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Prospects for Swedish technology contributing to reduced climate impact

A report produced under the auspices of Future Climate – Engineering Solutions

Sveriges Ingenjörer / The Swedish Association of Graduate Engineers, 2009

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1. Introduction and background

This report was compiled within the project Future Climate – Engineering Solutions. The project aims to present, before the United Nations' climate summit meeting, COP 15 in Copenhagen December 2009, the view of engineers on how climate problems can be managed. On one level, the climate issue is a matter of making international agreements on reducing emissions. To make such agreements feasible, however, technological solutions are required, i.e. the application of the best available technology as well as development of new solutions.

The project is directed by a project group from IDA in Denmark, NITO in Norway, VDI in Germany and the Swedish Association of Graduate Engineers. In addition, associations of engineers from Australia, Bulgaria, Finland, India, Ireland, Japan, the United Kingdom and the United States participate. An expert group, which is attached to the project, includes Professor Erik Dahlquist from Mälardalen University (Mälardalens högskola), Sweden, who has contributed background material for this report, and Tomohiko Sakao, appointed Professor of the Environment by the Swedish Association of Graduate Engineers and currently working at Linköping University. The challenge is to bring out promising technology that might contribute to reducing the temperature increase at 2 degrees centigrade globally, compared with the pre-industrial level. The strength of the project is the mobilization of members of the participating organizations worldwide.

The Swedish Association of Graduate Engineers has published a call on our website, www.sverigesingenjorer.se, requesting engineers to contribute knowledge and views on how Swedish technology might contribute to the achievement of the global targets. Valuable views have been submitted that constitute part of the substance on which the compilation of this report has been based. Some examples of other contributions are included in the list of references. In connection with writing this report we have also established the website www.energibruket.se, in collaboration with IVL Swedish Environmental Research Institute and Vinnova (The Swedish Governmental Agency for Innovation Systems) bringing together a number of services associated with improving energy efficiency.

2. Improving energy efficiency

The public debate in Sweden has for a long time focussed the supply of energy. Concurrently, many Swedish enterprises have for a long time been working on reducing their energy consumption. Recently, however, the energy streamlining issue has gained increased impact in Sweden. Prompting this change has, among other things, been an opportunity for electricity-intensive enterprises implementing streamlining measures to receive a tax reduction, the Commission for improving energy efficiency[1] and several reports showing a very great potential for improving energy efficiency.

The aforementioned website Energibruket is an initiative to gather engineers in Sweden for discussions and innovation on this issue. The site offers a forum for technology-oriented discussions under headlines like transport and construction. It is also possible to have an idea tested with support from the expertise that has been associated with Energibruket on issues such as energy, environment, intellectual property rights and commercialization. From our experience, many ideas conceived by engineers are never realized, since they are brought

[1] Energieffektiviseringsutredningen

forward in an environment where they are beside the core business By taking this initiative we want to offer an opportunity for such ideas to reach further.

Making energy consumption more efficient is one of the most important measures for managing the climate complex. It has also been shown that this is the step that, in the initial stage, can achieve the most at the least cost. Actually, there are many simple streamlining steps that are more profitable at short sight.

For two years the Swedish Energy Agency has operated a programme for stimulating streamlining in energy-intensive industries. The purport of this programme is that enterprises implementing steps will be exempted from the 0.005 SEK/kWh tax on process-related electricity that was introduced in 2004, following the EU Energy Taxation Directive. More than 100 enterprises participate in the programme, with a combined electricity consumption of 30 TWh per annum. Indications suggest that the saving so far amounts to 1 TWh per annum at a cost of 1 billion SEK. Savings have been made in production processes and in support systems such as pumps, compressed air, fans and engines.

A recent Swedish consultant’s report (Sweco 2009) indicates that it might be possible to reduce Sweden’s total energy consumption by almost fifty percent by means of control and new technology. The report maintains that the transportation sector has a great potential but technological development is required to make large-scale use of plug-in-hybrids feasible. Industrial processes need to be improved, but within many fields a great potential lies in minor changes of available technology. In the housing sector it is largely a matter of improving the existing building stock, but to a large extent the technology is already at hand

3. Energy production

Improving energy efficieny will also have an impact on the production of electricity. At the same time it is important to remember that electricity as carrier of energy could reduce the total energy need. To improve efficiency and reduce the consumption of energy we might have to increase the use of electricity. At an early stage, Sweden accomplished an extensive development of hydroelectric and nuclear power, which means that for a long time the emissions of carbon dioxide from our energy production have been small. In decades to come, bio-energy and wind power will grow and further increase the renewable portion. In a more distant future, sea-wave power and solar cells are interesting as well as separation of carbon dioxide from bio-fuels or industrial processes. A major factor of uncertainty in the Swedish electricity system is the future of nuclear power.

3.1 Hydroelectric power

For a long time hydroelectric power has been a cornerstone of Swedish electricity supply. Minor power plants were built already in the 19th century and in the 1930s the development gained momentum, laying a foundation for the emerging Swedish welfare society.

