Baltic University Urban Forum
Urban Management Guidebook II

Energy Management

Editors: Christine Jakobsson & Jan Lemming

Project part-financed by the European Union
(European Regional Development Fund)
within the BSR INTERREG III B Neighbourhood Programme.

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Series preface

The Baltic University Urban Forum, BUUF, project was designed to develop sustainability strategies for the local level. The project, conducted in a network of 20 cities and 15 universities in nine countries in the Baltic Sea region during 2003-2006, was coordinated by the Baltic University Programme Secretariat at Uppsala University in Uppsala Sweden, in cooperation with the Royal Institute of Technology, KTH, Stockholm, Sweden and the Union of Baltic Cities, UBC, the Environmental Commission in Turku, Finland.

The project was financed by the European Union through Interreg IIIB, the Swedish International Development Organisation SIDA, the Swedish Institute, and other sources, in particular the C-Framåt office in Uppsala County, as well as by the participating cities and universities.

Built on previous experiences ten areas were selected to be in focus in the BUUF project. These were.

1-3. Energy management; Water management; Waste management.
4-6. Traffic and transport; Urban green structures; The built environment and brown field restoration.
7-9. Socio-economic development; Urban-rural cooperation; Information and education;
10. Integration strategies in sustainable communities.

During the period 2003-2005 the project organised best practice conferences in all 20 participating cities addressing all ten topics as well as the integration between the topics, and sustainability strategies used in the participating cities. The discussions and study visits at the conferences inspired a series of guidebooks on the selected topics to be used for city administrations as well as researchers and teachers at universities dealing with sustainable urban development. These are herewith offered to the readers

The guidebooks are thus not proceedings of the conferences, even if several of the participants have contributed. The ten guidebooks were planned later and editors with editorial teams recruited. Authors include both practitioners from cities and researchers from universities. The production has been done during 2006 and 2007.

The main topic of the guidebooks is to report on sustainability strategies used and evaluate these strategies, and possibly suggest new strategies for sustainable development on the local level. The books also contain a number of detailed descriptions of how to work with city development in practice as well as reports more of research character. The format of the guidebooks is about 50 pages in A4 format and some 12 chapters.

The guidebooks are published as pdf documents on Internet to be available in the public domain and thus a generally available resource at the site www.balticuniv.uu.se/buuf. The site contains further resources developed in the BUUF project. These include an indicator book, city reports and benchmarking reports.

I want to express my gratitude to all editors and authors who have contributed to these books, and hope that the results will be used widely both by the cities and universities of the project as well as by many others.

Uppsala in May 2007

Lars Rydén
Project leader
Baltic University Urban Forum

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Fossil Fuels – How Long will they last?

Exploring the evidence of peak oil production

Kjell Aleklett, Uppsala University

Fossil fuels, oil, gas and coal, constitute the major energy source in the Baltic Sea region, as it does in the whole world. Our societies are dependent on them. We might even say that we are addicted to fossil fuels. We know that the reserves are finite, but it is hard to accept that there will be a time when we must use less then today. Very few are aware of the fact that we very soon have to change habits.

The known global reserves of crude oil are around 800 billion barrels. Some quote a higher number but we must put a question mark on some of the reported reserves. A problem we are facing when it comes to production is that the majority of remaining oil can be found in old oilfields and it is not possible to tap an old field in the same speed as when they were young. A yearly production of 30 billion barrels might be possible to sustain for some more years, but very soon, probably around year 2010, we will see a permanent decline in the production of oil. Three quarter of the oil reserves can be found in the Middle East and the northern part of Africa. The proven reserves of natural gas amount to less than 200 trillion cubic meters. Again more than 50% is in the Middle East. Coal reserves are larger and come up to just less than 1000 billion tonnes.

The Baltic Sea region, excluding Russia, is a fossil fuel importing area. We are, however, close to two major exporting areas. One is the North Sea where oil now is declining but gas will continue to be exported for a long time. The other area is the Russia which also partly belongs to the Baltic Sea region. For energy security of the region it is important that we find suitable projects for collaboration with Russia. But even if these reserves exist and will extract for a long time, oil and gas in a slightly longer perspective will come to an end soon. The period with plenty of oil will not be longer than some 100 years – the exact length depends on how we count. It is a short moment in the development in human civilisation. We are just now close to the mid point in this development. The point in time when half the oil resources have been used up is expected to coincide roughly with the time when production will start to go down. This is called Peak Oil and depending on change in demand it can be just now or come within 5 to 10 years.

Oil and economy

Oil is important for the world economy. Oil consumption is fairly well proportional to average income or the GDP of the country. In developing countries there are a one-to-one correlation between the increase of GDP and increase of consumption of oil. During the last 5 years China has had an increase of GDP with 8,2% and an increase of consumption of oil with 8,5%. The global problem that we now face is that there is not enough oil in the world for increasing GDP in the poorest countries.

Since the decline in the consumption in the 1970:s and 1980:s there have been an increasing demand with on average 1,6%. Using this trend the International Energy Agency, IEA, and US Energy Information Administration have predicted oil consumption for years ahead. Today the global demand is 84 million barrels per day and the forecast for 2030 is between 115 to 123 mbpd with increases between 1,4% and 1,6%.

In mature economies oil use and GDP do not follow each other as closely, and we talk about de-coupling. It is clear that the tight connection between oil demand and GDP is typical for early industrialisation. A de-coupling has been observed in western economies since the 1970s. However this economic growth without oil, is offset by the so-called rebound effect, that is total growth is much larger than decoupling, so oil demand is still increasing in absolute terms. In the European Union Sweden is

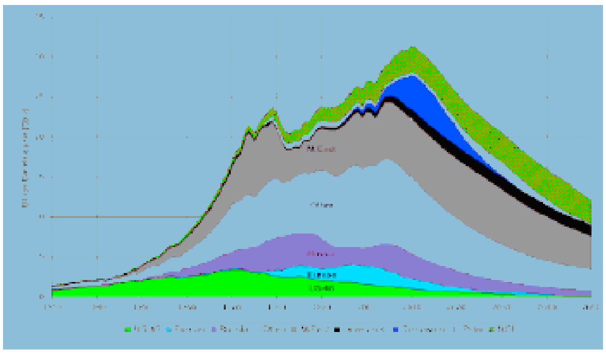

Figure 1. Peak oil. The ASPO 2005 base secenario for oil production divided between the major producers. (ASPO = Association for the Study of Peak Oil). The diagram predicts that peak oil will occur at about 2010.

the country where decoupling has been most pronounced, very much due to the expansion of nuclear power in the 1970s and 1980s.

How much oil will we find?

First we have to point out that there are different kinds of oil. The lighters and best oil is called crude oil. So far we have used 1000 billion barrels, have 800 billion barrels in the reserves and we might find another 200 billion barrels in the future. Heavy oil is found in big quantities in Venezuela and as oil sand in Canada. Production of heavy oil is an industry production that needs a lot of energy. A 30-year increase of the production can bring it up to 10-15 mbpd, this volume cannot offset Peak Oil.

It is perhaps not so easy to get a grip on these large numbers so let us simplify by assuming that we have a number of champagne bottles with oil, each one containing 100 Giga barrels, Gb, equal to the reserves in Iraq. If we pour this into four glasses, each glass (25 Gb) constitutes one year's global consumption as it was in year 2000. The bottle is thus enough for 4 years global consumption. Today the yearly consumption has increased to 30 Gb so it would not be enough even for the four years.

Looking into the history we may say that the world has so far consumed 10 bottles. The reserves that IEA reports are 10 bottles. Within the Association for the Study of Peak Oil and Gas, ASPO, we believe that this figure is a slight overestimation and that in reality there are only about 8 bottles. These uncertainties are due to the fact that oil companies are not always open about their findings. There are business reasons to sometimes exaggerate figures.

What about expected future discoveries of crude oil? According to IEA we need to find another 13 bottles the coming 25 years, 7 are new oilfields and 6 from enhanced recovery. Our studies suggest strongly that this is not realistic. We may expect only about two additional bottles from new discovery and the 6 might be just another 2 bottles. Today we know quite well in what kind of geological settings one may find fossil oil and gas. We thus do not expect great new surprises. In fact discoveries that should change the picture we have today fundamentally need to be very large indeed. This makes the present view even more credible.

The development of oil discoveries is very well described, as is the production. Plotting these two developments on the same diagram gives a very clear picture that at some point there will be a serious lack of oil and the world demand will be far from satisfied.

Discoveries in the past and in the future

The classic scientist in the area of oil exploration is M. King Hubbert (1903-1989). He studied discovery and production trends in USA. The discoveries

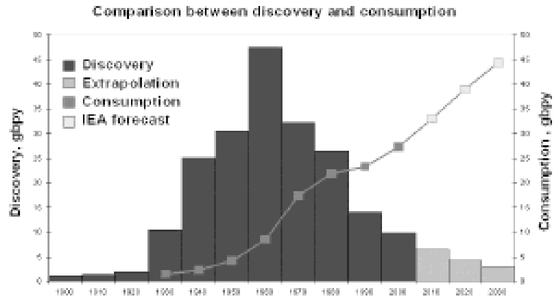

Figure 2. Discovery and Consumption scenario.

peaked in 1935 and by extrapolating the decline rate that he saw in 1956 he could predict that the USA oil production would peak around 1970. It turned out that peak production occurred in 1971 and production has since then declined. In Norway we had a peak in discoveries in the late 1970:s and the peak production occurred in 2003. Figure 1 shows the global discovery curve and the peak in the 1960:s. According to King Hubbert the consumption should peak around 1998. However, the taps was closed in the Middle East in the 70:s and 80:s and the normal Hubbert curve cannot be applied. Applying a decline rate model and accepting the fact that we cannot consume more than we have found there will be a peak in the production around year 2010. Figure 2 shows the 2005 scenario for crude oil divided into the regions USA, Europe, Russia, Middle East, Deep water, Polar Oil and the Rest of the world. We have also added the production of heavy oil as well as NGL, Natural Gas Liquids (NGL is gasses that at normal pressure are liquid).

The Russian oil fields

The situation in Russia is especially interesting for the Baltic Sea region. Russian oil production peaked in the 1980:s and collapsed when Soviet Union was dismantled. Modern technology in the old fields has brought up the production, but it will never come back to the rate it had during the 1980:s. According to IEA there might be a constant production around 10 mbpd, but our depletion model indicate that this might be an optimistic scenario. The available data suggests that there are still some 60 Gb to extract. We will in addition see an increase in the production in Kazakhstan and Azerbaijan but this production will be exported via pipelines through Turkey and to ports in the Black Sea, and not reach the BSR.

The Middle East oil and total global production

As mentioned the IEA scenario is that in 2010 the world will produce 90 million barrels per day oil, in 2020 107 million barrels and in 2030 it has increased to 120 million barrels per day. If this production is summed from now till 2030 we will consume 900 Gb of oil (9 champagne bottles!).

But does this much oil even exist and is it possible to increase the production? The prediction builds on an estimation of the productive capacity of the countries in the Middle East. Most of the Middle East oil is found in the so-called Oil Triangle, oilfields in Iraq, Iran, Kuwait, Saudi Arabia and the Emirates. This area accounts for 60% of all known oil reserves. According to the Cheney 2001 US Energy Policy document, in 2020 around 54-67% of the world production needs to come from this area. However Sheik Sadad Al Husseini, just retired vice-president of the Saudi oil company Aramco, says that "the American government's forecast for future oil supplies is a dangerous overestimate."

Saudi Arabia and the Russian Federation are today the two largest oil exporting countries in the world, followed by another 20 smaller exporters. It is obvious that if we should continue to use oil on the level we do today we need to find new oil fields. Exxon Mobile estimates that for 2015 eight out of ten barrels of oil need to come from new oil fields. However this would require that another 10 Saudi Arabias are discovered. Of course it will not happen. A more sober view of future oil production is that we can count on some production from new fields, but mostly on development of existing reserves and some so-called non-conventional sources.

