REPORT

Bioenergy in Sweden 2010-2020 a review of amounts, future trends and research

For SPIN

Kåre Tjus Uwe Fortkamp

2 feb2011 Archive number: U3013

Sustainable Production through Innovation in SMEs

Swedish Environmental Research Institute

Box 21060, SE-100 31 Stockholm
Valhallavägen 81, Stockholm
Tel: +46 (0)8 598 563 00
Fax: +46(0)8 598 563 90
www.ivl.se

Box 5302, SE-400 14 Göteborg
Aschebergsgatan 44, Göteborg
Tel: +46 (0)31 725 62 00
Fax: + 46 (0)31 725 62 90

Contents

1 Introduction

This report has been produced as part of the SPIN project. Spin is a project funded by Baltic Sea Region Programme 2007-2013 of the European Union . SPIN aims to increase the innovation potential of small and medium sized enterprises (SME) throughout the Baltic Sea Region.
For the report information has been gathered from different sources, the values and information reported are thus not necessarily values supported by IVL or SPIN, as it was not possible to check the data quality in all cases.
The aim of the report is to give an overview over the current and future situation for bio-energy in Sweden including potential and obstacles.

2 Renewable energy in Sweden

Bioenergy is regarded as a renewable energy source. According to EU decision the member states will increase their amount of renewable energy to 20 % until year 2020. The amount of renewable energy is calculated as amount renewable energy used, divided by the total energy consumption of electricity and fuel. In total energy are energy losses in the transmission system for electricity and district heating and own consumption by the electricity and district heating production units included.

The final levels for renewable ratio have been decided differently for each EU member, due to their different possibilities. Sweden with high amount of wood biomass and hydropower should increase the ratio from 39.7 % 2005 to 50 % 2010. Sweden has also decided that the transport sector should be fossil independent 2030.[1] [2] Also there is a vision that Sweden should be independent of fossil fuels in 2050. Another EU directive states that the proportion of renewable energy in the transport sector should increase to at least 10 % until 2020 for all EU members[3].

Renewable energy can for example be bioenergy, hydropower, wind power, sun energy and geothermal energy. Heat pumping from earth and water reservoirs is assumed as geothermal energy. According to the Renewable Energy Directive (RED) peat is not regarded as renewable, and burning of waste is regarded as only 50 % renewable energy[4]. With the available potential, bioenergy can contribute to reach the future goals towards renewable energy and fuels.

3 Available bioenergy potential in Sweden

The largest resource of bioenergy in Sweden is the forest, but also energy from agricultural land and from sewage treatment is substantial. There is often a competition between usage of biological material for bio-energy and for other purposes. Environmental aspects also play a role, e.g. if a much larger area would be used for energy crops. Thus, a theoretically reasonable potential is not necessarily a realistic potential, but gives an impression what can be achieved under certain pre-requisites. The numbers mentioned below are derived from different sources.

3.1 The forest sector

Sweden has 22.7 million hectare of forest. Today 80 million cubic meters round wood is harvested each year. This corresponds to 33 ton millions of tonnes of dry matter each year and 150 TWh if the round wood was used for energy production. 70% more biomass, equal to 23 million of tonnes, or 105 TWh could theoretically be exploited for energy use if collection of branches tops and stumps were maximized. [5]

Due to technical, economic and ecological restrictions maximum 30-40 TWh are supposed to be exploited until 2020, 50 TWh on a longer timescale.[5]

Also much of the energy from the round wood can be exploited from sawdust, and bark , the amount is approximately 35 TWh today, also the use of energy in black liquor from pulp and paper industry can give 40- 50 TWh. This gives a total amount of 105-135 TWh.

According to Svebio the potential can be higher, 129 TWh until 2020 and 190 TWh until 2050 [6].

3.2 The agricultural sector

Agriculture contributes today with approximately 1.5 TWh of renewable energy, from burning of straw, grain for ethanol production and willow and cereals used for combustion. From agriculture also smaller volumes of manure and straw are used to produce biogas. Another part is used to process oilseeds into RME. Overall about three per cent of the Swedish arable land is used for bioenergy production, equivalent to 70000 hectares (2006). [7]

It is possible to increase this amount many times if more crop residues and manure are used for biogas production. Maximum amount of straw and blast that can be collected is 30 TWh, but the practical amount is 6-7 TWh straw, for combustion, and 0.5 to 1 TWh blast for biogas production. Today manure with an energy value of totally 11 TWh is spread; if all this manure was processed into biogas an amount of 4-6 TWh could be produced.

If all the 330000 hectares arable land currently lying in fallow was used to produce energy, it would be possible to produce a further 5 - 10 TWh of energy crops. If also 250 000 hectares land used for grass land that are not needed for animal feed is used additional 5-8 TWh can be used.

Together this gives a total possible potential of:

- 7-8 TWh from crop residues,
- 5 -10 TWh if arable land now lying in fallow is used,
- 5 -8 TWh if grassland not needed for animal feed is used

Sweden's share of agricultural land for energy purposes would then increase from 70000 hectares to 650000 hectares, equal to 25 % of Sweden's total 2600000 hectares total available agricultural land.

This gives a maximal potential of 7 -8 TWh if existent crop-residues and manure are used, and additional 10-18 TWh if all land used for land fallow and grassland is used. [6] [7]

3.3 Sewage treatment

Today approximately 600 GWh biogas is produced from municipal sewage treatment , the potential can be increased to 700 GWh by using sludge from more treatment plants. Through optimization of the digestion process using simple methods such as digestion at optimal temperature, charging feed to the reactor evenly, have a sufficient residence time, adequate mixing of the digester, the collection of gas from the residue storage in the treatment plants that digest and different preprocessing methods and / or additives to increase the availability of the organic material in the sludge, the adopted biogas yield can be increased by 10 - 40%. The maximum biogas yield can thus be improved to between 770 -1000 GWh / year.[8]

3.4 Use of waste

According to the Svebio report the maximum potential from combustion of waste is 20-23 TWh and an additional 1.2 TWh from biogas production from bio waste. This gives a maximum potential of 21-24 TWh from waste compared with 13 TWh that is exploited today.[6]

3.5 Biogas potential

Biogas production is today approximately 1.4 TWh . According to the ”Proposal for a multisectoral biogas strategy”[20,] profitability is greatest for sewage sludge and restaurant and food waste the largest remaining potential exists for food waste. It is possible to enhance the collection of food waste and achieve the goal of biological treatment. Such an increased collection provides opportunities to increase the amount of food waste that is digested. However, the amount of attractive substrate is limited and corresponds to approximately 2.5 TWh. The study estimates that virtually all of the existing potential of the substrate in urban areas can be exploited at reasonable costs.

The other, less attractive substrates, corresponds to about 14 TWh in agriculture consisting of 2.8 TWh manure, 3 TWh of crop residues and 8 TWh crops, and are spread over large areas and rarely in so concentrated amount that large-scale biogas facilities are possible. Manure has relatively low energy content relative to its weight. This means that it is uneconomic to transport long distances and it is disperse around 9000 estates around the country. In total the proposed strategy estimates that with current technical conditions up to 700 GWh, i.e. around 25% of all manure, can be digested. Crop residues are an even greater potential supply than manure with about 3 TWh, but most of it consists of straw, which is difficult to digest, only about 0.5 TWh in the form of beet tops is appropriate to digest.

The survey estimates that several hundred GWh of biogas can be produced from crops, partly as a result of an extended environmental compensation for ley farming. The total amount of biogas through anaerobic digestion can thus be raised to between 3 and 4 TWh according to the survey.

There are however companies in Sweden that are positive about using much more crops for biogas production, for instance Swedish Biogas association[9].

4 Use of bioenergy and possibilities to increase the use in different sectors

To explore the energy potential for different sectors it is important to show the amount of different energy sources used in different sectors, such as industry, agriculture and forestry, transport and residential and to discuss the possibilities how to exchange for instance fossil fuels with renewable ones, such as biofuels. It is also important to discuss the potential of bio-energy in the production of electricity and district heating, which in turn are used for several different sectors.

