Viability of biogas as an agro-environmental measure

Assessment of stakeholder views on benefits and risks in Danish biogas development, with a case study from Bornholm

SEI STOCKHOLM ENVIRONMENT INSTITUTE

BALTIC COMPASS Part-financed by the European Union (European Regional Development Fund and European Neighbourhood and Partnership Instrument) Baltic Sea Region Programme 2007–2013

This report is based on policy analysis undertaken in Work Package 6 on Governance and Policy Adaptation in the project Baltic COMPASS (Comprehensive Policy Actions and Investments in Sustainable Solutions in Agriculture in the Baltic Sea Region). To learn more, visit www.balticcompass.org.

Compiled by: Rasmus Klocker Larsen
Stockholm Environment Institute, Stockholm, Sweden
Contact: rasmus.klocker.larsen@sei-international.org / Mob. +46 73 707 8564.

Bornholm case study developed in collaboration with: Elisabeth Falk (Bornholm Agricultural Advisory Service) and Frank Bondgaard (Danish Agricultural Advisory Service); see www.balticdeal.eu.

Thanks to Kati Beringer, environmental consultant; Mats Edström, Swedish Institute of Agricultural and Environmental Engineering (JTI); Henning Foged, Agro Business Park; and Kim Andersson, SEI, for their useful comments on a draft version of this report.

SUMMARY

Denmark, like other riparian countries in the Baltic Sea Region, is searching for innovative agro-environmental measures which generate 'win-win' solutions across sectors and interest groups and enable a more effective implementation on agreed policy targets. One technology that is receiving increased attention is degassing of livestock manure in biogas plants.

After an initial period of popularity in the 1970-80s, there has been stagnation in the growth in biogas plants in Denmark since the end of the 1990s. However, as a measure for renewable energy as well as greenhouse gas (GHG) emission mitigation, it is expected to boost biogas production tenfold: from around 5 per cent of total manure produced in the country being processed for biogas, to close to 50 per cent. This would equal 807 000 tonnes of CO_2 equivalent in annual emission reductions, and an increase in energy produced from biogas from 4 PJ in 2009 to around 17 PJ in 2020, to cover 20 per cent of national energy consumption based on biomass, equalling approximately 10 per cent of renewables (2010 level). While promotion of biogas is primarily driven by political objectives associated with a secure supply of renewable energy it is also promoted as an agro-environmental measure that could enhance nutrient control and reduce leaching into water bodies.

Building on the past lessons from the establishment and operation of biogas plants in Denmark, this report examines ongoing policy revisions and seeks to identify key enabling and disabling factors shaping the promotion of biogas. Also of interest is the extent to which biogas may generate multiple benefits, reconciling economic, energy, climate, and broader environmental objectives. In order to add value to previous analyses of biogas as an agro-environmental measure, the report pays particular attention to the institutional dimensions of the governance system and examines it through a multi-stakeholder assessment.

A qualitative assessment was conducted February – September 2011 and was organised as a participatory analysis involving professionals from government ministries and agencies, the private sector, and civil society. In total, 32 people from 23 organisations have contributed. In order to examine the implications of the governance environment for biogas in a local context, a case study of Biokraft A/S in Aakirkeby, Bornholm (6-8 June 2011) was undertaken in collaboration with Bornholm Agricultural Advisory Service and the Danish Agricultural Advisory Service. Although both the assessment and the case study have limitations, they offer lessons to support future policy revisions.

The report first describes the efforts to develop an enabling national policy environment. It then zooms in on the establishment and operation of the Biokraft plant as a concrete intervention and policy action. After a brief introduction to Bornholm, an island in the Baltic Sea, it describes the establishment of the plant and its current operation. It then outlines the factors that have enable or hindered the plant's success as an agro-environmental intervention. It then evaluates the challenges faced by national-level policymakers, and concludes with some preliminary reflections on what may be learned from this synthesis of experiences and views from engaged professionals.

The national outlook

Our analysis finds that Denmark, like the larger European energy market, experienced a significant liberalisation during the 1990s, yielding free-market conditions which alone are not sufficient to propel investment in renewable energy sources such as biogas. With the recent (and proposed) revisions of the national policy environment, the national government is making an effort to improve the incentives for biogas. Notably this includes a scheme for provision of establishment grants and a reformed pricing structure. While many of these efforts are acknowledged as valuable initiatives, the actors whose

perspectives are included in this assessment unanimously argue that further improvements are needed to boost biogas projects so they can reach the scale required to meet the ambitious biogas target.

Main challenges identified in this analysis include

- inability to achieve a break-even result with the existing pricing structure;
- lack of capacity of local actors to bear the financial risks in biogas projects;
- an overall infrastructural lock-in which works against biogas as a complement to existing energy providers;
- lack of intersectoral coordination in designing biogas action plans;
- a monetarisation of biogas that only captures some benefits while excluding others; and
- administrative and legal constraints and ambiguities at the national and EU levels.

These findings could provide important insights for the design of next steps under the new government energy strategy launched in November 2011.

Lessons from Bornholm

Our Biokraft case study identified several key enabling factors in the establishment of the plant, as highlighted by the people involved:

- political support from the municipality;
- improved sense of ownership amongst farmers and business sector;
- benefits for farmers associated with facilitating nutrient usage and exchange;
- incentives associated with optimisation of crop production.

Meanwhile, the main barriers identified were:

- technological problems and failed investments;
- problems with stability and quality in manure supply;
- weak finances and lack of farmer buy-in;
- a general economic depression in farming that prevented new investments;
- challenges in accessing alternative biomass and improving energy potentials; and
- doubts regarding environmental and public benefits.

The experiences with Biokraft and at the national level confirm earlier findings that biogas plants only become attractive from a socio-economic point of view when the multiple social and environmental benefits are fully taken into account. Biogas projects contribute to commoditising manure (i.e. making it a tradable commodity) and thus create a ‘nutrient economy’, which includes both monetary and non-monetary benefits. As many of the benefits are not captured by the market or by existing subsidy schemes, the local negotiation between stakeholders plays a key role in weighing different opportunities and agreeing on what is a ‘win-win’ situation.

While the case study from Bornholm highlights a number of clear benefits for the farming sector and the wider society on the island, it also shows a number of risks and negative consequences associated with the prioritisation of biogas. Based on these insights, the message from Bornholm appears to be that there is, in fact, no agreement on a clear and compelling argument for promoting biogas as an agro-environmental measure for combating nutrient pollution. Biogas appears to have potential as a measure for renewable energy provision, for supporting effective utilisation of manure, and for generating alternative income opportunities for farmers (and the biogas industry and entrepreneurs). Yet these benefits will have to be considered against the transaction and opportunity costs which arise when investments and biomass going into biogas plants are not used elsewhere (e.g. by other energy providers).

In this regard, it must be recognised that Biokraft on Bornholm may have a particularly traumatic history compared with other biogas projects, owing to failed investments and loss of public funds. The arguments presented in this report will have to be contrasted and discussed also in the context of other 'cases' from Denmark and lessons from general research, e.g. on the effect on nutrient leaching. It should also be acknowledged that Biokraft is now achieving a break-even point on its operational costs and appears to be on an upward curve, with increasing buy-in among farmers.

An interesting lesson is the significant role that public regulations on manure management play in motivating farmers to engage in biogas initiatives. It suggests that biogas is not only attractive as a means of boosting income generation on-farm, but equally as a mechanism to navigate the environmental regulations to expand production within the operating conditions offered by the regulative frameworks. Whether this navigation has a positive impact on nutrient leaching and run-off to the aquatic environment is not clear from the present assessment; rather it is obvious that different stakeholders have different views on this and seek to convince one another that biogas has or does not have such a positive impact.

The first centralised biogas plants emerged owing to extensive collaboration and social and institutional innovations based on collective efforts of a number of groups in society. There is no doubt that successful adoption in Danish localities requires similar innovation partnerships between project owners, donors, manure providers, advisory services, municipal politicians and administrators and various farming and environmental interest groups. If the Danish government maintains its ambitious biogas targets and wishes to see them implemented, then the national policy framework must be improved and local actors must be able to strike up the necessary partnerships. In order to enable public and private stakeholders to judge their stakes in such projects and whether/how they should engage, there is a continued need to unwrap what sometimes appears to be an uncritical euphoria about biogas and foster a more transparent debate regarding what the actual benefits and risks are in concrete localities.

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1. Introduction: Biogas as a 'win-win' measure?

Denmark, like other riparian countries in the Baltic Sea Region, is searching for innovative agro-environmental measures which generate 'win-win' solutions across sectors and interest groups and enable a more effective implementation on agreed policy targets. While the primary aim is to curb environmental impacts, measures must also support food production and economic gains for farmers and for 'downstream' agro-industry and markets. In addition, they are expected to deliver wider societal benefits for rural development and satisfy different sectoral and stakeholder interests. It is in this context that degassing of livestock manure in biogas plants is receiving increasing attention in the Baltic Sea Region.

Biogas denotes the mixture of CO_2 (carbon-dioxide) and CH_4 (methane) which is produced from bacterial conversion (co-digestion) of different types of organic matter under anaerobic (oxygen-free) conditions. The biological process occurs through bacterial digestion of organic matter in three steps: hydrolysis, acidogenesis (fermentation), and methanogenesis. It produces gas and a solid fraction containing undigested matter (digestate), including the nutrient contents (e.g. phosphorus (P), nitrogen (N), potassium). Given the resemblance to the functioning of the animal rumen, biogas plants are often popularly referred to as 'artificial cows'. Present-day usage of biogas technology is an industrialisation of an old technology practiced since mid-19th century in Europe as well as in some non-industrialised countries.

1.1 A brief history: 1970s to present

The first farm-level biogas plants were constructed in Denmark during the energy crisis in the 1970s. These efforts have been credited to autonomous initiative of grassroots movements led by the Folk High Schools, farmer organisations and local communities. The first centralised (or so-called 'communal') plants involving a number of shareholders and users were constructed in the 1980s to benefit from improved technology and economies of scale. Several villages pursued the construction of a centralised plant with the primary aim of achieving energy self-sufficiency (Raven and Gregersen 2007; Tafdrup and Hjort-Gregersen 2010).

While the subsequent decrease in oil prices worked against reliance on biogas as an energy source, the central government actively promoted biogas as a substitute for natural gas in areas where gas was not available. Biogas was then seen to fill an important gap in the newly constructed natural gas grid and the decentralised Combined Heat and Power (CHP) facilities (*kraftvarmeværker*). The 20 centralised biogas plants, which were constructed between 1984 and 1998, received investment subsidies of 20 to 40 per cent of the installation costs (Meyer 2004). These plants were promoted through the Cooperation for Technological Development of Biogas Plants (STUB) Programme in late 1970s and the Biogas Action Programme in late 1980s and 1990s (Raven and Geels 2010).

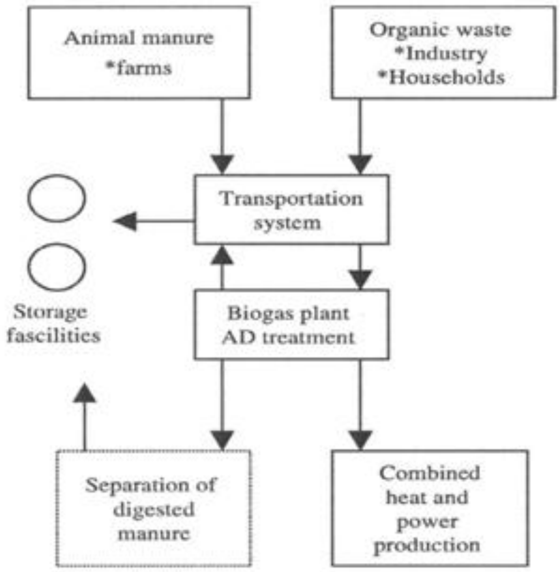


Fig. 1: Schematic description of a standard centralised biogas plant.
(Reproduced from Raven and Gregersen 2007).