Oil future and ASPO

The present knowledge of existing oil reserves can be summarised in the now well-known peak oil diagram, which has been published by ASPO since more than five years. (ASPO started in 2001)

The Association for the Study of Peak Oil and gas (www. peakoil.net) was formed in 2001 to study an area that so far had been the monopoly of the oil business, and not enough critically examined by independent researchers. ASPO is a network of scientists affiliated with European institutions and universities having an interest in determining the date and impact of the peak and decline of the world's production of oil and gas, due to resource constraints. The mission of ASPO is to:

1. Define and evaluate the world's endowment of oil and gas
2. Model depletion taking due account of demand, economics, technology and politics
3. Raise awareness of the serious consequences for Mankind

Reasons to reduce fossil fuel dependency in the Baltic Sea region

The Baltic Sea region will need, as all regions in the world, to decrease their dependency of oil. However at present some of the countries in the region rather increase their fossil fuel dependency, although it changes character.

Since long time back the use of black coal is decreasing. Coal mines became uneconomic 20 years ago in the west, and we have seen a wave of closing coal mines from Wales to Germany and into Poland. Probably we should expect the same to happen next in Ukraine. In parallel we see an increase in the use of natural gas. Additional large gas pipelines are planned for Russian gas to be exported to Central Europe. In the Nordic countries, especially in Sweden, the plans for a new gas infrastructure have been much questioned.

But there are more reasons to decrease the use of oil and gas. One is that the price of oil and gas will increase, even steeply, as the demand will not be met by production. The price of oil will not decrease in the future and we can probably expect an increase in the future. The price of natural gas has normally followed the price of oil, but it might be that we in the future will see a steeper increase as we now can see in USA.

The other concern is safety. The fact that someone else controls the basic energy supply to a country is of course unsafe and may in the worst case lead to conflict and blackmailing, and if not, costly negotiations if only one side in practice decide on the conditions. This was illustrated the last few months when Russia increased the price of gas delivered to Ukraine several fold. The final agreement between the two countries was influenced by the fact that Russia is dependent on Ukraine for its Black Sea fleet harbour. Without such a component in the negotiations it may have ended differently. It is of course noted that Ukraine is a transit country for gas delivered to Central Europe from Russia and also

Member State	CO_2 allowances in mio. tonnes	Share in EU allowances	Installations covered	Registry functional	Kyoto target
Czech Republic	292.8	4.4 %	435	No	-8%
Denmark	100.5	1.5 %	378	Yes	-21%*
Estonia	56.85	0.9 %	43	No	-8%
Finland	136.5	2.1 %	535	Yes	0%*
Germany	1,497.0	22.8 %	1,849	Yes	-21%*
Hungary	93.8	1.4 %	261	No	-6%
Latvia	13.7	0.2 %	95	No	-8%
Lithuania	36.8	0.6 %	93	No	-8%
Poland	717.3	10.9 %	1,166	No	-6%
Slovak Republic	91.5	1.4 %	209	No	-8%
Slovenia	26.3	0.4 %	98	No	-8%
Sweden	68.7	1.1 %	499	Yes	+4%
Total	6,572	100.0 %	11,428		

Table 10.1. Overview of Allowances and Kyoto targets across member states. Under the Kyoto Protocol, the EU15 has to reduce its collective greenhouse gas emissions by 8% below 1990 levels during 2008-2012. This target is shared among the 15 Member States under a legally binding burden-sharing agreement (Council Decision 2002/358/EC of 25 April 2002). The majority of the Member States that joined the EU on 1 May 2004 have individual targets under the Kyoto Protocol with the exception of Cyprus and Malta, which have no targets. (Figures do not take into account any opt-ins and opt-outs of installations in accordance with Article 24 and 27 of Directive 2003/87/EC.)

the supply in Germany was decreased during the conflict.

A third reason for reducing fossil fuel dependency is the need to reduce greenhouse gas emissions. This reduction is at present part of the Climate convention as detailed in the Kyoto protocol, which requires partner countries to reduce greenhouse gases by 8%, counted from the 1990 level, to years 20108-2012. Now, the European Union is the partner in the protocol, and EU has distributed its total agreed reduction between its member states. The decrease is much less difficult for the eastern part of the Baltic Sea region, since a dramatic de-industrialisation has taken place during the 1990s.

Policy recommendations

All countries in the region need to reduce fossil dependency. Counted only from the availability of oil this would be about 2% yearly. However, additional factors will probably make this reduction insufficient. Kyoto protocol requirements, and even more so expected rather drastic post-Kyoto agreements to reduce greenhouse gas emissions, is likely to be much larger. Further, souring prices and safety concerns are expected to push this development even more.

Sweden has taken a lead by declaring that the country intends to be fossil fuel free by 2020. This corresponds to an annual decrease by some 7%. As the fossil fuel component in the Swedish energy budget is only 35% it is not too unrealistic. It will be much tougher for the countries in the east where fossil dependency is larger, and the total energy budget is smaller. Still this development is essential for sustainability and needs to be seriously considered for all countries in the region.

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Renewable Energy Sources

2

Christine Jakobsson, Baltic University Programme, Uppsala University

I. Using bioenergy in Sweden and Europe, now and in the future

Sustainable energy sources

Energy resources can be described as renewable and non-renewable. Renewable energy sources are those which are continually being replaced. If an energy resource is being used faster than it can be replaced e g, coal, oil or natural gas which takes millions of years to form, then it will eventually run out. The global oil production peak is about now, and no new discoveries or oil wars will be able to alter the overall trend. Therefore, it's vital for our survival to visualize a change in sources of energy and also in the long run an alternative lifestyle. Previously sustainable energy was mainly concerned with availability relative to the rate of use. Today, when considering sustainable development other aspects are equally important such as environmental effects, the production of waste, safety and maximising the options available to future generations. Also, there is a clearly growing concern

about how we address energy needs on a sustainable basis due to global warming from human enhancement of the greenhouse effect. As the world's population and material standard is increasing in developing countries and will continue to grow for at least several decades, energy demand is likely to increase even faster.

Several different renewable sources of energy exist:

- Bioenergy: biomass
- Biofuels: biogas; bio diesel, ethanol, DME
- Waste
- Small-scale hydropower
- Wind energy
- Wave energy
- Solar energy: heat, electricity, fuel
- Others: e.g. geothermal energy

The first three types of energy (biomass, biofuels, waste) are dependant on different processes as combustion or digestion and burning. The second group (hydropower, wind and wave energy) are all dependant on the climate, as well as solar energy. Wind and solar energy are diffuse, intermittent, and unreliable by nature of their occurrence.

Geothermal energy will not be discussed here as it is mainly a carrier of energy. All sustainable energy sources are area dependant as their productivity is based on area. Construction of the plant or technical construction as well as the growing of e.g. forest residues or energy forest, straw, grain etc. all take space. Higher productivity per area is reached with wind, wave, hydropower and solar panel fields, while lower productivity per area is reached with biomass.

Bioenergy

Bioenergy commonly consists of:

- Biomass or wood fuels - wood, forest residues, plets, briquettes
- Black liquor - by-product from pulp industry
- Agricultural crops - straw, Salix, grain
- Peat

Regarding the usage of different bioenergy sources in Sweden, 54% comes from biomass or wood fuels, 39% from black liquor, 3% from agricultural crops and 4% from peat (2004).

In Europe the largest users of bioenergy are Sweden, Finland, Austria, Denmark and Germany. France is the largest user in Europe of mainly wood in small-scale usage. In the rest of the world, New Zeeland is in first place, with USA as second with their pellets heating of approximately 400,000 homes and China in third place, where the market is growing quickly especially regarding heating and bioelectricity.

If there are any emissions during the conversion process and the emissions from combustion, their size is smaller than from fossil fuels. Bioenergy does not contribute to the greenhouse effect. Combustion of bioenergy does not emit sulphur, which fossil fuels do. The size of nitrogen oxide (NOX) emissions are of a similar size as those from fossil fuels. The European Environment Agency is assessing how much biomass Europe can use for energy generation without harming the environment. Extending biomass use to produce bioenergy cuts greenhouse gas emissions and meets renewable energy targets. However, biomass production may create additional environmental pressures, such as on biodiversity, soil and water resources. Preliminary results suggest that there is a sufficient biomass potential in the EU-25 to support ambitious renewable energy targets in an environmentally responsible way. The European Union has set ambitious 2010-targets for the share of renewable energies in total energy and electricity consumption and for biofuels. Biomass can be used to produce electricity, heat and transport fuels, and currently accounts for about two thirds of renewable energy production in the EU. It will have to contribute even more in order to achieve the 2010 targets. The European Commission estimates that reaching the target of a 12 % share of renewables in total energy consumption requires around 13 0 Mtoe (1) of biomass (in the pre-2004 EU-15; EC, 2004).

Biofuels

Several options exist today regarding biofuels:

- Ethanol
- Biodiesel e.g. RME (rape methyl ester)
- Biogas
- Methanol
- DME – dimethyl ether

Ethanol is commonly used today in many places as fuel for cars, busses and trucks. It is also mixed with gasoline and sold in several countries as a more environmental option. RME can be used in diesel motors and is mainly used today by busses. Biogas is used mainly by different municipalities for busses, cars and trucks. DME is a liquefied petroleum gas (LPG) like synthetic fuel that is produced through gasification of various renewable substances or fossil fuel and catalyzed to produce DME. Black liquor can be used in this process. DME is a gas that becomes a liquid under low pressure and has excellent characteristics as a compression ignition fuel.

Brazil is currently the world's largest producer of ethanol. Approximately 26% of the cars in Brazil are running on ethanol and a large amount of their ethanol is exported. There are three types of biogas. Thermic gasification is considered to have the largest potential. Digestion is the second type and biogas production from landfills such as methane from garbage dumps is the third type.

Biogas can be utilized in different ways:

1) burned in a conventional gas boiler and used as heat for nearby buildings including farmhouses;
2) burned in a gas engine to generate electricity. Combined heat and power (CHP) systems, where heat can be removed in the first instance to maintain the digester temperature and surplus energy used for other purposes. A larger scale CHP plant can supply larger housing complexes or industry, or supply electricity to the grid;
3) upgraded to gas grid quality and used in vehicles. Different techniques for separation of carbon dioxide (CO2) and hydrogen sulphide from biogas (water absorption and molecular sieves for CO2 removal combined with activated carbon for removal of hydrogen sulphide).

Waste

To be able to utilize waste as a renewable energy source, increased sorting, collection and transport of the waste is necessary and a precondition. Depositing or tipping of waste is a practice that eventually will be phased out. Already within EU a ban on depositing exists combined with a deposit tax. From these waste deposits, it is possible to extract methane gas. Biological treatment is also a method for extracting energy from waste but the technology is considered to be rather expensive and the energy efficiency is low. Combustion of waste dominates and is the most effective treatment. It is usually used for district heating and therefore a well established network of district heating is an advantage. Combustion is likely to expand due to the ban on depositing waste. The possibilities of introducing a combustion tax are currently being discussed and will, if introduced, reduce the potential. The EU environmental legislation has tough environmental requirements for combustion plants which technically are easier to meet in larger and consequently fewer plants instead of many small plants. This could be a drawback for countries that are sparsely populated and have a small population.

There is a large difference in energy efficiency between the different ways of utilising waste. Digestion can produce 0,8 MWh per tonne, while combustion is much more effective and can produce 3 MWh per tonne.

II. Sun for electricity – solar cells and for heat – solar panels for individual houses and solar fields

Solar energy

The sun has shined for more than 4 billion years and is calculated to continue to shine for at least 6 billion more years. The little part of the sun's energy that reaches the earth's surface is almost 10,000 times larger than the amount of energy that humanity uses today as fossil fuel. With the help of new technologies, sunshine can be converted directly to electricity and heat without being transformed through biomass, wind or waterfalls.

It is solar energy and the natural greenhouse effect that creates a temperature on earth that makes it possible for organisms to live on earth. It is also solar

Figure 1. Solar panel field in Kungälv, Sweden - 10 000 m^2 delivers 4 million kWh heat per year to district heating

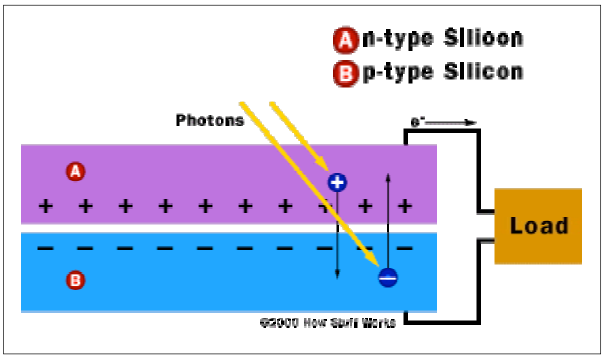

Figure 2 . Operation of a photovoltaic (PV) cell

energy that brings the energy that most living organisms on earth live from by photosynthesis. This also applies to humankind that has always eaten stored solar energy as food and

who has also during the past 100,000 years used stored solar energy as wood fuel.

