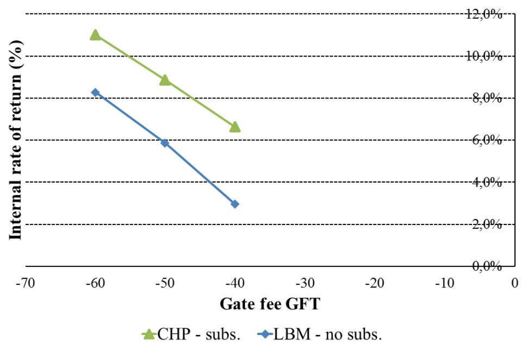

Figure 11: Gate fee variation of GFT

In figure 12 the products market price is varied. The IRR of the two scenarios is provided in the case of a 20% higher and a 20% lower price. The income obtained through subsidies is held constant. This is because market prices will always fluctuate. The SDE + subsidy is, once it is granted, fixed for a long period.

It is remarkable that, in the scenario in which subsidy is obtained, as well as in the scenario where it is not the case, the influence of the market prices in the IRR is relatively large (around 6%).

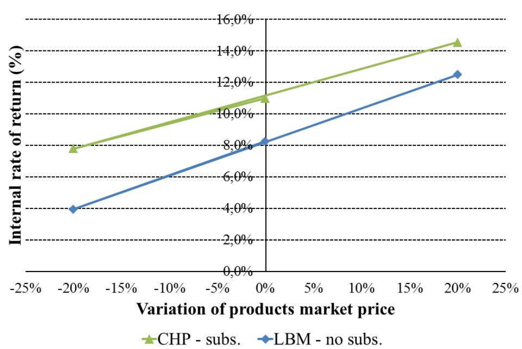

Figure 12: Variation of products market price (electricity, heat, LBM, etc.)

7 CONCLUSIONS

Excel models have been developed to determine the product outputs of an energy conversion park (ECP), based on i) the amounts and composition of biomass inputs, and ii) choices about the way in which biomass streams are treated.

These ECP models show that combination of various installations in combination with some added extra technology lead to a higher output in heat, green gas and electricity per ton biomass and invested capital.

The ECP multidimensional approach for utilization of locally available biomass waste streams improves the business case of utilization of biomass streams with low energetic value (manure).

Municipalities will want to use their green waste from households and park maintenance to supply green gas for their vehicle fleet and heat for housing areas, with the aim to make their city more “CO_2 neutral”. With the ECP models it can be decided which is the best use of these resources for that objective, what extra measures are needed, and which extra biomass should be acquired (for instance from forest maintenance). The goal to become CO_2 neutral will then be easier to reach.

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