Above and beyond the energy objectives, in the 1980s the promulgation of the first national Action Plan for the Aquatic Environment also provided the stimulus for promoting biogas as an agro-environmental measure to curb nutrient pollution from agriculture. The centralised plants were seen as an important measure to facilitate the management, transport and distribution of manure. This became a priority in particular because of the ongoing intensification and up-scaling of livestock farming in the country, generating an excess of manure compared with the agricultural area available.

Since the late 1990s, however, there has been stagnation in the growth in biogas plants, and few plants have been constructed in recent years (Raven and Gregersen 2007; Raven and Geels 2010). Today, according to the latest documentation available, there are 22 centralised biogas plants in Denmark. In 2008, the mid-way evaluation of the Action Plan for the Aquatic Environment III estimated that 5 per cent of the yearly production of animal manure was degassed in biogas plants (Waagepetersen et al. 2008). Despite the stagnation, in 2006, Denmark was ranked third among the EU-25 countries (after Germany and Austria) in terms of the volume of biogas from agriculture (AEBIOM 2009).

In Denmark, biogas can now be sold via the natural gas grid, one of the most developed examples of energy infrastructure in the country. Before entering the grid, the gas must be upgraded to ‘bio-natural gas’ (BNG) by removing CO_2 from the gas content. BNG is however traded virtually and is not physically transported in the transmission system together with natural gas, but in a separate distribution system with specific entry points for suppliers and exit points to consumers. The upgrading guarantees a roughly similar quality for the consumer. BNG entry points to the grid were introduced in 2010. The main advantage of distribution via the national grid compared with the other, still dominant model of direct delivery to decentralised CHPs is to manage local and seasonal variability in production and enable a national storage capacity and trade in biogas (see also Energinet.dk 2010).

1.2 New political targets for biogas in Denmark

Under the Kyoto Protocol and EU’s Renewable Energy Directive (2009/28/EC), Denmark is obliged to reduce emissions of greenhouse gases (GHG) from non-quota sectors such as agriculture with 20 per cent by 2020, compared with 2005 levels. Agriculture is currently estimated to contribute 16 per cent of total emissions, and thus there are high expectations that the sector will shoulder a solid part of the emissions burden as well as provide biomass for renewable energies (Ministry of Food, Agriculture and Fisheries 2008). The national Climate Commission also recommended that the use of biomass through waste incineration and biogas production, together with solar, geothermal energy and heat pumps, play an important role in supplying energy to the district heating network as well as to the electricity grid. These sources are expected to help guarantee security in supply and help offset fluctuations in the amount of power generated by wind farms (Danish Commission on Climate Change Policy 2010).

As a measure for renewable energy as well as GHG emission mitigation, biogas production from livestock manure is expected to increase from around 5 per cent 'use efficiency' (describing the fraction of total manure produced in the country being processed in a biogas plant), to close to 50 per cent. This would yield emission reductions of 807 000 tonnes of CO_2 equivalent per year (Food, Agriculture and Fisheries 2008), and increase biogas energy production from 4 PJ in 2009 to around 17 PJ in 2020, covering 20 per cent of the national energy consumption based on biomass, approximately 10 per cent of renewables (2010 level) (Danish Energy Agency 2011a). In order to reach this target, it is estimated that six new centralised plants will have to be established each year (Tybirk, 2010). First introduced in the analyses undertaken by Ministry of Agriculture (Food, Agriculture and Fisheries, 2008), the 50 per cent target 2020 has since been included in the national government's Green Growth Strategy, issued in 2009 (Government of Denmark 2009), and in the revised Strategy (version 2.0) issued in 2010 (Government of Denmark 2010a).[1]

It is thus fair to say that the impetus, both historically and presently, for promotion of biogas owes to political objectives, namely the desire for a secure supply of renewable energy. However, interest in biogas is much broader and also includes its potential as an agro-environmental measure. The degassing of manure in biogas plants is seen as a way to control and optimise the recycling of nutrients on and between farms. And together with manure separation, fodder efficiency and acidification, it is seen as a way to alleviate the public discontent with air pollution from manure (e.g. Government of Denmark 2004). In addition, this process can facilitate the exchange of manure from concentrated livestock farms to crop cultivators, which particular benefits for organic farmers, who cannot use industrial fertilisers (see, e.g., Halberg et al. 2007). In terms of benefits for combating nutrient pollution, it is expected that the degassing of manure, in combination with burning of the solid fraction, will reduce the discharge to the sea by about 470 tonnes of N as well as have an impact on phosphorous management (e.g. Government of Denmark 2010a) (see also Table 1 for a list of expected benefits from the use of biogas plants).[2]

[1] Since this assessment was undertaken, the Danish government has changed with the September 2011 national elections. A new energy strategy was presented on 25 November 2011, which – in terms of biogas – builds on many of the proposed policy revisions under the previous government (Government of Denmark 2011),

[2] Work Package 4 in Baltic COMPASS, focusing on investments, has through analysis of different technologies come to the conclusion that biogas production is one of very few voluntary technologies that help to increase nitrogen recycling in agricultural production, along with other net benefits, which has led it to become one of four prioritised innovative technologies that the Work Package disseminates in the Baltic Sea Region (Foged and Mortensen 2011).

Table 1: Profiled benefits of biogas as an agro-environmental measure
Non-comprehensive compilation from multiple sources.

Political objective	**Benefit**
Enhance energy security and reliance on renewable energy	Provision of alternative, renewable energy supply
Climate change mitigation	Reduction of GHG emissions
Water protection	Reducing nutrient leaching through increased control with waste products from animal farming
Nutrient management	Meeting storage requirements (e.g. under the Nitrates Directive) as replacement for tanks and containers
	Improved absorption and usage of nutrients by plants of digested slurry; in turn reducing reliance on industrial fertiliser
	Local recycling of nutrients; e.g. redistribution of the livestock manure from the livestock farmers to the crop producers.
	Easier to determine the nutrient value of the degassed manure than that of raw manure – i.e. improved control
Air pollution	Reduction of obnoxious smells from spreading
Biosecurity	Pathogenic germ content in manure is reduced
Business development	Provision of alternative income source for farmers, when manure is monetarised also as energy carrier

2. Purpose and scope

The topic of how to realise the ambitious energy targets and their benefits at a national scale is being actively discussed today among different sectors and interest groups, which is shaping political and administrative decisions on the promotion of biogas as an agro-environmental measure. Owing to the history of biogas in Denmark and the experiences of professionals, there is already a significant amount of literature with practical guidance for the establishment of biogas plants (e.g. Tybirk 2010; Pedersen et al. 2006). The history of biogas technology in the country has also seen a range of research and development efforts (e.g. Nielsen and Hjort-Gregersen 2002; Borch 2007; Raven and Gregersen 2007; Raven and Geels 2010; Tafdrup and Hjort-Gregersen 2010; Ministry of Food, Agriculture and Fisheries 2008). However, the renewed targets and ambitions to 'reactivate' biogas as a measure in the agricultural sector motivate further analysis of the efficacy of the policy environment in particular, including the enabling and disabling factors for localities to adopt the biogas objectives and foster processes of innovation.

2.1 Objective

The objective of this report is to examine the current policy debate and identify key enabling and hindering factors shaping the promotion of biogas. It builds on the past lessons from establishment and running of biogas plants in Denmark as an agro-environmental measure of relevance for nutrient management. This objective is pursued through a qualitative analysis of the ability of the Danish governance system to promote biogas as a 'win-win' measure, which is adaptable at the sub-national level and to specific local conditions. Of interest is also the extent to which biogas, as promoted today, may generate multiple benefits, reconciling economic, energy, climate, and environmental objectives. In order to add value to previous analyses of biogas as an agro-environmental measure, the present assessment pays particular attention to the institutional enablers and barriers in the governance system. Read with an eye to the limitations of the assessment and the nature of the case study, the below findings offer lessons to support future policy revisions.

2.2 Methodology

The assessment was conducted from February to September 2011 and was organised as a participatory analysis involving professionals from government ministries and agencies, private sector and civil society organisations. It approaches the promotion of biogas as a process of innovation, i.e. institutional and technological change, in which networks of stakeholders negotiate desirable pathways of action, which they may operationalise in their practice through the striking of win-win solutions and brokering agreements and trade-offs (e.g. Leeuwis and Van den Ban, 2004).

Professionals were contacted through an email with requests for a consultation, and meetings were organised with those who agreed to participate. In total, 32 people from 23 organisations have contributed to the analysis (Table 2). For the synthesis in this report, secondary sources have been retrieved based on suggestions from the contributors and from standard literature review via online repositories. Preliminary findings were presented and critiqued at a National Round Table organised by Baltic COMPASS and chaired by the Ministry for Food, Agriculture and Fisheries in Copenhagen on September 1, 2011. In the presentation of findings below, insights which appeared to be generally accepted by all contributors are included without specific references. When there is disagreement, this is highlighted, and the owners of the perspectives and opinions are indicated, albeit avoiding personal attributions.

In order to examine the implications of the governance environment for biogas in a local context, a case study of Biokraft A/S in Aakirkeby, Bornholm (6-8 June 2011), was undertaken in collaboration with Bornholm Agricultural Advisory Service and the Danish Agricultural Advisory Service under the umbrella of the Baltic Deal project.[3] As will be discussed below, Biokraft A/S (henceforth simply Biokraft) is a publicly owned centralised biogas plant. This is in contrast to the majority of centralised biogas plants in Denmark, which are owned by agricultural organisations and farmers. It is acknowledged that the special conditions surrounding the ownership and history of the initiative make it impossible to make direct comparisons with other plants. Accordingly, the purpose of this case study is to provide qualitative and contextual insights from one concrete initiative, in order to contribute to a learning process between different biogas projects, which will all have their unique features. It is also acknowledged that a large number of experts and stakeholders have not yet been consulted, and hence the report does provide a comprehensive overview. Rather, the purpose is to highlight key lessons and insights on the Danish biogas industry, which may contribute to the ongoing debate and add to existing documentations (see also Bondgaard 2011).

[3] To learn more, see http://www.balticdeal.eu/.

Table 2: Organisations and people consulted

Note that the contributors did not necessarily share the official view of their organisation.