Only 0,06% of the suns energy that reaches earth is transformed by photosynthesis and used by earth's vegetation as energy in biomass. Less than 1% of solar energy is transformed to wind. The potential for direct use of solar energy is enormous compared to biomass and wind energy. The world's total reserves of oil and gas and of uranium for today's type of nuclear reactors correspond to the solar radiation that reaches the earths surface during a few days. The global coal reserves represent the energy amount present in a few weeks of solar radiation.

There is a strong technical development and growth for the utilisation of solar energy. Solar collectors produce heat such as for tap water, in houses, and heating of swimming pools. Glazed solar collectors are relatively common in Germany, Turkey, Japan, Austria, Israel and Greece (1-2 m2/inhabitant). The largest potential for solar collectors is in cold countries as they can be used to both heat water and buildings. Solar cells produce electricity which is important for electricity production without mains connection, batteries and transformers and also for fuel.

Solar collectors

Flat, glazed solar collectors consist of an absorber that transforms solar radiation to heat. The absorber has a selective surface that gives high absorption for solar radiation and low emittance of heat radiation. The absorber is covered with glass to reduce convection losses and to protect the absorber's surface against wear. Heat energy is transferred by a medium (air or water with glycol).

- Air: direct usage of hot air or the heat can be stored in the building construction
- Water: main purpose to heat water or store heat in water

Different solar collector systems exist. Hot water systems: a solar panel is connected to a water heater with a built-in solar heat coil. Combination systems: solar heat is combined with other types of energy, e.g. pellets or wood furnace. Heat is stored in an accumulator tank. Solar panel field: many solar collectors are connected together to deliver heat for district heating.

Solar cells

Solar cells are profitable in places that lack electricity grids. They convert photons to electrons. They consist of photovoltaic (photo = light, voltaic = electricity) cells or modules (a group of cells electrically connected & packaged in one frame) that convert sunlight directly into electricity, batteries and charging regulators or inverters

Photons hit the solar cell and energy frees electron-hole pairs. Each photon with enough energy will free one electron and result in a free hole. If this happens close to the electric field or if free electrons and free holes wander into its range of influence, the field will send the electron to the N side and the hole to the P side. This leads to further disruption of electrical neutrality and if an external current path is provided, electrons will flow through the path to their original side (the P side) to unite with holes that the electric field sent there, doing work along the way. The electron flow provides the current and the cell's electric field causes a voltage = Power. A PV cell absorbs 15% or less of the light (How Stuff Works 2000).

CIGS solar cells

$Cu(In,Ga)Se_2$ absorbs sunlight and is used in CIGS solar cells. They consist of 5 very thin films on a plate of glass with a Molybdenum back contact (the plus side) that is deposited onto the glass plate. On top of that layer, the CIGS film, which absorbs the light, is evaporated. Two very thin films of cadmium sulphide (CdS) and zinc oxide (ZnO) are then put on top of the CIGS and the solar cell is completed by a layer of aluminium doped zinc oxide (ZnO:Al).

Module: several cells connected in series to get a voltage larger than 1 V. Current is decided by

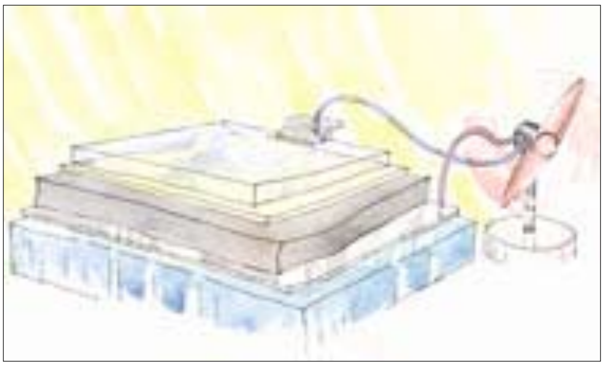

Figure 3. A CIGS solar cell. Ångström Laboratory, Uppsala University

the surface area and the number of cells in parallel. CIGS modules can be manufactured with high efficiency. 16,6% efficiency is the world record for thin-film modules and is held by Ångström laboratory at Uppsala University. CIGS technology has the potential of low cost. The total thickness of the solar cell layers is 3 micrometers and it has lower costs than the technologies that dominate the market today such as silicon.

Solar cells produce electricity which is important for electricity production without mains connection, batteries and transformers and also for fuel. Flat, glazed solar collectors consist of an absorber that transforms solar radiation to heat. The absorber has a selective surface that gives high absorption for solar radiation and low emittance of heat radiation. The absorber is covered with glass to reduce convection losses and to protect the absorber's surface against wear. Heat energy is transferred by a medium (air or water with glycol).

- Air: direct usage of hot air or the heat can be stored in the building construction
- Water: main purpose to heat water or store heat in water

III. Sun for indirect energy – wind, wave and water

Wind energy

Situated in the right place and with a suitable construction, wind energy will be an important complement to the electricity production system. Wind is the fastest-growing source of electricity in many countries counted from a low base and there is a scope for further expansion. The technical development is fast and new applications in ocean and mountain based wind energy are of importance, as the wind conditions are especially favourable there.

The production of wind energy is dependant on geographic conditions, as well as on environmental concerns. Danish and German equipment dominate the market. The production of wind energy is dependant of national energy policy. It can also be difficult to find risk capital for investments in wind power.

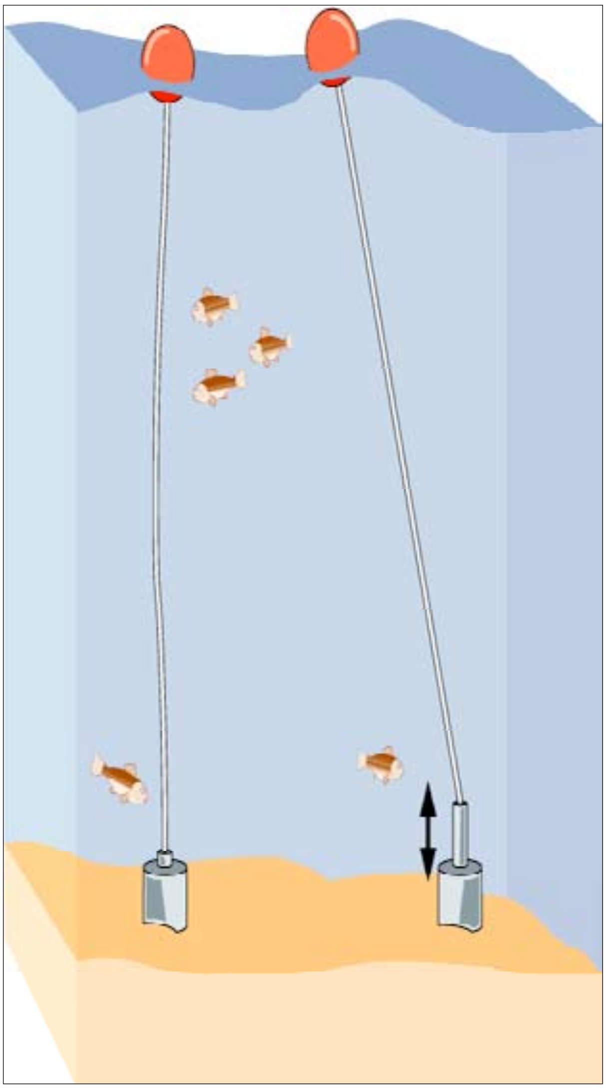

Figure 4. Two wave power plants in operation.

Wind energy is dependant on other energy sources to be able to be utilized effectively. Wind power stations are a part of a larger energy system. This is due to the fact that wind energy can not be stored and must be combined with other storable energy resources. The wind energy component in an energy system can be maximum 10%. Today's solutions are not optimal and there still is room for technical development and innovations.

Wave energy

Wave energy has a large potential and is an unexploited source of renewable energy. For ocean waves, the degree of utilization is relatively high and therefore wave power has a good economical potential. The challenge when developing wave energy lies in the relatively slow motion of the water and the very high peak energy density. Wave energy is created in a similar way as wind energy. It is also dependant on weather but waves continue for a longer time period even after windy periods have ended.

The red buoy follows the motion of the water surface and runs the linear generator, which is placed on the ocean seabed. Ångström Laboratory, Uppsala University.

The principle of wave energy is to use the difference in height between wave top and wave bottom. A buoy, floating on the water surface follows the motion of the wave. The buoy is connected to a hull, which can move vertically on a pillar. Permanent magnets are mounted on the surface of the hull. Outside the hull is the stator, which contains coil windings. The pillar and stator are put together on a concrete foundation, which stands on the bottom of the ocean. The hull and the assembled magnets are called rotor or piston, and a linear generator.

Small-scale hydropower

Small-scale hydropower has been difficult to utilize so far due to low electricity prices, environmental legislation, environmental lobbying, taxes, problems for producers to finance the constructions, as well as due to current politics. In the future, integrated systems solutions, reduced production costs by technical development of system solutions, and better conditions regarding legislation, taxes, risk capital and politics are needed to promote hydropower.

In a historical sense, hydropower has spared the environment from acidic emissions and their consequences for soil and water. At the same time, it has lead to a reduction of biotopes and biodiversity. Large focus has in this area been given to fish. Wind energy is renewable and technically available for production of electricity.

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Sweden's Renewable Energy Policy

Case study

3

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Electricity certificate, a tool to stimulate renewable electricity

Electricity Certificates system is one system to encourage development of renewable energy. Systems with certificates exist today in Sweden, the Netherlands, Great Britain and Italy. Here the Swedish system will be described. Producers of renewable electricity receive an electricity certificate for every produced MWh renewable electricity. The cost of the certificate is 200 SEK (≈ 20 Euro), while the electricity price is 250 SEK (≈ 25 Euro) and the fuel cost of producing the same amount of energy is 150 SEK (≈ 15 Euro). These certificates are sold to electricity consumers, who are requested by law to buy certificates for a certain part of their electricity use (quota). For the moment the quota is less than 10% of the total energy use. The producers of renewable electricity receive in this way extra resources for investments in increased production capacity, development of new technology and production of renewable electricity. The electricity certificates are sold and bought at a common market place. Every year the quota renewable electricity that the electricity consumers must buy increases. This increases the request for renewable electricity. The goal is to increase the annual electricity production from renewable sources with 10 TWh to the year 2010 compared to the level in the year 2002. To reach this goal the quota will increase every year.

In reality this has meant that 17 billion SEK has been or is intended to be used by district heating companies in Sweden for production of renewable energy and 4 billion SEK for forest industry as a result of the Electricity Certificates since they were introduced in May 2003 until 2010. From the 1st January 2007 Sweden intends to have a common Electricity Certificates system with Norway.

Sweden's sustainable energy policy

Sweden has been one of the countries that has invested substantial financing in research, development and demonstration on renewable energy. As can been seen in figure 1 most financing has been used for biomass.

This is also the area where the development has been enormous during the past years. In December 2004 the number of houses that were heated by biomass was for the first time in modern time larger than the number that was heated by oil.