In the figure below is Sweden's energy consumption divided in different sectors. The total energy consumption was 403 TWh 2008. [10]

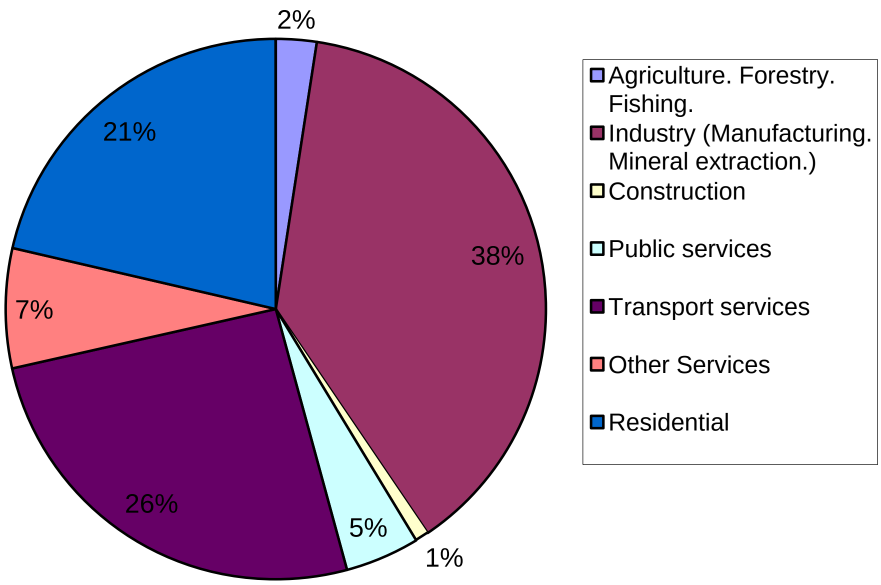

Figure 1 Energy use in Sweden 2008, divided on different sectors [10]

Industry accounts the dominant energy consumption for (39%), followed by transport- (26%) and residential sector. (21%)

Energy use declined between 2003 and 2008 from 419 to 403 TWh, see table 1 below
It is mainly energy consumption in the industrial sector and in households that account for this reduction. The transport sector's energy consumption has increased from 94 TWh to 100 TWh.

Table1 Energy consumption in different sectors between 2003 and 2008 [10]

TWh	Agriculture. Forestry. Fishing.	Industry (Manufacturing. Mineral extraction.)	Construction	Public services	Transport services	Other Services	Residential	Total category divided use*
2003	10	157	3	19	94	29	93	419
2004	9	157	3	19	98	29	91	419

2005	10	154	3	18	99	29	89	414
2006	10	152	3	17	99	29	85	402
2007	10	153	3	19	101	28	84	410
2008	10	150	3	18	100	28	84	403

*In this sum also a difference post of non-specified energy use is included; 13.8, 13.2, 12.1, 6.8, 12.2 and 10.7 TWh in the years 2003-2008

When dividing Sweden's energy consumption in different sectors, the numbers show that currently very little fossil fuel is used for domestic heating but a lot of fossil fuel is still used in the industry, in the transport sector, in the agriculture, forestry and fisheries and for construction. [10]

4.1 Residential sector

Table 2 Energy use in the residential sector during 2003 -2008, divided on different categories [10]

TWh	Coal. Coke	wood fuel ,black-liquor, garbage etc. peat	Oil products	Gas (nature-. city. blast furnace -&. coke oven)	Remote heat	Total fuels (including remote heating)	Electricity	Sum total
2003	0	11,9	10,7	0,8	26,8	50,3	43,0	93,3
2004	0	11,4	10,0	0,9	26,4	48,7	42,8	91,4
2005	0	12,1	7,0	0,8	26,8	46,7	42,2	88,9
2006	0	11,2	4,8	0,7	27,1	43,8	41,5	85,3
2007	0	11,7	3,6	0,7	26,9	42,9	41,1	84,0
2008	0	11,9	2,8	0,6	27,7	42,9	41,4	84,4

The use of fossil fuel for households have fallen sharply, but there are a still a few oil pans left, which probably will be almost completely gone by 2020.

Biofuel use has remained relative constant between 2003 and 2008 but the total energy consumption has reduced significantly in these years, due to more energy efficient houses.

4.2 Industrial sector

Table 3 Energy use in the industrial sector during 2003 -2008, divided on different categories [10]

TWh	Coal. Coke	wood fuel ,black-liquor, garbage etc., peat	Oil products	Gas (natur-. city. blast furnace -&. coke oven)	Remote heat	Total fuels (including remote heating)	Electricity	Sum totally
2003	14,5	55,3	21,3	6,9	4,4	102,4	54,5	156,9
2004	14,7	55,4	19,6	7,0	4,7	101,4	55,4	156,8
2005	13,7	55,2	17,4	6,9	4,4	97,6	55,9	153,6
2006	12,8	53,6	17,4	7,1	4,4	95,2	56,6	151,8
2007	14,0	54,7	15,9	7,1	4,5	96,3	57,1	153,3
2008	13,1	53,9	15,6	7,5	4,4	94,4	55,8	150,3

There is still much fossil fuel in the industry. The largest consumer is iron and steel industry, which account for approximately one third of the total fossil fuel consumption. Cement and lime accounts for almost 20 %, chemical industry and paper industry for 10 % each.[11]

Oil consumption has decreased substantially in the paper industry due to uses more use of internal biofuels and improved energy efficiency. A further major reduction in oil use in industry until 2020 is anticipated. Coke use in the iron and steel industry is not expected to decline much over the coming years. It is theoretical possible to replace coke reduction with reduction with natural gas or charcoal, but these substitutions require large investments.

4.3 Transport sector

Table 4 Energy use in the transport sector during 2003 -2008, divided on different categories [10]

TWh	Coal. Coke	biofuel	Oil products	Gas (nature-. city. blast furnace -&. coke oven)	Remote heat	Total fuels (including remote heating)	Electricity	Sum totally
2003	0	-	91,1	0,2	-	91,3	2,8	94,1
2004	0	-	94,6	0,2	-	94,9	3,0	97,9
2005	0	-	96,4	0,2	-	96,6	2,8	99,4
2006	0	-	96,1	0,3	-	96,4	2,9	99,3
2007	0	3,3	95,0	0,3	-	98,6	2,9	101,4
2008	0	4,0	93,1	0,3	-	97,3	2,4	99,7

Within the transport sector, including railways, road transport, inland waterway and domestic flights, there is a requirement that the relative share of renewable energy must be at least 10% in 2020.

This will primarily lead to increased use of biofuels for road transport. Particular by dosing of low concentrations of ethanol in petrol, respectively by dosing bio diesel in diesel, but also by an increasing number of cars running on pure biofuels or on electricity. In addition to ethanol and bio diesel, biogas, dimethyl ether and methanol can be used. For electrical cars, it is important to match electricity use with an equally large increase in renewable generated electricity.

4.4 Other Services

Table 5 Energy use in the other services sector during 2003 -2008, divided on different categories [10]

TWh	Coal. Coke	wood fuel ,black-liquor, garbage etc., peat	Oil products	Gas (natural-. city. blast furnace -&. coke oven)	Remote heat	Total fuels (including remote heating)	Electricity	Sum totally
2003	0	0,1	2,5	0,6	8,7	11,9	17,0	28,9
2004	0	0,1	2,3	0,6	8,9	12,0	16,7	28,7
2005	0	0,1	1,9	0,7	9,2	11,8	17,1	28,9
2006	0	0,1	2,0	0,8	9,2	12,1	16,8	28,9
2007	0	0,2	2,1	0,8	8,1	11,3	17,0	28,3
2008	0	0,2	1,8	0,8	8,2	10,9	16,7	27,6

Other services include a range of activities such as repairs, shops, banks, consulting firms, etc. Most energy is consumed for electricity use and space heating in buildings.

It is noteworthy that the relative share of oil is slightly higher than in the residential sector and that the use of bioenergy is small. In future however even the use of oil will probably be phased out and be replaced with electricity, district heat and biofuels.

4.5 Public services Sector

The public services sector includes health care, schools, social services, and public order, infrastructure, and waste management, cultural and business activities. As for other services most of the energy is used for electricity and heat in rooms. The proportion of bioenergy use is somewhat greater than the use in the other services sector.

