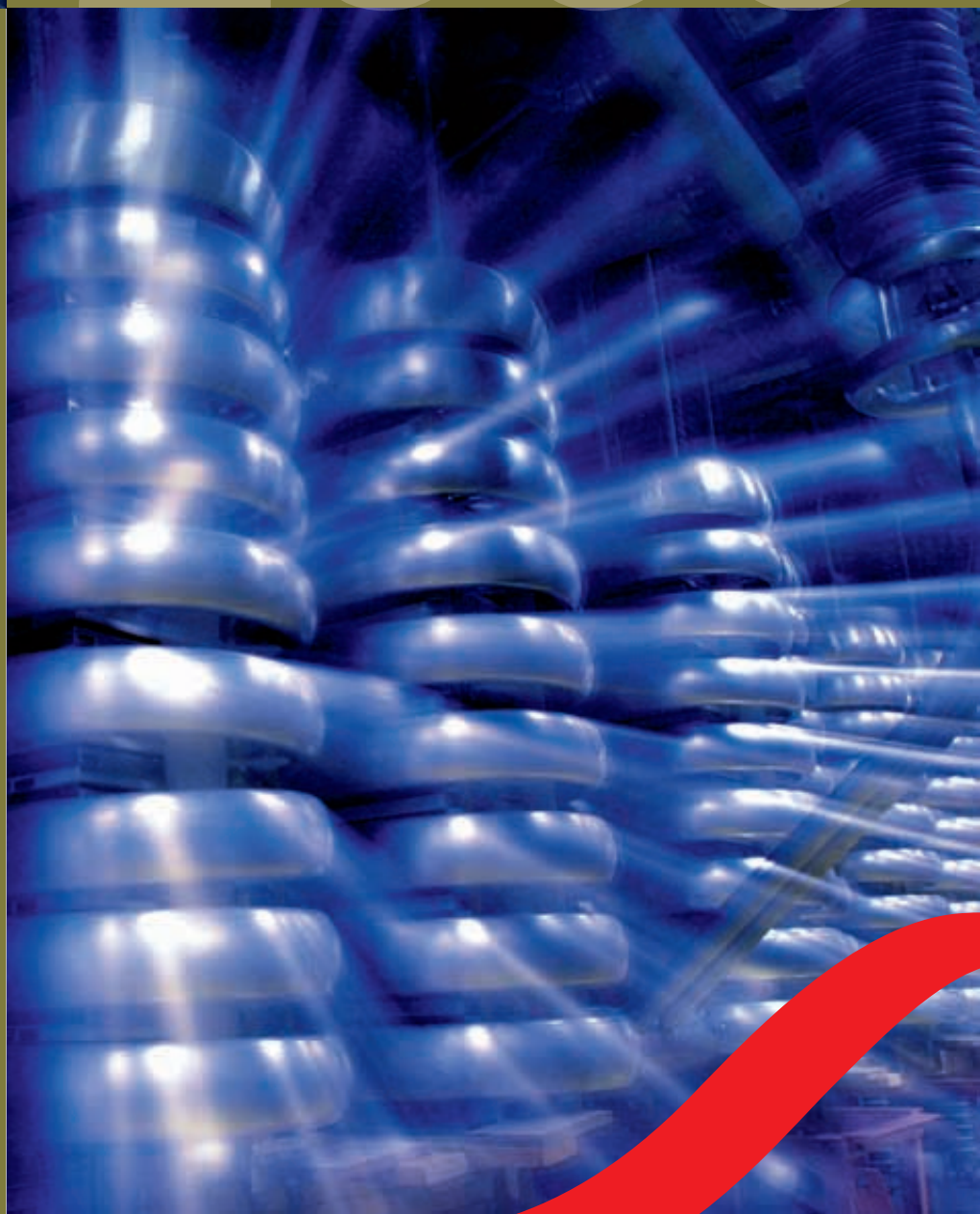
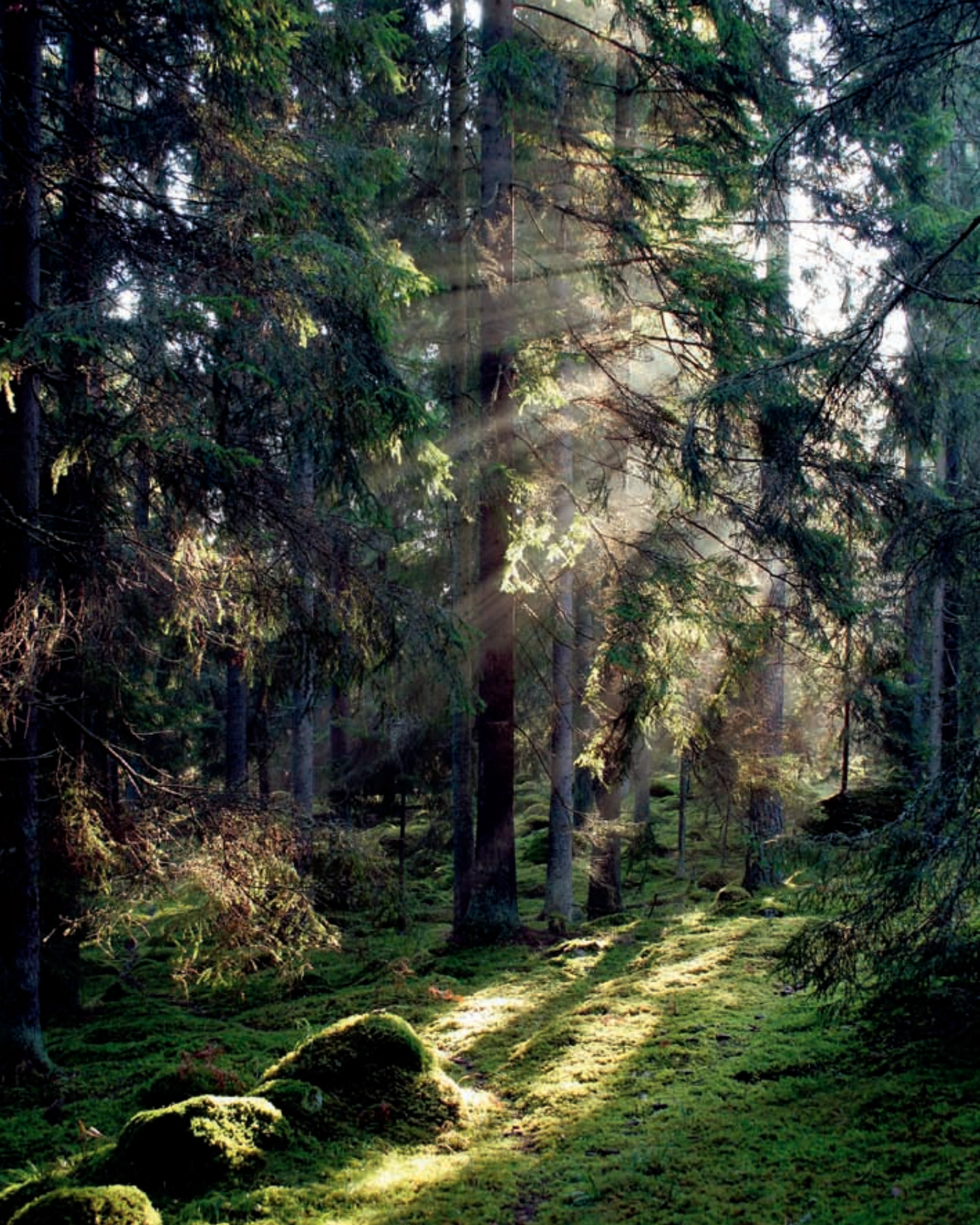
Publication Year 2009

Swedish Energy Research 2009





Usefull results

Efficient bioenergy systems, heat-pumps for heating and modern power transmission technologies adapted for electricity grids supplied by wind and solar electricity are major achievements of Swedish energy research. These success stories were initiated by my predecessor or directors before him.

Implementation of research often takes time – a decade or so. But the societal pay-back may still be significant. The free, low temperature, heat sources now utilised in Sweden via heat-pumps may be calculated to pay all heat-pump research and development funding in less than a week.

A grant from our agency of 40 million SEK to demonstrate a transmission technology connecting some early wind-power plants to the old grid led to a 4000 million SEK, rapidly growing, market ten years later.

The bioenergy research driven by industrial needs have contributed to Sweden enjoying more energy from biomass residues than from fossil fuels for stationary energy – a system that have been especially enjoyable since oil prices started rising and now appears to stay above 50 dollars per barrel.

After a year in office I am happy to have many experienced individuals in the organisation. Civil servants, who have used their scientific and bureaucratic skills to bring about the successes described above. And there are many other results too.

But there are changes going on. As the new director of the agency, I have also enjoyed the company of a largely new set of members in the Energy R&D Board.

Energy research has always had a role in the long-term development of the Swedish energy system, directed by policy towards a more efficient system fed with renewable energy. Recently the ambition has become more urgent.

The ambition is no longer a local political ambition repeatedly questioned by economic interests representing the parts of society that would not see themselves fit in such a scenario.