The development of energy supply in Sweden during the years 1970 – 2003 (Figure 2) shows that approximately 1/3 of the energy supply is renewable (hydro power, biofuels, waste heat for heat pumps- and geothermal pumps). Still another 1/3 comes from nuclear power (whereof 2/3 are losses) and the remaining 1/3 is from fossil fuels, with a large dominance for oil. The situation in 1970 was completely different with a large total dominance

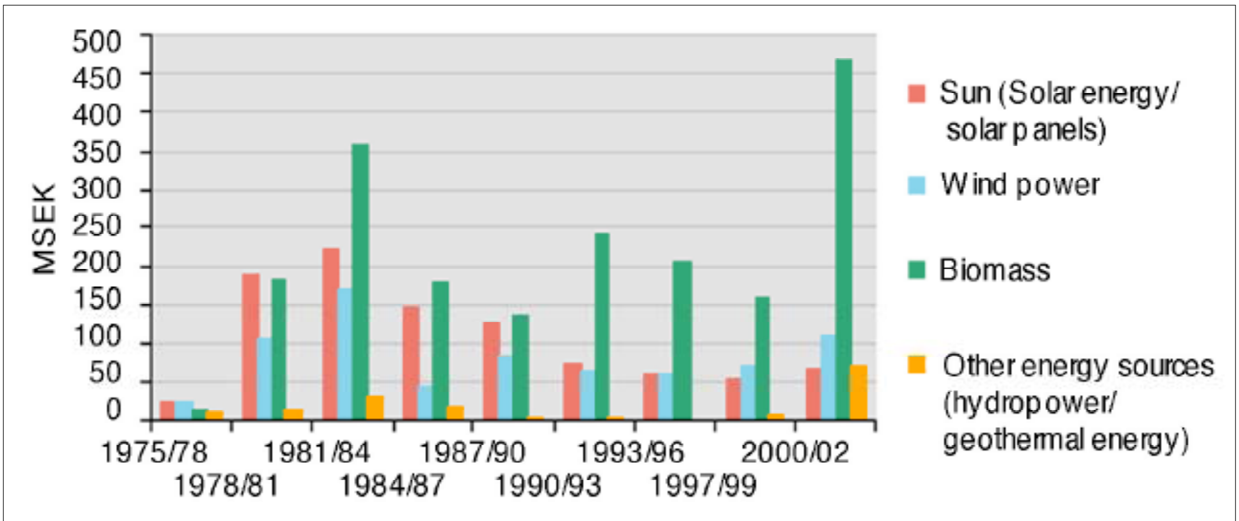

Figure 1. Research, development & demonstration on renewable energy in Sweden 1975-2002.

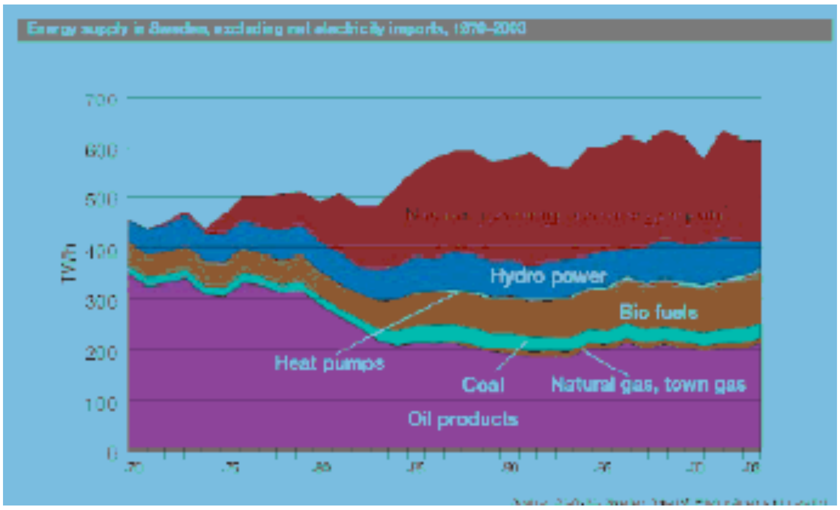

Figure 2. Energy supply in Sweden 1970-2003. Net electricity imports is excluded.

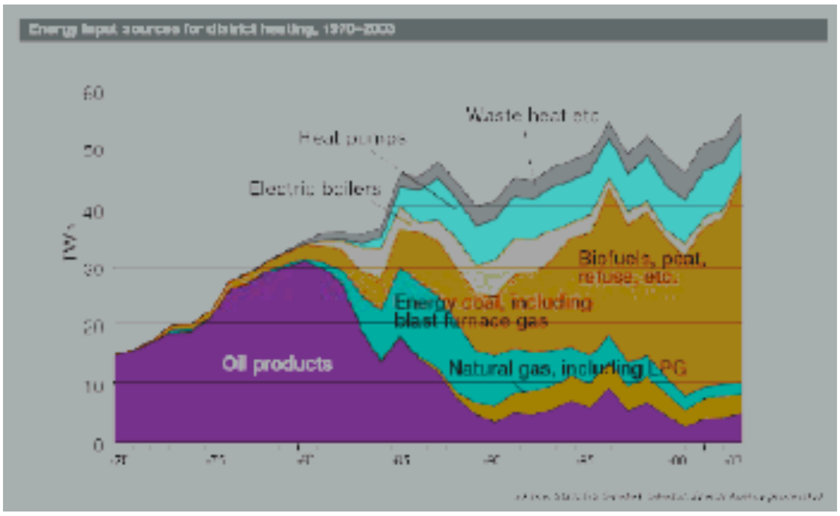

Figure 3. Energy input sources for district heating 1970-2000. The largest proportion of district heating in Sweden, 62%, is bioenergy.

of fossil fuels (77%) and only smaller amounts of hydropower and bio fuels.

As today the largest issue regarding energy and environment is the climate issue and greenhouse gas effect, it is very important to quickly change Sweden's and the rest of the world's large dependency on fossil fuels and replace them with renewable energy and fuel. The Kyoto protocol is one important step in that direction. Another good reason for changing to renewable energy sources is that oil is a limited non-renewable resource and peak oil is a current threat.

80% of the world's energy resource is still based on fossil fuels. Sweden has since 1982 doubled their production of biomass from approximately 50 to more than 100 TWh (about half of what oil supplies). EU:s goal for the transport sector and fuels is 5,75% renewable fuels in 2010. In Sweden the usage of fuels was 77 TWh in 2003,

whereof more that 98% came from fossil fuels. Ethanol represented 1,27 TWh, RME 0,05 TWh and biogas 0,11 TWh. Since then the import of ethanol from Brazil has increased and substitutes about 5% of the gasoline in low level mixtures.

The Swedish government decided in October 2005 that Sweden will be the first country in the world to break the dependency on fossil fuels by the year 2020. The Prime Minister is currently leading a commission with this task. A calculation and estimation of an energy budget for Sweden in 2020 (Table 1) could show that if Sweden will use the same amount of energy in 2020 as today and a maximum estimate is made for the renewable energy sources, it still could mean that 125 TWh must be taken care of by increased efficiency. At the same time nuclear power is not included in this estimation, as there is a governmental decision to close down nuclear power plants in the future. An interesting question is if this is possible at all?

The Swedish Farmers' Association Energy Scenario 2020

The Swedish Farmer's Association (LRF) presented in February 2005 an energy scenario for 2020. Due to the background of an increased global demand for energy, especially from the Asian economies, peak oil and increasing oil prices, as well as an increasing dependency on imported oil as a political and economical risk factor, as well as the greenhouse gas effect, LRF points out the key role that agriculture and forestry has in the change to renewable energy. This key role concerns the interest of an energy producer,

Table 1. Estimated approximate energy budget for Sweden in 2020

Total use today	400 TWh
Hydropower	65 TWh
Biomass	200 TWh
Wind	10 TWh
Solar, wave, etc.	10 TWh
Increased efficiency	125 TWh

Table 2. Potential of renewable energy (TWh)

	Today	Potential 2010	Potential 2020
Forestry and forest industry by-products	89	105-120	115-130
Agriculture and food industry	1	5	22
Waste	5	10	14
Peat	3	6	10
Wind power	1	5	10
Small scale hydro power	2	3	4
Total	101	135-150	175-190

Table 3. Long term potential from agriculture (TWh)

	Today	2020
Straw	ca 0.5	7
Biogas from agriculture, food industry	ca 0.05	3
Salix	ca 0.2	4
Grain for heat production	ca 0.1	2
Ethanol from grain and sugar beets	ca 0.3	5
Rapeseed for RME	ca 0.02	1

a user of energy and from the environmental side. Also considerable interest from society is noted.

The calculated potential is shown in table 2 and the long term potential from agriculture is broken down to the different sources in table 3. In the calculations an oil price of approximately $50 per barrel was used but in the future rising prices will affect this and lead to greater potentials for alternative renewable energy sources and increased efforts to find substitutes. Prices of $80-120 per barrel or even higher could be anticipated in the future.

A short term research and development priority was listed in the scenario:

Energy systems and energy supply on the farm level

- Energy efficiency
- Heat & CHP production (grain, straw, biogas…)
- Solar heating as a complement to biomass

Energy crops /Biomass resources for the heating market

- Straw; equipment, logistics & market potential
- Grain; sintering, corrosion, emissions, logistics
- Salix (willow); advice strategies for increasing cultivation & profitability
- Reed canary grass; market, economy, management
- Hemp; technology, market, economy, legal framework

Energy crops for biofuels

- Crops/varieties for ethanol, RME & biogas
- Reduce cultivation- & machinery costs for crop production
- Optimal bi-product value

”The farmer as an energy contractor and supplier”

- Business management models for co-operations
- ”Key to success” transfer

Proposal for a renewable energy policy for the Baltic Sea Region

Several different policies have already been mentioned in this document such as for the EU regarding biomass and renewable fuels and renewable energy for Sweden. When considering a proposal for a renewable energy policy for the Baltic Sea Region, certain components should be included:

- Replace fossil fuels with renewable energy;
- Increase efficiency in all energy use (energy savings);
- National policies must promote renewables;
- Agriculture and forestry should be self-sufficient & a deliverer of energy (new job opportunities);
- Solar energy should be a large, perhaps the largest source for heat & electricity;
- Potential of wave, water & wind energy should be fully utilized;

It is always an interesting question how far one can reach with the different renewable energy sources. Research and development will be intensified and new solutions will certainly be discovered. Time is a very important factor here and the level of expectations will increase in a longer time frame compared to a shorter time frame.

Another important issue to take consideration to is how efficient the renewable energy resources are in comparison to oil. Fossil fuel gives a large net energy value as they have been concentrated and processed during millions of years and are today the energy base for modern society. If different energy sources are compared in an emergy analysis (calculation and valuing of both natures unpaid work and humans paid work which are both valued on the same scale, see Odum 1996), it soon becomes clear that renewable energy has difficulties in competing with fossil fuels.

All the same, we don't have a choice, fossil fuels must be replaced. Technical development, energy savings and such national and regional policies must be highly prioritised to solve the energy dilemma for the future.

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RENEWABLE ENERGY RESOURCES

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Municipal Strategies
Biogas as an energy source

4

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Introduction

Anaerobic digestion is the engineered biological process that converts organic matter to biogas (mainly methane and carbon dioxide). The process has been applied for sewage sludge, farmyard manure and animal slurries since the beginning of the 20th century. The main benefits of employing this technology are that a non-fossil energy-rich gas (methane) and a residue that often can be used as a soil conditioner and organic fertiliser for arable land is produced. During recent years considerable interest has been focused on anaerobic digestion of various types of solid organic wastes, mainly because it offers a sustainable route for organic waste treatment and thus follows the European Community Waste Management Strategy (COM (96) 399). This strategy calls for minimisation of the quantities of waste going to landfills. In addition, the current European Common Agriculture Policy (CAP) encourages the production of energy crops on set-aside land. Harvested humid energy crops can be stored as silage and is suitable for conversion to biogas. Biogas can then be used to produce electricity and heat in combined heat and power plants or it can be upgraded to pipe-line quality being used as vehicle fuel or injected as "green gas" on the gas grid.

It is estimated that the total energy content of landfill gas and digestible agricultural wastes in the EU-15 exceeds 3348 PJ (930 TWh or 80 Mtoe). The contribution that could be made by biogas exploitation from livestock production, agro-industrial effluents, sewage treatment and landfill by 2010 is estimated to 628 PJ (174 TWh or 15 Mtoe). Animal manure contributes with more than 90% of the total digestible waste/biomass resources in Europe.

Anaerobic digestion – biology and technology

One of the fundamental aspects to consider regarding anaerobic digestion is that it is a microbiological process. This means that great concern has to be taken considering the environmental conditions that are necessary to achieve a high microbial activity and thus an efficient degradation of the organic waste to biogas. The most important environmental factors are temperature, pH, nutrient balance and the absence of air and toxic compounds in the feedstock.