Table 6 Energy use in the public services sector during 2003 -2008, divided on different categories [10]

TWh	Coal. Coke	wood fuel ,black-liquor, garbage etc., peat	Oil products	Gas (natural-. city. blast furnace -&. coke oven)	Remote heat	Total fuels (including remote heating)	Electricity	Sum totally
2003	0	0,3	1,7	0,3	6,5	8,8	9,9	18,6
2004	0	0,5	1,5	0,3	6,5	8,8	10,3	19,1
2005	0	0,3	0,9	0,3	6,4	7,9	9,9	17,9
2006	0	0,4	0,8	0,4	5,6	7,2	9,6	16,8
2007	0	0,6	0,9	0,4	7,3	9,2	9,3	18,6
2008	0	0,5	0,6	0,4	6,6	8,1	9,4	17,6

4.6 Fishing, agriculture and forestry sector

Table 7 Energy use in the public services sector during 2003 -2008, divided on different categories [10]

TWh	Coal. Coke	wood fuel ,black-liquor, garbage etc., peat	Oil products	Gas (natural-. city. blast furnace -&. coke oven)	Remote heat	Total fuels (including remote heating)	Electricity	Sum totally
2003	0	0,6	7,7	0,3	0,1	8,6	1,4	10,0
2004	0	0,6	6,6	0,3	0,1	7,5	1,5	9,1
2005	0	1,0	6,5	0,3	0,1	7,8	2,3	10,1
2006	0	1,0	6,6	0,3	0,1	8,0	1,8	9,8
2007	0	1,4	6,3	0,2	0,1	8,0	1,6	9,6
2008	0	1,7	6,6	0,1	0,1	8,4	1,2	9,6

Fishing, agriculture and forestry sector accounts for a relatively small part of society's energy use. The largest amount of the energy goes to power machinery and fishing boats, but also to space heating, such as stables, poultry production and more contributes. There has been an increase in biofuel use, mainly for heating buildings in the agricultural sector. For fossil fuels the consumption in agriculture sector accounts for around 3.5 TWh, of which approximately 3TWh is used for the operation of tractors and about 0.5 TWh for heating of buildings. Forestry-machines consume about 3.5 TWh of oil products in the form of primarily diesel and fishing boats consumes approximately 0.6 TWh diesel per year.[12] [13] [14]

Breaking the dependence on fossil fuels for machinery will require similar technology changes as in the transport sector with the difference that most machines are diesel powered. Low dosing of bio diesel can also here be a quick way to reduce fossil fuel dependency but more substantial decrease requires use of pure bio diesel and ethanol. Bio diesel and ethanol currently accounts for approximately 1% of fuel consumption for tractors.

4.7 Energy consumption in the production of electricity and the production of district heating

Electricity generation and district heating production is not a sector but are included as part of the various sectors. It requires input from various types of energy; nuclear power, hydropower and biofuels and fossil fuels are used to produce electricity. For production of district heating biofuels, fossil fuels but also electricity, as an input to produce heat through the heat pump, is used.

Table 8 Primary energy needed for Sweden's electricity production[10]

TWh	Coal. Coke	wood fuel ,black-liquor, garbage etc., peat	Oil products	Gas (natural-. city. blast furnace -&. coke oven)	Primary water-power	Nuclear power*	Electricity	Sum totally
2003	4,1	6,8	6,0	3,0	53,5	67,4	0,1	140,9
2004	1,6	10,1	2,4	3,4	60,6	77,7	0,1	155,8
2005	1,2	9,6	2,1	3,4	72,8	72,4	0,1	161,5
2006	1,3	11,0	2,5	2,6	61,7	67,0	0,0	146,1
2007	1,1	11,3	1,6	3,4	66,2	67,0	0,1	150,8
2008	0,7	13,4	1,2	2,9	69,1	63,9	0,2	151,4

*For the nuclear energy is not the heat energy cooled away as hot water included

It is noteworthy that in 2008 13.3 TWh bioenergy was used for electricity production, this is a doubling relative the 6,8 TWh that were used in 2003. In this figure the nuclear energy heat losses is not included.

It can also be noted that the amount of hydroelectric power increased slightly between 2003 and 2008, while nuclear power declined.

In district heating, the use of bioenergy increased from 29.7 TWh to 34.4 between 2003 and 2008, accounting for 74% of district heating production 2008.

Table 9 Primary energy needed for Sweden's district heating production [10]

TWh	Coal. Coke	wood fuel, black-liquor, garbage etc., peat	Oil products	Gas (natural-. city. blast furnace -&. coke oven)	Remote heat (through heat pumps)	Electricity	Sum totally
2003	1,1	29,7	5,0	3,9	6,6	0,5	46,9
2004	2,6	28,1	3,9	3,5	6,7	0,4	45,2
2005	2,3	29,4	3,4	3,2	6,2	0,3	44,8
2006	3,0	30,7	3,7	3,1	5,9	0,2	46,5
2007	2,0	32,3	2,1	3,1	5,8	0,3	45,6
2008	1,8	34,4	1,4	3,1	5,7	0,1	46,5

4.8 Bioenergy used totally

Table 10 Specific use of bioenergy in various categories and in the electricity and heat production in the years 2003 -2008 [10]

TWh	Agriculture. Forestry. Fishing.	Industry (Manufacturing. Mineral extraction.)1	Other services	Transport services	Public services	Residential	Electricity	Remote heat	Sum totally
2003	0,6	55,3	0,1	-	0,3	11,9	6,8	29,7	104,6
2004	0,6	55,4	0,1	-	0,5	11,4	10,1	28,1	106,2
2005	1,0	55,2	0,1	-	0,3	12,1	9,6	29,4	107,8
2006	1,0	53,6	0,1	-	0,4	11,2	11,0	30,7	107,9
2007	1,4	54,7	0,2	3,3	0,6	11,7	11,3	32,3	115,6
2008	1,7	53,9	0,2	4,0	0,5	11,9	13,4	34,4	120,0

It is primarily the increased use of bioenergy in district heating, electricity production and for transports that is behind the increase, from 105 to 120 TWh, between 2003 and 2008.

The single largest user of bioenergy is the industry, mainly paper and pulp industries through internal use of bark, black liquor with more. According to forecasts bioenergy will increase to 137 TWh in the current year (2010), mainly through an increase in the paper and pulp industries industry.[15]

In table below is the consumption of bioenergy compared with the fossil fuel consumption for the different sectors

Table 11 Specific use of bioenergy and fossil fuel in various categories and in the electricity and heat [10]

TWh	Agriculture. Forestry. Fishing.	Industry (Manufacturing. Mineral extraction.)1	Construction	Other services	Transport services	Public services	Residential	Electricity	Remote heat	Sum totally
Bioenergy	1,7	53,9	0	0,2	4	0,5	11,9	13,4	34,4	12(
Fossil fuel	6,7	36,2	3,2	2,6	93,4	1	3,4	4,8	6,3	154,

The use of bioenergy in the construction sector is today zero (see table 11).

The expected potential increase for bioenergy in Sweden until 2020 is expected to be approximately 23 TWh for heating, divided mainly on heat in industrial applications and remote heating, 7 TW for electricity production and 5 TWh for the transport sector. An increase of 0.6 TWh in the residential sector is expected.

According to a report from The Royal Swedish Academy of Sciences, KVA, it is possible to increase the use of renewable energy including bioenergy so far that there is only minor need of fossil fuels at 2050[16]. This is due to a 50 TWh increase of bioenergy, a 25 TWh increase of energy from sun and wind and a 5-15 TWh increase use of hydropower. KVA also suggests a total energy reduction by 45 TWh, from 570 TWh 2008 to 525 TWh 2050, caused by increased energy efficiency.

A European report, "Roadmap 2050: a practical guide to a prosperous, low-carbon Europe", shows a scenario where Europe could have 100% renewable energy by 2050 mainly by using wind and sun power.[17] Bioenergy can, according to this report, maximal stand for 12 % of Europe energy demand, corresponding to a total amount of 5000 TWh, where 20 -30 % are imported to Europe mainly in form of bio kerosene, 40 % of this biomass is intended to be used for road transport, another 20 % for sea and air transport and the remaining 40 % in intended to be used for power generation.

5 Obstacles and promotion measures for renewable energy use with biogas focus

There are a number of control measures to promote bioenergy and other renewable. Most of them are not specific, such as taxes for fossil fuels, but some are specific such as investment aid for the construction of biogas plants in agriculture. [1]

- Carbon dioxide and energy tax
- CO_2 trading in EU ETS
- Electricity certificate
- Conversion support – specially for changing of heating system in houses
- New technology support

We will in the following section focus on biogas, but the control measures for bioenergy from wood and wood residues will be similar.

A number of barriers for biogas production and consumption in Scania area in southern Sweden were investigated in 2009; these obstacles can be considered to be general for Sweden. Appropriate measures to overcome obstacles were suggested as well[18].

The investigation has identified the following obstacles:
for **Production of additional biogas**:

- lack of knowledge
- long delays in processing the permit's review
- unclear regulatory framework on building permit
- environmental effects difficult to evaluate
- poor knowledge in many municipalities of the condition of biogas production in the own municipality
- poor economics of biogas production

for **Provision of biogas to the consumer**:

- lack of infrastructure for biogas
- obstacle for biogas use in vehicles

and also :

Barriers for provision of bio-fertilizer and digested sludge

and:

Barriers to the financing of biogas plants

5.1 Obstacles for introduction of more biogas in Sweden

Profitability of the biogas is determined by both operating costs, primarily raw materials, energy, and investment costs for the facilities. In addition there is a cost of exploiting bio methane either in the form of heat, electricity or as upgraded biogas, i.e. construction costs and costs for the upgraded biogas as well as distribution costs.

