Energy Production in the Rural Landscape

16

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Energy in the Rural Landscape

Rural Society and Renewable Energy

One of the largest difficulties for sustainable development is the overwhelming dependency of most societies on non-renewable fossil energy supplies. The consequences of the large use of fossil carbon are twofold – first that supplies will come to an end; secondly that the end product – carbon dioxide – builds up and cause environmental damage. As for all non-renewable the effects of end products is felt typically before the source is emptied; here it is foremost carbon dioxide causing climate change although there are also a number of other serious pollution problems caused by combustion of fossil fuels long before global peak oil has been reached.

Non-renewable fossil fuels are concentrated sources of energy, stored by Nature after processes which took many millions of years. Renewable energy, continuously produced in nature, is on the contrary on the contrary spread evenly over a surface area, just as sunlight, and has to be harvested. The rural society therefore has an increasingly important role in supplying the society with energy. This is already seen by the increasingly larger role played by bio-energy, small-scale hydropower, wind power and more recently solar energy.

Energy production opens up new opportunities for the rural society, and is a main strategy for policies for rural development. We see new goals for rural development, new employment and a new economy in many countries. Moreover, planning for energy production could benefit the local society since it makes it possible to have locally owned production which in turn could mean better opportunities for starting local agricultural production, industries and services As an example the value of Finnish bio-energy production and processing in 2008 was 950 million Euro and provided 3,613 employment opportunities many of them at farms as a secondary activity. In Germany likewise a large number of new job opportunities from bio-energy production are reported.

The increasing role of renewable energy may be part of a transition to a sustainable society. It requires, however, that proper concern for other components in the sustainability agenda, such as biodiversity protection, is included.

Local Energy Production

Renewable energy is by nature most often local. But is it possible to provide all energy required from local sources – to build energy autonomy? This would be an important option and perhaps survival strategy for many rural societies. Obviously the possibilities for a municipality to provide all energy needed for itself varies dramatically with the circumstances. For the Nordic countries energy autonomy is probably a comparatively realistic option due to the reasonable small population and larger land area, and a geography e.g. allowing for large-scale hydropower plants as compared to the more densely populated continental Europe. Still there are a number of such projects in e.g. Germany, Austria, and the Netherlands.

Energy autonomy projects are so far most common for small communities, that is, towns in a rural setting (see box). In larger cities energy self-sufficiency projects are typically created in neighbourhoods often relying on more or less advanced technologies, such as passive

Box 16.1. Cases of Local Energy Resilience

The small town of Güssing, close to Graz in Austria, is an extraordinary case. From 1992 within eleven years, Güssing became self-sufficient with regards to electricity, heating, and transportation. Today more than 60 new companies and over 1,500 new "green Jobs" have been created and the share of commuters to other regions have decreased to 40%. Since Güssing generates more "green" energy than the regions needs, the value added to the region is over $28 million per year. Finally, green-house gas emissions were reduced by over 80%. The steps to energy autonomy include: 1992: New mayor elected; 1994: Public energy use cut 50%; 1996: 3 MW biomass CHP power plant, 1998: CHP power plant expanded to 8 MW; 2004: Installation of an advanced biomass gasifier. http://blogs.worldwatch.org/the-model-region-of-gussing-%E2%80%93-an-example-of-the-austrian-grassroots-strategy-for-energy-independence/

Växjö decided in 1996 to become "fossil fuel free". Växjö has since built two biomass plants and requested for the municipality green electricity. In 2000 the municipality developed the "local initiatives award" and in 2007 was awarded of "Sustainable Energy Europe Award". It is clear that Växjö there is political consensus of the fossil fuel free policy and several times the members in the city council take part in energy projects run by the municipality.

In Samsø in Denmark with 114 km^2 the 4,000 inhabitants changed their daily lives for greater energy efficiency. 21 wind turbines generating 28,000 megawatts annually have been built to meet the community's electricity demands and public transportation system; the surplus to sell is 10%. Farmers have adapted their tractors and other vehicles to consume ethanol or other fuels distilled from locally grown plants, like canola. The community experiments with electric cars as distances are very short, less than 50 kilometers. http://www.ipsnews.net/news.asp?idnews=49273

Figure 16.1. Energy independence growing on a regional level in Austria. The map depict regions indepenent of electricity, heat and/or transportation (red), regions with growing energy independence (yellow) and regions with high energy efficiency standards (green). Source: WorldWatch Blogs, 2011.

energy houses and smart grids. Much of the energy autonomy is also established on the household level, that is, houses are equipped with PV solar cells on the roofs for electricity production and/or with solar heat panels. Such solutions are available for any building, including those in towns or individual houses on the countryside.