The installed power is 16 GW and the production during a normal year amounts to 65 TWh, with variations depending on the precipitation. Hydroelectric power is important, not only for the production of electricity in the Nordic system but also for the effect regulation matching the production in every moment with demand, thus keeping the mains frequency constant. In accordance with a parliamentary resolution, hydroelectric power may only be further developed on a minor scale and four major rivers are protected from development.

Nevertheless, small-scale hydroelectric development takes place and gradual efficiency-raising of existing power stations is going on as older technology is replaced with new. This has entailed a rather considerable increase of the installed power, although the energy production from hydroelectric power has not increased in recent years.

3.2 Nuclear power

Nuclear power has been an important part of Swedish electricity production since the development started in the 1970s. All the time however, nuclear power has been a controversial form of energy in Sweden and the debate has been reinforced during the last year. At the most we had 12 reactors but after closing the two reactors in Barsebäck (1999 and 2005) there are today 10 reactors producing approximately 70 TWh electricity per annum. Like hydroelectric power, nuclear power has been subject of efficiency increases, which makes the present production from Swedish nuclear power higher than before closing Barsebäck.

The predominant political view has been that existing nuclear power should be used during the lifetime of the reactors but then be phased out as they wear out. Today we calculate with a lifetime of 60 years, which means that the time is approaching when the decision must be made whether to continue with nuclear power. The issue has taken a political turn as the current coalition government has made a deal implying that existing reactors may be replaced by new ones in the same locations as the present ones become too old. If it becomes reality, it would mean that Sweden has a possibility to continue with nuclear power throughout this whole century. It is noteworthy, that if all the reactors that are currently in operation were replaced, it would actually mean a considerable increase of electricity production from nuclear power, new plants being so much more efficient.

It is uncertain what will happen. Should the current government be re-elected next year, it is likely that it will launch something more tangible during the next term of office. Should a change of government take place, entailing a social democratic government, it is likely that it will cancel the existing resolution, but it is also conceivable that they won't. The Social Democrats want to phase out nuclear power but within the party there are strong proponents of nuclear power, not least in places that are dependent on electricity-intensive industry. In this context it is relevant that the public opinion in Sweden is rather favourable towards nuclear power. Around 80 percent want to continue using nuclear power and those wanting to develop are in majority over those wanting a phase-out.

Thus, when discussing the future Swedish energy system with the year 2050 as the time horizon, two different scenarios must be imagined – either an annual production exceeding today's 70 TWh electricity, perhaps more like 100 TWh, or a situation completely without electricity production from nuclear power. In the first case Sweden would be a great exporter of electric energy and in the second case a strong improvement of efficiency will be required to make us self-sufficient in electricity.

Sweden has comparatively good competence in nuclear technology, even if the uncertainty which has surrounded nuclear power has entailed certain problems, among other things a shortage of experienced personnel. However, there is a growing interest among younger engineers to engage in nuclear power and specializations are emerging in the engineering training programmes.

The new reactors that are being built today belong to what is called Generation III+. They are water-cooled reactors with integrated security system, significantly reducing the risk of meltdowns, in comparison with the reactors of today. The Fourth Generation reactors, which might become a reality around 2030, could use already depleted uranium for fuel, which, for one thing, would eliminate the need to supply new uranium and, for another, strongly reduce the necessary storage time for the long-lived waste.

The Swedish company for handling nuclear waste, SKB[2], has recently made the decision about the localization of terminal storage. Quite a long process remains before building the plant can begin but Sweden can thus become the first country in the world terminally storing burnt-out nuclear waste.

3.3 Bioenergy

Sweden possesses long since great know-how in bio-energy that is demanded from several other countries. In developing countries, bio-energy is often used in an inefficient way, which opens a potential for exporting our know-how. China exemplifies countries demanding Swedish know-how.

Of our energy supply 116 TWh originates from bio-fuels, corresponding to 20 – 25 percent of our total supply, depending on the way of calculating. By international comparison it is a very high share, not least for an industrial country. Almost half of this is used in industrial processes and almost one third is used for district heating, but bio-energy is also used for producing electricity and fuel.

As more than half of Sweden's area is forest-covered, there is ample access to biomass. Nevertheless, the competition for biomass is hard, since it is demanded by the forest industry for wood products, pulp and paper, by the energy sector for electricity and heating and as raw material for fuels. In the transportation sector bio-energy alone cannot replace fossil fuels. Generally speaking, a shift to renewable forms of energy must go hand-in-hand with improved energy efficiency.

From the energy point of view, concurrent production of electricity and heating in power and heat supply stations is appropriate. The problem is how to find a market for the produced heat in the vicinity of the installation. We also have a very large production of heat from our extensive processing industry, where a large share, but not all, can be used for district heating. Such aspects often make it necessary to deviate from what is best from a pure energy aspect. Choosing how to use energy resources also depends on what the overall objective is. Perhaps the most important thing is to minimize the emissions of carbon dioxide and then the choice of field of application for bio-energy will depend on what it replaces in that application. One example could be the first generation bio-fuels replacing fossil fuels but in some cases the raw material is used in a less efficient way than if it is used for producing electricity and heating.