Revenue consists of payment for electricity, heat or biofuel or the alternative costs that are saved because other fuel does not need to be purchased. Additional revenues are obtained if using biogas residue as fertilizer and also payment for treating organic waste treatment sometimes. Government subsidies, mainly in the form of investment grants, and also the opportunity to obtain electricity certificates[1], give additional revenues.

Biogas in Sweden is well established in the area of biological sludge derived from water treatment plants. Compared with most other countries, Sweden is at the top with regard to the use of biogas in wastewater treatment plants, most of the major sewage treatment plants have today biogas production.

Thanks to an early interest in biogas there has been much effort to develop technologies for upgrading biogas to vehicle quality, for example, in Linköping. A key driver in the Linköping case was that they wanted to avoid pollution from diesel buses.

But in terms of biogas from manure, agricultural residues and crops, Sweden has today a very small production compared to e.g. Germany. The main reason is that Germany has a generous benefit system that gives 10 cents or more per kWh produced biogas.

The interest in developing biogas as vehicle fuel in Sweden is also due to that it is difficult for Sweden to replace fossil fuels in the transport sector, while there are plenty of biofuels that can be used for electricity and heat production. Many other countries, such as Holland and Germany, have also an extensive natural gas network and use natural gas for cars and uses bio gas mainly for heat and electricity production.

5.1.1 Obstacles for increasing the biogas use

A major problem with biogas is that the availability of raw materials for biogas production and demand for biogas, heat and electricity is not always at the same location. Also biogas production and upgrade facilities are strongly favoured by size.

The most common biogas plants today in in Sweden are for sewage water treatment. At this places it is usually possible to use produced heat and electricity for the needs at the sewage plants but also able to supply heat and electricity to surrounding society. Especially in large cities a large part of the

[1] **Electricity Certificate**. Electricity produced from wind, solar, wave energy, geothermal energy, some biofuels, hydropower, and peat receive a certificate for each MWh as they thereafter can sell.. Quota obligation says that electricity suppliers and in some cases electricity users must buy a certain amount of certificates in relation to their electricity delivery / electricity use.

biogas is upgraded to vehicle quality and used in local bus fleets, such as in Linköping and Norrköping.

Stockholm has had a strong interest from the public to purchase biogas because biogas cars have been exempted from taxes and also have been exempted from local commuter taxes. Unfortunately has the demand for biogas at times been greater than the supply. The gas industries wish that the state should provide subsidies for investment in an extensive natural combined biogas and natural gas network, in which the biogas can also be transported. But for the moment there are no such plans. The natural gas network is currently only deployed in south western Sweden, from Malmö to north of Gothenburg. The transport of the biogas is therefore today usually in the form of compressed gas cylinders.

5.1.2 Barriers to increased biogas production and use in Sweden

• Lack of knowledge for producers, authorities and the public. To be addressed through demonstration plants, technology studies and through training

• Long delays in processing permit applications. Required training of advisers and consultants, and required a review of present procedures on the counties.

• Unclear regulations on planning permission. There is no need for planning permission if biogas is intended for own use, but if you want to sell it gets complicated, the rules need improvement.

• The environmental impact of biogas is difficult to evaluate. The proposal is to develop metrics for biogas production and to train climate administrators in the use of these.

• Poor awareness in many communities about the conditions for biogas production in the own municipality. There is also need for planning instruments for gathering information concerning amounts of raw materials and infrastructure needed.

• Poor economics of biogas production. There is a need of simpler and more efficient methods for handling raw materials; there is also a need for more efficient digestion processes and for good infra-structure and necessary stimulus to bring about cheaper procurement of biogas components and also stimulation of entrepreneurship in the biogas field

5.1.3 Barriers to the provision of biogas in Scania

- Lack of infrastructure for biogas. One method can be to build a gas network linking the production and market for vehicle biogas. An alternative in the short term may be to Barriers to the provision transport the upgraded and compressed bio gas loaded onto a special trailer for the pressurized gas. A new possible technique may be to transport the gas in refrigerated form cooled to -162°C, the energy density would then be higher than for compressed gas, this may eventually make it possible to transport the gas in tank truck. In south western Sweden there exists a natural gas net which also can be exploited for biogas. But to get the same energy content as the natural gas from Denmark that now are used, there is a need to mix propane into the bio gas[19].
- Obstructing law for converting engines to biogas operation
- Too sparse network of filling stations for gas distribution in Sweden

- General ignorance of biogas conditions and opportunities
- The marketing of bio gas cars have not been as high as for instance for ethanol cars

5.1.4 Barriers to the provision of digestate from biogas production

• The market is uncertain about the quality of sludge from wastewater treatment plants. Even if there has been active work to ensure the quality of the sludge very few farmers use sewage sludge for food production. However use of sewage sludge for energy crops is usual.

• For bio fertilizer obtained by digestion of manure there is no problem to sell

• There are problems with the transport of bio manure and sewage sludge. Solid contents are generally low; it is therefore expensive to transport bio manure by truck. There are, in some cases, systems with pipeline for transport of the produced bio manure on the fields.

5.1.5 Barriers to the financing of biogas plants

• Funding agencies need good basis for making it possible to make relevant risk assessments. As a rule these companies lack own technical competence to carry out an assessment, and therefore there is a need of technical evaluations of various standard facilities
• There is need for a "reasonable" level of funding other than loans

6 Policies and other Swedish government efforts to support biogas

6.1 Energy and carbon dioxide taxes

Carbon dioxide taxes are paid for fossil fuels. The size of the tax is dependent on in which sector the fuel is used and if it is used for heating or as fuels for transport. The tax for Carbon dioxide is elevated at several levels. The general level is 1.05 SEK per kg carbon dioxide (approximately 0,10 Euro).

For the industrial sector the level is reduced to 21 % of the general level for the industries that not are participating in The EU carbon trade system(EU ETS) and to 15 % for the participating industries. Fossil fuels for electricity production are not taxed, because electricity is taxed in the usage stage. Heat production has a specific reduction level.

Energy tax has historical been a fiscal tax, but more and more it is used in order to control the energy usage. The energy tax is varying between sectors and is at the moment zero for industry, agriculture, forestry and heat in combined heat power facilities.

Neither energy tax nor carbon dioxide tax is taken for most biofuels, including biogas.

The table below shows the carbon and energy tax levels that apply 2009.

Table 12 Carbon dioxide taxes 2009, Swedish crowns per kWh[20]

	Fuel s for transport*	Heating						
		Residential Service	Non-trading sector		Trading sector			
			Industry	Agriculture	Industry	Heating	CHP (combined heat power)	Electricity
Biogas	0	0	0	0	0	0	0	0
Nature gas	0,12	0,20	0,04	0,04	0,03	0,19	0,03	0
Diesel	0,30	0,30	0,06	0,06	0,05	0,28	0,05	0

Energy taxes 2009, Swedish crowns per kWh[20]

	Fuel s for transport*	Heating						
		Residential Service	Non-trading sector		Trading sector			
			Industry	Agriculture	Industry	Heating	CHP (combined heat power)	Electricity
Biogas	0	0	0	0	0	0	0	0
Nature gas	0	0,02	0	0	0	0,02	0	0
Diesel	0,13	0,08	0,00	0,00	0,00	0,08	0	0

Total taxes 2009, VAT excluded, Swedish crowns per kWh[20]

	Fuel s for transport*	Heating						
		Residential Service	Non-trading sector		Trading sector			
			Industry	Agriculture	Industry	Heating	CHP (combined heat power)	Electricity
Biogas	0	0	0	0	0	0	0	0
Nature gas	0,12	0,23	0,04	0,04	0,03	0,22	0,03	0
Diesel	0,44	0,38	0,06	0,06	0,05	0,36	0,05	0

Following changes in the taxes for fossil fuels and biogas is planned

1) Carbon dioxide tax for natural gas used for transport will increase to the general level
2) Carbon dioxide taxes for CHP will decrease to 7 % of the general level instead of 15 %
3) Carbon dioxide taxes within the Trading sector will be taken away
4) Energy taxes for heating will be changed so that it is more related to energy content
5) The level of energy tax for biogas should be considered in relation with the development of the biogas market [20]