The same ambition is now European or even global. The relevant technologies have reached markets and their use is growing. Oil prices, climate change concerns and security of supply issues have created a desire for efficient sustainable energy. And most industries have developed strategies to take advantage of the development.

In our research activities the new setting has implied more international co-operation. Nordic Energy co-operation is increased with a top level research initiative. We do more in an European context, we are more active in the International Energy Agency and we are more involved bilateral co-operation with China, the US, India, Brazil and others.

The oil situation has created threats and opportunities for the transport sector. Our engagement in vehicle and propulsion research has taken a leap forward in the last few years.

We are also more eager to see rapid utilization of research results. As demand is strong we hope to see current R&D projects – like the electric-hybrid forest-machinery and wave-power R&D described in the following pages – in use faster than the successful projects I described in the beginning.

Welcome to enjoy Swedish Energy Research 2009!

Tomas Kåberger is the general director of the Swedish Energy Agency.

The Swedish Energy Research Programme

The Swedish Energy Agency is responsible for Sweden's national energy research programme. Working closely with academia and industry, the Agency finances energy research, technological development and demonstration activities.

The objective of energy research

The objective of energy research is to "... acquire and develop such scientific and technical knowledge and competence within universities, institutes of technology, other research institutes, public authorities and industry as are needed to assist the move towards a long term sustainable energy system in Sweden through application of appropriate new technology and services, and to develop technologies and services that can be commercialised by industry in Sweden, thus contributing to the move towards a sustainable energy system and to developments both in Sweden and on other markets."

The objective is that these activities should result in application and/or commercialisation, which is essential if the work is to contribute to achieving the energy and climate policy targets. The results are expected to contribute to development of the Swedish energy system and business in the energy sector, and form a basis for supporting well founded energy and climate policy decisions.

Energy research: A part of the long term energy policy

Energy is a key factor in the development of any society. Today, the question of how to combat climate change while providing energy to a growing population is dominating the world's political agenda. At the end of 2008, the EU decided on tough objectives to reduce greenhouse gas emissions: a 20 percent reduction of CO_2 emissions by 2020, or 30 percent within an international framework, as well as binding targets for energy efficiency and renewable energy.

Greenhouse gas emissions must continue to be reduced even after 2020, which will require not only improvements in the efficiency of energy use, but use of a greater proportion of CO_2-neutral energy. Although renewable energy will play an important part, no renewable energy supply on its own can meet the world's energy requirements. Neither can carbon capture and storage or nuclear power meet the challange on their own. Local production of energy is important for energy supply.

As with many national energy policies, the overall aim of Swedish energy policy is to reduce the impact of energy use on the global climate, while creating favourable conditions for economic growth and securing energy supply. To meet EU objectives and to increase Swedens ambitions for climate and energy, the Swedish government presented a new cohesive climate and energy policy in March 2009. The government proposed a 40 percent reduction in climate gas emissions, an energy supply consisting of at least 50 percent renewable energy, and 20 percent more efficient energy use by 2020. The vision is to achieve zero net emissions of greenhouse gases by 2050. The government also decided on three priorities:

1. The use of fossil fuels for heating to be phased out by 2020.
2. By 2030, Sweden should have a vehicle stock that is independent of fossil fuels.
3. Renewable power production should be developed to become a third significant source of electricity production (in addition to nuclear and hydro power).

Energy research can contribute to achieving these targets through the creation of new knowledge, development of new technology,

formation of new companies, and identification of key players who may contribute to the process of transferring the results of research to applications in industry and society as a whole.

Energy research has been a part of Swedish energy policy since the seventies. The aim of the research and development (R&D) programme was originally to reduce dependency on imported oil. From the early eighties until the present day, a strong emphasis has been placed on energy efficiency and renewable energy. Since 2006, the programme has concentrated on fewer topics than before, but with greater emphasis on the utilisation of R&D results in practical applications in industry and society as a whole.

Knowledge, competence and commercialisation

The national energy research programme contributes to the creation of knowledge and understanding of the energy system through supporting research at universities and research institutes and in the private sector. It promotes the development of new technologies, their commercialisation and introduction on the market. Research helps to reduce the costs of new technologies and

The Energy R&D Board is appointed by the government, and is the decision making body for research funding. Members in 2009 were Tomas Kåberger (Chairman), Albin Andersson, Björn Sanden, Hasse Johansson, Bo Normark, Lena Neij, Susan Persson, Helen Andréasson och Eva-Katrin Lindman. Maria Sandkvist and Tomas Hallén is missing from the picture.

system solutions in the fields of energy efficiency and renewable energy. Energy research is also intended to create stable conditions and to support renewal and development to strengthen the industry and its competitiveness.

Lead times between research and implementation are long. Results being implemented today stem from work that was started ten or twenty years ago. To meet the challenges of the future, energy research requires a long term approach, an overall view and patience.

Achieving a sustainable energy system through policy measures

Although energy research, development and demonstration (RD&D) activities are necessary for a transition to a sustainable energy system, they are not enough on their own. Synergies with other measures, such as legislation, taxation, standardisation, grants and other financial incentives, as well as information to consumers and producers, are essential in order to reach the objectives. An example of one such instrument is the taxation of carbon dioxide emissions, which is intended to discourage the use of oil for heating purposes. Another example is the electricity certificate system, which supports increased production of electricity from renewable energy sources, such as bioenergy, wind power, hydro power and peat. Another important policy measure is that of technology procurement, which stimulates and accelerates the development and introduction of new technologies. Technology procurement of new products, systems or processes is intended to meet purchasers' needs better than existing products on the market.

A more sustainable energy system

Commercialisation has already resulted in a more sustainable energy system.

The results from more than thirty years of Swedish energy research play an important part in Sweden's energy system today. Heat pumps, CFC free refrigerators, energy crops, large scale and small scale biofuels combustion technology, flue gas

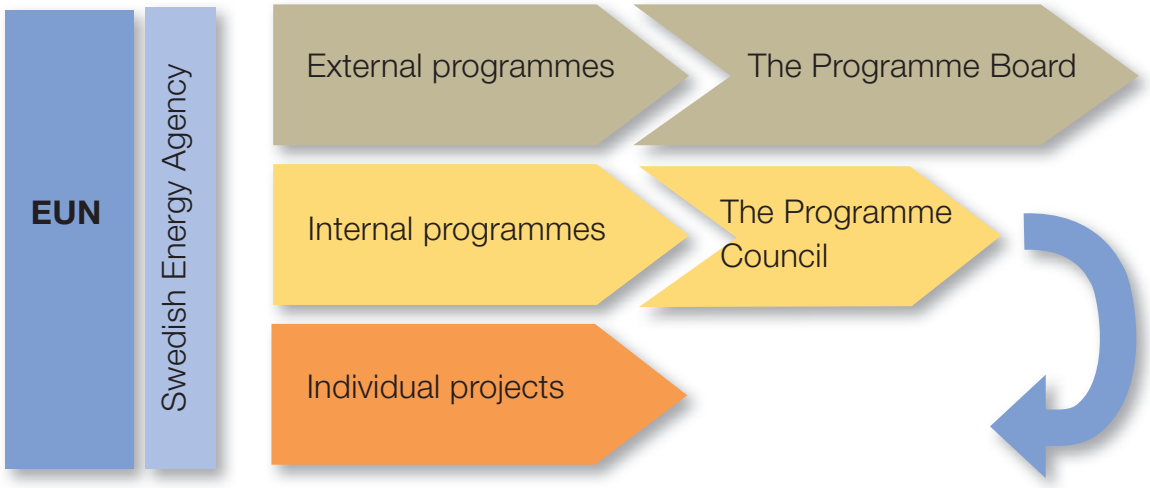


FIGURE 1: *The Energy Research and Development Board (EUN) makes the decisions concerning the Agency's financing of research and development, but can delegate decisions to the Director General. For external programmes, financing decisions are taken by the Programme Board: for internal programmes, financing is decided by the Energy R&D Board or by the Director General, after assessment by the Programme Council. Individual projects are considered by the Agency, with the financing decision made by the Board or the Director General.*

condensation, district cooling and energy system models are some examples of products and services that have been successful on Swedish and global markets, and where the energy research programmes have contributed in a significant way. Early energy research has also contributed to the present situation. Sweden finds itself in a relatively advanced position as far as fulfilling climate obligations, and in regard to other environmental objectives, are concerned. As a result of energy research and use of Sweden's natural resources, the country is not as highly dependent on oil, natural gas, coal or other energy imports as are many other countries in Europe. Swedish companies are successfully exporting both environmental and energy technology, making a substantial contribution to reductions in energy use.

How the Swedish Energy Agency works

The members of the Energy R&D Board are appointed by the government, and are the ultimate decision making authority for the energy research programme. It is normally the Board itself that decides on larger programme commitments and larger individual projects.

Long term energy research in the National Energy Research Programme is divided into six thematic areas: Energy System Studies, the Building as an Energy System, the Transport sector, Energy-intensive Industry, Biomass in Energy Systems and the Power System. In each of these areas, research is organised mostly into specific programmes, the number of which can vary with time, depending upon identified research needs. In 2008, about 42 programmes were active, in addition to a large number of individual projects. Working in thematic areas facilitates coordination and information exchange between different technology areas. Any synergy effects or overlaps between different theme areas are handled at a high level, and further investigated or monitored as part of the work of the Energy Systems Studies working area.