3.4 Wind power

In Sweden wind power has covered only a marginal share of electricity production and today it generates 2 TWh per annum. However, plans have been made for fast expansion of wind power to make it comprise 30 TWh in 2030, of which 20 TWh will be land-based and 10

[2] Swedish Nuclear Fuel and Waste Management Co

TWh at sea. By comparison with other types of power plants, wind power is the easiest to get permission for building and furthermore it is possible to build both small-scale and large-scale, which makes it interesting to more project makers. The Swedish energy system has mainly been adapted to a small number of big producers and therefore it might have to be modified. An important stakeholder for establishing wind power is the basic industry. Basic industry enterprises cooperate in VindIn, an enterprise building new electricity production but individual companies, too, engage in wind power. Thus, for example SCA and Norwegian Statskraft have established a joint venture that has applied for permission to build six new wind power parks with in all 445 wind power plants on land owned by SCA.

Internationally, too, wind power is facing a breakthrough and will be expanded considerably. A predominant design for wind power has been developed above all in Denmark and consists of a three-bladed horizontal axis wind turbine that curbs the wind and drives a generator through a gear box. Development in recent years has largely resulted in increased size of individual power plants.

There is no Swedish producer of full-scale power plants but one enterprise is testing a power plant of its own development, which charges fuel cells instead of delivering electricity straight to the supply system. There are several important Swedish subcontractors such as ABB and SKF. ABB delivers equipment for the whole power supply system between generator and mains. Among energy enterprises Vattenfall makes large investments and is a leading actor in sea-based plants.

Besides the predominant design an interesting development of vertical axis wind power plants is taking place at Uppsala University and has also become commercialized by Vertical Wind. One advantage is that it is independent of the wind direction and another is that the generator can be placed on the ground, while it is a drawback that it yields a somewhat lower total efficiency as higher winds are missed out.

3.5 Sea-wave power

Globally, sea-wave power is in an intense development phase but has not reached a commercial stage. However, there are pilot installations, such as off Lysekil on the Swedish west coast. The potential for electric energy generated from wave movement is very high. Advantages, compared with wind power, are the larger energy content in the wave and the fact that swells remain after the wind has abated. One problem for sea-wave power is the very difficult conditions at sea that make it necessary to dimension a plant for the very toughest conditions, although these only occur occasionally.

In sea-wave power, unlike wind power, there is no predominant design but several technologies competing with completely different methods for transmitting wave energy to electricity. Today it is difficult to say whether several solutions will survive in parallel or if one of the existing technologies will push aside the others. ABB and Vattenfall are involved in several of the ongoing development projects.

Uppsala University is strongly committed to one of these technologies and an enterprise, Seabased, has been established in this environment. A buoy is used to absorb the movements of waves. Typical for the Swedish solutions is the use of a linear generator that is placed on the bottom. This makes the technology comparatively simple and the most sensitive part is placed in the comparatively protected bottom environment. One intention behind the Swedish technology is to place several buoys together but making each buoy rather small. Therefore the solution may also be interesting along coasts with moderate winds, such as in Sweden.

Provided that Fortum gets the means for which they have applied with the Swedish Energy Agency, they are planning, in collaboration with Seabased, to build a full-scale commercial 10 MW installation in Lysekil. In such case manufacturing will be started and 600 persons become employed in the initial phase.

3.6 Solar energy

Solar energy development is still in a very early phase and is following several lines of development. In the long run solar energy has a very large potential, technologically as well as economically. The development is very much a matter of bringing the costs down without impairing the efficiency.

The installed power in Sweden is 4 MW and the development has been slow in comparisom with many other countries. We have not had special support for solar energy and the general means of control, green electricity certificates, has rather stimulated cheaper alternatives, such as wind power and bio-fuels.

Sweden ventured at a fairly early stage on solar cell research. Today we have in research terms a good position as to thin film, Grätzel and polymer cells. Thin film solar cells are usually described as second generation solar cells. Swedish research on these has become commercialized by Solibro, a company that however has been bought by the German giant in the field, Q-Cells. Research remains, however, in Sweden, while manufacturing takes place in Germany. Commercially, the efficiency is 10 percent, but in research environments 20 percent has been achieved.

Grätzel solar cells can be described as third generation solar cells and are not based on absorbing the cell’s light in a semiconductor but on energizing a pigment attached to a nano-chrystalline semiconductor to liberate its electrons and create a current. The potential for this technology is very high.

In addition to research and development, there are Swedish suppliers of components and systems. A potential obstacle to Swedish enterprises could be the non-existent domestic market.

Beside solar cells, electricity from solar energy can be obtained through thermal solar power, heating water to drive a steam turbine. This technology has been tested and international plans have been made to build large-scale installations in the Sahara. A Swedish enterprise uses a satellite dish to collect solar energy that drives a Stirling engine. One advantage is that it can be driven also by a different heat source and thus can be combined with biogas to keep electricity production even.