6.2 Taxes for biogas and other fuels used for transport

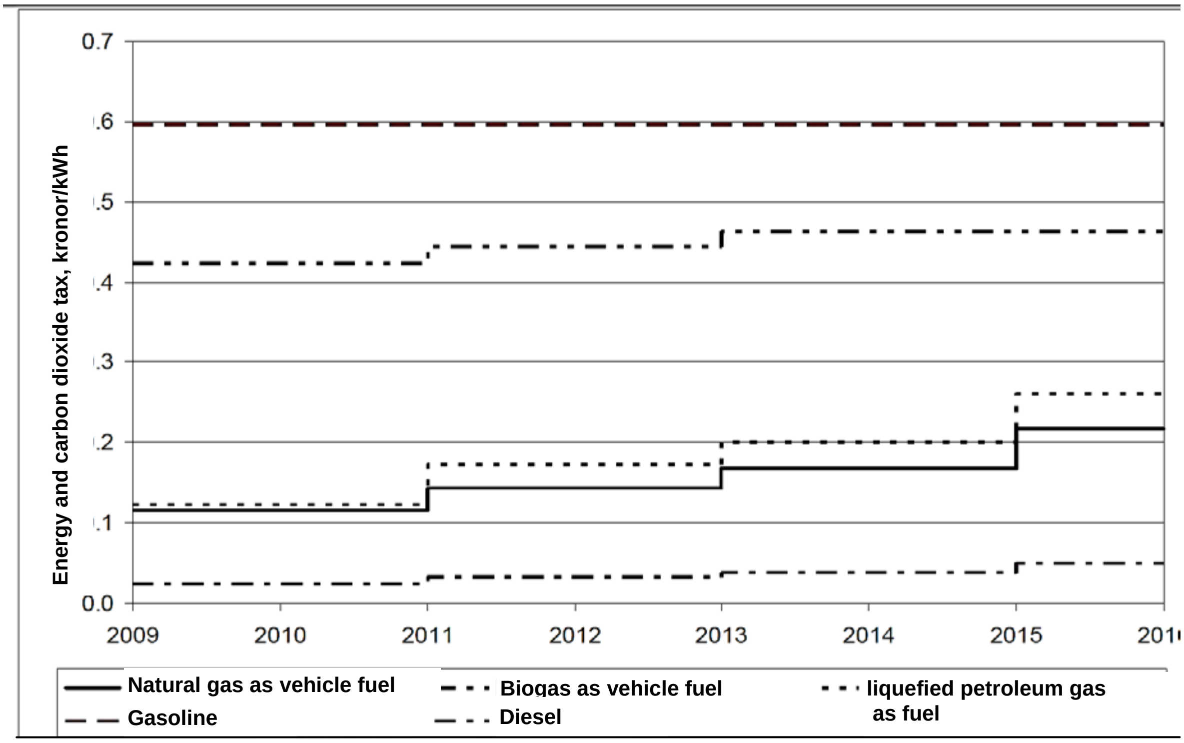

Figure 3 Proposed changes for fuels used for transport

According to Ministry of Finance in 2009 there should be a stepwise increase in the taxes for fuels used for transport until 2015.

Biogas is currently exempted from the carbon dioxide and energy taxes. It is proposed that tax exemption from 2011 should be replaced with tax credits. Deduction rules are introduced to meet EU sustainability Directive by ensuring that biofuels receiving tax breaks are produced in an ecologically sustainable manner.

Tax increases are most pronounced for propane and natural gas. Biogas used for vehicles requires a propane additive equal to 19% of the energy content in upgraded biogas when the biogas is introduced into a natural gas network.

6.3 KLIMP and LIP grants

Local investment programs, LIP, have been granted SEK 6.2 billion during1998-2002 to 211 programs, approximately 3%, or 180 million SEK of this money were granted bio gas. [21] The

Climate Investment Programmes," Klimatinvesteringsprogrammen", started 2003 Klimp, has granted 1.8 billion to 126 programs until 2008.

Totally 650 million SEK have been granted for biogas investments until 2008. The Klimp grants have approximately a 20% share of the total investments cost, which means a total investment of nearly 3 billion SEK. Of the investments, 50% have been granted for biogas production facilities, 25% to upgrading facilities for production of vehicle biogas and to tank stations and more than 10% to biogas vehicle, the rest has been granted for information activities about biogas and for evaluations of some projects. [20]

6.4 Investment Support for biogas production in rural programs

Payments for investments in rural programs are designed to assist rural businesses to adapt their businesses to new opportunities, increase quality in production and improve environmental and animal welfare.

For the specific action to invest in biogas facilities there are 200 million earmarked for the period 2009-2012 to support biogas. Another 100 million will be used during the years 2010 -2014. Biogas support can be given to investment to produce, store and process the biogas, mainly from manure raw material.

There will also be money allocated for information to farmers, Focus on Nutrients, "Greppa näringen ", in the order of 30 million per year, which aims to provide farmers with knowledge and tools to reduce nitrogen and phosphorus losses in a cost effective manner. It may be, for example knowledge of how manure can be digested and also to highlight biogas crops as new opportunities in crop rotation.

6.5 Electricity Certificates

Electricity certificates were introduced in 2003. Electricity produced from the following sources provides certificates: wind, solar, wave energy, geothermal energy, some biofuels, hydropower, and peat in the co-generation power. Producers receive a certificate for each MWh as they thereafter can sell. Quota obligation says that electricity suppliers and in some cases electricity users must buy a certain amount of certificates in relation to their electricity delivery/electricity use. The aim is to increase electricity production from renewable sources. Approximately 70% of certificates in 2008 originated from electricity generation with biomass as the source. At the end of 2009, the cost for the certificates was 300 SEK per MWh. Since the start of the scheme with electricity certificates 2003, the amount of green electricity production has almost tripled from 5.6 TWh to 15.6 TWh, mainly due to increased use of biofuels and wind energy (Swedish Energy Agency, 2010) [22] .The amount of certificates for biogas was in 2008 60 GWh [20].

6.6 Proposed new instruments for biogas

The Proposal for a multisectoral biogas strategy, written by three Swedish government agencies, suggests a grant for the production of biogas from manure at 0.2 SEK per kWh. This is because the biogas from manure provides a double environmental benefit due to methane that otherwise is emitted by non-digested manure is avoided.

The proposal discusses the re-introduction of tax on mineral fertilizers, as an incitement to increase the amount of sludge from sewage treatment plants that are used as fertilizer. Today only a small portion of the sludge produced is used. The total value of the sludge can be calculated to approximately 500 million Swedish crowns.

Waste legislation to increase the amount of organic waste returned to the cycle is also proposed to be strengthened so that almost all food waste from commercial, restaurants, household and food industry are treated either by composting or biogas production.

7 Market for bioenergy in different applications

Bioenergy is used in different applications, e.g. combustion for heat and electricity and transports.

To explore the different possibilities to use bioenergy resources there is a need of companies that can deliver the equipment needed, there is also a need of research and innovations in order to implement technical solutions to explore bioenergy resources in new ways, such as production of biofuels.

According to Sweden's national action plan Sweden should increase the renewable energy for heating/cooling with 26.8 TWh, for electricity with 13.6 TWh and for transport with 5.6 TWh between 2010 and 2020 [1].

Table 13 Prognosis for increase in renewable energy in Sweden [1]

TWh	2005	Prognosis 2010	Prognosis 2020	Increase 2005-2020	Increase 2010-2020
Heating and cooling	82,4	95,8	122,6	40,2	26,8
Electricity	76,8	83,6	97,2	20,4	13,6
Transport	3,3	6,1	11,7	8,4	5,6
Total	162,6	185,5	231,5	69,0	46,0

The authors assume that the biomass proportion for the increase between 2010 and 2020 will be:

- 90 % for heating , equal to ~ 24 TWh
- 50 % for electricity , equal to ~ 7 TWh
- 90 % for transport , equal to ~ 5 TWh

During next 10 years we can also presume that combustion plants and burners for residential sector that have been installed 1981-1990 have to be replaced. The market for different techniques is analysed and a rough estimation of total investments needed is given later in this capter.

In figure 2 the progress for Biomass in Sweden until now is presented[23]. From this figure we estimate that 20 TWh biomass that were installed from 1981 to 1990 has to be replaced during 2011 to 2020.