Organisation	Contributor(s)
	Bornholm
Biokraft A/S	Three people: director, head of operations, board member (farmer).
Østkraft Holding A/S	One person: project leader
Regional Municipality of Bornholm (BRK)	Two people: coordinators from relevant office units
Joint Municipal Waste Removal System for Bornholm (BOFA I/S)	Two people: director, consultant for waste and environment
Nordea Bank A/S	One person: agricultural advisor
Bornholm Agricultural Advisory Service	Two people: crop advisor, environmental advisor
Local branch of Danish Society for Nature Conservation	One person: member and farmer
Municipal politicians	Two people: member and previous member of the Committee for Technical Concerns and the Environment (*Teknik- og Miljøudvalget*).
n.a.	Person involved in the launch of Biokraft A/S
	National level
Ministry of Finance	Two people: advisors (*fuldmægtige*)
Ministry of Climate and Energy	Two people: advisors (*fuldmægtige*)
Environmental Protection Agency	Two people: advisors (*fuldmægtige*)
Danish Food Industry Agency	One person: advisor (*fuldmægtig*)
Ministry of Food, Agriculture and Fisheries, the department	One person: advisor (*fuldmægtig*)
Secretariat for Biogas, Danish Nature Agency	One person: head of secretariat
Danish Society for Nature Conservation	One person: agricultural policy expert
Danish Agricultural Advisory Service	One person: project leader, planning and environment
Department of Management Engineering, Technical University of Denmark (DTU)	One person: senior researcher
Institute of Food and Resource Economics, Faculty of Life Sciences, University of Copenhagen:	One person: senior researcher
Agro Business Park	One person: project leader
Danish Biogas Association	One person: head of secretariat
The Trade Union NNF	One person: senior consultant
Ecocouncil	One person: project leader

Below, we begin by describing the efforts to develop an enabling national policy environment. We then focus on the establishment and operation of the biogas plant Biokraft on Bornholm, as a concrete intervention and policy action. After a brief introduction to the setting, we describe the establishment of the plant and its current operation. We then outline the factors that have been seen to enable or hinder the Biokraft as an agro-environmental intervention. Based on this local example, we then present the challenges facing the ongoing national level revision, as seen from the perspective of national level actors. The report concludes with some preliminary reflections on what may be learned from this synthesis of experiences and views from engaged professionals, and invites the reader to share her/his own reflections, including considering the adaptations, which may represent possible pathways in the governance system to enable or promote the use of the biogas plant.

3. Findings Part A: Creating an enabling national policy environment

Civil servants in the Ministry of Energy and Climate and the Ministry of Food, Agriculture, and Fisheries explained how they were now tasked with promoting good market conditions for biogas initiatives in order to enable the achievement of the ambitious 50 per cent target. The principal aim was to change the framework conditions (*rammevilkår*) to improve pricing on biogas (*prisdannelse*). Accordingly, a number of initiatives have been launched to promote expansion of biogas plants, which combine investment subsidies with enabling electricity/energy tariffs and tax exemptions. Some of these initiatives were already launched when this assessment was undertaken. Others were in the pipeline, or had been put forward for deliberation in Parliament, notably under the framework of the Energy Strategy of 2050 (Government of Denmark 2011a).

A subsidy scheme has been launched, which offers 20 per cent of the investment cost associated with establishment of centralised plants that utilise a minimum of 75 per cent manure as substrate (farm-based plants are not eligible for this support). The Green Growth Strategy allocated 300 million DKK for a period of 13 years, with the first 100 million DKK to be expended in 2010-2012 (Government of Denmark 2010a). The subsidy is part-financed by a number of state income sources, including the national tax on electricity (which also finances the support to the windmills sector), with co-financing from the Rural Development Program (RDP) and even from the tax on natural gas. The statutory order on subsidy for investments in plants producing biogas (Statutory Order no. 1109 of 23/09/2010) outlines the subsidy system administrated by the Food Industry Agency.[4] The subsidy is intended for new facilities (*anlægsstøtte*) but can also be allocated to associated investments on farms, or major developments on existing plants, such as a new reactor. At the time of this assessment, the first round of applications had been completed, with 17 applications received, of which three fulfilled the requirements to receive the grants. This meant that 30 million DKK of the planned 100 million DKK would be allocated. Under the 2050 Energy Strategy, the government had launched a proposal to increase to the investment subsidy even further, to 30 per cent of the costs. The civil servants deemed the number of applications to reflect a significant interest among project entrepreneurs.

The price structure for electricity and heat delivered from biogas plants has been revised (see Table 3, left column). The price for biogas when traded into the BNG entry points or directly to CHP units was raised already with a political agreement on energy in the parliament in February 2008 (*energipolitisk forlig*). A revised pricing support package was recently been put forward, which included raised feed-in tariffs, subsidies and tax exemptions to both the biogas plant as well as the users (Table 3, right column).

[4] The agency has since been restructured and is now called the Danish AgriFood Agency (http://agrifish.dk/home.aspx?ID=16472).

One major feature of this proposed revision is the provision of a permanent subsidy of 27 DKK / GJ for all biogas, a subsidy for manure-based biogas of additional 22.5 DKK / GJ when the plant runs on minimum 75 per cent manure in the plant (*'gyllebonus'*), as well as a number of specific tariffs for different energy purposes (see Table 3 for overview of the price structure revision). This proposal is estimated to be above what the biogas branch organisations originally said was needed (Danish Energy Agency, 2011b).

A significant aspect of the proposed revision is that the subsidy would be redistributed, providing an increase in the competitiveness of biogas plants vis-à-vis the CHP units as the recipients of the gas. This reflects a 'decoupling' of the support from the CHP units to give the biogas plants more leverage in the negotiations with energy purchasers. The previous regulation of biogas as separate from natural gas (*'hvile-i-sig-selv'*) has also been partially removed, which means that biogas can be traded on more equal footing with natural gas, which is deemed a requirement to attract investors. Further, some contributors had an expectation that a three-step tariff (*treleds-tariff*) would be applied in order to vary the payment to electricity over night and day, matching the demand. One contributor explained that in a political agreement in 2004 biogas had been pushed out of this arrangement. Contingent on these proposals, it was highlighted that the Ministry of Finance was drawing up guidelines for revision of contracts between biogas plants and CHP units. As biogas plants and CHP units are normally distinct legal entities with different shareholders, the revision in the subsidy and pricing structure may stimulate a renegotiation of how revenue shall be split between the commercial parties.

Over and above the proposal for specific interventions directed towards biogas plants, the Energy Strategy 2050 (Government of Denmark 2011a) also contained a suggestion to liberalise the choice of fuels for the decentralised CHP units. This was expected to enable the CHP units to better react to market fluctuations and in turn lower heating costs for consumers. However, it was mentioned that such an intervention could have negative consequences for biogas plants, which could lose in competition with other biomass-based energy providers. One contingent proposed measure has therefore been to subsidise specifically the expansion of biogas related infrastructure to alleviate possible negative consequences of free fuel choice for CHP units, including 25 million DKK to establish the required grid from biogas plants to decentralised CHP units.

Further, in addition to the investment support, the state now provides a national compensation to municipalities if they act as guarantors for the financial risks (*kompensation for garantiprovision ved kommunegarantistillelse*). And, under the RDP, Statutory Order 307 of 26/03/10 also allows for subsidising of energy crops through a one-year scheme for growers.[5]

[5] See http://2.naturerhverv.fvm.dk/lovgrundlag.aspx?ID=53603.

Table 3: Current and proposed price structure for biogas based on animal manure
RE = Renewable Energy. Figures are in DKK / GJ in 2012. The application of RE grid based tariffs is possible because biogas is upgraded to BNG (Source: Danish Energy Agency 2011a).

	Current system				**Proposed revisions**			
	Subsidy for biogas plant	Subsidy for user	Tax exemption	**TOTAL**	Subsidy for biogas plant	Subsidy for user	Tax exemption	**TOTAL**
RE subsidy for CHP	0	44	31	**75**	50	17	31	**98**
RE Subsidy for process	0	0	8	**8**	50	12	8	**69**
RE subsidy for the grid	0	0	0	**0**	50	48	0	**98**
RE subsidy for transport	0	0	0	**0**	50	12	0	**62**
RE subsidy for collective heating	0	0	48	**48**	50	0	48	**98**
RE subsidy for individual heating	0	0	57	**57**	50	0	57	**107**
RE subsidy for own process	0	0	8	**8**	50	0	8	**58**
Total				**188**				**590**

A final significant government initiative to mention here is the Biogas Secretariat, which has been operational as of 2010. This Secretariat was established under the Nature Agency, Ministry of Environment, to support sub-national actors in overcoming challenges in finding locations for and establishing biogas plants. As explained by the head of the unit, the Secretariat is supporting municipalities that wish to promote biogas. A biogas project may evolve through different routes. One option is that it is initiated by the municipal executives, who will then ensure that the municipal administration includes biogas plants in its spatial plans and reaches out to investors. Another option is that a group of 'project owners' composed, typically, of a group of farmers and an advisory service or consultants, draws up a concept and reaches out to potential investors as well as the municipal government. Once a concrete project proposal is ready, it goes through the required environmental impact assessments and other permitting processes. As new projects are encouraged by the government's targets and programs, the increasing activity highlights the need for clearer guidelines, rules and procedures.

As biogas development has stalled for many years, there is now a need to dig into which rules work and which do not, and to clarify how the system can work better. New questions are also emerging as things are happening, and people see biogas plants being established with unintended consequences. The Secretariat has an important role in mediating between national level agencies and sub-national project owners. When civil servants in the national administration address emerging issues raised by biogas projects, the Secretariat assists with information possible solutions and provides guidance to procedural and legislative improvements. The Biogas Secretariat thus works both 'outward' with project developers, and 'inward' with its ministry colleagues. It was established building on the positive experiences with the Windmill Secretariat, which had a similar role, albeit focusing on wind farms.[6]

4. Findings Part B: Case study Bornholm

4.1 Background: Setting and risks

Bornholm is the easternmost island in Denmark, situated in the Baltic Sea, 40 km from the Swedish coast. The island has a total land area of 588 km^2 and a coastline of 158 km. With a population of close to 42 000 inhabitants (representing about 0.8 per cent of the total Danish population), Bornholm accounts for close to 1 per cent of the Danish agricultural area, 1 per cent of the milk production and nearly 2 per cent of the national pork production. The main crops are grain (barley and wheat), grass seed, rape, peas, maize and grass. In the period 2003-2010 the total UAA (utilised agricultural area) was 33 000 ha, managed by between 400 and 500 farms. Approximately 2 300 people are employed in the sector, representing around 12 per cent of the total work force (for further information on agriculture on Bornholm, see BAAS 2011).

The Regional Municipality of Bornholm (BRK) was formed five years before the national municipal reform in 2007, upon request from the island's municipalities. This led to a build-up of experience with coordinated environmental regulation before the combined structure of the municipalities received a mandate to take over formal responsibility. When the field visit was undertaken, Bornholm was waiting for the public hearing of the River Basin Management Plans (RBMPs) to be concluded. Several civil servants expressed concern that a very limited budget was available for implementation of the RBMPs, i.e. the water and nature plans, for the rest of 2011. There was also uncertainty regarding the balance between voluntary and compulsory measures in these plans, i.e. how much freedom there would be for the municipal actors to design the most appropriate implementation schemes.

Østkraft A/S (literally 'East Power', henceforth simply Østkraft)[7] is the municipal electricity company servicing all of Bornholm. It delivers electricity to Energinet.dk and the Nordic energy wholesale market and also trades electricity on the national trading platform, Elbørsen.[8] In the early 1990s an electricity cable was installed connecting Bornholm with southern Sweden and a significant portion of the electricity is today received from Sweden. Østkraft also delivers district heating, including for the island's capital city, Rønne. Another large energy provider is the municipal waste treatment plant, BOFA I/S, the Joint Municipal Waste Removal System for Bornholm (henceforth simply BOFA).[9] Organic and inorganic combustible waste from households and industry is treated in the incineration plant, producing district heating. Wind energy is also providing a significant share of the electricity supply: 35 wind turbines deliver close to 33 per cent of the total electricity demand (compared with 20 per cent in the rest of the country).[10] Part of the heating in BRK is also derived from burning of wood chips and other biomass, as well as fossil fuels.