Sectorial advisory boards have been

Thematic Areas

The National Energy Research Programme is divided into six thematic areas:

- Energy System Studies, page 16
- The Buildings as an Energy System, page 20
- The Transport sector, page 26
- Energy-intensive Industry, page 32
- Biomass in Energy Systems, page 38
- The Power System, page 46

established for each of the six thematic areas, bringing together experts from industry, public authorities and other stakeholders, and supporting the Agency in developing strategic research plans for each thematic area. The boards also assist the Agency in identifying and analysing the needs of different players that are energy users, and in identifying obstacles that could prevent the energy system from operating effectively.

From fundamental research to market

The Agency is responsible for all aspects of the innovation system in the energy sector. All initiatives aim to achieve a core of benefit from, and commercialisation of, the results in order to ensure that they contribute to economic growth and the acquisition of knowledge that can help to improve competitiveness. This means that work is often fokused on areas for which there is a global market and where Sweden has favourable export prospects. In addition to financial support, the Agency also provides active business development support with the aim of exploiting the results of research.

Industrial participation doubles funding

Research is carried out by universities, institutes of technology, various sector and research institutes and by industry. Fundamental research at universities and institutes of technology may receive 100 percent state funding. However, the closer to the market a technology, product or service becomes, the higher the proportion of the costs are financed by industry. Industrial research which is to a greater extent applied, can (e.g.) receive only a maximum of 50 percent of its finance from the state in the form of energy technology funding. Activities even closer to the market, i.e. experimental development, may be funded only to a maximum of 25 percent. This means that researchers, companies etc. must contribute to the

FACT: One fifth is bioenergy

- When the first oil crisis struck at the beginning of the 1970s, almost 70 percent of Sweden's energy was supplied by imported oil. Today, fossil fuels provide about a third of the country's energy supply.
- Bioenergy provide about a fifth of the country's energy; 116 TWh 2006. About half of this energy is used in the forest products industry.
- District heating provides about half of the heating requirement for residential buildings and commercial premises in Sweden. Almost three quarters of residential buildings are heated by district heating.
- District heating is the dominating form of heating in the central parts of almost 250 of the country's 290 municipalities.
- In 1970, bioenergy provided 2 percent of district heating. In 1980, oil still supplied 90 percent of the energy input to district heating plants. Today bioenergy, waste and peat provide two thirds if the energy input.
- Since 1990, the use of wood fuels in the district heating sector has increased by more than five times.
- Wood fuels supply about 20 TWh of the 36 TWh of district heating supplied by bioenergy, peat and waste.
- In 2006, bioenergy also produced a total of 10 TWh of electricity, of which 6 TWh came from CHP plants.
- Expressed as carbon dioxide equivalents, Sweden's total emissions of greenhouse gases in 2006 amounted to 66 million tonnes.

funding of the project. Financial support from industry ensures the industrial relevance of the work, effectively more or less doubling R&D funding (see Figure 3).

Working together in Competence Centres

Competence Centres are fora for research cooperation between universities, companies and the Swedish Energy Agency. Research is concentrated on companies' long term interests, and can often range over several disciplines. The intention is that universities are involved in meeting the research needs of industry, while at the same time delivering results of an assured high scientific quality. The time between research and implementation is shortened. The centres contribute to 'adding know-how', both in terms of producing well-educated persons and of new knowledge as such.

Financing of these Competence Centres is shared equally by the three parties: academia, industry and the Agency. A necessary condition for effective cooperation and application of results is that there must be special agreements that set out the parties' commitments and ownership of results.

The Agency is at present financing six competence centres: the Combustion Engine Research Centre (CERC) at Chalmers University of Technology in Gothenburg, the High-Temperature Corrosion Centre (HTC) at Chalmers, the Catalysis Competence Centre (KCK) at Chalmers, the Electric Power Engineering Competence Centre (EKC) at the Royal Institute of Technology in Stockholm, the Competence Centre for Combustion Processes (KCFP) at Lund Institute of Technology, and the Centre for Internal Combustion Engine Research Opus (Cicero) at the Royal Institute of Technology.

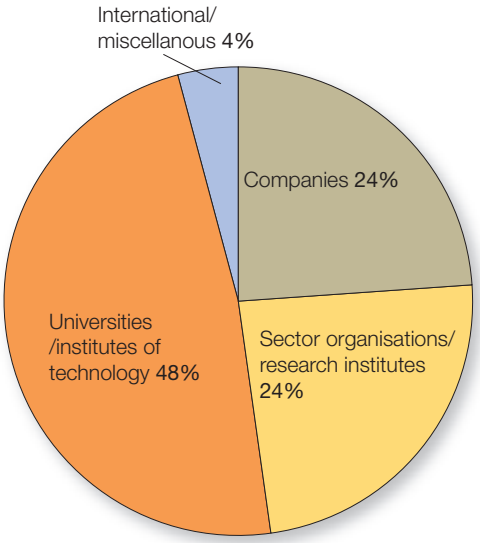
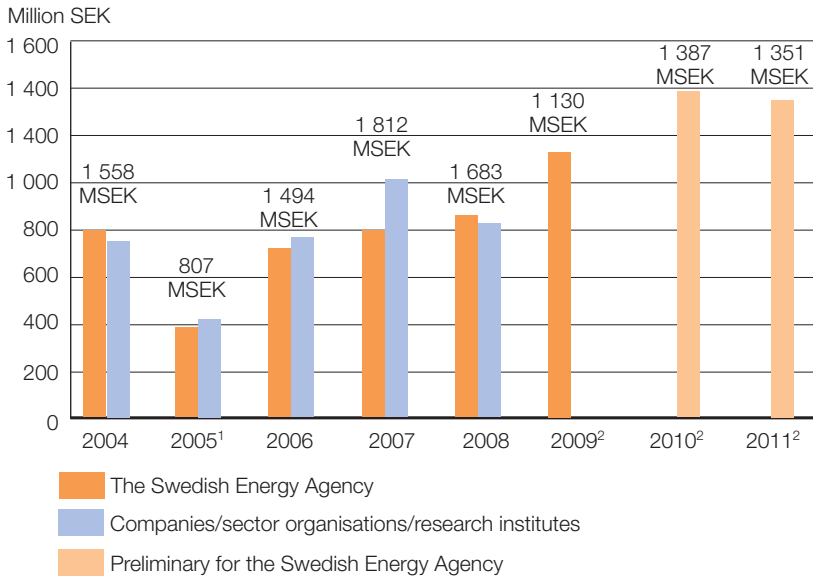


FIGURE 2: *Recipients of funding in 2008*

FIGURE 3: *Industrial participation doubles funding*



1. 2005 saw a temporary reduction in public funding of research activities.
2. The figure for 2009 is as allocated in the national budget for the year, while those for 2010 and 2011 are as presently expected.

International cooperation is essential

In proportion to its GDP, Sweden is one of the countries that invests more in energy research and development than does other EU country. Developing and introducing new energy solutions to the market requires a high degree of specialisation and cooperation between experts from many fields and organisations in different countries. For a small and R&D-orientated country such as Sweden, international cooperation is an essential part both of energy policy and energy research policy.

The fora utilised are primarily the EU Seventh Framework Programme, the International Energy Agency, the Nordic Energy Research Programme and bilateral agreements with a number of strategically selected countries.

EU membership increases the scope for international cooperation

Increasingly, research in Europe is carried out sharing the work between countries. It is therefore important that Sweden's research environments possess the skills and characteristics that make them interesting for international stakeholders. In some areas, it is more cost-effective to work with other countries than to establish Sweden's own research. An essential aspect of membership of the European Union is also that it gives access to an important market for Swedish exports, giving increased opportunities for commercialisation of research results.

New EU directives in the energy sector influence the research agenda and development activities to greater or lesser extents. Another international area that can have an effect is standardisation, where various elements of research may also be involved.

EU's Seventh Framework Programme

The Seventh Framework Programme for Research and Technological Development (FP7) is the EU's main instrument for funding research in Europe, and runs from 2007-2013. In it, the Energy thematic area has a budget of about EUR 2 350 million. On assignment from the government, an expert from the Swedish Energy Agency takes part in the work of the Programme Committee for the Energy thematic area. The Committee is consulted by the European Commission on the issues of objectives and content of annual Work Programmes, which form the basis for calls for proposals.

Co-funding research with FP7

The Swedish Energy Agency can co-fund research projects in Sweden that receive financing from FP7.

Research funding bodies work together, publishing common calls for funding of applications

The concept of a European Research Area (ERA) was launched in the Sixth Framework Programme. Its intention is to bring together the European Community's

R&D resources in order better to coordinate research and innovation activities at the level of both the member states and the European Union. In order to facilitate coordination between member states, an instrument known as ERA-NET has been introduced in the Framework Programme. The objective is for research-funding bodies within the ERA to work together more closely and coordinate research and development efforts that would otherwise be carried out at a national level. Within each network (ERA-NET project), the intention is that the countries involved should inform each other of their respective programmes and activities, as well as identify obstacles and opportunities for increasing coordination of research and development. The countries can also decide on common activities and develop a strategy for carrying them out, as well as investing in projects that involve several countries.