4. Transportation

The automotive industry is very important to Sweden. We have research, development and manufacturing of heavy vehicles as well as private cars and, in addition, a large number of smaller companies being subcontractors to the automotive industry. Volvo and Scania have made gradual improvements of their heavy vehicles, thus reducing the fuel consumption by 40 percent during the last 30 years. Improvements have been made on the transmission (engine, gear box and axes), rolling resistance and weight. The engine's performance has increased, while the emissions have decreased considerably. Volvo has a hybrid lorry with an electric engine operating at acceleration and when driving in queues.

However, technological improvements have been eroded by increased transportation on trucks and poorer degree of loading. The amount of goods that is transported by trucks in Sweden is increasing faster than the GNP, which is not the case for transportation by train and ship. There should be an opportunity to shift goods from trucks to trains and ships. Improved logistics could lead to increased degree of loading in the cars.

As to private cars, Volvo and Saab are owned by Ford and GM, respectively. During the current financial crisis these enterprises are, like most automotive enterprises worldwide, under pressure. In a way, however, both Volvo and Saab are in good starting positions since they have prioritized environment and security aspects, which is demanded by customers. Saab, having had profitability problems through several years, is dependent on finding a new owner. Now it seems settled, that Saab will be taken over by Koenigsegg Group which is comprised by a small Swedish manufacturer of sports cars and Norwegian financiers.

Volvo had even in 1992 developed a hybrid car called Volvo ECC, in collaboration with ABB. It was driven by an electric engine connected to a big battery package. The batteries could be charged on the mains or through the diesel-driven gas turbine engine. Towards the late 1990s Volvo again developed a hybrid resembling the Toyota Prius, which dominated the market, but Volvo withdrew the project. Then it would be a long time before Volvo tested the hybrid technology again. Now, however, a venture on a plug-in hybrid has just been presented in collaboration with Vattenfall.

Lately Volvo has otherwise primarily concentrated on conventional diesel cars but with reduced emissions meeting the new EU requirements. This year's models are available in different sizes but with emission around 115 g CO_2/km. They have been successful with improving the following: air and rolling resistance, engine control, power-steering, gearbox friction, changed transmission with reduced number of revolutions, automatic engine shut-off when standing still and battery charging especially when braking.

In 2005 Saab launched its Biopower, which is an ethanol car adjusted to yield high effect when driving on E85. The following year a hybrid car was introduced, combining a Biopower engine with an electric engine. However, it has not reached the market. Saab is also developing a concept based on pure ethanol driving. Although the Saab cars that have reached the market have mainly been conventional cars, Saab is considered to possess good technological competence in hybrid technology, which strengthens the position of the enterprise versus GM before the take-over by a new owner.

Sweden produced ethanol from forest raw material even in 1980 and later in the same decade tests were made with gasifying biomass to produce fuel. These efforts however stopped short and instead it was ventured to develop combined heat and power (CHP) technology. Ethanol and biogas were still introduced at an early stage but only small-scale.

First generation biofuels are plants from which sugar, starch or oils can be extracted. They are not very energy efficient and, for example, willow can be used more efficiently in the production of electricity or heat than for making fuels. Now, development is going on to make bio-fuels from a broader base of raw materials, such as wood, crops that are not used for food and waste. Second generation fuels will be more efficient and made from gasifying biomass. From black liquor, which is a residual product from pulp production, methanol can be produced, dimethyl ether or Fischer-Tropsch diesel. Ethanol can be produced from cellulose, such as forestry residues.

The IVA Academy[3] recently presented a vision of Sweden in 2020 having 600,000 electric cars (Vägval energi 2009). An electric engine is much more efficient than a petrol engine, as it transforms more than 90 percent of the electric energy into mechanical energy, whereas the corresponding level for the petrol engine is just 20 – 30 percent. The electricity need for 600,000 electric cars is only around 1.5 TWh per year. Toying with the thought of replacing all private cars in Sweden with plug-in hybrids it would mean replacing 40 TWh fuel with 10 TWh electricity.

A breakthrough for electricity cars and plug-in hybrids depends upon the development in battery technology. Currently the most interesting path is to proceed with the development in lithium ion batteries. These batteries have suitable properties which were previously wanting, high conductivity and storage capacity, high electrochemical and mechanical stability – at a reasonable cost. Much development work remains and research is, inter alia, focussed on new electrode materials that can store more lithium ions.

Battery development for vehicle applications can learn a lot from computer battery development. Basically, it is the same wish that capacity not deteriorate too much after many charges. The problem is just even more evident in vehicles, as it is not acceptable having the potential driving distance shortened too much after some time. Charging time and battery dimensions are also important car qualities. Today charging a battery with 10 kWh from an ordinary wall socket takes around five hours, which is fast enough, if the car is charged overnight. This amount of energy is sufficient for around 50 kilometers and many commuting trips are shorter. Besides, however, it is necessary to set up a system for fast charging and with high effects such a battery could be charged in 10 minutes.

Certain research on lithium ion batteries in Sweden focuses the automotive industry. One Swedish researcher has managed to go all the way from basic research to commercialization and is today CEO of Boston Power, delivering batteries to HP and now targeting the automotive industry. The enterprise is supported by Swedish financiers but is located in the US.