Today, Bornholm has two farm-level biogas plants and one centralised plant. Two additional sites have been identified for installation of centralised plants: one near Nexø and one near Aakirkeby. Only the plan for Aakirkeby was subsequently implemented, which became Biokraft. The first farm plant was said to have been established in 1985, by Kaj Westh, a pig farmer near Klemensker, who built the plant

[6] See also http://www.naturstyrelsen.dk/Planlaegning/Det_danske_plansystem/Kommuneplan/Detaabneland/Biogassekretariatet/FAQ (in Danish).
[7] For more information, see http://www.oestkraft.dk.
[8] For more information, see http://www.energinet.dk.
[9] For more information, see http://www.bofa.dk.
[10] http://www.bornholm.dk

to generate heating for the stables. At that time, it was not possible to trade via the public infrastructure, but the investment helped reduce the costs from own purchase of heating.

Recently a new initiative for second-generation (lignocellulosic) bioethanol production has been started: BiogaSol.[11] A demonstration module to show the feasibility of this technology is planned on Bornholm, with several local partners, including BOFA I/S and Biokraft. The plan is to use, among others, cellulose from paper, cardboard and some garden waste.

As a supplementary energy provider, BRK has invested in a wood chip plant and associated grid. The plan, as described during the assessment, is to ship wood chips to Rønne from Sweden. The intention to burn wood chips is a source of concern from some people because of the added CO_2 burden. An agreement on price levels for the energy has been made, as required per legislation, and the plant is operated by Bornholms Forsyning A/S, a shareholding company owned by the municipality.

Above and beyond the energy requirements, Bornholm is facing a number of challenges dictated by its nature as an island. The farming community has limited land availability for crop production as well as for spreading of manure from livestock. As in other regions with large rural areas and few bigger cities, a number of rural development issues are visible, including the struggle to retain young people and a sufficient work force. When industries are optimising production chains and closing factories in the periphery, this also affects the agri-food sector on Bornholm, meat processing. Some people had expected to see a rise in pig production on Bornholm some years ago, but this has not happened. The slaughterhouse has maximum capacity of 500 000 pigs but is unable to reach this intake. Some contributors expressed concern for the survival of the slaughterhouse (and the jobs it provides). In general, Bornholm has experienced the same trend as the rest of the country with merging and closure of farms, leading to up-scaling and concentration of production.

Amongst the contributors, there were different reasons highlighted for the decision to invest in Biokraft, including an expectation to i) improve the delivery of carbon-neutral energy to the municipality, ii) address a problem of excess waste on the island, and iii) alleviate the problems faced by livestock farms that were producing more manure than allowed for their amount of land.

[11] See http://www.biogasol.dk.

4.2 Intervention and outcomes: Establishment and operation of Biokraft

The construction of Biokraft was initiated in 2005, after the necessary planning and environmental permit (*miljøgodkendelse*) had been obtained, as a biogas plant within Østkraft Holding, and thus as a public installation owned by the municipality. This coincided with a nationwide privatisation of the electricity sector. Within Østkraft, Biokraft has a role as compensatory supplier and reserve when other supplies fall out, e.g. if wind power is reduced owing to fluctuations in wind, or if a cold winter means that Sweden consumes more of its own electricity and thus raises the prices on the overseas sale. Biokraft provides only electricity, which it delivers as an independent company within Østkraft Holding to the national grid. When electricity prices fluctuate, responsibility lies with Østkraft Holding to purchase energy at the best prices to secure the financial viability in delivering energy within Bornholm to the agreed price structure. The provision of district heating is relatively new for Biokraft, which – since the required grid was established – is now delivering surplus heat to Aakirkeby, the nearest town. It is expected that when the district heating grid is further developed, Biokraft will have more potential customers, such as schools, including in Vestermarie (another nearby town).

Since the launch, there have been changes in the governance structure of Biokraft (see section 4.3.2 below). Today, the plant is driven by market conditions and has its own director and an independent board, which enables self-governance. The board includes the chair and the director of Østkraft Holding, businessmen from the municipality, and the head of another biogas plant in Jutland, and thus functions as a platform for sharing of ideas and learning between different businesses and biogas plants.

The manure used at Biokraft comes from pig and cattle farms. As of November 2011, Biokraft operates 67 contracts with 42 farmers for delivery of manure, where some farmers have several farms connected to Biokraft under different contracts. In addition to pig and cattle manure, which are the two largest substrates, the plant also relies on chicken manure, maize ensilage, grains and other animal products (Table 4, Fig. 2). Some of the manure is separated at the farms before transport, but the majority arrives to the plant as liquid manure with low energy content. Co-digestion of low-energy substrates with high-energy and easily degradable substrates – such as maize and other grains – enables the plant to increase biogas production.[12] Pig manure has less dry matter than cattle manure, which provides more feed for the bacterial process. In order to maintain an adequate balance between liquid and dry organic matter, separation technology can be applied at farms prior to delivery of manure to the plant, in order to increase dry matter content. Biokraft also pays attention to mixing pig and cattle manure in the reactor tanks in order to create the best conditions for the bacteria.

[12] Co-digestion of manure with organic waste, particularly animal fats and fisheries waste, is popular in biogas plants. Centralised plants normally use close to 80 per cent manure and 20 per cent other organic waste (Tafdrup and Hjort-Gregersen, 2010). All of 20 centralized plants reviewed by Maeng et al. (1999) were dependent on co-digestion.

Table 4: Biomass substrates for Biokraft
(Source: Biokraft A/S, 2011, English translation by author).

Biomass	Substrate input (Tonnes)
Separated manure	3 630
Chicken manure	3 900
Raw manure (pig)	14 500
Raw manure (cattle)	54 000
Maize ensilage	3 300
Grains	750
Molasses	570
Intestines	1 022
Biomass output (degassed manure)	91 000

Biokraft employs one driver and hires another external driver in order to organise its own logistics and transport of fresh manure to the biogas plant. The maize ensilage is delivered directly by a network of farmers, who are responsible for this supply. Upon arrival to the plant, the trucks are weighed and the data is used for compilation of nutrient accounts, based on the standard nutrient contents for different substrates.

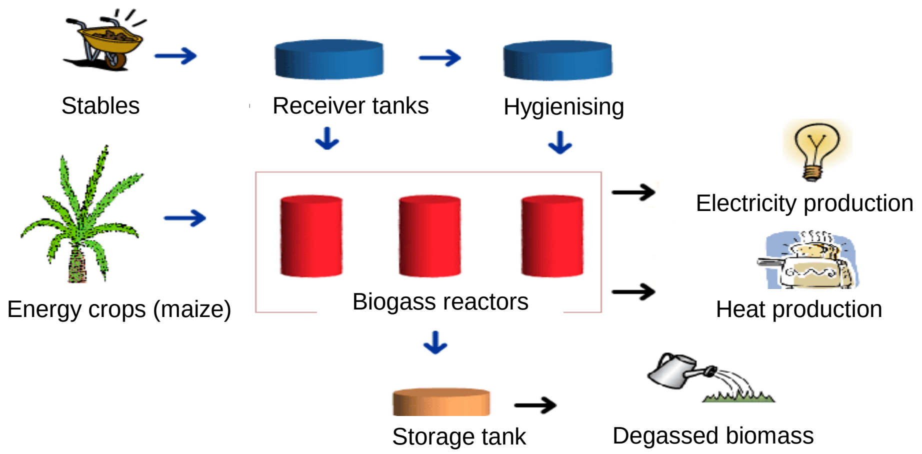
The plant has the potential to treat 40 per cent of manure on Bornholm, but today the process runs at a lower rate. The total annual production of electricity and heat is, respectively, 8 700 MWh and 8 400 MWh. The plant includes a 'high-technological' element, which was intended to separate the contents of the manure and co-substrates into ammonium, clean water, inorganic nitrogen, phosphorus, kalium, etc. The plan was to produce an equivalent to industrial fertiliser from the organic products, which would provide high-value outputs to be traded with farmers. However, in practice this part of the process has never been operational (see section 4.4.1).

The investment in expensive but malfunctional equipment has been one of the reasons for the difficulty for Biokraft to make a profit or even break even. According to the management team at the plant, the financial results have improved recently, from a 5 million DKK deficit three years ago, to a 2.5 million DKK deficit two years ago, to about break-even in its own operations today. However, they also acknowledge that more adjustments are needed in order to improve the finances.

The team at Biokraft is continuing its effort to improve the ability of the company to be an asset for the farmers and to ensure rewarding those farmers who associate with Biokraft. As was expressed by one of the staff, this requires "one third technical skills, one third logistics, and one third entrepreneurship". According to municipal politicians and board members of Biokraft, closing down the plant has been seriously discussed on several occasions. However, so far the effort continues to make the operation viable, and a number of reinvestments have been made recently by Østkraft Holding. This includes investments in improving the logistics and in stabilising for bacterial digestion process. A new gas-container was also installed with an improved air pollution control system. As one example of improvement, it was cited that 2010 saw 15 complaints on air pollution, while in 2011 the management has only received one such complaint.

Overall, the operation of Biokraft has been associated with clear benefits, which have stimulated the adoption of and buy-in to the plant as an agro-environmental measure. However, it has also faced significant challenges in its operation and in meeting the planned energy production. Below, the report presents these enabling and disabling factors, as they were expressed by the contributors to this assessment.

Fig. 2: General description of the process at Biokraft
(Source: Biokraft A/S, English translation by author).



4.3 Enabling factors for adoption

4.3.1 Political support

The establishment of Biokraft was championed by Østkraft and several municipal politicians. Prior to 2005, there was an awareness of the technical and financial challenges faced by centralised biogas plants elsewhere in Denmark, but there was a high degree of trust in the leadership in Østkraft and the projected plan. While Biokraft is still not generating revenue, the new strong national political agenda promoting biogas technology is also a source of confidence for some people to continue the effort to make Biokraft viable, hoping for increased national-level support in the near future. The political buy-in to the project from the municipality and the ownership by Østkraft has also enabled the provision of financial capital, both in the launch of the project and in the subsequent reinvestment phase (which according to the contributors required 20 million DKK).

4.3.2 Improvements in ownership

The strong political support also had initial disadvantages, several of the contributors said. The board was initially composed of political representatives from the municipal council, who did not have the necessary connection to farmers' interests and needs, nor the required sense of the market conditions. It was also experienced that the board became a forum for political negotiations rather than caretaker of business interests. The political steering was experienced as overly restrictive and cautious by some people, preventing necessary adjustments in the organising of contracts and pricing for delivery of manure. Without the proper liberal market thinking, business-minded people were seen to be scared away from the initiative. The public ownership and the initial political steering were also cited by one person as reasons why Biokraft

> "ended up in political tug-of-war between costumers of district heating and farmer interests in the handling of manure; …this was a reason for a resistance to adapt the accounting model for the manure handling".