There are a wide variety of engineered systems that have been developed over the years. Basically, the digestion process takes place in a sealed airless container (the digester), which needs to be warmed and mixed thoroughly to create the good conditions for the microorganisms. Anaerobic digesters can be operated at two different temperature ranges , mesophilic and thermophilic. During mesophilic digestion the digester is heated to ca 30-37°C and the average retention time of the feedstock in the digester is approximately 15-30 days. Mesophilic digestion tends to be more robust and tolerant than the thermophilic process, but larger digestion tanks are usually required. During thermophilic digestion, the digester is heated to 50-60°C and the average retention time of the feedstock is typically 10-15 days. Thermophilic digestion systems offer a higher methane production rate, but require a greater energy input and a higher degree of monitoring.

Anaerobic digestion technology can also be divided into wet and dry processes. In wet continuous digesting systems (<10% dry solids) solid waste can be digested with more dilute feedstocks such as sewage sludges or animal manures in order to be able to use conventional pumps and stirrers. In dry digesting systems the dry solid content is 20-40%. The minimal water addition requirement makes the overall heat balance favorable. However, well functioning systems for feeding digesters and removing digestate are important issues with high-solids anaerobic digestion

The main steps at an anaerobic digestion plant can be divided into pretreatment, anaerobic digestion and post-treatment. A principle flow diagram is presented in figure 1. During the pretreatment step contrary materials are removed and the feedstock is reduced in particle size and homogenized. As a general rule, material handling is much easier when the required fraction has already been separated at source. Thermophilic processes gives a better sanitation effect than mesophilic processes but in order to reach an appropriate reduction of pathogens, controlled sanitation at 70°C for 1 hour is becoming more and more applied. After the anaerobic digestion step the digestate may be spread directly onto

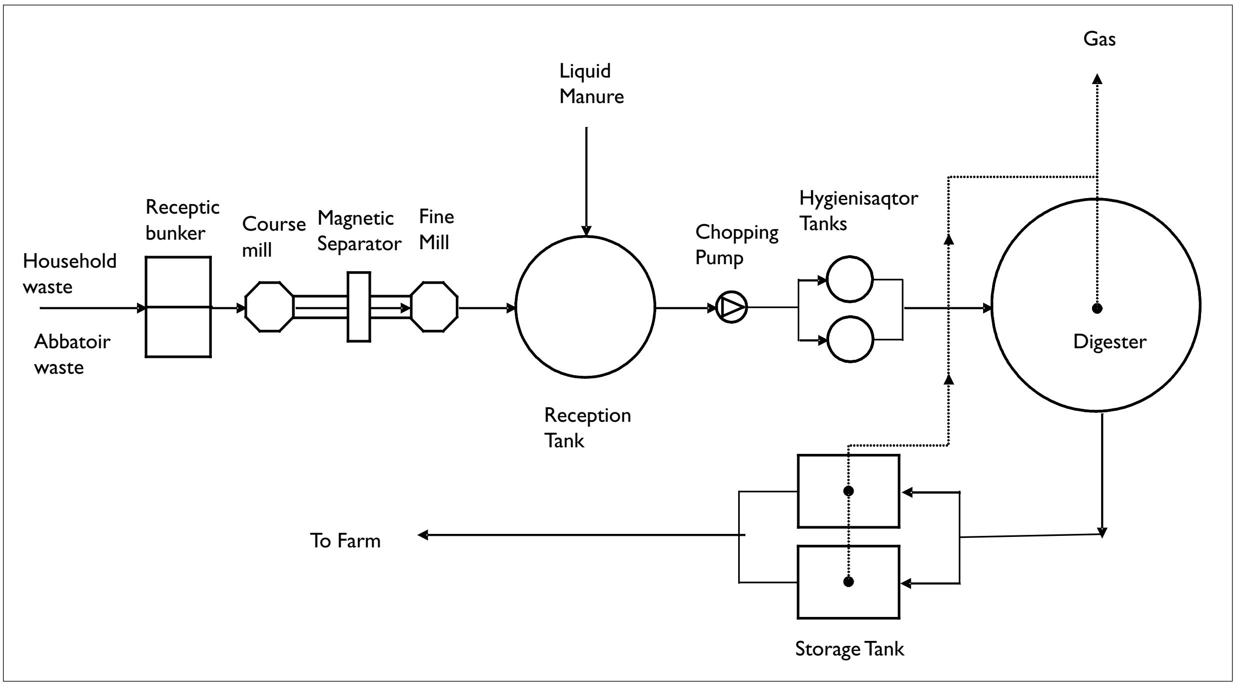

Figure 1. Example of a principle flow diagram for a biogas plant.

farmland as slurry or it can be separated into a liquid and a solid fraction. The solid fraction is thereafter matured to provide a compost-substitute.

Different feedstock suitable for anaerobic digestion

Generally, waste of biological origin and wet biomass is suitable for anaerobic digestion. A common concept of operation is so called co-digestion, which means that different wastes are mixed before entering the digester. The feedstock will provide all the necessary nutrients for the microbes and the mixture of different wastes will therefore lead to a more optimal nutrient balance. The C/N-ratio is important to consider since a protein rich waste with low C/N-ratio, such as animal by-products from slaughter, might cause a high level of ammonia-nitrogen. This can lead to inhibition of the microbial activity thus reducing gas production. The addition of a carbon-rich waste (increasing C/N-ratio) will then reduce this effect and improve operation efficiency. The microbes producing methane has a special requirement for trace elements (e.g. Ni, Co, Mo) and a deficiency of these metals might lead to a decreased degradation activity. However, during co-digestion of several feedstocks this will not likely be a problem.

A major resource for biogas production is manure, which is available in many farms. However, the limited methane yield makes it important to introduce energy-rich co-substrates, such as organic waste from the food industry. The biogas productivity can be greatly improved resulting in a better economic situation. While large amounts of energy-rich co-substrates are available as domestic or industrial wastes, the use of such co-substrates is partly restricted for farm-scale plants due to waste-related regulations and precautions regarding the dissemination of contaminants and pathogens.

Energy crops can represent a valuable alternative to exogenous energy-rich wastes in the agriculture sector. If nitrogen-fixing ley crops, such as red clover (Trifolium pratense L.), which are usually grown together with grasses, were used as an interchangeable energy crop in cereal-dominated crop rotations, the physical properties and nutritional status of the soils could be improved. The digestion of 1 ha grass/clover-mixture can produce enough methane to generate ca 20 MWh/y of energy . If 400 000 ha was to be used for biogas production instead of food production, 8-10 TWh/y could be generated. This would not only facilitate soil management, but would also reduce the need for costly fertilizers. Moreover, problems with plant pathogens and insects should decrease owing to the more varied crop rotation, thereby reducing the need for pesticides, as well as the environmental and economic costs associated with their use.

Energy use

There are three basic options available for utilization of biogas:

1) it can be burned in a conventional gas boiler and used as heat for nearby buildings including farmhouses.
2) it can be burned in a gas engine to generate electricity. If generating electricity, it is usual to use a more efficient combined heat and power (CHP) system, where heat can be removed in the first

Table 1. Summary of capacity and amount of treated waste 2003 in Swedish biogas plants approved for treating animal by-products (Data from the Swedish Association of Waste Management)

Treatment capacity	300 000 m^3
Used capacity	220 000 m^3
Produced biogas	120 000MWh
Manure	68 000 m^3
Source-sorted household waste	12 000 m^3
Source-sorted from restaurants etc.	2 200 m^3
Slaughterhouse waste	101 000 m^3
Waste from other food industry	27 000 m^3
Other organic waste	6 000 m^3
Water	7 500 m^3
Total amount of substrate	223 700 m3

instance to maintain the digester temperature, and any surplus energy can be used for other purposes. A larger scale CHP plant can supply larger housing or industrial developments, or supply electricity to the grid.

3) it can be upgraded to gas grid quality and used in vehicles. There is a range of different techniques for separation of carbon dioxide and hydrogen sulphide from biogas. The most common techniques are water absorption and molecular sieves for carbon dioxide removal combined with activated carbon for removal of hydrogen sulphide.

Digestate use

Anaerobic Digestion also provides a method of increasing the plant availability of the nutrients contained in organic material. With correct storage and application methods of the digested material, best agricultural practice for the application methods and restrictions on the season of application, the risk of volatilisation and runoff of nutrients can be greatly reduced compared to storage and application of untreated organic waste and manure.

Thus, anaerobic digestion makes nutrient management much more accurate and reduces the risks of excess application of artificial nutrients on top of organic based nutrients. However, contaminants in municipal waste such as heavy metals or organic pollutants represent a hazard regarding human and animal welfare if they accumulate in the soil when recycling waste products. Therefore, the willingness among farmers of using digestate from plants co-digesting municipal organic waste, as soil conditioner might be low if not proper regulations is adopted. The use of digestate originating from biowaste is currently not subject to EU-rules and national legislation does only occur in a few countries.

Implementation of anaerobic digestion in Sweden

Anaerobic digestion is well implemented in Austria, Denmark, Germany, Sweden and Switzerland. This positive development has been a result of national incentives such as investment subsidies, reduced taxes and higher price on renewable energy through green certificates. Due to the different issues relevant to anaerobic digestion, policies covering agricultural, environmental and energy aspects will affect its implementation. Therefore it is important that different governmental ministries and authorities act together in the same direction in order to promote biogas technology.

In Sweden, there are approximately 220 biogas plants in operation. The majority of these plants (134) are represented by sewage sludge treatment facilities. At 60 sites the biogas is generated from landfills or cell digesters at landfills. During the last decade different governmental programmes have given subsidies to municipalities for building biogas plants. The use of biogas as a vehicle fuel has been promoted in particular, since biogas has been classified as the most environmental friendly fuel (except for hydrogen and electricity). In Sweden, there are presently 15 full-scale plants treating solid wastes, which are in operation or in the start-up phase. Ten biogas plants are in August 2004 approved by the authorities for utilising animal by products as a feedstock in co-digestion processes. However, the major part of the waste is treated in 7 plants (Table 1).

Most of the plants are wet continuous digesters and are operated as mesophilic or thermophilic one stage, completely mixed, conventional reactors. All plants have equipment for controlled sanitation of the waste at 70°C in order to guarantee an appropriate reduction of the most abundant pathogens. The plants are in the vicinity of major agricultural districts and the digester residue is generally distributed as a slurry fertilizer. Concentrations of heavy metals are very low. In fact, in some cases concentrations are lower in the waste than in the manure. A low content of heavy metals and controlled sanitation guarantee that farmers will accept the digester residue as a soil supplement.

In 2003 approximately 120 GWh of raw gas was produced. This is an increase by 13 per cent on 2002. The major part of raw gas from biogas plants is upgraded to vehicle fuel. The remainder is used to produce heat and electricity. The advantage of using biogas as a vehicle fuel is that the vehicle emissions are much less hazardous to health and the environment compared to petrol or diesel. In addition, biogas is CO_2- neutral.

Economic consequences for production-scale operation – example from a feasibility study

In order to exemplify the economic conditions for constructing a biogas system, a feasibility study made for a Swedish municipality is presented. The proposed biogas system would annually digest 5,000 tonnes of slaughter by-products, 7,300 tonnes of manure and digestive tract content and 2,300 tonnes of food waste. In addition, process water would be added resulting in total 28,500 tonnes/y of digestate after digestion. The plant would annually generate vehicle fuel equivalent to ca 17 GWh (corresponding to 1.7 million litre of petrol). The calculations made include management and treatment of waste at the biogas plant as well as the up-grading facility (separation of CO_2, H_2S and H_2O, compressing to 250 bars, high pressure storage, pipes for gas transport and a filling station). In addition, costs associated with digestate management are included. The total investment for the biogas system was calculated to be ca. 9 million Euro with the biogas plant contributing with 6.5 million Euro and the up-grading plant with 2.5 million Euro. The total cost, i.e. capital, operating and maintenance costs, are presented in table 2.

The calculated income is based on an average gate fee of 44.3 Euro/ton of waste (Table 3). In addition, a calculated income from the digestate in relation to nutrient content (60% of total N, 100% of P and K) and based on the price of artificial fertilizers is accounted for. In order to balance the cost, the price of up-graded biogas at the filling station has to be at least 0.054 Euro/kWh. Biogas for vehicles is free from tax in Sweden and can be compared with the price of petrol (0.10 Euro/kWh excl. VAT) or diesel (0.075 Euro/kWh excl. VAT). Thus, the best economic outcome is to use biogas for replacing petrol. However, the best environmental effect is reached if diesel in inner city busses is replaced.