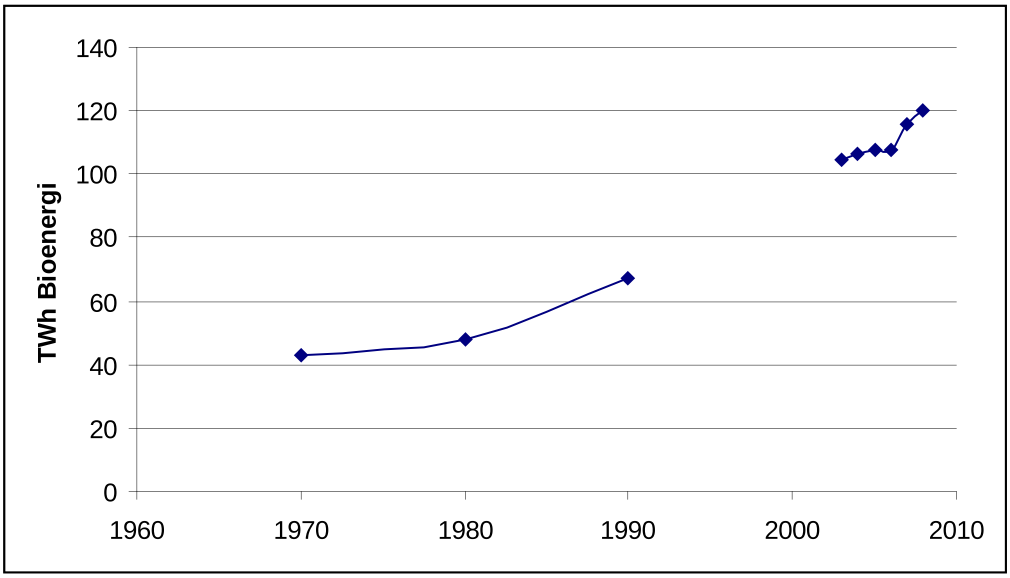

Figure 4 The increase of bioenergy use between 1970 and 2010

7.1 Biomass combustion plants

There was 2008, according to a survey by Swedish Bioenergy Association, a total of 147 production facilities for bio-power spread over Sweden. Of those, 74 are CHP plants and 40 industrial plants for biomass power. Swedish Bioenergy Association tracked in October 2009 also 24 planned biomass power plants; some of these are bioenergy combination facilities that will use surplus heat in business combinations. Electricity production in CHP plants for district heating can otherwise occur only when there is a need for heat . [24]

In the future there will be a big demand for new combustion plants.

Table 14 Number of biomass combustion plants 2008

Combined heat and power plants, CHP for municipalities	Industrial power plants
74	40

7.2 Boilers for small residential houses

Most houses that were heated with oil have been converted now to either electricity or burning biomass. The investment has decreased to 5000 units 2009 from nearly 37000 units 2006.[25]

Totally 550 000 house are using biomass alone or together with electricity. There are still 50000 houses that are heated with oil and approximately 5 % of the today installed 550 000 burners might be replaced in the next decade. Of new houses are approximately 25 % using biofuel alone or as part of the heating system.

Reningsgraden blir då i genomsnitt 85.5 %.
Driftstillgängligheten på årsbasis har varit 87 % mellan den 4 januari och den 29 december.

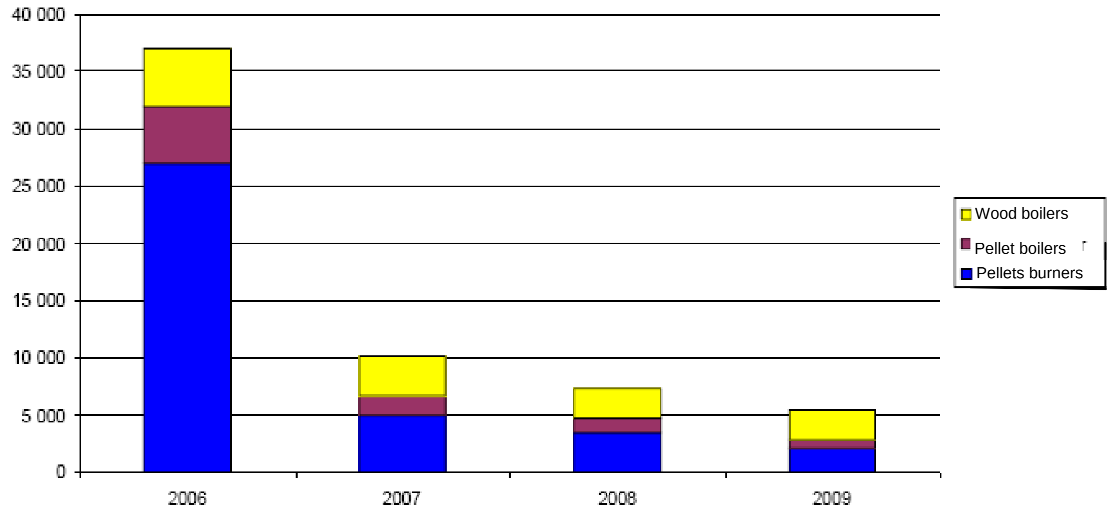

Figure 5 Amount of wood, pellet boilers and pellet burners that were installed during 2006 to 2009.

The number of installed smaller burners has decreased during the last years. This is due to that most oil burners are already replaced and due to increased use of heat pumps and district heating.

7.3 Biogas

Biogas production in 2009 was 1.36 TWh in total. Table 15 shows the amount of biogas produced in different bio gas categories between the years 2005 -2009[26].

Table 15 Biogas production from different plant categories 2005-2009, GWh

TWh	2005	2006	2007	2008	2009
Sewage treatment	559	582	573	605	605
Co. digestion plants	163	184	205	240	299
Farm plants	12	14	13	15	18
Industrial plants	94	91	125	130	106
Landfills	457	342	342	369	335
Total	**1285**	**1213**	**1258**	**1359**	**1363**

Table 16 Use of biogas 2005-2009, GWh

TWh	2005	2006	2007	2008	2009
Heat	667	678	732	720	667
Electricity	37	99	62	59	64
Upgrading to vehicle quality	112	218	303	355	488
Flaring	122	158	140	195	135
Missing data	327	60	21	30	9
Total	**1285**	**1213**	**1258**	**1359**	**1363**

Table 16 shows how much of the produced biogas that has been used for production of heat, electricity, upgrading to biofuel and flaring. Flaring means that the gas must be burned without that the energy in the gas can be utilized.

According to the previous section, the feasible potential is about 8.4 TWh from waste, the potential for landfill gas was 250 GWh, but is expected to reduce due to ban of putting organic waste to landfill..

The biogas production today is approximately 1.4 TWh. The estimated increase in production between 2010 and 2020 time is 2.2 TWh. Approximately 1.6 TWh of this biogas can be expected to be used for heat and electricity production and 0.6 TWh for biofuel.[27]

The increase is expected to be 1 TWh bio gas production for sewage and waste, 0.7 TWh for treatment of manure and 0.5 TWh from crop residues and crops.

7.4 Biofuel for transport

Biofuels accounted 2006 for 2.7 TWh of total 99.3 TWH used in the transport sector, divided on 1.9 TWh ethanol, 0.5 TWh FAME and 0.2 TWh of biogas [28].The goal is to increase the use of renewable to 10% in the transport sector, including road and boat transportation, rail shipments and air, but the measures are primarily intended to be within the road transport, for both regular vehicles and freight3. This means that the share of renewable in road transportation must be greater than 10%. Much of the effect is intended to be solved by mixing low content of ethanol in all petrol and low content of biodiesel in all diesel sold. There are now also plans to eco-label renewable fuel based on the way it is produced, in order to ensure that there is a climate and ecological profit by using biofuel.

There are many different biofuels that could be used for transport.

- Ethanol
- Bio diesel through Fisher Tropsch
- Methanol[29]
- Rapeseed methyl ester
- Upgraded biogas for vehicle[30]
- Di methyl ether trucks[31]
- Electricity
- Hydrogen gas

8 Examples of needed investment costs

Below are rough estimation given to give an expression of the possible investments needed .

8.1 Cost for heat and electricity production in combustion plants

The installation cost for combustions plants for heating and for electricity is approximately 2 Swedish crowns per installed kWh[32 33]. According to chapter 6 there will be a demand of 24 TWh new heating capacity and 7 TWh new electricity capacity from biomass combustion the next ten years. Replacement installation can be assumed to be equal to 15 TWh heat and 5TWh of electricity.

Altogether this gives a total installation cost for new combustion plants large scale burner of approximately **102 billion** , divided on 62 billion new capacity and 40 billion replacement of old burners.