It was thus seen as strongly enabling for the operation of Biokraft that the board composition was changed to better represent farmers and market interests, who had always been part of the board, but were outnumbered by municipal politicians. After a gradual replacement of political representatives with farmers and business representatives, the last municipal politician left the board in 2010. It was expressed by some that this reorganisation has enabled a broader appreciation of farmer interests rather than single groups, such as pig farmers. One of the improvements has been a stronger buy-in from farmers in delivery and receipt of the substrates and degassed manure. This has led to a much improved standing of the initiative amongst farmers.[13] Today, the municipal council is seen to have little direct involvement in the steering of the activities, and only steps in when environmental cases are raised, such as complaints pertaining to air pollution. Here, citizens file complaints to the Committee for Technical Concerns and the Environment, a committee under the municipal council (see also section 4.4.3 for further information).

According to some contributors, further improvement in ownership amongst farmers – and thus willingness to deliver manure – would enable a further 25 per cent increase in gas production. This is because the operation is still constrained, with a need to optimise logistics (transport) and ensure secure delivery of substrates. With the market-driven approach, farmers are signing contracts to deliver manure

[13] Reference was made to the fact that many other centralised plants in Denmark are owned through shareholding arrangements (*andelseje*), and that this probably enables better ownership and incentive for farmers to engage and deliver manure and make sure it is profitable. However, other contributors highlighted that farmers alone typically cannot attract investors and that farmers will also depend on partnerships with trained entrepreneurs to judge and create a viable business.

to Biokraft once they are convinced that this arrangement will benefit them. As will be discussed below (section 4.3.3) a major incentive for farmers is the ability to get nutrient-rich water left over from the process, as well as the degassed manure, to use as fertiliser – a particular benefit for cattle farmers who want to improve the growth of their pastures. However, as farmers have to pay to join Biokraft, including paying to deliver the manure, there may not always be a net benefit for the farmer, and many do not wish to sign up to the service.

4.3.3 Facilitating nutrient usage and exchange

Application of manure to fields is in Denmark regulated through statutory norms for the utilisation of nitrogen in manure, minimum use efficiency, and what is known as harmony requirements (*harmonikrav*). Harmony requirements are intended to 'harmonise' the relationship between the size of livestock production and the land area available for spreading of the manure. Maximum application rates of manure must for cattle manure correspond to 1.7 livestock units (LU) per ha, and for other types to 1.4 LU/ha. (1 LU corresponds to 100 kg total N in the manure). As animal manure contain different levels of nitrogen, a conversion factor is used, known as 'livestock units', for each animal type.[14]

One of the strongest motivators for farmers to engage with Biokraft has been that the delivery of manure to the plant facilitates the ability of the farms to meet the harmony requirements. A base condition for this is that Bornholm, like much of Denmark, is densely populated with livestock farms, one of the highest concentrations in the Baltic Sea Region, so access to land for spreading of manure has become a limiting factor. In fact, a key objective of the 'high-tech' part of the plant (aiming to produce inorganic N and P etc.) was to 'take out' LUs from the farming sector, in the form of fertiliser which could be shipped away from the island. However, as this is not operational, Biokraft is now operating simply as a distributor (*formidlingscentral*) of LUs.

Some farmers deliver their manure to the plant and in this way remove LUs from their production; these LUs are subsequently received with the degassed manure by the farmers who have agreed to use the digestates. Some farmers will have a special interest in receiving such degassed manure. One example is organic farming, where it is otherwise difficult to access sufficient acceptable fertiliser, as industrial fertiliser is not permitted by the organic standards. However, Biokraft encourages its clients to sign contracts which require them to take the digestate back after treatment. For these farmers there are multiple benefits with this redistribution of manure-bound nutrients. One benefit is that farmers receive more active N than they deliver. For farmers who deliver cattle manure and receive degassed manure from the plant, the nutrient content is improved in the manure after treatment. Cattle manure contains a relatively high fraction of organic matter (close to 10 per cent) and the treatment (together with the more liquid pig manure and other co-substrates) converts this material into plant-available nutrient compounds.

The second significant advantage is that farmers 'earn' LUs through the treatment. This means that they are able to apply more manure-based fertiliser on their fields, or raise more animals relative to the area available. One way to exemplify the 'earning' of LU through biogas treatment is to refer to another technology, namely on-farm separation of liquid manure from the organic dry matter in the manure. Separation yields a) a solid fraction with a high concentration of dry matter, organic nitrogen and most of the phosphorus, and b) a liquid fraction with nutrients soluble in water, such as ammonia nitrogen and potassium. The liquid form (the reject water) will be applied directly on the farm, while the dry matter, which has now been separated, will be transported to Biokraft. The separation produces two fractions; nutrient-rich liquid manure (high nutrient content per kg) from dry organic matter (low nutrient content per kg). Most of the water soluble nutrients are thus left at the farm with the liquid fraction after separation, but a significant fraction of nitrogen and phosphorus incorporated in the organic matter will

[14] http://www.pdir.dk/Files/Filer/Topmenu/Publikationer/Vejledninger/Goedningsregnskab0203/kap08.htm

be transported away to the biogas plant. When the dry matter is transported from the farm to Biokraft then the truck is, in effect, also transporting LUs away from the farm. Current legislation also allows a redefinition of LUs after separation, namely 120 kg N per LU instead of 100 kg N pr LU.[15] Further, it was suggested by some people that as Biokraft uses co-substrates such as maize, the nutrients from this biomass (which is not accounted for in the farmers' fertiliser and crop plans) will be adding value to the digestate when leaving the biogas plant. Overall, these are reason why farmers with an agreement to both deliver and receive manure (*byttegylle*) with Biokraft in fact get more N than they deliver. According to some contributors, this aspect is one of the most crucial advantages, which could be made clearer to farmers, in particular since the statutory crop specific nitrogen norms are set at 15-18 per cent below the economic optimum.

The above motivation has changed radically with the revision of the agricultural legislation under the first years of the Green Growth Strategy. When farmers are permitted to form shareholding ventures and the upper limit on farm land owned per farmer was dissolved this also, for many, removed the barrier to access land for spreading of manure. As suggested by several contributors, this in effect means that the inclination to use Biokraft will decline. Many even talk about this legal revision as if the "harmony requirements have been removed".

4.3.4 Optimising crop production

Another central motivation for farmers to sign contracts with Biokraft to receive digestate from the treatment process is that the fertiliser value in terms of N is improved in the process of degassing. According to some contributors, this may even lead to higher protein content in grain because of more optimal growing conditions. Much of the nutrients such as P and N are bound in the organic matter in the manure, and are released in the bacterial conversion in the plant. This, together with the fact that there is an increase in plant-available nitrogen, ensures more efficient use by plants rather than loss to water. Since cattle manure has more organic content than pig manure, there is especially something to gain for cattle farmers. However, while N use is thus improved, the efficiency of P utilisation is unchanged. Further, if the digestate is burned, P becomes more heavily bound in compounds and therefore not directly available as plant nutrient.

An interlinked benefit, raised by some, is the reduction in air pollution from degassed manure. One person explained that the degassed manure smells only for three days, whereas normal manure smells for up to 14 days. It was recommended by some people that while liquid manure must be injected into the surface soil (a compulsory requirement as of 1 February, 2011), application of digestate should be exempted from this regulation. Injection is costly and troublesome for farmers, in particular as it causes structural damages on fields owing to the heavy machinery, destroying plants and causing soil compaction. Some farmers have even experimented with application of acidifiers during spreading of the manure, as an alternative means to reduce ammonium emissions. It was also mentioned by some contributors that the use of co-substrates such as maize changes the characteristics of the digestate, creating a heavier product, which does not as easily filter down in the soil.

[15] According to information received, four or five farmers on Bornholm use fibre separation. The use of such separation technology and whether farmers sign up as clients with Biokraft A/S will be incorporated into the environmental permits of the farmers, to show how their LUs are managed. In general, separation technology is an advantage for pig farmers, as pig manure has high liquid content. Cattle farmers do not separate, as the manure has higher dry matter content, and no effect is assumed. Separation can both rely on chemical separation via polymers to capture nutrients or use mechanical separation.

4.4 Barriers to adoption

4.4.1 Technological problems

As mentioned above (section 4.2), the 'high-tech' part of the biogas plant has never been operational. It was explained that the supplier of the equipment chosen by the Board of Østkraft, BioScan, could not deliver what it promised. One of the people involved with the establishment of the plant said that the equipment that was delivered did not live up to the technical specifications. Meanwhile, BioScan was close to insolvency, and the order from Østkraft was crucial for its future. In this view, it was also hoped that Biokraft would become a 'reference plant' for BioScan, to stimulate further orders elsewhere. When the project management refused to pay the remaining instalment for services, owing to a perceived breach of contract, BioScan filed a lawsuit. In the preparations for the project, several technology providers had been reviewed, and BioScan had been selected based on its BIOREG patent for defractioning manure into industrial fertiliser compounds of N, P, Potassium etc. Members of the Biokraft project management team at the time say that when they complained about BioScan, Østkraft leadership intervened in favour of BioScan.

Several contributors highlighted that this failed investment represented a main challenge to the total operation of Biokraft, as it undermined the finances. One person compared the total investment in Biokraft to what could have been achieved if the 67 million DKK investment had gone into windmills, which he said would have yielded four or five 7 MWh windmills. One contributor, whose views were echoed by others, stated that

> "Biokraft is a failure. It will never generate revenue. [The technological problems] meant that the finances in the project were undermined. As a power plant, Biokraft will never be a success…it is the most expensive MW north of the Alps!"

Others highlighted that even though the energy production is not comparable to wind turbines, the main argument when proposing the plant was to ensure a stable energy production, which could fill the gaps when wind and other sources fluctuated. Similarly, there were different views on the future prospects for the plant. Some expressed that while Østkraft had indeed incurred a great loss on the establishment and the subsequent 20 million DKK action plan to save the plant, it now seemed to be able to reach break-even in operations and avoid further deficits on operation costs. Other said that while they were happy to see Biokraft improving its business, it was hard not to recall the many disappointments, and that they had lost trust in the project.

4.4.2 Stability and quality in manure supply

Over and beyond the immediate technical challenges, Biokraft has faced a significant struggle to build a stable and adequate supply of manure for the process. It was pointed out by several contributors that, contrary to many other Danish biogas plants, Biokraft BK is almost fully-manure based, which in turn raises the need for a solid anchoring among farmers and an effective supply system. In fresh manure, the water content is too high relative to the organic dry matter to enable efficient bacterial digestion. Transport of manure with its original high water content is also more costly owing to a high volume and weight relative to the gas production.[16] For these reasons, it is desirable to use manure separation technology on the farms, to retrieve only the valuable fibres and, in turn, enable farmers to use the reject water directly on the farm. However, the gas potential declines significantly over time and it is thus equally important to ensure delivery of fresh fibres. The experience of the management team at Biokraft is that a significant part of the gas potential is lost (from 'natural degassing') while waiting for transport.

[16] Similar challenges were highlighted in the national-level meetings. Some estimates find that transport exceeding 20 km is not economically feasible, and the density of manure in the 'catchment' area of the biogas plant is thus important (see e.g. Danish Biogas Association et al. 2009 and http://vbn.aau.dk/da/publications/costeffective-production-of-biogas-from-manure--retrogas-project(5c23a9f6-d529-4584-aa15-9d7ede46e17f).html).

Thus, the storage of manure for separation at the farm before transport to Biokraft is seen to potentially cancel out the benefit of fibre concentration.