Energy efficiency measures are an important part of making local energy supply sufficient. Especially in the heating sector the needed energy may be reduced substantially by energy efficiency projects. District heating is one of the most efficient. In Sweden close to 90% of houses are today connected to district heating using bio fuels. In the heating sector thus the vision of local energy supply are already close to a reality. The actions of households are important, as they may choose to improve insulation, change heating system or actually provide their own heating through e.g. heat pumps or panels for solar heating.

Local electricity production is still in its infancy, much due to the circumstance that national supplies are mostly safe and sufficient. However discontents with the changes in prices have made a number of both individuals and local municipalities develop their own local generation of electricity. Most important is probably electricity from power stations using bio-fuels, but wind power and hydropower for local needs increase rapidly. For the local communities which today are energy independent on electricity wind energy seems to be by far the most important source.

Probably the most difficult issue for local energy is fuel for transport. Imported fossil fuel by far dominates the market. Other options develop, however, such as buses using locally produced biogas, buses using locally produced biodiesel, cars on bio-ethanol and a few electric cars.

Estimations of the extent of locally produced energy today are close to guesswork. It is however obvious that it is not unimportant. Heating in the housing sector accounts for some 40% of the energy need and is mostly provided for by local sources, and that the other two energy sectors – electricity and fuel for transport – is marginally taken care of locally. If these are estimated to 5% each we will still arrive at a total of 50% local energy supply at least in the Nordic countries.

Policy/strategy Options and the Food-energy Dilemma

A country, region or municipality which decides to become fossil fuel free is confronted with a number of policy options. One of them is how to manage the resources they have in terms of available land. Should it be used for growing energy crops or food crops? In developing countries this choice may be critical, as bio-energy developments can pose a threat to food security because it may compete with the same natural resources. In the Baltic Sea region it is not critical unless we import food or energy, e.g. bio-ethanol; then we are part of the game. In our local markets it is more than anything a question of price.

Bio-energy development may also provide opportunities for increasing welfare. It can generate employment and raise incomes in farming communities and provide a sustainable source of energy that is an affordable substitute for imported fossil fuels. Investments in bio-energy may increase harvests for both food and fuel crops.

The most common strategy for improving sustainability in municipalities is rescaling. Both up-scaling (e.g. from individual heating of houses to district heating) and down-scaling (e.g. from district heating to heat pumps) are common. Striving for energy autonomy is typically downscaling from dependency on global or national sources of energy.

Local energy policies have repeatedly been shown to be beneficial for the local business life. It is obvious that producing energy locally offers work opportunities, and money used for buying fossil energy is then instead used for local business. An extreme example is Güssing in Austria (see box) where a completely new commercial sector developed based on local energy production and the competence developed in connection with this project.

Support of local energy production at least in the beginning requires some policy tools, especially economic ones. A most efficient one is the feed-in tariffs used in Germany, which guarantees that (extra) electricity produced locally will be bought by the national grid for a set (good) price. The economy of an investment is thus secured and has therefore made Germany number one in local electricity, especially from PV (photovoltaic cells) on roofs. Positive incentives include governmental subsidies for changing heating system from fossil dependent to e.g. pellet boiler. This incentive has been used in Sweden. Negative incentives include carbon dioxide taxation. In Sweden this is 1 SEK (about 10 Eurocents) per kg, enough to make use for fossil fuels for heating less attractive, while it is typically much less in other countries.

Heating Houses

Heating has since centuries in most countries in the Baltic Sea region been provided for by wood. In a well forested region this should be no problem. However resource constraints have during periods been a reality also for wood. In the 18th century the forest crisis made wood a limited resource. One result of this was the development of the tiled stove, which improved the energy efficiency of wood combustion several-fold (see p. 165). Today we are in a similar situation. We have to stop using coal –traditionally used for heating e.g. in Poland – or oil, earlier the standard in Sweden – or natural gas, the normal source in Latvia e.g. for heating houses. Reducing the need for heating, improving resource efficiency, and exchanging the resource used are all strategies required, and quite easily applied in a rural setting.