Table 17 Installation demand for biomass combustion plants 2011-2020

	Replacement Installation		New Installation	
	Cost (billion crown)	Capacity(TWh)	Cost (billion crown)	Capacity(TWh)
Combustion plants				
Heat production	~30	15	~48	24
Electricity	~10	5	~14	7

8.2 Cost for residential burners

At least 10000 new houses per year can be assumed to be building for the next ten years. If we assume that 20 % of these will use biomass burners and also that 20000 of existent oil burners are replaced with biomass burners and that 20000 of existent biomass burners will be replaced with new biofuels burners we can prognosticate a total need of at least 60000 burners or 6000 burners per year.

If each burner is producing 15000 kWh at average this gives an installed capacity of 0.9 TWh. The cost for each new boiler is 65000 Swedish crowns.34 Approximately 0.6 TWh will be new biomass burners and 0.3 TWh replacements of old biomass burners.

Totals investment cost can be estimated to **3.9 billion** Swedish crowns.

8.3 Investment cost for biogas

The expected increase in biogas production in the next 10 years is 2.2TWh , from 1.4 TWh to approximately 3.6 TWh. The investment cost per kW installed capacity varies a lot depending on the size of the biogas plant and also if heat, heat and electricity or biofuel gas are produced by upgrading the biogas.

For small scale biogas production at farm houses, in the size 7-100 kW,
installation cost varies between 8 to 20 SEK per kWh installed. For larger units in the size
25 000 kW the installation cost is 1.60 SEK per kWh installed capacity.[35 36 37]

If we estimate an average of 3 SEK per kWh we can calculate expected installation cost of **6.2 billion for bio gas production**.

For energy of heat and electricity production an extra cost of 25 % is needed at average.
For upgrading of biogas to biofuel the cost will increase with 50 % (excluding cost for bio gas infrastructure) [35].
This gives a total cost **of 6 billion for heat and electricity production and 2.7 billion for biofuel production.**

8.4 Investment cost for biofuel

We have found some examples of investment cost for different biofuel such as ethanol from wheat, biodiesel from rape and from crude tall oil, upgraded biogas from waste and sewage treatment, methanol from wood and dimethyl ether from black liquor (residue from paper making). [37]

Table 18 Investment costs for biofuel facilities

Fuel	location	Production/year	Energy content kWh	Investment	Investment SEK per kWh
Ethanol	Norrköping	154 000 m^3	5.9 per liter	1.00E+09	1.10
Biodiesel	Tolefors gård, Linköping	300 m^3	9.8 per liter	1.05E+06	0.36
Biodiesel	Haraholmen ,Piteå	100 000 m^3	9.8 per liter	2.50E+08	0.26
Methanol	Hagfors	100 000 m^3	4.3 per liter	3.00E+09	7.0
Dimethyl ether	Örnsköldsvik	100 000 ton	8.8 per kg	2.80E+09	3.2
Biogas	Karpalund, Kristianstad	28 million m^3 raw gas(70 % methane)	9.67 per m^3 (97 % methane)	1.09E+08	1.36
Biogas upgrading	Karpalund, Kristianstad	13 million m^3 raw gas(70 % methane)	9.67 per m^3 (97 % methane)	2.25E+07	0.26
Biogas production and upgrading	Karpalund, Kristianstad	13 million m^3 raw gas(70 % methane)	.67 per m^3 (97 % methane	7.31E+07	1.62
Ethanol	Norrköping	154 000 m^3	5.9 per liter	1.00E+09	1.10
Biodiesel	Tolefors gård, Linköping	300 m^3	9.8 per liter	1.05E+06	0.36
Biodiesel	Haraholmen, Piteå	100 000 m^3	9.8 per liter	2.50E+08	0.26
Methanol	Hagfors	100 000 m^3	4.3 per liter	3.00E+09	7.0
Dimethyl ether	Örnsköldsvik	100 000 ton	8.8 per kg	2.80E+09	3.2
Biogas	Karpalund, Kristianstad	28 million m^3 raw gas(70 % methane)	9.67 per m^3 (97 % methane)	1.09E+08	1.36
Biogas upgrading	Karpalund, Kristianstad	13 million m^3 raw gas(70 % methane)	9.67 per m^3 (97 % methane)	2.25E+07	0.26
Biogas production and upgrading	Karpalund, Kristianstad	13 million m^3 raw gas(70 % methane)	.67 per m^3 (97 % methane	7.31E+07	1.62

It is quite obvious that investment of biogas, ethanol and biodiesel are much cheaper than the investments for dimethyl ether and methanol.

If we suggest that 3 TWh of the needed new energy can be produced from techniques with an average cost of 0.8 crown per kWh, and that 1.4 TWh will be produced with techniques with average investment costs of 4 crowns the total needed investments can be calculated to be **8 billion, excluding the cost for biogas as biofuel.**

Table 19 summarises the need for investment for bioenergy in the coming years in Sweden.

Table 19: Estimated investment needs in Swedish crowns for combustion plants and plants for biofuel production in Sweden during 2011-2020

	Replacement Installation		New Installation	
	Cost (billion crown)	Capacity (TWh)	Cost (billion crown)	Capacity (TWh)
Combustion plants				
Heat production	~30	15	~48	24
Electricity	~10	5	~14	7
Smaller burner for domestic	~1.3	0.3	~2.6	0.6
Biogas				
Biogas for heat and electricity			6	1.6
Biogas for transport			~2.7	0.6
Biofuels for transport (excluding biogas)			~8	4.4
Sum of needed investments	~41	20.3	~81	38.2

These figures are uncertain, and also the costs only include investment costs.
However they give a good indication about the relative sizes of investment needed.

There as well other investment needed, such as infrastructure for biofuel and remote heating.

The largest investments are needed for combustion plants. This technique is today well known, but there is still important to develop gas cleaning systems and also there is a need to build new infrastructure for district heating. Much of the heat and electricity from larger burners can be used for industrial heating and for heating of stables, pig farms and poultry in agricultural sector, replacing existent fossil fuels. There are today a number of Swedish companies that can deliver large scale burners, but also some finish suppliers has a part of the market.

As discussed the market for residential burners are foreseen to be 6000 units per year, this is due to a trend of using more electricity in combination with heat pumps and more district heating.
A higher relative prize of electricity might change the proportion.

Biogas could increase more than in our scenario, if all manure and crop-residues present are used, but the transport costs for using more bio gas increases if more extensive resources are used. If also grasslands and arable land in fallow are used for biogas production the production could increase even further.

Other biofuels for transport are ethanol, biodiesel, and methanol and dimethyl ether.

The amount of ethanol and biodiesel are today mainly produced from crops, in order to increase the production it is necessary to use wood and crops residues as raw material.

Therefore it is very important with new techniques such as second generation ethanol and dimethyl ether from wood. In a longer perspective, beyond 2020, the hope is that most of the transports should be maintained by electricity and hydrogen, depending of the evolution of better batteries and fuel cells.

9 Do biomass supply and demand match?

According to the previous sections it was estimated that there must be an increase of 24 TWh power and 7 TWh electricity produced from biomass, and 5 TWh increase for biofuels for transport, between 2010 until 2020.

This chapter discusses how much bioenergy raw material that can be used and if it fits the demand.

In 2005, the use of bioenergy was 108TWh. In 2008, the use of bioenergy had increased to 120 TWh, the share directly from the forest was 104 TWh. To reach the goals set by the government on use of renewable energy the amount must then increase further by 36-37 TWh until 2020. According to chapter 3.1 bioenergy output of the forest could with today's withdrawal increase to 120 TWh, due to increased collection of branches, tops and stumps. There is a further theoretical potential in the size of 20 TWh if the scope to increase forest production in Sweden is fulfilled.

In many cases, the use of biological material for bioenergy production is in competition with other possible uses of the same material, e.g. in woods or agricultural production. That can has to be taken into account when setting possible increased production of bioenergy, but is not discussed here.

The numbers mentioned above result in an increase of 36 TWh relatively 2008. From agriculture around 7-8 TWh can be collected from straw and blast. Increased biogas production of bio waste and sewage sludge can produce approximately 2 TWh.
In 2008, energy recovery from waste was 13.7 TWh in Sweden. According Svebios forecast, this energy recovery could be increased to 20 TWh, i.e. an increase of 7 TWh.

Altogether, this gives a possible increase of approximately 53 TWh between 2008 and 2020, which means that it an increase of 36-37 TWh between 2010 -2020 might be possible.[38] [39]

What are needed in the long run are boilers that also can handle fuels with high ash content. There is also a need to develop good collection practices for both wood and agricultural residues.