This is one of the reasons why Biokraft and Bornholm's Agricultural Advisory Service are now raising funds for a mobile separation machine, which can be moved between farms and facilitate delivery of fresh manure fibres to Biokraft, as well as support farmers who do not have funds to invest in their own technology. Continuous collection from the farms also reduces the need for storage tanks on-farm (one of the legal requirements included in the farm's environmental permits). For most farmers, storage tanks are expensive. Typically, farmers will have only one tank, which mixes old and new manure, thus making the provision of fresh manure difficult.

As was mentioned by the advisory service, the need for separation partly arises out of a change in the organisation of the stables in modern livestock production. Previously, farmers would apply a housing design for tied cattle, where liquid and dry manure would be separately managed. Many poultry farms still use this system. For most pig and cattle farms dry and liquid manure is now blended in the stables. As mentioned by one farmer, it is also possible to integrate 'manure capture' objectives into the planning of stables from the outset, for instance in the organising of floor cleaning. Another person highlighted the goal conflict that emerges when farmers apply acidification measures on the farm to prevent ammonium emissions, as this lowers the pH in the manure, which in turn constraints the bacterial process in the biogas plant. Further, the ongoing feeding optimisation, which aims to maximise the uptake of energy contained in the feed by the animals, lowers the amount of organic material left in the manure for biogas conversion.

With transport, Biokraft has problems with driving permits, since the environmental permit only allows delivery trucks to arrive at the plant on weekdays from 7.00 to 18.00. This regulation is understandable from the perspective of neighbours, since delivery creates noise and air pollution; however, from a process perspective it is problematic, as the plant requires continuous feeding with fresh manure, also on weekends and holidays.

As was shown in Table 4, Biokraft relies on co-substrates besides manure (maize, waste etc.). The challenges associated with provision of co-substrates are discussed below (section 4.4.5).

4.4.3 Finances and farmer buy-in

The use of manure for biogas adds a new layer to the commoditisation of manure as a product traded between producers and users. Owing to the environmental regulations (see section 4.3.3) livestock farmers are required to consider how they stay within the harmony requirements and fulfil the requirements for use efficiency. While delivery of manure to Biokraft is one option, they may also choose to give the manure to neighbouring farmers or to purchase or take a lease of new land (*forpagte*) for spreading of manure. With the revision in the agricultural legislation to remove the upper ceiling on land ownership, the latter option has been facilitated, thus making it harder for biogas plants to compete as a manure manager. As the manure management forms part of the farmers' general economic transactions, the choices made whether to deliver to Biokraft or exchange directly between farmers, is also dependent on the price fluctuations of industrial fertiliser, and even expected income from crop yields, as dictated by market prices on grains and other crops.

Biokraft thus has a continuing challenge to convince its clients (farmers) that there are economic gains associated with signing a delivery contract with the biogas plant. Until now, separation of fibres from liquid manure was expected to be paid for by the farmer. Upon delivery, the farmer further pays a 'gate fee', which is inversely correlated with the quality of the manure; i.e. high quality means low fee. The estimation of quality is, for instance, based on origin (cattle, pigs), fibre content, and storage time.[17] The incentive to pay a gate fee was higher in the early years of Biokraft's operations, but with the legislative changes, which removed the barrier to access land for spreading of manure, this incentive has declined somewhat. Further, as Biokraft compensates the farmer according to the weight of the dry matter, some farmers may choose to store the manure on-farm to increase the fibre content through evaporation of water (which also leads to a loss of gas content). As the high-tech part of the plant did not become operational, and a significant source of revenue thus was removed, the gate fee has had to be increased.

The people involved with Biokraft appreciated the efforts by the Danish government and national ministries to improve the framework conditions (*rammebetingelser*) for biogas (see section 3). However, as commented by the director of Biokraft, the values associated with manure remain limited. The tariffs per KWh, which is provided under the current conditions, were seen to be sub-optimal and not adequate for securing the finances. Today, Biokraft earns 10 DKK per tonne of liquid pig manure, through gas production and gate fees, but it costs 22 DKK to transport each tonne.[18] Further, like other biogas plants, Biokraft cannot deliver energy matching 100 per cent of its potential (this was, according to some contributors, said to be an underlying assumption for the estimates supporting the proposed national pricing structure). Often, it is only possible to reach 60 per cent effect, as the plant also must generate heat and electricity for its own process. When cleaning the reactors, the effect also declines. The inability to ensure continuous delivery of the required manure substrates (section 4.4.2) is also a cause of sub-optimal effect. In addition, the new tax on methane emissions, which also hits biogas plants, is perceived as working counter to the government's desire to promote biogas operations.

4.4.4 On-farm economic depression

As highlighted above, the effective operation of Biokraft is contingent on decisions and investments made on-farm among its suppliers. Many of the farms on Bornholm, as in the rest of the country, suffer from a lack of liquidity and are very constrained in making further investments. The hike in land prices over the recent years, which have also been capitalised by the European single payment scheme, has led more and more farmers to take out loans, using the land as collateral. When the land prices decline, as has been the case recently, many farms become insolvent, and those that survive lack the capacity to expand or invest in production because of debt. Many contributors referred to how, in effect, the direct payments have held land prices artificially high and contributed to maintaining forms of production that are not viable. As one person stated, for several years farming has been the only business sector making money simply from rising land prices. This has led to a lack of caution in ensuring annual income; it is only now that land prices have collapsed that they depend on making a profit annually.

The team at Biokraft estimates that up to 15 000 tonnes of cattle manure is lost every six months because of lack of separation machines on farms. A separation installation amounts typically close to 250 000 DKK, funds which most farmers do not have access to. In Nordea Bank A/S, one of the large credit institutes on Bornholm, there are two clients with credits for separation installations. These installations are written into the environmental permit of the farms, and thus comprise part of the farm-level nutrient management. No other applications have been received in recent years. A lesson learnt is that the separation technologies typically require more electricity than is indicated by the providers, thus leading to higher costs for the farmer and in turn making manure exchange agreements (*gylleaftale*) with other farmers more advantageous.

Financial institutions and banks own the financial risk if their clients go insolvent. When the market is characterised by uncertainty this also causes reluctance amongst some credit lenders to take on new

[17] See http://www.biokraft.dk/prispolitik.asp. The design of the gate fee pricing was changed as of 1 September, 2011. This led to a reduction in gate fees for farmers to facilitate increased delivery.
[18] However, this is an average figure. The net result will depend on the quality of the manure and other factors.

projects from existing customers, or to take on new clients altogether. Another obstacle to making new investments in on-farm separation technology is that the revenue incurred by the farmer typically is only available by the end of the fiscal year. Farmers thus have to negotiate the financial guarantee during the year with their financial institution(s).

4.4.5 Alternative biomass access and energy potentials

The challenges associated with maintaining an adequate and high-quality manure supply, combined with a need to include co-substrates to boost the process, motivates the search for alternative biomass. Maize, the main co-substrate at present, has a good energy density to fuel the process, but is, as a food crop, vulnerable to price fluctuations. Here some people were concerned that the biogas process relied on a substrate which ultimately was taken away from food production. One person stated that "given the global population growth and the need for food production, is it not wrong to use agricultural land for biogas? Biogas can solve waste problem [from manure] – this is the real value". In contrast, others commented that "what goes into Biokraft is maize from no more than 300 ha arable land, which corresponds to 1 per cent of Bornholm's cultivated area; it is virtually nothing".

It is useful here to recall the constraints imposed because of the location of Biokraft on an island, where there is a limited amount of organic waste available and transport options are also limited by the cost of shipping. In this sense, the conditions for Biokraft are different than for plants in mainland Denmark, where the marginal costs of retrieval and transport of biomass are lower. More important, perhaps, much of the available biomass is already mobilised by the incineration plant at BOFA I/S and by Østkraft's other units. Biogas plants, such as Biokraft, face the interlinked challenge that a certain economy of scale is needed to make the process viable. Existing technical solutions require a certain scale of production to reach sufficient production levels.

Biokraft is engaged in dialogue with the other units under Østkraft and with BOFA to identify possible wastes which can be made available for the biogas plant. Both BOFA and other Østkraft units are more established biomass consumers and energy providers. BOFA, as a case in point, receives industrial, unsorted organic waste as well as household organic waste, kitchen waste; and garden and park waste, which is composted and returned to the towns. The suppliers pay according to the waste-specific tariff system in order to hand over the waste to BOFA. These waste products could, technically, be used by Biokraft (as is the case in other centralised biogas plants in Denmark), but such a potential redistribution would raise a number of questions: how would it affect BOFA's process and what would be the net benefits in terms of energy and provision of services through the treated waste products? For instance, BOFA, as other waste incineration plants, has a quite efficient energy conversion process, delivering heat which is close to being CO_2 neutral. If the heat supply is reduced, would Biokraft compensate this loss or would other fuels have to be used? If removing parts of the waste feed, the combustion process would have to be adapted accordingly. Further, the residues from the composting and waste incineration are currently used by different non-farm users, whereas Biokraft returns the digestate to farms. If kitchen waste is to be used for biogas production, it may also require very effective sorting at the household source. Recently, BOFA had a 50 million DKK upgrade in its installations reflecting expectations that it will continue to deliver district heating at the same capacity, or above.[19]

A special challenge is encountered regarding accessing glycerol and fat-rich waste, which is an excellent booster of the bacterial process in the biogas plant. Currently, BOFA is burning frying fat from industrial kitchens. It was suggested that the Biokraft hygienisation step (See Fig. 2) would not be

[19] Fruergaard and Astrup (2011) note that waste incineration with energy recovery is in practice the ''reference'' treatment technology for municipal solid waste in Denmark. Life cycle analyses based on Danish conditions have shown that incineration with energy recovery of organic waste is more advantageous from an energy perspective than digestion in biogas plants.

sufficient to treat such glycerol, and that it would require further procedures to control health risks (in particular bacteria and viruses). The same problem of biosecurity and health risks is associated with meat and bone meal, which – unlike glycerols and fats – would add N and P to the process. Even sludge from waste water could be a potential substrate for the digestion. However, while it is legal to apply sludge residues on farm land as long the sludge is treated according to the statutory order,[20] the dairy industry in Denmark has decided not to allow such applications to farm land used for purposes of milk production, in order to avoid possible consumer concerns.

These considerations are stimulating efforts to pilot the use of catch crops as co-substrate in Biokraft. Unlike to maize, catch crops are not market-dependent, and they are grown in large quantities as mandated by legal requirements, yet without any direct economic value to farmers. Reference was made to a number of projects in Denmark, testing the gas potential of grasses and beets, as well as from ditch vegetation. Together with Bornholm Agricultural Advisory Service, Biokraft is also interested in exploring the feasibility of growing crop rotation grasses specifically for biogas production instead of the currently legally required cultivation of catch crops. The hypothesis is that such grasses grown for biogas potentially could retain more nutrients than catch crops which are not thriving under the specific growth conditions (dry climate) on Bornholm. However, the legislation does not allow this at present.