Table 2. Calculated capital, operating and maintenance costs for a production scale plant per ton and per kWh produced.

	Cost Euro/ton	Cost Euro/kWh
Biogas plant	78.4	0.067
Upgrading	38.3	0.033
Total	116.7	0.100

Table 3. Calculated income per ton and per kWh produced.

	Income Euro/ton	Income Euro/kWh
Gate fees	44.3	0.038
Vehicle fuel*	63.3	0.054
Digestate	9.3	0.008
Total	116.9	0.100
* price to balance the cost		

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5

Household Waste

Incineration, Co-generation and District Heating

Vattenfall, Uppsala

Background and history

In the beginning of the 1960s, district heating was introduced in Uppsala. Initially, the production took place in small mobile boilers that were linked up with the ever-widening network of district heating piping. The two first blocks for waste incineration with heat recovery at the present site, Brännugnen in Boländerna, were built in 1961. The steam produced was sold to the neighbouring pharmaceutical company, Pharmacia. Previously, waste has been incinerated for many years at the same place without the heat energy being utilised.

In the mid-1960s the Brännugnen area became established as a suitable site for continued waste incineration and co-generation production. In pace with the widening network for steam and district heating, new boilers using waste and oil were built for steam and district heat production at the main site in Brännugnen. The co-generation plant started operation in 1972 and a reserve plant for district heating started operation in 1975 in Husbyborg on the northwestern side of Uppsala.

Apart from household waste, only oil was used as fuel. In the late 1970s the dependency on oil was about 92% and about 240 000 m³ were used annually for production of power and heat. During the 1980s this dependency on oil was almost entirely replaced, see fig. 1 below. The first step was taken by establishing a regional cooperation with increased waste incineration, heat pumps at the sewage works, and electric boilers. In Knivsta, two district heating boilers for forest fuel were built, and in Storvreta a solar heating plant was built with seasonal heat storage.

The next step was to convert the co-generation boiler for operation with solid fuels. At the same time a new district heating boiler was built at the main site, also for solid fuels. These were in operation temporally for some years together with coal as the main fuel until peat could be introduced with full effect in 1989. At this stage the dependence on oil had been reduced to a minimum and replaced with domestic fuels.

In 2005 a new boiler for waste fuels was built. This new boiler increases the capacity of waste incineration by 60 % on a yearly basis.

Products

Almost all of Uppsala's heat requirement is today covered by district heating. The distribution of hot water is done through a system of culverts covering a total of 420 km. At present the deliveries amount

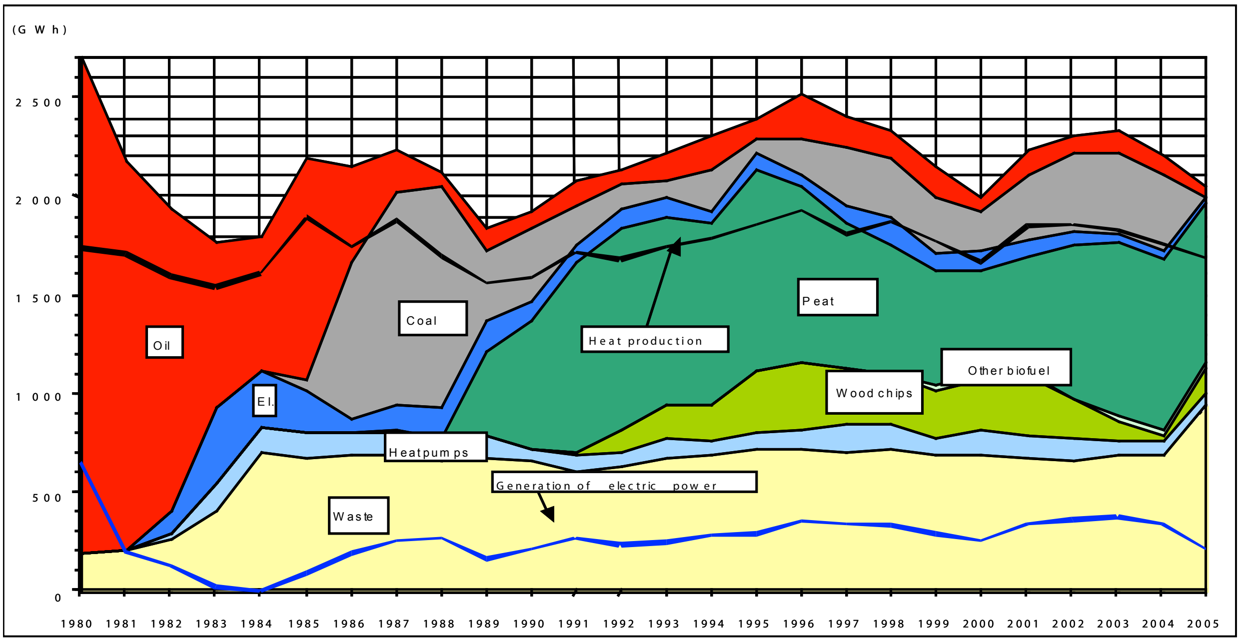

Figure 1. Energy Sources for district heating in Uppsala 1960-2005.

Table 1. Production units, fuel and energy capacity.

	Fuel	Capacity	Comments
Waste incinerator	Waste	Steam and hot water 30 MW Cooling 11 MW	
Cooling machines	Electricity	Cooling 3 MW	
Electric boilers	Electricity	Steam 60MW	2 boilers
Heat exchanger		Hot water 150 MW	Heat exchange from steam to hot water
Co-generation plant	Peat/sawdust, coal, oil	Electricity 120 MW Hot water 245 MW	
Hot water boiler	Peat/sawdust, coal, oil	Hot water 100 MW	
Hot water boilers (Boland)	Oil	Hot water 250 MW	4 boilers
Hot water boilers (Husbyborg)	Oil	Hot water 150 MW	3 boilers
Heat pumps	Electricity	Hot water 39 MW Cooling 20 MW	

to 1 500 GWh/year under normal weather conditions. The total requirement varies between 30 MW on a hot day in summer to 600 MW on a cold winter's day.

The co-generation plant produces electricity and district heating simultaneously. Production of electricity is about 200 GWh/year.

The present deliveries are 30 GWh/year.

Apart from the district heating network, there is also an 8 km of culvert system for distribution of steam to some of Uppsala´s major companies and to the hospital. Deliveries are currently about 90 GWh/year.

Production units

Steam is foremost produced in the waste incineration plant (AFA). In situations of surplus capacity the heat energy can be transferred from steam to the district heating network via heat exchangers. The waste incinerator also produces hot water directly into the district heating system.

For production of district heating there are a number of hot water boilers, a co-generation plant and a heat pump unit. The co-generation unit and one of the hot water boilers are operated with solid fuels (peat/wood chips, coal) that is prepared in a separate mill. The boilers can also be fuelled with oil as a reserve for the powder fuel. The heat pumps are powered by electricity and utilise waste heat in the municipal wastewater for production of district heating and district cooling. The district heating system includes an accumulator for levelling out the variations throughout the day in the heat load.

District cooling is produced in steam-driven absorption heat pumps, cooling towers and in electricity-driven cooling machines. An accumulator is used for levelling out the variations throughout the day in the cooling load.

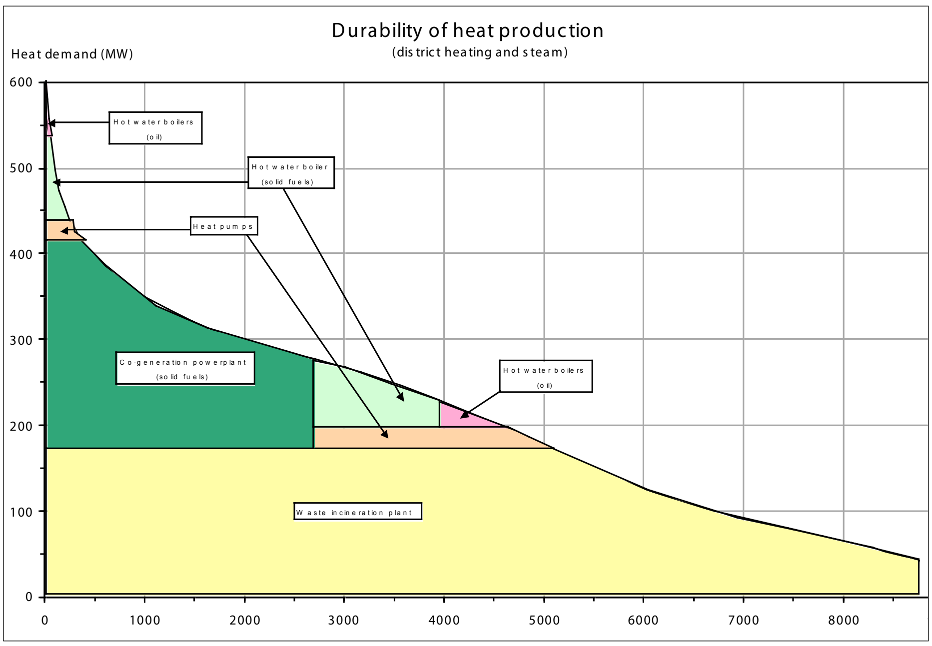

Figure 2. Durability of heat production.

The total installed capacity for production of district heating (hot water) is higher than the maximal requirement on a cold winter's day. A capacity excess of this kind is essential if reasonable delivery reliability is to be maintained. If, for example, the co-generation plant, which is the largest single production unit, becomes unavailable on a cold day during the winter then the reserve capacity must be sufficiently large to be able to maintain deliveries of district heating. In practice, the current reserve capacity is only just sufficient. The margins can be improved either by obtaining a higher reserve capacity or by increased base capacity.

Production conditions

Customer requirements of steam, district heating and district cooling govern the overall utilisation of the production units. Production of electricity is not governed in the same way and depends on the extent to which the co-generation plant is operated for heat production.

Which individual unit or fuel that is utilised at different times is governed by the technical and economic conditions. On the whole, the unit with the lowest variable cost is first brought into operation. Subsequently, as required, other units are brought into operation for as long as required.

Planned maintenance is done to the greatest extent possible during the summer months when most units are no longer needed owing to the reduced requirement for heating.

The production requirement for district heating can vary strongly from day to day depending on the time of year and type of weather. The figure above shows the district heating load in daily values sorted in decreasing order. The height of the curve shows the effect requirement whereas the magnitude below the curve represents the total energy requirement. The same applies to the fields that represent the various production units. In general, the higher up in the figure a unit is placed the lower is its production volume.

The total production volume is thus determined by customer demand. The space for each individual unit is determined by its variable costs and its capacity.

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Vattenfall, Uppsala, Sweden

Fossil Fuel Free Municipalities

6

Wendelin Müller-Wille, Enköping

General assessment of energy supply

In order to meet the requirement of sustainability, technology must be environmentally responsible and socially acceptable, as well as profitable in a national economic sense, not just economical for single businesses.

It must also be easily understandable; all possible technical, social and ecological impacts must be calculable. It has to be flexible, able to tolerate error, and at the same time pose little potential for damage or conflict. The primary question for evaluating any technology must be, "Will it promote, obstruct or be neutral to developing sustainability".

What would we like to require of a convenient energy supply.

- Endless access everywhere any time.
- No transport. No litter (residue). No conflicts.
- Appropriate economy. Simple and reliable techniques. Low entropy.

Table 1 shows some energy carrier for "stored energy" and "flowing energy". Biomass is a complicated link between both fields. But notice: the more steps from the source to the consumer the more vulnerable and expensive energy supply will become and again: every step has to be serious analysed concerning the impact on the environment.

Solar energy

When discussing future energy supply there often is a deep resistance to consider alternative energy carriers like sun light and wind power. Unproved methods and high costs are the most frequent arguments against solar energy. We should prove these statements without bias.

Photovoltaic, solar collector, wind power, and hydropower do very well fulfill our conditions of a sustainable energy supply.

Sun radiation can be directly transformed in to heat or electricity (100.000 roof-project in Germany), wind and hydropower in to electricity and mechanical energy.