Sweden, but also the Baltic states have much wood that can be used for burners. The total potential in Europe of biomass is, in proportion with total energy consumption, lower in Europe than in other continents. This is due to a high population density and high incomes. Although the relative proportion of biomass to fossil fuels and hydro is low, it can be increased from 3 % to 12 % of PEC, primary energy consumption, of fossil fuels & hydro.[40]

10 List of important innovations for Baltic Sea Countries the next decades

Examples of techniques that are important in the Baltic Sea Countries to increase the use of bioenergy. Many are attended in the "Fuel-based energy", Swedish energy authority report [39] , and others were found from our interviews with entrepreneurs within the SPIN project are here mentioned, some might be so well investigated and used so that further improvement might be minor, these are marked (x).

- Collection equipment for crop residues such as straw and beet tops

- New burners that can manage combustion of biomass with higher ash content.
- Production of biomass from crops residues- for example with dry anaerobic digestion
- Improving the exchange of the bio gas process
- Electricity and heat production for small scale biogas units
- Water based heating systems
- Small scale pellets burners for houses and farms
- Bio gas conversion of tractors
- Drying system for pellet production
- Trade systems for bio mass
- Forest friendly machines for harvesting of wood stumps, branches and tops
- Biogas production from algae
- Salix systems –planning, planting and harvesting
- Collection system for food waste
- Gasification Technology
- Hydrogen production from biomass
- Ecological warning systems for agricultural and forestry
- Biomass production optimizer system for use of land fields, economic and ecological aspects
- Large biomass combustion plants (x)
- Increased district heating (x)
- Flue gas purification in the combustion of biomass (x)

11 References

[1] Sweden's national action plan for promoting renewable energy , in Swedish http://www.sweden.gov.se/sb/d/12566/a/149023 **20110202**

[2] Bioenergy Sweden's largest energy source , in Swedish http://www.svebio.se/attachments/33/1310.pdf**20110202**

[3] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC Text with EEA relevance

[4] Renewable Energy Directive http://www.r-e-a.net/policy/european-policy/Euro-legislation/renewable-energy-directive **20110202**

[5] Wood fuel, in Swedish http://www.skogsstyrelsen.se/Global/PUBLIKATIONER/Skogsskotselserien/PDF/17-Skogsbransle.pdf **20110202**

[6] The potential for bioenergy , in Swedish http://www.svebio.se/attachments/33/902.pdf **20110202**

[7] Bioenergy from agriculture - a growing resource, pp77-78, pp 82 , in Swedish http://www.regeringen.se/content/1/c6/08/19/74/1c5245b7.pdf **20110202**

[8] The Swedish biogas potential from domestic waste, in Swedish http://www.energigas.se/Publikationer/~/media/Files/www_energigas_se/Publikationer/Rapporter/biogaspotential_slutlig0809.ashx **20110202**

[9]Biogas state of the art –Sweden 2006 http://www.aebiom.org/IMG/pdf/Dahlgren.pdf.

[10] http://www.scb.se/statistik/EN/EN0202/2007I08/EN0202_2007I08_SM_EN20SM0904.pdf **20110202**

[11] Sectorial examination of ways to reduce energy demand in Sweden , in Swedish http://www.naturvardsverket.se/Documents/publikationer/620-5726-X.pdf **20110202**

[12] Energy use in agriculture-2007, in Swedish http://www.scb.se/Pages/Product_226792.aspx **20110202**

[13] Model Estimation of energy consumption in the forest sector 2007, in Swedish http://www.scb.se/statistik/_publikationer/EN0116_2006A01_BR_ENFT0701.pdf **20110202**

[14] Energy consumption in the fishing sector 2005, in Swedish http://www.scb.se/statistik/_publikationer/EN0115_2005A01_BR_ENFT0601.pdf **20110202**

[15] The bio-energy is growing fast in Sweden, in Swedish http://www.klimatsmart.se/?page=news&id=6530 **20110202**

[16] Sweden almost fossil free year 2050 , in Swedish http://www.kva.se/sv/pressrum/Pressmeddelanden-2010/Sverige-nastan-fossilfritt-om-fyrtio-ar **20110202**

[17] EU roadmap to 2050 renewable energy http://www.renewableenergyfocus.com/view/8853/eu-roadmap-to-2050-renewable-energy **20110202**

[18] Barriers to increased use of biogas in Scania, in Swedish http://www.lst.se/NR/rdonlyres/941B1162-46A4-4596-B3CA-E247271DC6C6/0/LST_Hinder_for_okad_biogasanvandning_i_Skane_090212.pdf **20110202**

[19] Energy Market Inspectorate, in Swedish http://www.energimarknadsinspektionen.se/For-press/Pressmeddelanden/Nya-regler-ska-oka-andelen-biogas-i-naturgasnatet **20110202**

[20] Proposal for a multisectoral biogas approach , in Swedish http://www.energimyndigheten.se/Global/Press/Pressmeddelanden/Biogas_Slutrapport_final30aug2.pdf **20110202**

[21] Biogas boom - a climate friendly development, Swedish Nature Protection Association, in Swedish http://www.naturskyddsforeningen.se/upload/Biogasboomen.pdf **20110202**

[22] Electrical certificates, in Swedish http://www.energimyndigheten.se/foretag/Elcertifikat **20110202**

[23] Energy supply , in Swedish http://www.ekonomifakta.se/sv/Fakta/Energi/Energibalans-i-Sverige/Energitillforsel **20110202**

[24] Electricity and Bioenergy , in Swedish http://www.bioenergiportalen.se/?p=1442 20110202

[25] Energy statistics for single-family homes in 2008 , in Swedish http://213.115.22.116/System/TemplateView.aspx?p=Energimyndigheten&view=default&cat=/Rapporter&id=60373ee0cdc743898284fec420067527 **20110202**

[26] Production and use of biogas i Sweden 2009 , in Swedish http://www.biogasportalen.se/BiogasISverigeOchVarlden/~/media/Files/www_biogasportalen_se/BiogasISverigeOchVarlden/Biogas%20i%20siffror/ES2010%2005W.ashx **20110202**

[27] Proposal for a multidisciplinary approach biogas, in Swedish http://www.energimyndigheten.se/Global/Press/Pressmeddelanden/Biogas_Slutrapport_final30aug2.pdf **20110202**

[28] Action Opportunities in Sweden- a sectoral review. checking station 3 , in Swedish http://www.naturvardsverket.se/Documents/publikationer/620-5726-X.pdf

[29] Use of methanol as fuel in vehicles , in Swedish www.ecotraffic.se/getpublikfile.asp?publikid=49&file=file1 **20110202**

[30] Fossil independent vehicles 2030, in this way can biogas contribute, in Swedish http://www.handelskammaren.com/uploads/media/Rapport_biogas_juli_2010.pdf **20110202**

[31] Pulp mills make fuel for trucks, in Swedish http://www.byggindustrin.com/energi--miljo/massabruk-gor-drivmedel-till-lastbilar__6348

[32] Investment cost for 5 MW thermal plants, **in Swedish** http://www.kmwenergi.se/Project.asp **20110202**

[33] Investment costs for the 34 MW combined heat and power plant, in Swedish http://www.landskronaenergi.se/landskrona-kraft/om-landskrona-kraft **20110202**

[34] Cost of wood boiler , in Swedish http://www.linkoping.se/sv/Bygga-bo/Energi-och-sakerhet/Energi--och-klimatradgivning/Varme-i-villan/ **20110202**

[35] Biogas from manure and waste products -Swedish case studies http://swentec.se/Documents/Swentec/Bibliotek/Biogas%20from%20manure%20and%20waste%20products%20-%20Swedish%20case%20studies.pdf**20110202**

[36] Investment costs for bio gas facilities , in Swedish http://boffe.com/rapporter/Energi/Broschyr_g%25C3%25A5rdsbaserad_biogas.pdf **20110202**

[37] Investment costs for biofuel facilities , in Swedish http://bioenergitidningen.se/files/resourcesmodule/@random46d6cce6d449a/1220270237_biodriv.pdf **20110202**

[38] Statistics on waste incineration in Sweden , in Swedish http://www.naturvardsverket.se/sv/Produkter-och-avfall/Avfall/Hantering-och-behandling-av-avfall/Avfallsforbranning/Siffror-om-avfallsforbranning-i-Sverige/**20110202**

[39] Fuel-based energy, Swedish energy authority , in Swedish http://webbshop.cm.se/System/ViewResource.aspx?p=Energimyndigheten&rl=default:/Resources/Permanent/Static/f7d24384d1bb4c108a6a6764ad7ddc01/ER2010_05W.pdf **20110202**

[40] Biomass resources and production potential , European Biomass Industry Association http://www.eubia.org/215.0.html **20110202**