Work has reached different stages in the various ERA-NETs. ERA-NET Bioenergy, for example, has published three calls for project proposals. The exchange of information within ERA-NET is particularly valued by the partners involved in the work.

EU technology platforms for world-leading research and development

The Seventh Framework Programme has introduced a new concept for the EU – Technology Platforms. The purpose of these platforms is to bring together representatives of companies, research institutes, public authorities and consumers. Working in specific and carefully delineated technical development areas, the different parties are intended to develop common European visions of technical development and identify possible ways forward, known as Road Maps.

ERA-NET

The Swedish Energy Agency is, or has been, a member of five ERA NET: Bioenergy, Hydrogen (HY-CO ERA-NET), Solar Cells (PV ERA-NET), Innovative Energy Research (INNER ERA-NET), and Eracobuild for the construction and property management sector. The Swedish Research Council Formas provides energy-related research funding. Formas also participated in ERA-NET for the Eracobuild construction and property management sector, Sustainable Urban Development (URBAN-NET), the wood and wood fibre WoodWisdom network, and the CIRCLE climate change network.

SET Plan

The SET Plan contains a number of European Industrial Initiatives. The aim of these Initiatives is to strengthen industrial research and innovation, and to achieve key objectives in six priority sectors:

- Wind power
- Solar energy
- Bioenergy
- CO_2 capture, transport and storage
- European electricity grid
- Sustainable nuclear fission

The EU's Strategic Energy Technology Plan (SET-Plan)

In 2007, the European Commission published its proposal "A European Strategic Energy Technology Plan (SET Plan) – Towards a low-carbon future". One key element of the SET Plan involves setting out a long-term energy research, demonstration and innovation agenda for Europe, to guide the research and development of new energy technologies and promote their uptake by the market. The Plan also includes a governance structure and mechanisms to guide and track implementation of the Plan. A high-level European Community Steering Group for Strategic Energy Technologies has been created to coordinate and facilitate joint efforts.

It is important for Swedish energy R&D to take account of the joint European efforts in the SET Plan. Some of the Industrial Initiatives are highly relevant to important parts of Swedish industry. The work is also essential in ensuring fulfilment of EU and national targets for 2020.

More effective research through IEA cooperation

The International Energy Agency (IEA) is one of the most essential international cooperative fora for Swedish energy research. The Swedish Energy Agency participates together with the Ministry of Enterprise in IEA's higher management bodies, such as the Committee on Energy Research and Technology (CERT) and the Standing Group on Long-Term Co-operation (SLT). The IEA work also engages a large number of Swedish researchers and representatives from industry. Within IEA, there are 41 technology orientated cooperation groups, known as Implementing Agreements (IA). Belonging to 23 IAs, Sweden is one of the countries participating in the largest number of IAs. Work is carried out mainly in the form of limited time projects, known as Annexes or tasks, within each IA. Production of In-depth Country Reviews, to provide assessments of energy policy in member countries, forms an important part of work within the framework of IEA.

Country Review of Sweden

An In-depth Country Review of Sweden was performed in 2008. The key recommendations were to:

- Clarify the conditions for the use of existing and future nuclear power capacity, with due consideration of electricity prices, climate change mitigation and security of energy supply.
- Continue efforts to reduce the use of oil in the transport sector, especially by encouraging more efficient fuel use and by promoting alternatives to oil-based road transport, including transport of freight.
- Focus efforts to increase the supply of renewable energy on sources that are deemed the most sustainable, based on an evaluation of their economic, environmental and social benefits.

The Nordic Energy Research Programme

The Nordic countries have a similar approach to, and share, high ambitions regarding renewable energy and energy efficiency. A common Nordic Energy Research Programme has been running since 1985. At first, the focus was on researcher mobility between countries and grants to scientists enabling them to collaborate with other Nordic universities. Since 1999, the Nordic Energy Research Programme has been organised as a Nordic institution of its own under the Nordic Council of Ministers, with headquarters in Oslo. The research programme is strategically concentrated on a number of priority areas. Overall strategy and detailed application plans are determined for a four-year period at a time. For the current period, 2007 to 2010, funding is being provided for research in the fields of integration of energy markets; renewable

energy; more efficient use of energy; the hydrogen society and climate change resulting from activities associated with the energy sector. The Nordic Energy Research Programme is at present running 16 projects in these areas within the framework of its long-term research portfolio. In addition, it is also participating in a number of ERA-NET projects.

Country Review

- Funding from the Nordic Energy Research Programme facilitates trans-national networking and increases the status of each country's research.
- The value of networking and contacts should not be underestimated, and there is much to be gained from participating in Nordic energy research projects.

A new top-level research initiative

The idea of a top-level research initiative within the sphere of overall Nordic cooperation was launched at the summer meeting of the Nordic Council of Ministers in Finland in 2007. The initiative is in a start-up phase at present, with the Nordic governments having agreed to invest SEK 480 million over the period 2009-2013 for research and development of new technology to do with climate, the environment and energy. The initiative is not concentrated only on research into new technology or development thereof, but is also partly a research programme aimed at better understanding of climate and associated areas of relevance.

Top-level research initiative

The top-level research initiative for the environment, energy and climate consists of six sub-programs:

- Effect studies and adjustment to climate changes
- Interaction effects between climate changes and ice, snow and glaciers
- Nanotechnology and energy efficiency
- Integration of large-scale wind power
- Sustainable bioenergy
- Separation and storage of carbon dioxide

In addition, within the framework of the above themes, the programme will also include advanced climate modelling, social science and liberal arts.

Bilateral agreements

Sweden has bilateral agreements concerned specifically with energy with several countries: Brazil, India, China, Poland, Ukraine and the USA, and one with the state of California. The following paragraphs briefly describe those involving cooperative energy research.

Sweden – China

Discussions on cooperation on research and development in the bioenergy field have been in progress since 2005. One project has started, intended to investigate the research environments and research areas that should be given priority. In addition, the links between research and development and the Kyoto Protocol's flexible mechanisms (CDMs) and related projects will be investigated with the aim of designing business models for application of Swedish know-how and technology in the bioenergy sector in China. In addition to this, a programme of researcher exchange between Sweden and China has already started.

Sweden – India

In 2005, India and Sweden signed an agreement on cooperation in the fields of science and technology. Four areas of cooperation are listed under a Protocol of Cooperation; one of them being "Sustainable Environmental Technology". Scientific contacts through exchange visits and participation in scientific activities, such as joint projects, workshops/discussion meetings, training courses, science and technology exhibitions etc. in each country are assisted.

Sweden – USA

An Implementing Arrangement forming part of the 2006 agreement between Sweden and the USA, concerning scientific and technical cooperation between the two countries, includes an agreement on special cooperation in the energy sector. The Arrangement concerns cooperation on research and development of products, services and resources relating to renewable energy. The main concentration of the work is on biobased motor fuels, but other areas such as improvements in the efficiency of energy use can also be covered. The emphasis is on cooperation in research, but can include information exchange, standardisation and market development.

Sweden – Brazil

A memorandum of understanding between Brazil and Sweden was signed in September 2007 concerning cooperation on bioenergy, including biofuels. It governs cooperation on policy dialogues, research and development, cooperation with third party countries, and encouragement of trade and investments.

The Swedish Energy Agency's climate policy research programme

The Swedish Energy Agency is the main Swedish financier of international climate policy research in a number of Swedish research groups. Through this work, the Agency assists researchers from developing countries to participate in international research. The Agency also collaborates with research institutes in developing countries in connection with the implementation of Clean Development Mechanisms (CDM) under the Kyoto Protocol.

Fact: IEA

The International Energy Agency (IEA) is an intergovernmental organisation which acts as energy policy advisor to 28 member countries in their efforts to ensure reliable, affordable and clean energy for their citizens.

The five main IEA committees are:

- Committee on Energy Research and Technology (CERT)
- Standing Group on Emergency Questions (SEQ)
- Standing Group on Long-Term Cooperation (SLT)
- Standing Group on the Oil Market (SOM)
- Standing Group for Global Energy Dialogue (SGD)

Most energy research work is dealt with by the Committee on Energy Research and Technology. Swedish work with the various Implementing Agreements is carried out within the following working parties (the figure indicates how many IAs Sweden participates in per Working Party):

- Working Party on Fossil Fuels (2)
- Working Party on Renewable Energy Technologies (6)
- Working Party on Energy End Use Technologies (12)
- Cross-cutting activities (3)

THEMATIC AREA

Energy System Studies

Energy system research is concerned with the interaction between people, organisations, institutions and technology. It is often aimed at acquiring knowledge of synergies to provide a better decision making basis for those involved in the energy system, whether they are politicians, companies, organisations or households. Energy System Studies are often cross disciplinary or multi disciplinary, which is of importance for drafting policy measures, negotiations on climate policy or creating future visions of the energy system.