In the debate on optimal use of biomass, one also has to consider biofuels production through bio-refineries. The second generation bio-ethanol initiative BiogasSol in Årkirkeby is also engaged in the discussions regarding the distribution of available biomass substrates. It is slated to start receiving paper and cardboard shortly from BOFA. This is considered economically smarter than shipping to Sweden for inclusion in paper mills, as is currently done. Some contributors predict that in the near-future, biogas will compete with second and third generation biofuels. They commented that biogas is one simply type of production, and not as fine-tuned as bio-refineries, which can deliver multiple products.[21]

4.4.6 Doubts regarding environmental and public benefits

The launch of Biokraft was motivated by the expectation that it would deliver clear environmental benefits to Bornholm's citizens. The benefits expected included the full range listed in Table 1. However, several of these benefits were challenged. For instance, several contributors referred to the fact that a key motivation for Biokraft was to reduce air pollution (including foul smells), but that other means, such as on-farm measures, could have been more cost-effective. According to one person, even though the degassing helps, the digestate still stinks. Danish regulations do not restrict where and when manure can be spread, as long as the spreading is kept within the specified amounts. As one farmer commented,

> "Then the argument of reduced air pollution is used, but fact is that if just one farmer in the vicinity does not degas his manure then the neighbours won't feel a difference even if other farmers use the biogas plant… The whole parish has to degas its manure".

Others mentioned the fact that the degassing only removes carbon, while N and P contents are still left in same quantities, which do not match the requirements by crops. Thus, problems of nutrient management on-farm remain. Some referred to research that shows the actual effect on nutrient discharge to the aquatic environment is minimal, and that while in theory, nutrient uptake by plants is facilitated, in practice it is not possible to measure a difference on leaching.

[20] See https://www.retsinformation.dk/Forms/R0710.aspx?id=13056.
[21] Several biorefinery installations are under way in Denmark. Life cycle analyses of biorefineries are highlighting the dependency on fossil fuels in the cultivation of the feed stocks and the refining itself as a weakness. Some initiatives intend to integrate biorefinery with biogas production (Holm-Nielsen et al. 2009).

In the view of those who found that there are few, if any, environmental benefits, the decision to build Biokraft was founded primarily on a wish to benefit the agricultural sector and the associated agro-food industry, in particular to address what was then an urgent challenge to stay within harmony requirements and stop the build-up of surplus manure on the island. Thus, several people perceived the biogas plant as a way to support farmers through the use of public (municipal) funds, although it officially was portrayed differently. One person said:

> "Politically, biogas is primarily a means of increasing pig farming on Bornholm… the environmental impact is not reduced."

A municipal politician explained the experience with the process leading up to the approval by the municipal council to fund Biokraft. In this view, the decision to establish Biokraft was made at Østkraft, and it was the leadership at Østkraft and its stakeholders who championed the decision, not the municipal council. The council was only informed about the investment when it was asked to amend the municipal spatial plan to accommodate Biokraft. The Committee for Technical Concerns and the Environment was then asked only to contribute to implementing the initiative, not to suggest alternatives. As such, the project was championed on the basis of political interests who were dominant at the time. This was possible also as the composition of the Board of Østkraft mirrored the distribution of mandates received by the municipal council at the elections.

Civil servants in BRK explained that, during the planning process, there had been complaints submitted on procedural irregularity and lack of impartiality (*uvildighed*). If a new construction implies a major revision of the spatial plan in the municipality, then a pre-public hearing (*foroffentlighedshøring*) is conducted, which is quite extensive. In case of Biokraft, Østkraft pushed for a very rapid process, so the hearing was concluded within only three weeks. As required, the environmental impact assessment (*VVM*) was prepared as the basis for the environmental permit. However, the environmental permit did not capture requirements for air pollution. The permit was subsequently also subject to a complaint.

5. Findings part C: Critique of the national policy environment

According to national-level actors, when considering the economic bottom line, the main challenge for biogas projects in general is that the plants often are not financially viable under the current investment climate. Despite the policy revisions, civil servants in the national ministries explained that they are informed that many projects are pending, and there is a push for better pricing and subsidies. The establishment subsidy and partial risk guarantee from the state are in many cases not functional, since municipal funders refuse to carry the remaining financial risk for biogas projects. Some people noted that municipalities will not pay for the implementation of a national strategy that will hit municipalities with many livestock farms harder than those with fewer. This means that many projects have problems simply securing the necessary start-up capital. Civil servants highlighted that there was a revision of the establishment subsidy scheme in the pipeline, for this very reason. Here it is expected to remove the requirement for documented co-financing when biogas projects apply for establishment grants. It may instead be replaced with a requirement to document such co-funding following the receipt of the establishment grant. In brokering with investors, it is also a challenge for project owners who are farmers that investors may question whether the initiative is sufficiently professional. As was stated by one civil servant,

> "A pension fund does not want to fund 10 farmers who are experimenting with a biogas plant if they are not sure the technologies are well tested and the project management is really professional to secure revenue."

However, many contributors noted that setting up biogas plants is not the major problem, but rather, the overall conditions are not sufficiently favourable. According to some estimates, only one-third of existing centralised plants achieve break-even. For farm level biogas plants, two of four plants examined by Pedersen et al. (2006) were at break-even or better in the period 2002-2004. The challenges to financial viability are well recognised (e.g. Danish Commission on Climate Change Policy 2010; Ministry of Food, Agriculture and Fisheries 2008; Vetter 2010) and have been the key factor motivating the proposed revisions by the government (see section 3). In sum, this means that biogas still is often unable to compete with fossil fuel technologies, and even other biomass-based energy providers.

Yet some contributors were critical of the manure use incentive proposed with the revision of the pricing structure (the '*gyllebonus*'), which they saw as a hidden agricultural subsidy that would work against compelling biogas plants to ensure optimal efficiency in their operations. However, while some people admired the German model, which had led to a biogas boom through subsidising of energy crops, others were proud that Denmark was trying to find synergies between energy and food production, rather than promoting biogas at the expense of food production.

Another challenge facing biogas initiatives, both within the renegotiation of pricing structure and in the actual project implementation, is competition between different energy providers. One of the underlying themes in the revision of the price structure is negotiating an acceptable and level playing field. It was considered a scarcely hidden secret that the purpose of biogas promotion is to partially replace natural gas (see also Danish Biogas Association et al. 2009). Here, the policy revisions are addressing what people referred to as an 'infrastructural lock-in', as the CHP units are very efficient and have been supported through many years to address waste treatment from industry and households. With a liberalised energy market, large market actors will need to see a clear economic benefit for buying biogas. As one civil servant explained, Denmark is partly tied by the existing system of tariffs, quotas, and taxes to established energy providers, and the downturn in the state budget means that the necessary funds are lacking for more significant biogas tariffs. Another person stated:

> "It is clear that CHP units have often not invested in promoting biogas as a solution… since they have a good position. They can shift between different providers and feeds, and use what is financially lucrative over time. Then it is hard competition for biogas plants."

Several people traced these economic challenges back to issues related to how the 'public goods' delivered by biogas – such as cleaner air and water and a reduced climate-change risk – are valued. The ambitious target of 50 per cent degassing of manure in biogas plants was set already in the Green Growth Strategy in 2009, and several initiatives were launched, including the establishment subsidy and the Biogas Secretariat. However, it was only with the Energy Strategy 2050 that significant interventions in the pricing structure were proposed. According to civil servants, this reflects that biogas was not among the agro-environmental measures considered for the design of the RDP, and there was no formalised involvement of the Ministry of Energy and Climate in the deliberations on nutrient measures (e.g. in the Nitrates Committee). As they stated, nutrient discussions are complicated in themselves, and biogas was not coordinated in this region, but rather managed as an energy measure instead. Thus, they said, throughout the process of preparing the Green Growth Strategy up to the final political agreement, more and more climate- and biogas-related targets were added without concrete measures, with the idea that these measures would be handled by the Ministry of Energy and Climate. One civil servant stated:

> "CO_2 reductions were not factored into Green Growth discussions. If measures under Green Growth lead to CO_2 benefits, then they will naturally be included in the actions under the Energy Strategy 2050, but Green Growth was not oriented towards this, but rather the compulsory targets under the Water Framework Directive. It is quite common

to look at the hardest target [from the EU], not multiple benefits… DKK/ kg N is what counts."

Further, civil servants from agencies under the Ministry of Environment explained that the environmental benefits were not yet clear. While there is relative agreement on the CO_2 savings, it is more complicated for nutrient management. Nutrients may be more easily taken up by plants after treatment, but there is still leaching, and the same amount of nutrients to be handled. Some people even mentioned that the management of the residues in the digestate required new environmental regulation. Thus biogas deliberations under Green Growth did not include CO_2 considerations, nor is the 2050 Energy Strategy seen to factor in nutrient impacts. Furthermore, according to one contributor, employment benefits have not been factored in when assessing the cost-efficiency of biogas from a socio-economic perspective.

In this regard, professionals involved with the prioritisation of measures under the Green Growth Strategy explained that the formalised selection of agro-environmental measures in Denmark is not based on cost-benefit analyses, but on cost-efficiency estimates. Multiple benefits are indeed acknowledged, but only in qualitative terms; i.e. whether measures 'pull in the same direction'. Here, the estimates rely on standard figures for valuation of measures, which are based on the best available – and most accepted – knowledge. A number of uncertainties are here reduced to a generally acceptable figure; for instance the nutrient content in manure, which changes over time due to animal breeding efforts and other factors. As mentioned by one person, this raises questions as to whom the uncertainties shall benefit. Another example was constructed wetlands, where available documentations shows an impact on nutrient leaching between 2 and 80 per cent, thus making it difficult to agree on a reasonable cost-effect value.

Further, a number of administrative constraints were highlighted as important obstacles. As noted in the case from Bornholm (sections 4.3.3), the need to meet harmony requirements is one significant motivator for farmers to consider involving in biogas initiatives. The use of biogas treatment of manure will typically be included in the environmental permit for livestock operations. The impression from one contributor from the work in the national livestock committee under the Green Growth Strategy (*Husdyrudvalget*) is relevant here. It was shared how the procedures for obtaining and revising environmental permits appear opaque and differ widely between municipalities in terms of approval requirements. The responsibility for these permits was transferred to the municipalities following the 2007 public sector reform, but civil servants have often been overburdened and unable to process the applications. The slow permit procedure constrains the ability of farmers to experiment with biogas technology.

Civil servants involved with spatial planning also pointed out that environmental planning procedures are increasingly complex. Under the law on environmental evaluation (*Miljøvurderingsloven*), requirements for hearings and review have been strengthened, improving transparency; however, this puts a considerable strain on civil servants as well as on the interest groups expected to participate in the process. It enables more informed decisions, but also leads to permits which contain a much larger number of conditions (*vilkår*) which in turn require specific attention. Furthermore, the procedures leave more space than earlier for individual interpretation, which causes anxiety with the responsible civil servants who may consequently slow down cases to ensure avoiding making mistakes. The backdrop to this is that biogas establishment is relatively flexible, with more guidance than concrete rules, which leads to a need for a higher number of local judgments (*afvejninger*), balancing various priorities against one another: location to ensure easy access to biomass, incorporation of views from neighbours and the general public, optimal distribution and sale, adequate infrastructure, etc..

Additionally, it was highlighted that the Regions (the second-tier administration between state and municipalities) could be important coordinators for biogas initiatives, but that they had to 'find their feet' after the public sector reform of 2008. Some people were even sceptical as to whether the Regions would continue to exist and were thus hesitant to place too many investments under their wings.

Finally, the state financing of biogas initiatives was seen to be complicated by constraints placed by the European Commission on the application of EU funds within the RDP. As explained by one civil servant at the Food Industry Agency, this is because the European Commission does not accept biogas as a so-called Annex 1 product from farms. This is a legacy from the Treaty of Rome, where provisions defining what agricultural subsidies can be allocated to, were intended to ensure that farm support went only to farms. As such, eligible subsidies must be directed towards products grown on field, and to gas production that is consumed on-farm. In turn, this means that Denmark has to use its national co-funding to support biogas aimed for the market, rather than drawing on EU funds. This issue is well known amongst civil servants in Denmark and has been raised with the Commission on several occasions, including in the 2013 revision of the Common Agricultural Policy. There is a perception of a conflict between the goals espoused by the EU's 2020 Strategy, which emphasises the need for increased energy delivery from agriculture, and the lack of tools provided to civil servants.