5. Separation and storage of carbon dioxide

Sweden has almost no coal-based electricity production. Swedish Vattenfall, however, operates coal power plants in Germany and has a pilot installation there for separation and storing carbon dioxide. The energy enterprises Fortum and E.ON carry out smaller-scale tests in Sweden. Research takes place for example at Chalmers, KTH Royal Institute of Technology and Mälardalen University in collaboration with Chinese universities as well as at Umeå University in collaboration with the cement producer Cementa. In Sweden the most immediate issue is separation of carbon dioxide from large point sources in e.g. steel industry or from material of biological, non-fossil origin, which may be from pulp and paper industry. In the latter case it would be possible over time to achieve a reduction of the carbon dioxide amount.

[3] Royal Swedish Academy of Engineering Sciences

The price of carbon dioxide emission is decisive for the profitability of choosing the technology. On geological grounds it is believed that southern Sweden is the main area of interest, which also means that, to avoid too long transportation distances, energy-intensive industries in that part of the country will come in focus.

6. Housing and service

Statistically the housing and service sectors are grouped together. In 2007 they used 143 TWh, of which the Swedish housing sector represented 124 TWh, roughly corresponding to 30 percent of our country's energy consumption. In many countries, this sector's share is even bigger, around 40 percent. Sweden has set a target of halving its housing-related energy consumption by 2050.

Sweden's energy consumption in the housing and services sector has decreased somewhat since 1970. However, a big change has taken place in so far as oil consumption has decreased substantially from 119 TWh in 1970 to 13 TWh in 2007. Instead, in the same period the consumption of electricity increased from 22 to 72 TWh and district heating was expanded from 12 to 42 TWh. Approximately 80 percent of Swedish blocks of flats are heated with district heating while the share for office premises is somewhat lower. District heating covers 55 percent of the total heating of dwellings and business premises.

The large share of energy going to this sector, combined with the long period during which new dwellings will be in use, makes it important to make new construction so energy efficient as possible. Three key aspects of energy efficient construction undertakings can be pointed out: use less energy, "create" energy in the buildings and use surplus energy in a good way.

It is characteristic for construction projects that many operators are involved, sometimes poorly coordinated. The process can be compared to a relay race where different operators take turns. Energy service competence that could contribute to decreased energy consumption enters the picture only when the building has been put into operation. These circumstances constitute obstacles to constructing in unconventional ways. Bridging this obstacle requires structured co-operation even from the start, know-how, will and leadership in the construction industry.

Experience from building energy efficient houses with a good indoor climate has been collected during a couple of decades. However, it has been difficult for low-energy houses to score a success on a wide front. Calculated life-cycle costs indicate that really energy-efficient buildings could yield lower costs than houses built in accordance with minimum standards. More stringent means of control could promote more frequent use of the best technology available. Besides trying to minimize the need for heat supply, as the costs for sun panels and solar cells will drop in future, individuals might consider mounting them on their roofs.

Most existing blocks of flats are over 30 years old and face major renovations. In connection with other major renovation it is appropriate to also improve the energy performance of the houses, for example overhauling windows and ventilation. But some incentive is needed for the house-owner and one option would be that the supplier of energy services assumes not only the operation and maintenance for a period of time but the energy costs as well.

It was estimated recently by a commission of inquiry (Energieffektiviseringsutredningen 2009) that the potential for improving efficiency in housing as early as 2016 amounts to 23 TWh.

The Swedish enterprise Skanska is one of the ten biggest construction enterprises in the world. Business properties that they construct must be certified in compliance with Green Building, meaning considerably lower energy consumption than prescribed by current standards.

7. Opportunities in Swedish industry

Swedish industry uses 157 TWh annually, allocated on 36 percent electricity, 34 percent bio-fuels, 13 percent oil, 11 percent coal and coke, 3 percent district heating, and 3 percent natural gas. The energy consumption per unit produced has fallen to one third since 1970. During this period the consumption of oil has decreased whereas it has increased for electricity and bio-fuels. As mentioned above the potential for improved efficiency is great and amounts to at least 15 TWh as soon as 2016.

7.1 Basic industry and its processes

Sweden has a large proportion of basic industries, which rely on ample access to electricity at competitive prices. These industries are also located in places with few alternative employers, and therefore the survival of the enterprise becomes a matter of survival for their whole local community. Some of these industries use coal for their processes, e.g. as reducing agent in iron and steel industry, thus generating a great deal of carbon dioxide that cannot be removed except by capturing and storing. Should this industry in Sweden be knocked out, the equivalent capacity will become set up in developing countries, with negative implications for emissions worldwide. For many years Swedish basic industry has improved its processes and reduced its emissions. At an early stage we imposed a carbon dioxide tax that has been conducive to this development. Energy consumption has remained fairly constant for a number of years, although the production volume has increased considerably. As one result Sweden today has very low carbon dioxide emissions, proportionately to its GNP, in this respect surpassed only by Switzerland (2006).

7.1.1 Forest industry

Worldwide, Sweden is the third biggest exporter of sawn timber and the fourth biggest exporter of paper and pulp. The forest industry represents 10 – 12 percent of our industrial employment, turnover and added value. Forest industry is energy-demanding, but the consumption of fossil fuels has decreased continuously since the 1970s and today 90 percent of the heat demand is covered by bio-fuels. The forest industry has also accomplished extensive improvement of energy efficiency and improved the use of its own fuels such as return lye, bark, chips and pitch fuel. The objective is not to use fossil fuels at all in the manufacturing processes.