Table 1. Energy carrier for "stored energy" and "flowing energy". Biomass is a complicated link between both fields. But notice: the more steps from the source to the consumer the more vulnerable and expensive energy supply will become and again: every step has to be serious analysed concerning the impact on the environment.
Supply links of different Energy carriers:
influence on the environment
harmfull to the environment
ECO-RESEARCH according to H.Scheer

PHOTO-VOLTAIC		→	Roof-project	storing?	converter	electr. →	consumer
SOLAR-COLLECTOR	?	→	Lyckebo	storing?	converter	heat →	consumer
WIND POWER	?	→		storing?	windmill	electr. →	consumer
HYDRO POWER	reservoir				turbine	electr. transport	consumer
BIOMASS	cropping harvest woodchips	local-transport	pelleting fermentation	Transport	power plant residue petrol station	electr./ heat transport →	consumer residue
MINERAL OIL	drilling	transport	refinary storing petrochemistry	Transport	power plant residue petrol station →	electr./ heat transport →	consumer residue
PIT COAL	mining	transport	processing industry	Transport →	power plant residue →	electr./ heat transport →	consumer residue
NUCLEAR POWER (FISSION)	Uran-mining	transport	enrichment	Transport	nuclear reactor	electr./ heat transport	consumer

Figure 1: SALIX and drip pipes

The disadvantage is that the access to this energy carrier is not possible anywhere or anytime. This problem can be solved by storage. We use already reservoirs for waterpower.

Sun radiation and wind should mainly be used for rural areas and small settlements to produce heat for hot water and heating. Storing takes place in accumulator tanks, as it was done in Lyckebo/Sweden. Surplus electricity can be used locally or be fed in into the national power grid.

Electricity can also produce hydrogen from water to use in cars or for cooking.

Sun cells or collectors can be integrated in house roofs; accumulators and hydrogen tanks can be placed under ground surface

In the19th century over 200.000 windmills were at work in Europe. Today, the remainder is a culture attraction.

Location of a water reservoir might lead to international conflicts Reservoir dams can burst.

Biomass (converted solar energy, stored energy)

We – as heteronomos beings – can get our food only from biomass.

The use of biomass for energy is to day a key strategy in reducing carbon dioxide (CO2). In the first place, biomass should be used to substitute fossil fuels in the traffic sector and raw products in "petrochemistry" (fermentation, gasifying).

For heat production biomass is used as well in district heating power plants as in detached houses. To produce electricity from biomass can be very expensive.

Biomass resources and productive land are limited. Agriculture is a controversial process with reference to the ecosystem (humification and carbon sequestration). Cultivated land can get in a position to convert from a sink to a source of CO2 (Live Semb Vestgarden; Lars Bakken; FAL Agriculture Research, Special Issue 280)

Fossil (converted solar energy)/Nuclear energy

Mineral oil, pit coal and nuclear power (fission) should be substituted as fast as possible by solar energy. Already, the conflicts that these energy carriers cause, should convince us not to use them. Fusion technique is very complicated and will not be practicable for common use within 50 years. It is not important if we ever are able to copy the process that takes place in the sun. Only a few nations could afford these techniques and dominate the rest of the world. Power plants for fusion would be gigantic centralistic installations, hundred times bigger than fission reactors.

Technique

It is unimaginable that our sun sends so much energy to the earth during 15 minutes, as all humans' worldwide use in a year. Sun energy is the only alternative. To use sun energy is not a technical or an economical problem - it is, as I see it, a political problem.

The contention that there is no advanced technique on the market is not really proved. We did not wait with the mass production of TV-sets until we developed the color TV. The predecessor of the mobile telephone was the telegraph.

We should not use risky techniques, when there are safer techniques.

Recently 60.000 birds got killed at the coast of Brittany by mineral oil spill from a shipwrecked tanker. More birds than ever were killed by windmills. Fishery, oyster beds and recreation areas are damaged for a long time.

Oil transport is risky (150.000 long tailed ducks, (calangula hyemalis), are dying in the Baltic Sea by ship oil spill. It is no way to increase security on oil tankers. We have to free us from the dependence on oil, so we can finish to transport it in all directions of our globe. There are local solutions for energy supplies.

Economy

To say, solar energy is too expensive, is unfounded. As long as we do not calculate under the same assumptions, we cannot compare the expenses. There are hidden subventions. External costs are not taken in to account. Tell the consumer what one m3 air, mining, transport, environmental damage, processing industry, storing of residues, and research costs. Give a transparent account to consumers for the price of example one KWh of electricity, for net (power grid) rates, taxes, and fees.

It seems that specialist of the conservative energy system often judge and seldom calculate the technique and economy of alternative systems. It is for theirs own advantage or to convince politicians to support their system.

Case Study – A multifunctional solution; ENA ENERGI AB.

A good example is how the Municipality of Enköping integrates energy supply, wastewater treatment and rural production in its master plan.

We have linked our woodchips fired Combined Heat and Power Plant with the Waste Water Treatment Plant and the local agriculture production (fast rotation forest, willow plantation, further called Salix) to a closed material cycling with interesting side effects (heavy metal balance). This system can be used in large as well as in small scales.

Enköpings district CHP-Plant (Combined Heating and Power-Plant) mainly supports the city with warm water. The plant could deliver 100% of the city's demand (20.000 inhabitants) but only 95% are connected to the system. It is heated all year round only by biomass (bark, woodchips, Salix and sawdust).

Electricity can be produced and could cover 50% of the city's consumption.

The main idea of the district heating plant is based on three separate water borne systems.

- The producer, the plant itself with the boiler and generator.
- The supporting net as pipelines.
- The consumer, private households, industry, and public institutions.

The advantage with this construction is, that we can change the fuel only by adjusting the boiler. A future side effect is that the consumer could switch to a producer by feeding in solar energy from his roof backwards; using the water borne system as an accumulator.

Maindata:

Electrical output net:	22,5 MW
District heating output:	55MW
Steam pressure at turbine:	100 bar
Steam temperature:	5400°C
Consumption biomass:	400,000m3s/y

District heating system 2005

Consumers connected:	11480 (1160 households)
Delivered heat:	206 GWh
Total district heating pipeline:	83 km
Total water volume in the system:	3.400 m3
Total accumulator volume:	7.000 m3

Waste water and sludge

According to Swedish legislation (based on prop. 1990/91:90, 91/271/EGG and SNFS 1994:7) the nitrogen outlet from our wastewater treatment plants has to be cut by half.

Figure 2: Enköping CHP-Plant

Our wastewater treatment plant lies between our CPH - Plant and borders agricultural land on one side.

The power plant needs Salix. Sludge from individual and local wastewater treatment plants can be used as fertilizer as well as bottom ashes from the power plant (notice: there are dumping taxes on bottom ashes and sludge). To fertilize our Salix-fields (fast rotation forest) with ashes, sludge and reject water made it possible to produce 60GWh more. The outlet to Enköping River was reduced: nitrogen from 120t to nearly 60t and phosphorus from 8,5t to zero (1999-2000). That includes a minimizing of artificial fertilizer to about 50%. Salix demands phosphorus, potassium and micronutrients, which ashes cover to 100%. Sludge covers the nitrogen demand up to 50%.

Nynäs project

Nynäs farm borders to the Waste Water Treatment Plant (WWT-Plant). Here an 80 ha (189 acre) Salix plantation is used to treat and utilize decanted water from dewatering of sewage sludge. This water contains about 25% of the nitrogen entering the WWT-Plant, but only 1% of the income water (30.000 m3, 30 t nitrogen, 1 t phosphorus). This water is stored in ponds during wintertime - the "non growth period" - which under this time also reduce the number of pathogens. During May – September the purified water is used for irrigation of Salix. It is distributed through the 350 km irrigation hoses (drip pipes) laid in every double-row - so low – in order not to be cut of or being an obstruct during the harvest. A total amount of 200 000 m3 water (reject- and decanted water is blended with the 30 000 m3 from the ponds) are dispersed under this period. The plantation is divided in 6 units, where each unit is watered 3 hours a day. This makes 3mm rain every day – it doubles the normal precipitation (500mm/year). The result is a load of some 270 kg nitrogen and 7 kg phosphorus per ha/year. This fertilizing shortened the harvest period from 4 to 3 years, with the same yield.

Figure 3:Village district heating plant Örsundsbro

Bio cycle solution

Ca. 1,500 t bottom ash from the power plant and approx. 1,500 t of sludge-water is compounded, and - free of charge - delivered to the local Salix farmers, who showed interest in the project.

About 1,200 ha (2.965 acres) Salix are cultivated in Enköping. On 10 % of this area ash/sludge is spread every year by Agrobränsle AB. Soil-analyses are done by SLU (Sveriges Lantbruks Universitet) and ash-analysis are done by ENA ENERGI AB.

The cooperation of the local authority, the power plant and the local farmers made it possible to continue with the ash/sludge spreading and a 12-year permit was granted for the programme; with the condition that the emission of heavy metals comply with the prevailing regulations.

Enköping´s municipal council adopted the idea of utilising Salix and natural processes for purifying waste water coming from private septic tanks as well as the municipal sewage plant. This step must be taken to reduce the effluence of nitrogen and phosphorous through the Mälaren into the Baltic Sea.

At four farms two sludge ponds each were constructed with about 3,500 m3/pond. Sludge from septic tanks and minor waste water treatment plants is transported and pumped by trucks into Pond 1 up until the end of June. The sludge rests for a year to get fully sterilized (purified). In the meantime, Pond 2 will be filled and after the sterilisation (purified) process, the sludge from Pond 1 is spread on the Salix plantation. ENA ENERGI AB has contracted the whole Salix production from the irrigated field.

Heavy metals cycle

One side effect of burning Salix is, that we reduce Cadmium in the soil by 90% through the fly ash. Salix has a high uptake of Cd from the ground. 90% of Cd is precipitated by an electrostatic filter and can be stored on a save deposit. So it is possible to get a Cd-balance in our Salix fields. The threshold values off 0.75 g Cd/y/ha make it very hard to use all nutrients in the ashes or sludge.

In the beginning I maintained that "*this system can be used in large as well as in small scales*."

In our community we have two smaller power plants for residual areas with about 800 inhabitants.

In 2002 we started a project with four so-called e4more - energy-units. The energy unit contains a boiler and accumulator and all regulation equipments are intended for to supply a detached house on the countryside, it looks like a garage. This unit claims a waterborne heating system and needs pellets as fuel. Pellets are pressed from wooden chips and sawdust and hold a very equal quality concerning humidity and composition. This Keeps the chimney gases in a proper proportion.

Some facts about CHP, village district heating plant and e4more energy unit are given in tab. 3.

Benefits and Visions

Benefits for the local infrastructure are:

- Renewable energy provides (secures/increases) local employment.
- There is a particular benefit for rural economies. The countryside can begin to flourish.
- Our community is getting interesting for industry.
- Probably more people like to live and work in our community.
- Focus on network city/country.
- Side effects create new applications.
- Nutrient flow to lakes and the Baltic Sea under control

Table 2. Metal cycle in Enköpings CHP-Plant shows the reduce of heavy metals, except Cu (coursed by warm water pipes) and Pb, probably from traffic.

Metal	Salix input 25% Uptake g/ha/y	Chips, bark, sawdust	Bottom ash + digested sludge g/ha/y	Sludge- and clean water Irrigation project g/ha/y	Bottom ash %	Fly ash %	Diff. Cd in/out g/ha/y
Cd	9,8		0,75	1,1	10	90	-9,05
Cu	55		194,5	183	50	50	139,5
Cr	41		26,1	13	60	40	-14,9
Hg	0,34		0,33	0,4	20	80	-0,01
Ni	28		12,9	25	30	70	-15,1
Pb	9,86		15	13	20	80	5,14
Zn	731		324	341	20	80	-407

Table 3. Some facts about CHP, village district heating plant and e4more energy unit.

	Enköping CHP-Plant	Village	Detached houses
Boiler	55 MW 22,5 MW el	0,9 MW	20-40 KW
Prod/y	230 GWh 59 MWh el	3 GWh	30-60 MWh (25% solar collector)
Pipeline	83 km	1,2 km	30 m
Biomass	100.000 t 400.000 m3	1.500 t 6.000 m3	6-10 m3 (+ 10 m2 solar collector)
Ashes	1.000 t 50/50% bottom/fly	15 t	40 kg

We can do more:

- To produce ethanol from wheat to replace gasoline.
- Storing pellets in silos to ensure the fuel for e4more units.
- Establish an orangery and a gardener school (it is today reality).
- To produce cold for air condition in buildings e.g..
- To install solar collectors on roofs of (power plant connected) buildings to avoid using bio fuel under summertime.