Research direction

System research is focused on studies that:

- assist politicians and authorities to make energy policy decisions
- assess the use of available policy measures
- facilitate a responsible discussion with different parties about future development
- deliver broad knowledge of complex questions to various stakeholders
- apply a long-term perspective (future studies)
- provide material for climate policy negotiations, and
- assess different technology alternatives.

Both technology and social science use the term 'system'. Studying 'technology as a system' means different things to different persons, depending on the working area and views of those concerned. For the Swedish Energy Agency, the Energy Systems Studies thematic area includes not only system science research as often defined by scientists, but also investigations of the behaviour and actions of individuals or organisations, viewed from such perspectives as the national economy, legal aspects or sociology.

The basis for this system perspective is that all technology can be seen as closely or loosely linked parts that create a whole. Technically, an energy system can be defined as consisting of a number of sub systems, either hardware-defined, such as a district heating plant and distribution system, or an electricity distribution network, or structure-defined, such as a utility owned by a local authority. But these technical systems are owned, controlled, developed, operated and used by many parties and organisations, all of whom affect the various systems and who can be regarded as connected with them.

Energy systems and those involved in or with them are also affected by taxation, legislation, regulations and events in the wider world. Most of these factors also have reciprocal effects upon each other. It is therefore not sufficient to look for one answer to a question at a time, as this fails to consider the underlying understanding of the relationships within the whole. If questions are, instead, put from a system perspective, it should be possible to build up a multi faceted view of the energy system's function, and to develop conditions promoting work towards sustainable energy systems. An important element of the work in this thematic area is that although it is individuals who construct and build the systems, the systems in their turn affect society, organisations and individuals.

The potential of energy behavioural change

Consumers reveal their behaviour towards, or awareness of, energy matters through their investment responses or actions and their habitual patterns of energy use. Changes in consumer behaviour can lead to significant savings in energy use. Savings occur as a result of changes in energy use, such as change of lifestyle, increased awareness, low-cost actions or minor investments.

Transition of the energy system

Energy systems play a central part in the development of society, not least against

the background of growing demands for efficient and long term sustainable management of the earth's resources. Changing energy markets, developments on the oil market and the threat of climate change, are examples of factors that mean that we must increasingly regard energy from an international perspective. New energy and climate policy measures are being drawn up both nationally and internationally.

Bearing in mind the general principle that system research should focus on and facilitate transformation of the energy system, the overall criteria for prioritising among the activities include studies that:

- clarify relations between different sectors, and underpin dialogue and more desirable solutions (i.e. avoiding sub-optimisation),
- facilitate energy policy decisions and long-term consistency in energy policy,
- apply a long-term perspective (20–100 years), and identify those measures and connections, obstacles and opportunities, that are most important for evolution of the energy system;
- employ a system approach to deliver broad knowledge of complex questions to various stakeholders.

Add to this a general need to develop methods and theory of energy systems research.

The Energy Systems Programme and research school

The Energy Systems Programme trains scientists with a broad system view of energy matters

The Energy Systems Programme brings together five departments at four Swedish universities to train PhD students and develop knowledge concerning the energy system. The programme has two main elements: a long term research component, and a graduate school that trains groups of PhD students. Between ten and fifteen PhD students are accepted every two years for training. The course is cross disciplinary, with elements of both technology and social science, and aims to provide the future PhDs with a common level of general knowledge within the energy sector and a diverse basis for their continued work. At the same time, they acquire advanced specialist knowledge within their respective research areas. From an international point of view, the school is unique in its objectives. Many of those who have presented their theses continue to

Power Aware Cord. Concept by Interactive Institute.

Energy systems course for graduate students

In collaboration with a university consortium, the Swedish Energy Agency operates an energy systems course for postgraduate students. The course is intended for doctoral students funded through the agency's programmes, but is also open to other graduate students. The aim is to provide a good knowledge of the Swedish energy system and its various components, as well as international links. The course is also intended to contribute to cross-sector contacts and networking with researchers working in different scientific disciplines.

work in the energy sector, in key positions in industry and administration. By 2007 the programme celebrated ten years and 40 PhD.

International climate policy

As the main financer, the Swedish Energy Agency has contributed to the establishment of climate policy research by a number of research groups at different Swedish universities. The agency also sponsors leading international research programmes. Questions addressed include: What solutions should be promoted to reduce emissions in order to tackle climate change, and how do different measures relate to each other? How quickly can new technology find its way onto the market? What is the cost of climate change mitigation, and what policy measures are necessary in order to do so cost-effectively? What policies should be implemented to provide a realistic reduction of land use-related emissions? How can Swedish experience from energy and climate policy implementation be transferred to developing countries?

The research is divided into four areas:

- Strategic aspects concerning the Kyoto Protocol and post-Kyoto negotiations
- Climate policy instruments in the context of acceptance, technology diffusion and policy transfer
- The carbon market within the context of post-2012 negotiations
- Sustainable Development – Policies and Measures: from side effects to co-benefits.

The General Energy Systems Programme

The General Energy Systems Programme has a long history. Within the programme, research is conducted in two major areas:

- The cost efficiency of policy measures and their suitability for their respective purposes. The liberalisation of energy markets has led to a greater need for understanding of how policy instruments work, how they interact and how they can be employed to contribute to the overall goals of tackling climate change, assuring energy supply and maintaining or increasing industry's competitiveness.
- The energy markets and their parties, as well as technology shifts. The internationalisation of energy markets and efforts of the EU to create an internal market for energy make it more important to understand how energy markets work, how those involved behave (especially the interaction between supply and demand side), and how the markets themselves interact. The liberalisation of energy markets has turned the spotlight on the previously neglected area of consumer behaviour. To understand future developments, we also need a greater understanding of technology changes, factors underlying change and the effects of change.

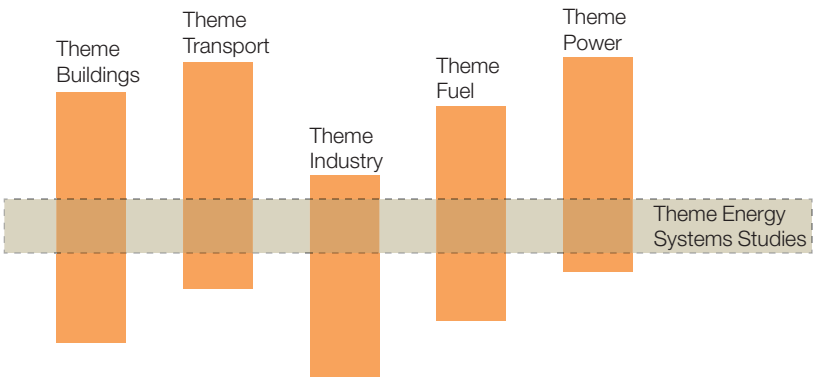
Research is also conducted within the following three subsidiary areas:

- Development of methods and models for energy system analysis and production of future scenarios
- System critical research and comparative studies
- Gender and generation perspectives.

The LETS Research Programme

The LETS programme ("Governing transitions towards low-carbon energy and transport systems 2050") is hosted by Lund University and runs from 2008 until 2011.

FIGURE 4: *The systems perspective cuts through all technology areas.*



The basis of the system perspective is that all technologies can be seen as closely or loosely linked parts of a whole. Some research fields, such as gasification, are applicable to several theme areas.

The main purpose of the programme is to identify and explore routes to implementation of low-carbon energy and transport systems for 2050, in order to achieve ambitious climate policy objectives. The core question is expressed as: "What societal changes are implied by low-carbon futures, and how can these changes be governed and implemented?"

The programme is organised in five research areas:

- Future Policy Scenarios and Alternative Pathways
- Governance: Developing Institutions and Policy
- Urban and Regional Planning and Infrastructure
- Markets, Industry and Policy for Bioenergy
- Citizen-consumers and Voluntary Instruments

Energy, IT and Design

In 2006, the Agency started an R&D programme under the title of Energy, IT and Design. The main emphasis of the programme is to influence the everyday habits, values and behaviour of users as far as improving the efficiency of energy use is concerned, with some concentration on improving the efficiency of electricity use through application of both IT and design. It has been calculated that the potential for improvement in the efficiency of (in particular) electricity use in residential buildings is of the order of 20–30 percent.

The programme's vision is that of a society in which members are aware of their daily energy use and can easily control it, whether at home, at work or while travelling, to create a society in which its members' use of electricity is characterised by high and improving efficiency, and with Swedish industry being a leader in terms of products and services for improving the efficiency of energy use.

The programme aims to combine competence in the IT sector with design competence and knowledge concerning individuals' attitudes towards electrical energy, their everyday habits and use of technology. This is an applied programme, intended to result in a number of prototypes and demonstration activities:

- Attractive design solutions are intended to make individuals aware of their daily use of energy.
- Informative IT solutions provide detailed and usable information on energy and electricity consumption.
- Simple but at the same time advanced IT solutions enable operation and control of residential energy use.
- Relevant and motivating decision making material that assists the move towards more resource efficient and energy efficient everyday habits.

THEMATIC AREA

The Building as an Energy System

Although research into the design and construction of buildings with higher energy efficiencies has been carried out for many years, the results have been slow in finding their way on to the market. It is important that all parties involved in the sector work together if energy efficient homes and other premises are to be built, and if existing buildings are to be renovated to produce intelligent designs with low energy demands.