By making better use of branches, tops and other residues from logging, the extraction of bio-fuels, keeping the felling constant, might increase by a factor of four from today’s 7 TWh. Properly managed the forest will also be important for bonding carbon and reducing the volume of carbon dioxide.

The paper and pulp industry alone takes almost half the total electricity consumption of Swedish industry, but it also produces 5.5 TWh electricity by back-pressure.

One problem is the strongly increased road transportation of rough timber. Forest industry representatives want to drive with bigger timber trucks, but it would increase the road wear considerably.

Bio-refineries present an exciting development. The intention is to extract more from forest industry products than today in an efficient and coordinated manner. Between Örnsköldsvik and Umeå enterprises possessing know-how in forestry, processes and energy have clustered with several universities to pursue research and development in fields such as new fuels (ethanol, bio-diesel and biogas) and residual products from processing industry that could be refined into bio-fuels or production of chemicals for food, industry and medical care.

7.1.2 Mining industry

The biggest source of carbon dioxide emission from Swedish mining is the production of pellets at LKAB. This enterprise is more and more shifting towards producing pellets and the production approaches 30 million tons a year. Energy is, however, reclaimed from the production and used for heating. Transports from mining are extensive but are mainly done by rail. The production of pellets uses coal and oil but additives such as dolomite and calcite also contribute to carbon dioxide emissions.

One advantage with Swedish iron ore mining is the fact that it mainly extracts magnetite, which by contrast with hematite releases energy during the refining process. It implies that 60 percent of the heat that is required when producing pellets comes from magnetite oxidation, which reduces the need to add fuels. When producing pellets worldwide, hematite is the most frequently used, which requires approximately 15 litres of oil per ton finished product, compared with the LKAB mines using 5 litres/ton.

The emissions per ton produced are decreasing, but the total emissions increase due to increasing total production. The technological trend goes towards bigger units and thus increased efficiency. Progress is taking place in terms of equipment and methods to optimise the control of the processes. Several Swedish mining enterprises are involved in EU projects such as ULCOS and BioMine to reduce their climate impact.

7.1.3 Steel industry

In 2007 Swedish industry produced 5.7 Mton crude steel. Of this volume 82 percent is exported, which means that the steel industry represents 7 percent of the Swedish export of goods. Of the world’s combined production of 1,344 Mton, countries outside the Kyoto protocol represent more than two thirds.

In the furnace, iron oxide is reduced into iron with assistance from carbon, which results in the formation of carbon dioxide. The processes are close to the theoretical limit for how little carbon can be used. It means that the only possibility to reduce emissions of process-related carbon dioxide is to separate it for storing.

Research is in progress on the production process as well as managing the carbon that is formed, inter alia within the framework of the aforementioned ULCOS program. By heating and thermal treatment at high temperatures, oil or gas is used. The emissions might be reduced by a shift to natural gas, but this would require considerable investment. Residual energies from processes are already being used either for fuel in other parts of the process or for producing electricity and district heating. However, here is a potential for making use of more residual energy.

The big energy costs in this line of industry have been conducive for improving efficiency. Besides the carbon used in the process, the steel industry has improved the efficiency of its energy use since 1990 by 20 percent. The emissions of carbon dioxide, however, originating mainly from coal in the furnace and with a forecast increase of the production volume, the total emissions will increase, too.

To make a more extensive reduction of emissions from the steel industry possible, improving today’s technology is not enough, but technological shifts are necessary as well. Fields that need to be subject to research are carbon dioxide capture and storing, new steels that could reduce the amount needed for various products, atom-near modelling to develop new steels, better control of processes and development of alternative processes.

7.1.4 Chemical industry

The chemical industry, too, is a pronounced export industry and together with refineries and the plastic and rubber industry its export makes up 18 percent of our total export. Foreign ownership is substantial in this line of industry, manifest for example in our extensive pharmaceutical industry.

Since many years, Swedish chemical industry has been engaged in improving the efficiency of its processes and reclaiming the residual energies that are formed in the processes. During the last 15 years the production has increased threefold, while the use of energy has increased by 30 percent.

The potential for this line of industry to reduce its emission of greenhouse gases lies mainly in the use of alternative raw materials and in separation and storing of carbon dioxide.

7.2 Engineering industry, its products and their use

The automotive industry, which is so important to Sweden, is dealt with in the chapter on transportation.

Engineering industry in Sweden consists of many small enterprises, while the greater part of the employees are found in a number of large global enterprises. The export amounts to 67 percent and is even higher in terms of finished products. The enterprises in this sector are at work to reduce their own climate impact but they make their major contribution as suppliers of technology that, when applied, can be conducive to reduced environmental impact.

White goods technology has been developed in Sweden for a long time and stands out as a line of industry, which has coped with technological leaps, as in the case of phasing out Freon, while also being characterized by continuous efficiency improvement. Faster implementation of new technology would be desirable here, since one third of Europe’s refrigerators are more than ten years old, thus consuming 40 percent more energy than new ones.