In the heating sector the needed energy may be reduced substantially by energy efficiency projects. In Sweden IVL (Swedish Environmental Institute) estimates that 20% of the energy demand in the housing sector (150

TWh) can be reduced by efficiency measures. New buildings are increasingly low-energy houses.

District heating, even in smaller towns or villages, is important since the use of fuel improves dramatically by having a more advanced boiler possible in a district heating network. In individual houses efficient pellet burners, or modern stoves using bio-fuels, are far better than the old time classical stoves.

There are several other technical options. Solar heating is one. Solar panels may be mounted on the roof of one house or expanded to many houses or even to the municipal scale. Thus in Kungsbacka in Sweden 48 one-family-houses cover 70% of its annual consumption of hot water from a 900 m^2 solar panel field, one of the largest in the world. The solar panel field in Aeroe in Denmark is another system heating the whole town. These very advanced solar panels may provide hot water and heating between March and November.

Another option is a heat pump. Many households – in 2010 estimated to 800,000 in Sweden – use heat pumps. These rely on electricity but are up to five times more efficient than direct electricity for heating.

Mapping Local Energy Resources

A rural local authority, which adopts a policy of energy production or energy autonomy, may start by mapping their energy resources. Energy appears in many different forms and one should be able to list at least 20 or so sources. In a second phase each of these resources need to be looked at in more detail. How much, which investments are needed, which is the payback time for investments are obvious questions. Finally one needs to assess which mix of resources will provide the best price and the best energy security.

The mapping of *local energy resources* should be divided in three categories: electricity, heat and fuels. An example of the resources to be included is listed in Table 16.1.

Data on wind speed or waves may be obtained from the meteorological institutes. Size of wetlands is found on a ordinary land use map. Forest production and agricultural production is the subject of local farmers and forest companies etc. A local energy company is a very good partner in a project of this kind, while the large international companies often are not interested.

Table 16.1. Mapping of local energy resources divided into the three categories electricity, heat and fuels.

I. Electricity	
Solar	Solar cells (direct sunlight to electricity)
	CSP (Concentrated Solar Power
	Combination panels for electricity and hot water
Water	Hydropower (Small scale from water flows from reservoirs and lakes
	Streaming water (developing technology)
Wind	Map average wind speed
Wave	Map average wave at the coast
II. Heat	
Solar	Solar panels for hot water
	CSP (Concentrated Solar Power)
	Combination panels for electricity and hot water
Geothermal	Heat pumps relying on renewable electricity
Biomass	Wood chips
	Wood pellets
	Other (straw etc)
III. Fuels	
Solid Biomass	Wood or wood waste from forestry
	Energy forests
	Peat
	Household waste
Ethanol	Crops harvest to ethanol
Bio-diesel	Oil crops (rape seed) to biodiesel
	Cellulose wood or straw (second generation bio-ethanol)
Biogas	Slaughterhouse and fishery waste to biogas
	Reed and other biomass from wetland
	Agricultural waste from farms
	Manure
	Sludge from wastewater treatment

Table 16.2. Production of hydropower in the nordic countries and the European Union. El (GWh) samt procent av den totala elproduktionen år 2008. Source: Wikipedia, 2012.

Land	2003	2004	2005	2006	2007	2008	%
Norway	106,216	109,373	136,441	119,726	134,736	140,522	98
Sweden	53,598	60,178	72,874	61,859	66,262	69,211	46
Finland	9,591	15,070	13,784	11,494	14,177	17,112	22
Iceland	7,088	7,134	7,019	7,293	-	-	-
Denmark	21	26	22	23	28	26	<1
EU 27	338,307	357,147	341,744	344,348	344,236	359,185	11

Renewable Electricity Production

The Dilemma of Intermittent Sources

Hundred years ago electricity for a town was produced locally in an electricity works. Later, when the technology of long distance transfer of electricity developed, larger national facilities, hydropower stations of power stations using fossil fuels, became the norm and electric current became something coming out from two holes in the wall.