The Swedish Energy Agency's vision for the built environment is that, in future, all energy should be used efficiently, and should be supplied from sustainable sources. This means that, for example, interior heating in buildings must be delivered with minimum losses through the building envelope. The amount of any additional heat that may be necessary must be efficiently provided from renewable energy sources. The most suitable choice of heating system for any particular building must be determined in relation to the particular circumstances, with efficiency improvement measures being applied at the correct point. The electricity used in buildings, too, must be from renewable sources.

The overall target is that the use of energy in residential and commercial buildings must be reduced by 20 percent by 2020, and by 50 percent by 2050, both in relation to the 1995 level. Additionally, these reductions must be accompanied by a drastic reduction in the use of fossil fuels for heating purposes. As the rate of new building in Sweden is only one percent of the total building stock per year, it will be necessary – if these targets are to be reached – to achieve the energy efficiency improvements mainly in existing buildings. This can be done through more efficient maintenance and operation of buildings, and/or by renovation and conversion. There is a substantial need for renovation and improvement of residential buildings constructed during the 1960s and 1970s, and it is essential to develop and spread the use of energy efficient designs for ventilation, insulation, windows and lighting etc.

Another important direction of research is users needs and imporved construction processes. Investigations of the construction

FACTS: Research direction

The **Building as an Energy System** research sector is concerned with developing technical knowledge of the building and building services systems, as well as with development of the necessary relationships between systems in order to achieve the desired functions. Energy efficient products and designs are needed both for new buildings and for conversion and renovation. Solutions must also be user friendly, have a long life and have as little environmental impact as possible.

The **Behaviour, Processing and Policy Measure**s sector is concerned with non technical aspects, such as the relationships between the various parties involved in the sector during the design, construction and use stages. Better knowledge is needed in order to enable the many parties involved to work together in order to bring new, energy efficient technology to the market.

process look at how the various parties involved in the sector work together in connection with planning, construction, operation and renovation of buildings. Other areas of investigation focus on how the amount of energy used can be reduced, and with how well occupants' needs are met by the features of buildings and by their services systems. How, for example, can buildings be designed in order to make optimum use of solar heating? Or, conversely, how can building services systems intended to distribute solar heat be best designed to suit the plan, construction and appearance of the building? Research into occupants' behaviour, and into energy policy measures and physical planning, are also important in aiding understanding of the entire energy system relating to buildings. It is important that all those who influence, or who are affected by, the design of a building – from architects, via construction companies, building managers and operators, to residents – should be involved in the renovation and conversion process in order to ensure maximum benefit of any improvement work. In this context, involvement of the management of construction companies is particularly important.

The Swedish Energy Agency has therefore developed a comprehensive programme for energy efficient building construction and facilities management (CERBOF), providing a forum for representatives of the construction sector and research organisations to investigate how energy can be used most efficiently. 33 projects were started in this programme during 2008.

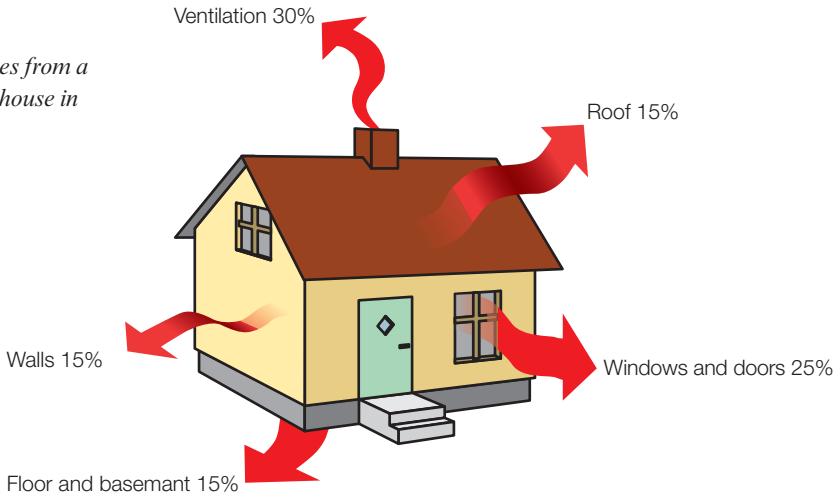
Although present day technology can reduce the amount of energy used in buildings, new buildings are still generally designed and constructed in accordance with traditional principles and using traditional heat sources. However, residential buildings can be designed and constructed so that the amount of energy that they use is less than half of the amount at present specified in building regulations.

Passive houses – houses without heating systems

The term passive houses is used for houses where only a very modest input of additio-

FACT: Energy use

In 2007, energy use in the residential and commercial buildings sector amounted to 143 TWh. After correction for normal-year weather statistics, this represented an increase of 1 TWh relative to 2006. 60 percent of this energy was used for space heating and domestic hot water production, with the remainder being used for powering equipment and building services systems.



Heat losses from a detached house in Sweden.

nal heat over and above body heat from the occupants themselves, heat from electrical equipment and incident solar radiation. Instead, the reduced costs for a heating system are spent on well insulated floors, walls, roofs and windows, in order to ensure comfortable indoor conditions. The heat in ventilation exhaust air also needs to be recovered.

The Swedish Energy Agency has run a demonstration programme under the name of 'Passive Houses and Low Energy Buildings', with the aim of showing how new buildings in the future can use a minimum input of purchased heating energy. This objective will be achieved by improving general levels of knowledge and encouraging development of the necessary skills and awareness in the building industry. The programme is linked to a number of demonstration buildings that will be constructed at different places in the whole country in order to ensure the best demonstration effect. The programme is now under evaluation, but a continuation is foreseen.

Brogården in Alingsås was built during the Million New Homes programme of the 1960s and 1970s, and is now being renovated to bring it up to a high energy standard. This is the first renovation example of which the aim is to reduce energy use levels to those of passive houses. The project has high demands of energy efficiency and of availability. The results are being evaluated by scientists financed by the Swedish Energy Agency.

FACT: Passive houses

The first passive house was built in Germany in 1991, having been developed at the German Passive House Institute, and later at the Lund Institute of Technology. There are at present about 10 000 houses built to passive house standards in Germany, Switzerland and Austria. In addition to houses in Sweden, the concept is also represented in Norway and Denmark.

The customer's needs

In addition to new technical designs and more energy efficient equipment and systems, the move towards a sustainable society cannot disregard the effect of individuals, whose purchasing choices decide the inherent energy and efficiency standards of equipment, and whose behaviour affects the amount of energy drawn by the equipment when in use. Although technical development and policy measures have meant that domestic equipment has become increasingly energy efficient, there has not been a corresponding reduction in the overall domestic use of electricity. Improvements in energy efficiency are sometimes swallowed up by changed behaviour or patterns of use. One example of this is that worn out products that have been replaced for one duty continue to be used in some other context.

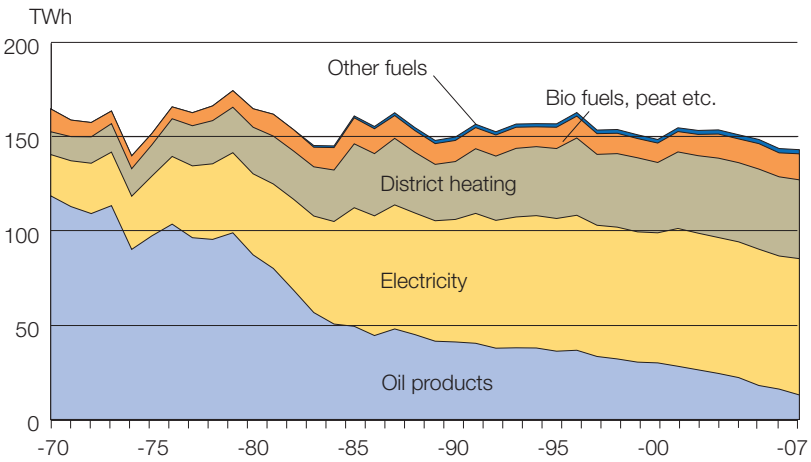
Patterns of domestic electricity use have undergone changes so. Lighting that is now the largest individual item of domestic electricity use, with refrigeration and freezers (which previously accounted for the largest individual load) now taking second place. It is interesting to note that standby energy for electronic equipment is increasing rapidly, to the extent that it is now the third largest user of electricity.

An important element in looking for explanations for changes in the patterns of energy use is that of analysing human behaviour. What are the details of domestic evaluations, habits and behaviour, and what are the factors that affect domestic purchasers and users when deciding on decisions or user situations? To this end, the Elan programme was started in 1998 with the aim of obtaining more knowledge on how behavioural patterns and values affect the use of electricity. The programme is also intended to provide long term consolidation of knowledge, with a sub objective of serving as a knowledge node between electrical utilities, scientists, the state and consumers in the behavioural field of electricity use. The programme, which is jointly financed by the Agency and a number of energy utilities, is financing several projects, aimed at making domestic electricity use visible and analysing patterns of use.