6. Preliminary reflections for further innovations

Like the larger European energy market, Denmark experienced a significant liberalisation during the 1990s, yielding free-market conditions that are not sufficient, on their own, to propel investment in renewable energy sources such as biogas (Meyer 2004). With the recent (and proposed) revisions of the national policy environment, the national government and its agencies are trying to create a more favourable environment for biogas promotion. While many of these efforts have been acknowledged as valuable initiatives, the people interviewed for this assessment agree that the establishment grants scheme and the pricing structure require further improvement in order to boost biogas projects to reach a scale that makes it feasible to meet the ambitious biogas target. The comments communicated through this report could provide important insights for the design of next steps under the new government's energy strategy (Government of Denmark 2011b).

The experiences recounted for Biokraft on Bornholm as well as by national level actors confirm earlier findings that it is only when the multiple social and environmental benefits of centralised biogas projects are fully taken into account can biogas plants become attractive from a socio-economic point of view (e.g. Nielsen and Hjort-Gregersen 2002; Jacobsen et al. 2010). Biogas projects contribute to commoditising manure and thus create a 'nutrient economy', which is characterised by monetary as well as non-monetised benefits. As many of the benefits are not captured by the market or by existing subsidy schemes, the local negotiation between stakeholders plays a key role in trading off different opportunities and finding acceptable 'win-win' situations. This provides an example of how promotion of green – and in particular emerging – technologies requires a negotiation between different views on what sustainable agriculture, in fact, entails (Borch 2007).

While the case study from Bornholm highlights a number of clear benefits for the farming sector, and the wider society on the island, the contributors also outlined a number of risks and negative consequences associated with the prioritisation of biogas. Based on these insights, the message from Bornholm appears to be that there is, in fact, no agreement on a clear and compelling argument for promoting biogas as an agro-environmental measure to combat eutrophication. Biogas appears to have potential as a measure for renewable energy provision, for supporting effective utilisation of manure, and for generating alternative income opportunities for farmers (along with the biogas industry and entrepreneurs). Yet these benefits will have to be considered against the transaction and opportunity costs that arise when investments and biomass going into biogas plants are not used elsewhere (e.g. by other energy providers). In this regard, it must be recognised that Biokraft on Bornholm may have a particular traumatic history compared with other biogas projects, owing to the failed investments and loss of public funds. The arguments presented in this report will have to be contrasted and discussed also in the context of other 'cases' from Denmark and lessons from general research, e.g. on the effect on nutrient leaching. It should also be acknowledged that Biokraft now is seen to achieve a break-even on its operational costs and appears to be on an upward curve, with increasing buy-in among farmers.

An interesting lesson is the significant role that public regulations on manure management play in motivating farmers to engage in biogas initiatives. It suggests that biogas is not only attractive as a means of boosting income generation on-farm, but equally as a mechanism to navigate the environmental regulations to expand production within the operating conditions offered by the regulatory frameworks. Whether this navigation has a positive impact on nutrient leaching and run-off to the aquatic environment, however, is not clear from the present assessment; different stakeholders have different views on this.

The first centralised biogas plants emerged through extensive collaboration and social and institutional innovations (Raven and Gregersen 2007). While there is disagreement on the benefits and risks associated with promoting biogas plants as an agro-environmental measure, there is no doubt that successful adoption in Danish localities requires similar innovation partnerships between project owners, donors, manure providers, advisory services, municipal politicians and administrators, and various farming and environmental interest groups. If the Danish government maintains its ambitious biogas targets and wishes to see them implemented, then the national policy framework must be improved, and local actors must be able to strike up the necessary partnerships. In order to enable public as well as private stakeholders to judge their stakes in such projects and whether/how they should engage, there is a continued need to unwrap what sometimes appears to be an uncritical euphoria about biogas and foster a more transparent debate regarding what the actual benefits and risks are in specific localities.

References

AEBIOM (European Biomass Association) (2009): A Biogas Road Map for Europe.

Al Seadi, T. (2000): Danish Centralised Biogas Plants - Plant Descriptions. Bioenergy Department, University of Southern Denmark.

BAAS (Bornholm Agricultural Advisory Service) (2011): Agriculture on the B7 islands – Bornholm. Brochure, 14 pp.

Birkmose, T., Foged, H. L., Hinge, J. (2007): State of biogas plants in European agriculture. Report for the European Parliament. Danish Agricultural Advisory Service.

Bondgaard, F. (2011): Biogas on Bornholm can reduce loss of nutrients to the Baltic Sea. *Innovative agro-environmental technologies for sustainable food production in the Baltic Sea Region* 5: 2-7. Newsletter, Baltic COMPASS.

Borch, K. (2007): Emerging technologies in favour of sustainable agriculture. Futures 39: 1045-1066.

Danish Biogas Association, Energinet.dk, EUDP (2009): Forsknings- og udviklingsstrategi for biogas. August 2009.

Callesen, I. Grohnheit, P. E, Østergard, H. (2010): Optimisation of bioenergy yield from cultivated land in Denmark. Biomass and Bioenergy 34: 1348-1362.

Danish Commission on Climate Change Policy (2010): Grøn energy – vejen mod et dansk energisystem uden fossile brændsler. Sammenfatning af Klimakommissionens overvejelser, resultater og anbefalinger. Copenhagen, Denmark.

Danish Energy Agency (2011a): Øget udnyttelse af biogas. Energistrategi 2050 – fra kul, olie og gas til grøn energi. Faktaark 1-28 (Improved utilisation of biogas. Energy strategy 2050 – from coal, oil and gas to green energy. Fact sheet 1-28).

Danish Energy Agency (2011b): Omlægning af støtten til biogas (Revision of subsidy to biogas). Note 11 april 2011, J.nr. 3401/1001-2919.

Energinet.dk (2010): Gas i Danmark 2010. Forsyningssikkerhed og udvikling (Gas in Denmark 2010. Security in supply and development).

Fruergaard, T. and T. Astrup (2011): Optimal utilisation of waste-to-energy in an LCA perspective. Waste Management 31: 572–582.

Foged, H. L. and Mortensen, C. G. E. (eds.) (2011). Sector Study - Prioritised innovative agro-environmental technologies for sustainable food production in the Baltic Sea Region. Published by Agro Business Park A/S, Tjele. 129 pages.

Government of Denmark (2004): *Aftale om Vandmiljøplan III 2005-2015 mellem regeringen, Dansk Folkeparti og Kristendemokraterne* (Agreement on Action Plan for the Aquatic Environment III 2005-2015 between the Government, Danish Peoples Party and the Christian Democrats).

Government of Denmark (2009): Agreement on Green Growth. 16 June 2009.

Government of Denmark (2010): Agreement between the Government and Danish People's Party about Green growth 2.0. 9 April 2010.

Government of Denmark (2011a): Energistrategi 2050 – fra kul, olie og gas til grøn energi (Energy strategy 2050 – from coal, oil and gas to green energy).

Government of Denmark (2011b): Vores energy (Our energy). Danish Ministry of Climate, Energy and Building.

Halberg, N., Dalgaard, R., Olesen, J.E., and T. Dalgaard (2007): Energy self-reliance, net-energy production and GHG emissions in Danish organic cash crop farms. Renewable Agriculture and Food Systems 23 (1): 30–37.

Hjort-Gregersen et al 2007: Assessed economic results from 6 European case studies, barriers and recommendations. In: Ad Seadi (ed.): The Future of Biogas in Europe III. Proceedings from the European Biogas Workshop, 14th -16th of June 2007, University of Southern Denmark: 20-30.

Holm-Nielsen, J. B., Boland, L., Cybulska, I., Brudecki, G. (2009): Terrestrial Biomass Potentials – Food –Feed – Fuels Considerations. Case Studies of Two Large Scale Biorefineries in Denmark. Paper presented at 16th European Biomass Conference and Exhibition - From Research to Industry and Markets, Hamburg, 2009.

Jacobsen, B., Lundsbjerg, H. M., and Dubgaard, A. (2010): Ligevægtspris for biogas under forskellige forhold og konsekvens af opgradering til naturgas (Balanced pricing for biogas under different conditions and the consequence of upgrading to natural gas). Note, FOI, KU: Copenhagen.

Jørgensen, P. J. (2009): Biogas – green energy. Process, Design, Energy supply, Environment. Faculty of Agricultural Sciences, Aarhus University, 2nd edition.

Leeuwis, C. and Van den Ban (2004): Communication for Rural Innovation: Rethinking Agricultural Extension, 3rd Edition. Wiley-Blackwell Publishing.

Mikkelsen, S. A., Iversen, B. H., Kjær, S. S., Feenstra, P. (2005): The regulation of nutrient losses in Denmark to control aquatic pollution from agriculture. In: Evaluating Agri-environmental Polices. Design, Practice and Results: 295-308. OECD Publishing.

Ministry of Food, Agriculture, and Fisheries (2008): Landbrug og Klima – analyse af landbrugets virkemidler til reduktion af drivhusgasser og de økonomiske konsekvenser (Agriculture and Climate – analysis of the policy instrrments in agriculture for reduction of greenhouse gasses and the economic consequences).

Maeng, H., Lund, H., and F. Hvelplund (1999): Biogas plants in Denmark: technological and economic developments. Applied Energy 64: 195-206.

Meyer, N. I. (2004): Renewable energy policy in Denmark. *Energy for Sustainable Development* 8 (1): 25-35.

Nielsen, L. H. and Hjort-Gregersen, K. (2002): *Socio-economic Analysis of Centralised Biogas Plants*. Report no. 136, Risø National Laboratory and University of South Denmark.

Pedersen, H. F., Olsen, J. V. and J. Hinge (2006): Økonomi i fire biogasgårdanlæg 2002-2004. Danish Agricultural Advisory Service, Knowledge Center for Agriculture, and Byggeri og Teknik.

Raven, R. P. J. M. and Gregersen, JK. H. (2007): Biogas plants in Denmark: successes and setbacks. *Renewable and Sustainable Energy Reviews* 11: 116–132.

Raven, R. P. J. M. and F. W. Geels: Socio-cognitive evolution in niche development: Comparative analysis of biogas development in Denmark and the Netherlands (1973–2004). *Technovation* 30: 87–99

Tafdrup and Hjort-Gregersen (2010): Centralised biogas plants - biogas from livestock manure and organic waste. In *Biogas* 34: 34-37.

Tybirk, K. (red.) 2010. Kogebog for etablering af biogas med 12 faktaark (Cook book for establishment of biogas with 12 fact sheets). Agro Business Park/ Innovationsnetværket for Biomasse.

Vetter, K. (2010): Vi skal have politikerne på banen! (We need the politicians in the game!) *Bioenergi Magasinet* Oktober 2010: 2.

Waagepetersen, J., Grant, R., Børgesen, C. D., Iversen, T. M. (2008): Midtvejsevaluering af Vandmiljøplan III (Mid-way evaluation of Action Plan for the Aquatic Environment III). DJF and DMU, Aarhus, Denmark.