Generation and transmission of power current is another early Swedish field of strength, where we still are conducing towards technological development. Competence in this field has also been important for developing our industrial know-how in all the electrotechnological field, including trains and nuclear technology. High Voltage Direct Current, HVDC, is a technology for transmitting high-voltage direct current across vast distances without the losses that are associated with conventional alternate current technology. This technology was developed by ABB and is an important component in the electric power system for locating electricity production in favourable places, while concurrently reaching the final consumers.

Still another field where Sweden possesses competence that might be interesting for managing the climate issue is the information and communication technology, ICT. Properly used, ICT could conduce towards substantially reduced travelling, which would have a positive impact on the emission of carbon dioxide. ICT could, however, also improve the efficiency in other activities and could thus contribute better process control and more efficient logistics for transportation, to name two examples.

Engineering industry uses electricity mainly for machines, compressed air, ventilation and illumination. The consumption of energy remains constant, although the production volume increases. Improved efficiency in engineering industry could be achieved by assembling the final product in such a way that it will be more energy-efficient when it is used but also by the suppliers' refining the components.

8. Conclusions

All in all, there is a great potential in the short term as well as towards 2050 to reduce Sweden's climate impact. Also, several Swedish technologies could contribute to limiting the temperature increase to 2 degrees centigrade, globally, compared with the pre-industrial level.

First and foremost we want to emphasize the potential in improving energy efficiency and we can see a great potential in almost every field. Even if the major enterprises have been working on the issue, simple steps still exist that would pay in the short term. The minor and medium-sized industry has not yet tackled the issue in a systematic way. Reduced energy costs is an incentive per se, but the change is accelerated if enterprises, that are not big energy consumers, are covered by an instrument of control, similar to the one that gives the energy-intensive enterprises a tax reduction opportunity. Further, enterprises could often be aided by someone from outside looking unbiased at its activity. Through the initiative Energibruket, the Swedish Association of Graduate Engineers wants to draw attention to technology and ideas on improved energy efficiency.

To a large extent, our production as well as our consumption of electric energy will be affected by political resolutions on nuclear power in the following years. If we choose to replace all existing reactors as they grow too old, we will have a big surplus of electricity that could be exported, whereas if we choose to phase out nuclear power completely we will have to improve energy efficiency considerably to be self-sufficient in electric power. In any case the renewable electricity production will continue to grow from wind power and bio-energy in the first stage. We can see a great potential for Swedish know-how in hydroelectric and nuclear power playing an international role but also for contributions in wind, sea-wave and solar energy.

In the transportation sector, the future of Volvo and Saab is highly essential for our prospect of being conducive in technological progress. Continued survival for the two manufacturers of passenger cars requires continued adjustment to a market that will to an ever larger extent demand solutions with low climate impact. Should Volvo and Saab succeed with the conversion and if their new owners allow development and manufacturing to remain in Sweden, they will be important pacemakers for the evolution of a multitude of Swedish technologies in the vehicle sector. In the current financial situation,Volvo Trucks[4] and Scania are having big problems but strong positions in terms of ecological adaptation and they will be able to join in and lead the global development of heavy vehicles.

Since Sweden by and large has no production of electricity from coal-fired power plants, we have not like Norway ventured into capturing and storing carbon dioxide. The Swedish electricity producer Vattenfall is, however, involved in a pilot project in Germany and, in addition, research and some experimental activity takes place in Sweden. What might be of immediate interest is a Swedish effort in this field concentrated on developing solutions for capturing and storing carbon dioxide either from industries whose processes inevitably generate carbon dioxide or from emissions of using biomass.

The Swedish housing sector is characterized by the fact that we rather early reduced our dependence on oil, choosing instead to a large extent to use electricity for heating. This technology was chosen at a time when electricity was cheap in Sweden. District heating has also been expanded, but since Sweden has a large area and a small population a comparatively large proportion of Swedes live in small houses in regions where district heating is not profitable. Occasional low-energy houses were built in Sweden as early as 25 years ago, but the technology has never had a large-scale breakthrough. The reason is not, however, a lack of technology but rather the absence of collaborative work between the operators in the construction process and a traditional sector's lack of breakthrough for holistic views on building and using dwellings.

Sweden has an extensive basic industry which is a major energy consumer. Access to electricity at competitive prices is an essential condition for the survival of these enterprises . To the extent that these enterprises move or close down, corresponding operations will be run somewhere else in the world, where environmental requirements are probably lower. Thus, the global environment would not gain if activities in Sweden were driven out of business. Basic industries are in many ways working to make their operations more efficient and by international comparison they have come far on the road to sustainable products and processes. Besides the basic industries Sweden possesses an extensive manufacturing industry, to a large extent developing products which, when used, are conducive to reduced environmental impact.