Outlook Conflicts/behavior

Conflicts that humans carry out are often to strengthen our power to use resources: E.g. space for life, mineral resources, food and cheap labor. We should be aware that these conflicts would intensify in the future, if we continue to hold fast to fossil and nuclear energy. A big, central power plant has a monopoly position. Blackmailing and terror attacks can use this situation. Society is vulnerable. Even politicians can be interested to strengthen their power through monopolies.

On the other side, dismissing fossil and nuclear energy means a crisis for countries whose export income depend wholly on these products.

We have to stress socio-economic and behaviorally based aspects, which are caused by limited but sought after resources, particularly those resources, which exist only in certain locations on our globe.

Figure 4: e4more unit for supplying a detached house at Litslena

Another problem is who decides which conditions should be applied? Which qualification should the decision-makers have?

It is paramount to answer urgently why political decisions are really related to the problem itself. I have the uneasy feeling that 'scientific proof' is often based on democratic consensus and that therefore political decisions represent "convictions of belief" and are not always based on realistic and verifiable facts.

It is important to ourselves, to understand the environment and our attitudes to it. This provides us with the only chance to search for a sure way to a secure and sustainable energy supply for the future. We can alter systems! But do we understand the consequences?

The human species has developed in an environment where space and resources have been unlimited for a small population over several million years. Only during the last millennia has humankind reached the barriers of the biosphere's carrying capacity. The quick feedback was better living conditions. At that time the possibility of future threats humankind could not understand, and today with clear signs we will not see the risks.

Life has given humankind two valuable qualities - emotions and intellect. With these tools we should find a way to survive in an increasingly complex world.

What is worth to preserve and protect depends only on human values and norms. We have to make ethical rules….

To understand humankind's attitudes and behavior it is also indispensable to recognize the dimension of human ecology such as genetic heritage, learning, behavioral imprint and survival strategies in the context of evolutionary development.

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Energy efficient houses

3

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The European Solar Building Exhibition

Most old buildings in Germany are not very energy efficient. There is thus room for considerable improvements. During the last 20 years the heating energy demand for new buildings has halved from 150 to 80 kWh/m2a (kWh/m2a = annual amount of heating per m2 usable floor area). This should be compared to the current German Heat Protection Regulation (EnEV 2002) of 100 kWh/m2a (including PE-Heating), which is an internationally recognised standard, equivalent to e.g. the Swedish Construction Standard (SBN). But it is possible to be even more efficient. There are thus considerably energy gains to be made in the building sector. The figures mentioned here are even higher as primary energy demand for the buildings, especially for electricity in Germany.

In 2003 the ZEBAU GmbH joined a number of European stakeholders to created in 2005 the European Solar Building Exhibition, an international building exhibition project for solar and low energy housing. The project was funded by the ALTENER-programme of the European Commission. Twelve European cities developed innovative concepts for bioclimatic urban redevelopment, forward-looking new developments, passive housing and the integration of renewable energy sources. The intention in Germany was to build either so-called very low energy houses with 40 kWh/m2a or passive energy houses. Passive energy houses are properly speaking houses without a conventional heating system, but more often it is understood as a building with heating requirements of 15 kWh/m2a or less.

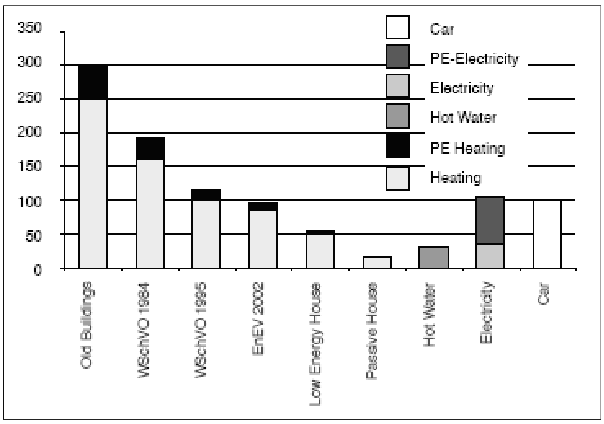

Figure 1. Comparison of Energy Ratings of German homes. WSchVO = German Heat Protection Regulation. EnEV = Current German Heat Protection Regulation.

The aim of the Solar Building Exhibition Hamburg 2005 was to show how houses with particularly low energy requirements and high quota of renewable energy supply can be built in Germany. The two construction areas selected were Hamburg-Heimfeld and Hamburg-Wilhelmsburg, Either passive houses or very low energy houses were constructed. An external quality control was organised with the help of Hamburg Building Authority in order to achieve, if possible, a faultless higher standard in comparison with ordinary new buildings. The control of the energy planning and construction was originally made by the Technical University of Hamburg-Harburg and since the beginning 2005 the Detmold Low Energy Institute, while the inspection of the construction work was made by the Low Energy Institute.

Passive energy houses

A passive house is a building in which a comfortable interior climate can be maintained nearly without

Figure 2. Multiple family dwellings passive house

The calculation of energy demand should be made according to the EnEV software, not those of the PHPP. This is important, since the need for heating a KfW-40 house can vary greatly. Depending on house technology and kind of fuel, it can approximate a passive house or also be considerably higher. The minimum insulation standard of a KfW-40 house is still considerably less than for a passive house. Solar profits and efficient ventilation are relatively unimportant for the KfW-40 house. The primary energy consumption requests can be most often be achieved by using renewable energy sources, such as pellet furnaces. This was frequently the case at the exhibition. The costs connected with that can make heating costs three or four times higher than for a passive house, despite a low level of primary energy consumption.

active heating and cooling systems. The house heats and cools itself, hence ”passive”.

According to European standards a passive house is a house, whose need for heating, i.e. annual amount of heating, is not higher than 15 kilowatt hours per square meter and annum (kWh/m2a). In a 150 m2 house this amounts to 22 50 kWh/a and corresponds to 22 5 liters of oil or m3 gas. Warm water consumption, the electricity consumption as well as losses in heat production and distribution are not included in the energy balance.

With this as a starting point, additional energy requirements may be completely covered using renewable energy sources. The combined primary energy consumption of living area of a European passive house may not exceed 12 0 kWh/m2a for heat, hot water and household electricity.

The current Passive House standard was developed for Northern (heating load dominated) climates and indeed most existing passive houses are found in Austria, Germany, northern France, Sweden and Switzerland.

The combined energy consumption of a passive house is less than the average new European home requires for household electricity and hot water alone. The combined end energy consumed by a passive house is therefore less than a quarter of the energy consumed by the average new construction that complies with applicable national energy regulations.

The heating demand for a passive energy house is calculated using the PHPP software (passive house project package, Dr. Wolfgang Feist, Passive House Institute, Darmstadt). The following factors are included in the calculation: • Heat losses over the building cover (control areas and heat bridges),

• Heat losses through ventilation subtracting heat recovery by a heat exchanger and the containment of the building.

• Heat recovery through passive solar heating through windows,

• Heat recovery from people, equipment, hot water, etc.

This method of calculation is used e.g. when applying for loans for construction.

Very low energy houses

A very low energy house, also called a KfW-40-house, should fulfil the following requirements:

1) The specific transmission heat loss must be at least 45% lower than the upper limit of the German Energy Economy Establishment (EnEV) standard valid for the building. The calculation of the need for heating for a KfW-40 house is carried out according EnEV software. Ventilation losses as well as solar and internal recoveries are not taken into account in this case. The heat losses can consequently only be reduced by improving the insulation of the building, or by using smaller windows, or windows with lower U values, and the reduction of heat bridges. Heat losses indicate primarily this ”construction heat protection” and can only be taken as an indicator for the general energy saving.
2) The primary energy consumption may not exceed 40 kWh per m2 of the usable floor area and year. This includes heating, hot water and electricity, all losses during transformation and distribution, and added the contribution of other sources such as active solar technologies. The demand for a low primary energy use can be met by a low request for heating, as in the case of the passive house, or by particularly efficient or renewable energy supply. The requirements of the KfW-40 houses originate from the promotional program ”ecological construction” of the Kreditanstalt für Wiederaufbau (KfW) (Credit Institution for Reconstruction in Berlin, www.kfw.de), which provides reduced construction loans for particularly energy-saving house

Figure 3. Passive house insulation with 20 cm core insulation.

Total energy supply in built area

The buildings of the Solar Building Exhibition Hamburg 2005 were, on the average, well insulated, well sealed and equipped with ventilation units, mostly with efficient heat recovery. The need for heating and expected consumption of heating energy were therefore considerably lower than in normal new houses, built according to the minimum requirements of the EnEV. The living comfort is noticeably higher. The demand KfW-40 or passive houses nevertheless does not seem optimal in retrospect. Particularly the KfW-40 house, despite its popularity, is rather a suboptimum. Particularly those, who hope for very low heating costs similar to those a passive house, will be disappointed.

In Heimfeld the houses were supplied with three central pellet heating bolers, used for three common heating systems. One system was supported by thermal solar panels. The electricity need for the area was partly met by two big photovoltaic plants. In

Figure 1. Comparison of Energy Ratings of German homes. WSchVO = German Heat Protection Regulation. EnEV = Current German Heat Protection Regulation.

Wilhelmsburg many houses were heated by pellet furnaces or heat pumps, each

supported by thermal solar panels. The electricity was supplied from several smaller photovoltaic panels. On both sites renewable energies are used for heating and hot water generation. Energy for hot water and heating was provided from solar collectors, wood pellets or heat pumps provide. Photovoltaic systems generate the electricity.

How to build a passive energy house

To meet the current Passive House standard, the construction of the houses meet certain general principles, here briefly explained: Highly insulated building shell and compact form. All components of the exterior shell of the house are insulated to achieve a U-value that does not exceed 0.15 W/(m2K) (0.026 Btu/h/ft2/°F) which typically corresponds to 20-40 cm of insulation.

Southern orientation and shade considerations. Passive use of solar energy is a significant factor in passive house design. Shading is absolutely necessary in all climates with high levels of solar radiation.

Highly insulated windows. Windows are constructed of low-e triple glazing (U-value of 0.75 W/m2K and a solar transmission factor of 50%) and highly insulated frames (U-value of 0.8 W/m2K).

Elimination of thermal bridges. By suitable application of insulation, linear thermal transmittance is reduced to below 0.01 W/mK (exterior dimensions).

Air-tight building shell. Air leakage through unsealed joints must be less than 0.6 times the house volume per hour at 50 Pa. This should be controlled with a blower door test. The house has forced ventilation with exhaust air heat recovery.

If comfortable indoor climate conditions differ greatly from outdoor conditions, it is always recommendable to use a ventilation system with heat recovery (or vice versa with cold recovery) to maintain a high indoor air quality without the need of huge heating or cooling demands in accordance with ISO 7730 for a definition of "comfortable indoor climate".

Passive houses have a continuous supply of fresh air, optimized to ensure comfort of those living in the house. The flow is regulated to deliver precisely the quantity required for excellent indoor air quality. A high performance heat exchanger (efficiency > 80%) is used to transfer the heat contained in the vented indoor air to the incoming fresh air. The two air flows are not mixed. On particularly cold days, the supply air can receive supplementary heating when required. Additional fresh air preheating in a subsoil heat exchanger is possible, which further reduces the need for supplementary air heating. Fresh air may be brought into the house through underground ducts that exchange heat with the soil. This preheats fresh air to a temperature above 5°C (41°F), even on cold winter days.

Finally it should be added that the building companies contracted to build the area agreed to refrain from using fossil fuels. Likewise, fossil fuels were abandoned on the exhibition sites of Heimfeld and Wilhelmsburg. Thus no gas and oil is used.

Passive houses are not very expensive

The shift from conventional energy demands to solutions described here is not necessarily very expensive. It is sufficient to minimize energy use with simple systems from conventional sources. The passive house is the most energy efficient standard with only 10% additional construction costs in Germany and a very good combination with renewable energy supply.

There is always the chance to find your individual energy standard using the principles of the passive house idea.

But never forget, if you build your energy efficient building 20 km away from your office and there is no chance to use public transport, the energy demand for the car is as high as PE-electricity.

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