Energy to meet customers' needs

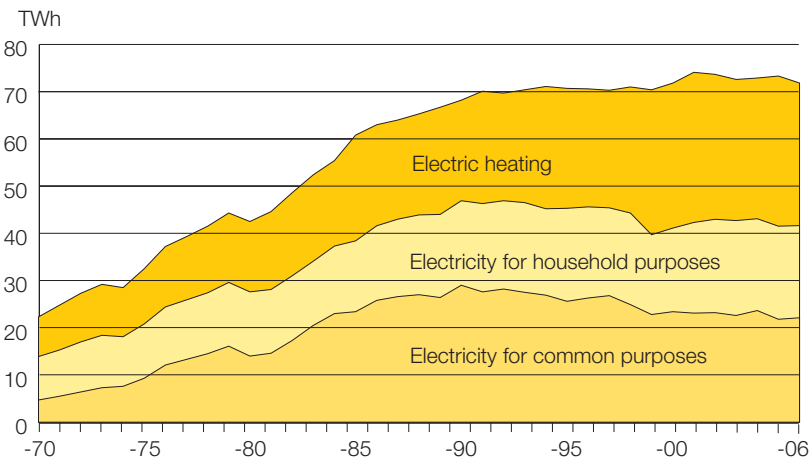
The 'Design for Awareness' project intends to look at energy use from the consumer's perspective. Its aim is to establish conditions for future product development by including energy considerations in the design of everyday equipment. Domestic equipment could, for example, be designed to provide information on, the amount of energy that it is using. Other examples include developing DVD, TV or entertainment centres that do not draw any current in the standby state. This project is one of five that form part of the Energy, IT & Design programme. The objective of the programme is to develop modern IT methods, in combination with product design, that are capable of influencing domestic energy use levels, with particular emphasis on domestic electricity, space heating, domestic hot water production and electric heating.

FIGURE 5: *Energy use in residential buildings and the service sector is relatively constant, although its mix of sources has changed considerably over the years.*



SOURCE: ENERGY IN SWEDEN 2008

FIGURE 6: *The residential and service sector offers substantial potential for improvement in the efficiency of electricity use.*



SOURCE: ENERGY IN SWEDEN 2008

HIGHLIGHT

– a success story where funding from The Swedish Energy Agency has played an important role

Leading heat pumps

Sweden is world leading in heat pumps: several decades of dedicated research have resulted in successful sales and world wide recognition of Swedish expertise.

The market for heat pumps in Sweden saw a rise in sales in the 1970s followed by a fall in the middle of the 1980s, before taking off again ten years later, reaching almost an explosion in sales in the last few years.

Although there are not many heat pump manufacturers in Sweden, the value of their output amounts to several thousand million SEK. However, success has not come without effort: According to Martin Forsén, director of the Swedish Heat Pump Association (SVEP), which brings together about 700 manufacturers and installation companies, it has depended mainly on two factors.

– One is the long term approach to research. The other is the public funding support and the cooperation with Vattenfall. Having the country's largest electricity company on our side has been extremely important. Vattenfall became one of the pioneers when it invested SEK 380 million between 1979 and 1985 to assist the construction and installation of no less than 433 experimental and demonstration installations. This six year support amounted to almost twice as much as the entire funding support from the public purse. From 1975 until today, the state has invested SEK 200 million in the heat pump sector, equivalent to 1 percent of its support for all aspects of energy research over the same period. Nevertheless the results have been excellent.

It was the oil crisis of 1973-74 that prompted Swedish interest in indigenous energy, and thus also in heat pumps. Research and development took off at the end of the 1970s with the support of substantial research funding. One of the large heat pump plants that was built at that time was the Värtan plant in Stockholm, which extracts heat directly from the water of the Baltic. With its 260 MW, it is still the world's largest heat pump plant. However, expansion in heat pump installations came to an abrupt stop in the middle of the 1980s, due to an overheated market with poorly working products and an unexpected substantial drop in the price of oil. The incentive to replace oil fired boilers disappeared, together with the state support subsidies.

– The 1980s were difficult, says Johnny Wärnelöv, previous group chief executive at the heat pump manufacturer IVT. The subsidies for buyers were stopped, the price of oil fell and interest rates were sky high. Many companies went bankrupt or left the market.

In 1993, in order to break the log jam of the almost stationary market, and to try to restart the move away from heating by oil or electricity, the National Board for Industrial and Technical Development (Nutek) announced a technology procurement competition to accelerate technical development and to restart the market. With 800 000 electrically heated houses, and half a million oil fired house heating systems, replacement by effective heat pumps would save significant quantities of electric energy and replace oil with big amounts of renewable geoenergi. Sixteen manufacturers were therefore invited to compete to develop heat pumps that where 30 percent more effective than those on the market at a 30 percent lower cost. Two winners were announced; IVT and Eufor, both manufacturing companies.

The results for the small IVT were remarkable: over a short period, the number of employees had to be increased from 8 to 15 in order to produce a further 3 400 heat pumps. At the time of entering the competition, the company had sales of SEK 30 million: by 2007, it had risen to SEK 1300 million, with the company now being represented in 19 countries.

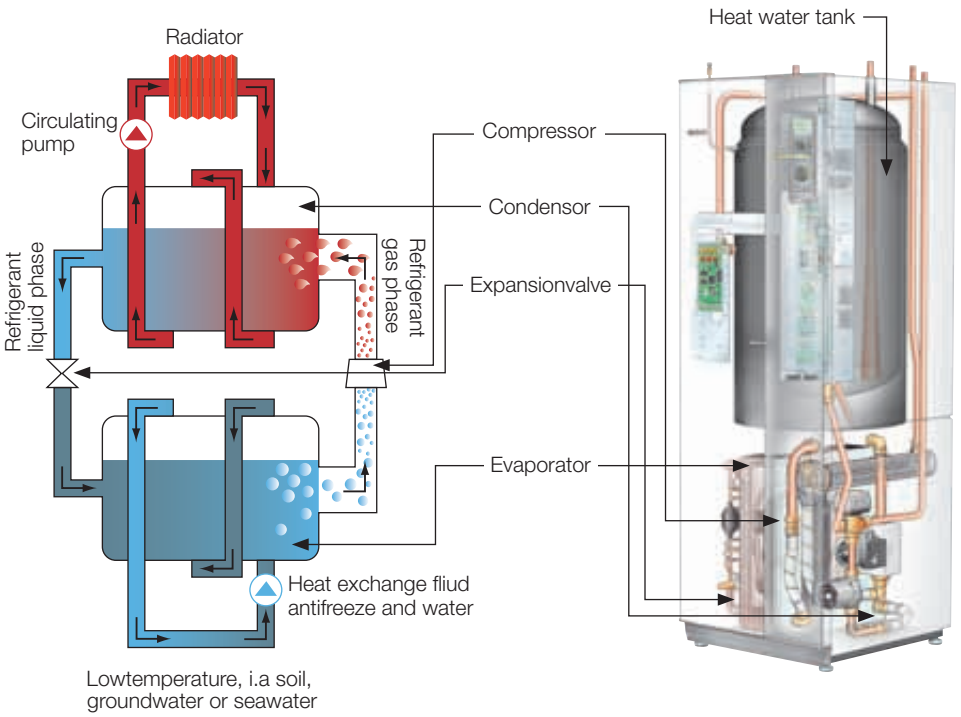
– The competition was a great success for us, says Johnny Wärnelöv.

Nevertheless, not everything was plain sailing. None of the winners' compressors were suitable for use with the new refrigerants, with the result that they failed in service. Many compressors broke down after a short amount of time. Fortunately, the companies managed to keep the market on their side.

– The companies replaced the heat pumps, at no cost to the purchasers. This created goodwill for the manufacturers, enabling them to start to build up the market up again, says Egil Öfverholm at the Swedish Energy Agency.

Several research projects were quickly started in cooperation with the branch in order to increase knowledge and to solve the quality problems, with the state paying half the cost.

– Today, Swedish heat pump technology is recognised throughout Europe. We receive many enquiries from heat pump installation contractors who want to come here and learn how it's done, says Martin Forsén, of the Swedish Heat Pump Association.



Heat pumps: some basic facts

- Over 500 000 heat pumps are in use in Sweden today, with the majority in detached houses.
- Sweden has half the European heat pump market. Now the market expands rapidly in several European countries, but from a rather low level.
- 20 percent of Swedish detached houses now have some kind of heat pump.
- 90 percent of all newly built detached houses in Sweden have exhaust air heat pumps.
- Two out of three consumers chose heat pumps when replacing heating systems.
- In 2007, heat pumps in use in Sweden supplied around 15 TWh of renewable "free energy", equivalent to 143 000 tonnes of oil.

THEMATIC AREA

Transport

The Swedish Energy Agency's long term research and development objectives include the production of motor fuels from renewable sources and more efficient vehicle systems running on fossil (conventional), renewable fuels and electricity.