9. Selected reading

Energiläget 2008, [The energy situation 2008] Energimyndigheten (2008)

Energiutblick 1/07, [Energy survey 1/2007]Energimyndigheten (2007)

Halva energin – hela välfärden, [Half the energy – all the welfare] Sweco (2008)

Industrin, regeringen och klimatpolitiken – dags för handling!, [Industry, government and climate policy – time for action!]Industrikommittén (2008)

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[4] Volvo Lastvagnar

Översättning, slutversion, 2009-06-26

Transportsektorns energianvändning, [Energy use in the transportation sector] Energimyndigheten (2008)

Vinnova Analys 2009:06-10 (2009)

Vägval energi, [Choosing energy route] Ingenjörsvetenskapsakademien (2009)

10. Appendix, Energy data for Sweden
First we present the data for 2007 with respect to the energy ”consumption” in Sweden. There is a significant difference between production and consumption from one year to another depending on weather conditions. A high number of days with very cold weather combined with a low amount of rain will increase the import, while a high number of very rainy days will lead to a huge export of electric power instead.

Concerning biomass we only count the formal energy like oil and pellets/bark, while products like pulp and paper and refined materials like steel are not included in the energy calculus.

The official ”consumption” of energy in Sweden 2007:

Hydro power	66 TWh (238 PJ)
Nuclear	64 (231)
Oil	131 (471)
Fossil gas	8 (28)
Coal	17 (60)
Fossil fuel total	156 (562)
Bio-fuels incl. peat and waste	116 (432)
Wind power	1.4 TWh (5)
Total	404 TWh (1455)
Renewable energy	45.4 %
Non-fossil	61.2 %

Energy by sector 2007:
Industry 157 TWh (564 PJ) of which almost 50% pulp and paper
Transportation 105 TWh (564 PJ)
Housing and services 143 TWh (515 PJ)

Renewable fuels for transportation 2 TWh ethanol, 0.3 TWh biogas and 1,2 TWh FAME.

The emissions of GHG was with respect to CO2 (fossil) 51 million tons 2007.
We can divide this by different sectors (2006):
Electricity, gas and heat power 11 million tons
Combustion in industry 11 million tons and industrial processes another 4.6 million tons.
Total 15.6 million tons
Transportations 20 million tons
Housing 4.5 million tons

The import of oil was 18 million tons and the emissions of NOx was approximately 170 000 tons 2007.

We also should state the probable development of the energy utilization until 2030. If we look at the official statements we might have no nuclear and 30 TWh of wind power by 2030. The real figures will depend on what control mechanisms are introduced. We learned that from our experience after the referendum on nuclear power in 1980, when the government aimed at doubling Combined Heat and Power, CHP, and biomass utilization in 10-15 years. At the same time no mechanisms were introduced. There was no energy tax at all in 1980, and no tax on negative emissions on carbon. No stimulations were made on CHP as well. The amount of biomass was almost the same in 1990 as in 1980 – 50 TWh, from which 45 TWh was in pulp and paper industry. CHP was almost on the same level as well. In 1992 a decision was made on a high carbon tax on coal, and a little less on oil and fossil gas. After that, biomass utilization and CHP has increased dramatically, and in 2007 the biomass utilization was 116 TWh, or more than the double! The CHP usage has also doubled.

In 1980 wind-power was considered obsolete in Sweden, as being totally uneconomical. Today the Swedish power organization declares that small wind power plants are the most economical (40 kW) after hydroelectric power and significantly more economical than nuclear power! The reason is that the wind power now is a reliable technology, with low demand for service, and the interest rate is very low. We also have ”green certificates” even further subsidizing wind power. On the other hand wind power has the disadvantage to be available only when it is windy, which limits the usability compared to CHP, hydroelectric power and nuclear power.

In Sweden 45 TWh electricity is used to heat buildings. At the same time we use more than 100 TWh oil for transportation. If we start utilizing electricity combined with biogas in plug in hybrid vehicles, we could replace the 100 TWh oil by 20 TWh of electricity and 20 TWh of biogas or ethanol. Also the residual oil, natural gas and coal use can be replaced by bio-energy and the 45 TWh for heating buildings can probably be reduced to some total need of 10 TWh long-term, and almost zero with respect to electricity. This means that the total need for electricity could be reduced by some 25 TWh at the same time as we take away almost all the need for oil and natural gas! The increased need for biomass can be met by using more organic waste, and by growing new species of energy crops and trees. From this discussion we have tried to make a prognosis that has a reasonable probability assuming that the driving mechanisms are sustained in different ways by the government.

	2009	**2015**	**2030**	**2050**
Hydro power	70	70	75	80
Nuclear power	70	70	50	30
Oil+ NG+Coal	140	110	50	10
Wind	1.4	10	30	30
Solar power (PV)	0	0.5	2	5
Biomass	120	140	170	200
Tot	400	400	377	355

By new technologies we believe it may be possible to replace fossil use in different areas by other energy forms like renewables and electricity:

Fuels for Vehicles	**2009**	**2015**	**2030**	**2050**
- Oil and NG	100	85	30	0
- Renewables	1	4	10	20
- Electricity	0	1	10	20
Biogas/ethanol/DME	1	6	10	20
Gasification High temp	0	3	5	10
Biogas	1	3	5	10
Industrial use	40	25	20	10