Today locally supplied electricity is again an interesting option after having taken the decision to reduce the dependency of fossil fuels and thus reduce CO_2 emissions. The renewable resources include wind, water and sun. But these are different from power stations as they are only working when the wind, water or sun is available. We may save water in a reservoir, but sun and wind cannot be stored. These sources are intermittent. This may the biggest dilemma with locally produced electricity. Only for very limited use may an ordinary battery be sufficient, e.g. in remote places where electric lights in the evening come from a solar cell on the roof using daylight sun.

New and better batteries will hopefully one day be aviable but today it is far from sufficient for storing electricity on a regional scale. In a modern European country the most realistic option is to sell excess electricity to the national grid and get it back when the intermittent sources are silent. In Sweden this is working well since the large hydropower plants provide the storing capacity needed. In other countries where this opportunity does not exist, storing capacity in practice relies on power plants most often using fossil fuels. However power plants, especially smaller power plants, may be run using bio-fuels. In this case a system – consisting of intermittent sources and the power plant – completely or almost completely sustainable can be built. An example is Enköping in Sweden where the power plant is using forest wood waste and wood chips from an energy forest. It is a CHP, combined heat and power plant, in which the hot water is used for district heating and electricity is used for the town. There are also more advanced technical solutions such as pumped-storage hydroelectricity, or moving the problem by importing or exporting electricity to neighbouring countries or reducing demand when intermittent sources are low.

In practice countries such as Denmark, which has much wind power, install excess production capacity using fossil fuels to be used when the wind is low. In other countries nuclear power has a similar role. Nuclear power has the advantage of not emitting carbon dioxide when running, but still it is not a renewable resource. Another important aspect is to learn to reduce peak demand, by using electricity more evenly during the day and night.

Hydropower

Hydropower is by far the most import renewable energy source. In the Baltic Sea region Norway has the largest hydropower sector followed by Sweden and Finland, but it is also important in Latvia and Poland. In Sweden there are about 1,900 hydropower stations, and 85% of the rivers are exploited. Hydropower many be regulated and for this reason has an important role in the energy mix of a country. Hydropower today accounts in Norway for 140 TWh (98%), in Sweden for 69 TWh (46%), and in Finland for 17 TWh (22%) of the electricity use in the countries.

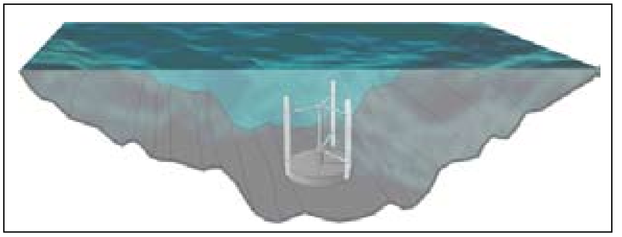

Figure 16.2 *Streaming water electricity*. Electric energy may be extracted from the rural landscape in many ways. To the established hydropower, wind power, and solar electricity we may add this new method of generating electricity from streaming water. The technology is similar to the one used in wind power. A main difference is that water has a density 800 times larger than that of air. The energy density of a water stream of 1 m/sec thus corresponds to the energy density in air at 9 m/sec. Streaming water electricity is predicted to be mostly useable for ocean currents at coasts, but it can also be used in rivers. An advantage is that it does not require any large constructions, such as water reservoirs, and it is not visible from the outside making it much less provoking in the landscape. Streaming water electricity is studied at Uppsala University to develop new ways of renewable energy production. Illustration by Karin Thomas.

Hydropower has been used for hundreds of years. However the big development took place in the end of the 19th century. The turbine then replaced the water wheel and thus made it possible to install a generator to produce electricity. At the same time the technology for long distance transfer of electric power developed and made it possible to use electricity from the far north of the Nordic countries for the urban centers further south.

The large hydropower stations influence large land areas for its upstream reservoir or dam. Land used for valuable nature and human settlements may have to be abandoned. The stations also influence the seasonal migration of fish and may kill substantial amounts of fish in the turbines. Some stations compensate for this by building stairs for fish upstream migration and cultivating fish fry for implantation. Still the environmental costs are substantial.

One way to get around the problem is to use smaller mini- or micro-hydropower. These are stations often built where a dam has existed for centuries for a small industry or mill. In the mid 1950s Sweden had about 4,000 small hydropower stations with a capacity under 1.5 MW. In 2008 only 1,500 of these were still running producing a total of 1.5 TWh (more than wind power!). It is estimated that another 2.5 TWh would be possible by renovation and starting old and abandoned mini stations. Micro-hydro stations have an important role to play in the economic development of remote rural areas, especially in the mountains.

The technology for small-scale hydropower is in a phase of rapid development. One system uses a combined turbine and generator in mobile machine housing. It can be installed under water in existing dams with only minor changes. It is thus invisible from the surface and also well adapted to the water fauna and flora. A German station with a capacity of 500 kW is expected to generate approximately 2.75 million kWh of electricity a year according to the company. This corresponds to the power consumption of more than 600 four-person households. Another construction uses a water wheel at the bottom of a stream, thus no dam is needed. This streaming water electricity is presently under testing.

Wind Energy

Wind power is the conversion of the energy in wind – moving air – to mechanical energy and most often to electricity in a rotating wind turbine. Wind power in the shape of windmills and wind pumps has a long history (and even longer if we add sailing!). The use of generators to convert the power of the rotating wings into electricity was made only shortly after the generator was introduced in the end of the 19th century. The modern wind turbine was introduced much later by Danish inventors. The first turbines had capacities of 20-30 kW; today the largest turbines may deliver up to 7 MW capacity. Wind energy in 2010 provided 2.5% of global electricity supply and is increasing rapidly with 28% yearly (2010 figures).

Wind turbines may be installed as a single, often not so large, unit to provide a farm or smaller group of households with electricity. More often however they are built as a group of turbines, forming a wind farm. Very many of the wind farms are built off shore. In Sweden the largest planned wind farms are in the Scandinavian mountains and others in the Baltic Sea off shore. The most successful wind energy countries in the Baltic Sea region are Denmark and Germany. The largest off shore wind farm in Denmark is *Horns Rev* on the Jutland west coast with a capacity of 209 MW. For the year 2010 7,8 TWh (21%) of Danish, 35,5 TWh (9%) of German and 3,4 TWh (2%) of Swedish electricity was provided by wind energy. The

Figure 16.3. Solar plant farm in Sala Heby, Southern Sweden. Photo: Heby Municipality. Sala Heby Energy AB, SHE.

installed capacity was 3,734 MW in Demark, 27,215 MW in Germany and 2,046 MW in Sweden. Most of these belong to the big power companies. However increasingly we see small companies as well as individuals or groups of individuals planning, financing and installing smaller wind turbines as part of local energy supply. It remains to be seen how large this trend will become. .

A wind turbine uses comparatively little land and the (formal) ecological footprint of wind power is small. It is however comparable to hydropower in the sense that landscape intrusion is large. A wind turbine can be seen and heard over large distances; this is not always so popular. The Swedish Energy Authority in 2008 indicated 423 areas with a total area of 9,673 km² of national interest for wind power in the country. Of this 5,817 km² are on land; if fully utilized these would be able to produce about 20 TWh.

Technical development of wind power continues. Of special interest is so called vertical wind power, which may be both more efficient and needs to be less tall, and in addition is almost silent. Only pilot scale vertical wind power exists presently

Solar Electricity

The conversion of sun light into electricity may either rely on photovoltaic (PV) cells or so-called concentrated solar power (CSP). In PV sun light is directly converted into an electric current. In CSP the sun rays are focused by mirrors into a small area to heat a liquid to high temperature which is pumped into a turbine to produce electricity. Research on how light can be transferred into an electric current exists since 100 years and commercial PV cells since the 1980s. From a slow beginning the development of commercial solar electricity has since the mid 1990s increased rapidly in response to higher oil prices and concern over climate change. The global increase is estimated to about 40% per year since about 2000. At the end of 2010 installed capacity was 40 GW. Germany, with an installed capacity of 17.4 GW, (together with Japan and China) is world leader in the field. The German solar PV industry installed 7,400 MW in nearly one-quarter million individual systems in 2010. Globally solar PV provided 12 TWh of electricity in 2010, about 2% of total electricity.

Solar electricity, more than any of the other renewable electricity sources, illustrates that renewable electricity depends on surface. It is thus an interesting opportunity for rural landscapes. Surprisingly to many the solar irradiation is enough – also in mid Sweden – to make a fairly small surface (25 by 25 km) enough for supplying all electricity needed in Sweden. In practice it is not so easy, but it illustrates that the sun is sufficient in large parts of the Baltic Sea region, although obviously not during winter far north. Since 2011 the largest photovoltaic plant is Finsterwalde Solar Park in Germany, with 80.7 MW capacity and Ohotnikovo Solar Park in Ukraine with 80 MW capacity. There are also some PV parks in Czech Republic (about 1,700 MW) but very little in the rest of the Baltic Sea region. The environmental impact of these is minimal as is the ecological footprint (not regarding the LCA of the cells which may be more problematic).

Presently the world market price for solar electricity is estimated to 1.1 Euro/W by the end of 2011 (Bloomberg New Energy Finance) and the price is falling rapidly. The payback time for PV systems are thus estimated to be about 8-12 years. Since they are expected to last 25-40 years PV electricity is since some years profitable. Solar electricity is, as is wind power, an intermittent energy source and thus requires some kind of back up. This is presently the largest problem with the technology.

Wave Electricity

Wave power produced along the coasts is in its infancy, but a promising technology. At present a first wave power farm consisting of several hundred units is installed on the Swedish west coast. It will be less intrusive as the only thing one can see are the floating devices on the surface. The generators on bottom seems to be very compatible with marine life and is colonized by sea stars and other animals and plants.

Bio-energy Production

Solid Biomass

Solid biomass was always simply firewood to be burned in a stove to give heat, or used in the kitchen to cook. Today biomass is still mostly wood or wood products such as wood waste from forestry (roots and branches), or sawdust made into pellets for easy management, or wood chips. To this should be added grass and trimmings from agriculture or horticulture, and various domestic refuse mostly household wastes. Classical crops may also be used for energy purposes, such as barley or oat. In practice this is a question of price, markets and practical circumstances.

Wood biomass is produced either from forestry or special energy forests mostly from Salix cultivation (See chapter 16). For forestry products such as wood waste or pellets there is no competition with food production. Energy forests may compete with food production as the land could be used differently.

Solid biomass in all its forms may be used in power plants to produce heat and electricity. In individual households pellets is more convenient to use for heating since they may be handled a little like a liquid, such as oil, to avoid the necessity of everyday's management of the boiler. Still many people like to use wood for a tiled stove or a modern stove. The drawback with this is that

Figure 16.4. Biogas-production on the farm. This pig farm in mid Sweden, with an average occupancy of 3,000 pigs, use all manure for biogas production. The gas is used in a combined heat and power equipment, which provides all electricity and heat needed for the farm and a surplus sold to the electricity grid. To the right the anaerobic digester, also called fermentation tank. Photo: Lars Rydén.

flue gases contain much smoke, particles, aromatic substances and dioxins. Efficient cleaning of flue gases is in practice only done at larger facilities such as municipal power plants.

Wood is considered a renewable source of energy. However this should be said with the reservation that the time it takes to replace a tree is long, many decades even 100 years. With the concern that GHG emission should be reversed within only few years the climate mitigation contribution from wood biomass is limited.

The use of biomass is increasingly important in the countries of the Baltic Sea region. In Sweden biomass accounted for 139 TWh in 2010, an increase of 9% from the year before. More than 32% of all energy use in the country is bio-energy. About 90% are forest products and an additional important part is byproducts from the industry (e.g. black liquor from pulp production). In Germany bio-energy accounts for 4,9% of overall primary energy, or 7.3% of total fuels and 6.3% of total heat (2007 data).

Biogas

Biogas is produced when all kinds of organic matter is fermented (biologically broken down) in the absence of oxygen or air. Biogas consists of methane, also the main component in natural gas, as well as water and carbon dioxide, which has to be removed before it can be used as a fuel. Biogas is formed in many different situations, most notably in landfills as much organic material, e.g. food waste, is stored, and when ruminants, most importantly cows, digest grass. Biogas can just as natural gas be used in all kinds of combustion processes. It is thus useful for heating, for producing electricity in a power plant, and for motor vehicles. The residuals from the fermentation can be used as fertilizer as all phosphorus and most nitrogen is retained. An important concern is to carefully stop all leakage from the process since methane is a strong greenhouse gas.

Biogas is produced in a fermentation tank using the substrate - the food waste or other organic material - and a proper brew of microorganism. It is not often as simple as it may sound. The process is very different for different substrates, it may be very long, several weeks or even months, and the process of producing a good bio-methane from the biogas is added. The economic reasons for interest in biogas are both a question of taking care of organic waste as it is the production of a renewable fuel. However the technology is developing and biogas production increases.

Germany is Europe's and thus the Baltic Sea region's biggest biogas producer. In 2010 there were 5,905 biogas plants in the country mostly used for electricity production in CHPs with a net production during the year of 12.8 TWh which is 12.6 per cent of the total generated renewable electricity in the country. Denmark has also a relative large biogas production. In 2009 Danish authorities reported 60 biogas stations at sewage treatment plants using wastewater sludge as substrates, 20 municipal plants to treat manure, food industry waste etc and another 60 on-farm facilities, in addition to facilities connected to landfills and some industries. Figures from 2006 report a total energy production of 1.1 TWh. In Sweden a handful of cities have fermentation plants to produce biogas for city buses and there are a few facilities on farms. The production of biogas increases dramatically in the country.

Biogas production offers a means to take care of manure at farms, straw and other agricultural waste as well as wetland bio-production, food waste and waste from slaughter houses, fishing industries etc. But it is also a way to process biomass. Biogas in Germany relies primarily on co-fermentation of energy crops; in 2011 ca 800,000 ha was used to grow energy crops for biogas. This is the outcome of governmental subsidies and has resulted in a new development in rural districts especially in southern Germany.

In Sweden biogas is mostly used for motor vehicles. The authorities estimated in 2011 that projected Swedish biogas production should be able to meet the demand for all buses in the country. Biogases buses give rise to very little air pollution and much less noise than ordinary diesel buses and are thus more convenient in city streets with much people.

Bio-fuels – Bio-ethanol and Biodiesel

Liquid bio-fuel is mainly bio-ethanol and biodiesel. Bioethanol is produced by fermentation of sugar, a process just the same as used for wine or beer making. Sugar is received from starch crops such as corn or sugarcane or sugar beets but it may also be other crops. New technologies allow ethanol production from cellulose that is wood, trees and grass. This so-called second generation

Figure 16.5. Rapeseed field near Eslöv in Southern Sweden. The fatty acids from the oil in rapeseeds can be used for bio-diesel after methylation. Photo: Håkan Dahlström.

Figure 16.6. Bio-dieselbus in Cambridge, UK. Photo: Hamster. Source: http://www.flickr.com.

bio-fuels require that the cellulose is hydrolyzed in a special step. It is an area in rapid development.

Bio-ethanol is used as fuel for motor vehicles substituting fossil oil products. Motors for ordinary petrol can also use ethanol with very little adjustments. Today in the European Union by law petrol includes 5% ethanol. This could be increased to 10% without any technical problems. Ethanol cars use a mix of 85% ethanol and 15% petrol (E85) as fuel. Ethanol increases the octane number of the fuel, allows higher compression, and reduces exhausts.

Biodiesel is produced from oil, mostly rapeseed oil, by transesterification with methanol to get fatty acid methyl esters. This is a fairly uncomplicated process and can be done on the farm where the vegetable oil is produced in an oil press. Biodiesel may replace ordinary (mineral) diesel fuel in a standard diesel motor, although one often uses a mix of mineral and biodiesel. In Europe much diesel is mixed with 5% bio-diesel.

Europe produced 53% of world bio-fuels in 2010; Spain, Germany and Italy were important production countries. In total 2010 worldwide bio-fuel (ethanol and biodiesel) production reached 86 billion liters of ethanol and 19 billion liters of biodiesel, an increase of 17% from 2009.

Sweden had the largest number of bio-ethanol vehicles – 200,000 cars use E85, 600 ethanol buses use ED95 (2010 data) – very much the results of considerable governmental subsidies. Still using bio-ethanol as a renewable fuel for cars is often referred to as "transition stage" on the way to electric cars. An important reason is that a combustion motor is only 25% as efficient as an electric motor. Another reason is that ethanol often is grown and harvested with conventional machinery on farms which use fossil fuels. Thus emission reductions of cars using bio-fuels are far from the potential it would have if the production of the fuel would be more sustainable. Hybrid cars offer today an intermediate solution. While bio-ethanol cars may approach a decline, biogas vehicles seems to increase.

Chapter 16

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