EU member states have a common commitment for the transport sector, for which a number of targets to be achieved by 2020 have been set within the EU. Among the most important of these includes a special requirement that 10 percent of energy used by the transport sector must be supplied from renewable sources by 2020. This is complemented by the Fuel Quality Directive, which requires suppliers of motor fuels in the EU to reduce CO_2 emissions, with effect from December 2008, by 6 percent per unit of energy (as seen in a life cycle perspective) from the level in 2010. In addition, there are requirements applicable to the automotive industry, under which the average value of energy efficiency of new cars within the EU must not exceed 130 g CO_2/km, with effect from 2015. The same proposal sets a preliminary target of reducing this value to 95 g CO_2/km for new private cars with effect from 2020.

Vision for 2050

The vision has four main areas:

- The transport system is sustainable. Availability and mobility is good for everybody and efficient freight transport exists.
- The use of energy carriers that are CO_2-efficient, and which have a high system efficiency.
- Commercialisation of production technology for carbon dioxide efficient motor fuels.
- A successful automotive industry will be producing energy efficient vehicles, and Sweden will have a successful vehicle development industry.

Priority areas

Since environmental and energy supply considerations are one of the two greatest challenges for the transport sector, priority is given to achieve *more energy efficient vehicles and renewable energy* for replacement of fossil motor fuels.

For the production of bio based motor fuels, priority is being given to projects that:

- Aim to achieve substantial reductions in greenhouse gas emissions from an overall system perspective, and equally low emissions of other regulated emissions.
- Have high system efficiency and a potential for large scale introduction and use, and which can also generate export revenues.
- Have a potential for achieving production costs equivalent to, or less than, the price of fossil fuels.

Renewable motor fuels or energy carriers are particularly interesting if they:

- Are suitable for use in the existing infrastructure (examples being ethanol and electricity).
- Can be integrated with existing motor fuels and replace diesel.
- Have synergy effects with other

important export industries, e.g. the manufacture of pulp and paper.

For vehicle related projects, priority is being given to:

- Energy efficiency of vehicles and energy converters.
- Reduction of climate gases, primarily through reduced CO_2/km emissions.

Renewable motor fules

The Agency is financing several large research projects covering the entire chain from cultivation of raw materials for biobased motor fuels to the use of new fuels.

Second generation biobased motor fuels

Energy efficient carbon dioxide neutral solutions are the targets of work on second generation biobased motor fuels. The concept includes conversion of forest raw materials and short-rotation crops: in addition, it involves the use of advanced new technology in efficient processes aimed at increasing the energy yield from the biomass. Gasification of biomass, for example, permits flexible choice of raw materials as well as of end products. Second generation motor fuels deliver a significantly better energy yield throughout the production chain than do traditionally produced biobased motor fuels.

Sweden has three large development plants for the production of bio based motor fuels, which are partly supported by funding from the Agency. The purpose of these plants is to establish a foundation for what are known as bioenergy combination plants, in which several processes operate together in order to provide maximum overall energy efficiency. In addition, research is being carried out at several universities directly linked to the plants. A recently revived interest in the production of biobased motor fuels means that more parties may become involved in research and development, as new stakeholders in Sweden discuss whether to join the sector. One working area that will probably be expanded is biogas.

Black liquor gasification in Piteå

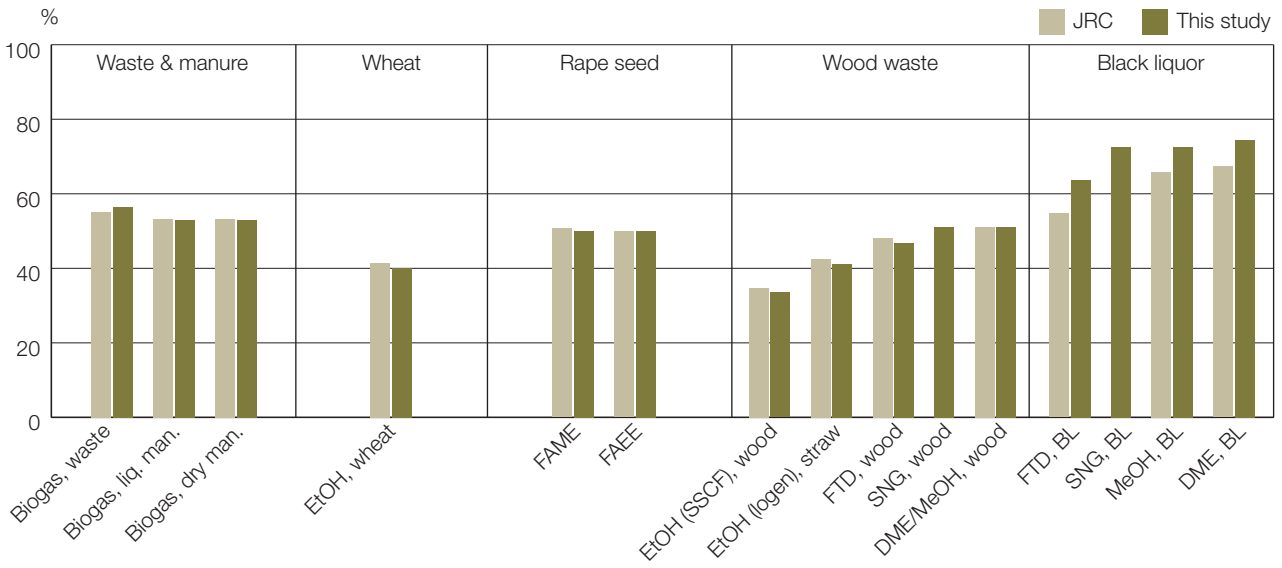
A development facility in Piteå for gasification of black liquor from the Smurfit Kappa Kraftliner pulp mill was commissioned in 2005. Its purpose is to develop gasification technology, and to investigate recovery or production of chemicals, electricity, heat and motor fuels from the process. The project was originally focused on the production of electricity and heat from synthesis gas. The Agency is a funding partner of a cooperative element of the work between the USA and Sweden.

The main focus of development today is to produce DME (dimethylether), which can be used as a fuel in diesel engines. Crude synthesis gas produced in the existing gasifier will be used as a feedstock

An ethanol hybrid city bus

This project is concerned with demonstration of ten hybrid city buses, which will be tested in regular traffic. The technology principle is that of a series hybrid, with supercapacitors as an energy store. The prime input power is delivered by an ethanol-fuelled diesel engine, connected to an electric generator which in turn supplies the main electric propulsion motor and the supercapacitors. This arrangement allows the diesel engine to be run at a better load point in terms of energy efficiency, and some of the braking energy to be recovered and used to charge the supercapacitor. There is a potential for saving about 20–40 percent of the energy requirement.

FIGURE 7: *Fuel production efficiency*



SOURCE: WELL TO WHEELS FOR HEAVY TRUCKS, ECOTRAFFIC, 2009

Test Site Sweden

Test Site Sweden is a national project and a neutral meeting place for joint research projects in safety, the environment and Intelligent Transport Systems and Services (ITS). Its purpose is to promote the growth of knowledge and the development of new technology in the field. Test Site Sweden is intended also to serve as a showcase for Sweden's expertise in the automotive industry, road safety and the traffic environment.

to produce 4–5 tonnes of renewable DME per day. This part of the work is partly financed by the EU Seventh Framework Programme, and is intended to develop and demonstrate the entire production chain from biomass to end use of a renewably sourced biofuel, which will involve field trials using goods vehicles developed by Volvo. The Piteå gasification plant has a capacity of 3 MW of fuel per day.

Värnamo – gasification of biomass

A demonstration plant for the gasification of biomass, having a fuel input power of 18 MW, was built and operated by Sydkraft in Värnamo during the 1990s, with the object of producing electricity via an Integrated Gasification Combined Cycle (IGCC). The gasifier and gasification technology are still of interest for the production of synthesis gas for the production of bio based motor fuels. The plant was partly restarted inthe EU Chrisgas project. Both the gasification process, which is now in operational condition again, and the gas cleaning process are vital for successful production of a second-generation bio based motor fuel, primarily Fischer-Troops diesel fuel.

Örnsköldsvik – ethanol from cellulose

Ethanol can be manufactured from cellulose by first breaking the cellulose down to simple sugars, which can then be fermented. The main thrust of ethanol research is to find ways of reducing production costs, such as through the use of cheaper and more efficient enzymes, improved strains of yeast that can ferment all the sugars encountered in the cellulose feedstock, and optimisation of the processes in such ways as reducing the amount of water and energy used. A pilot plant for investigating the entire process chain on a larger scale was started up in Örnsköldsvik in 2004. This plant is intended to be used for several years as a centre for development of the process technology and as a test bed for research results produced by university departments.

Biogas

1.2 TWh of biogas were produced in 2006 from various sources such as sewage sludge, food industry waste, stable manure and food waste that had been sorted at source. Current research in the biogas sector, which is being carried out at a number of universities and institutes of technology, is concen-

trated on process optimisation. In addition, a number of development projects for the production of biogas are ongoing.

Energy efficient vehicles

Renewable motor fuels and more fuel efficient vehicles

The Swedish Energy Agency supports research aimed at reducing motor fuel consumption as well as developing new technologies, such as, electric and hybrid vehicles. The efficiency of conventional petrol and diesel vehicles must be improved, with reduced emissions and compatible for use with renewable fuels such as synthetic fuels, alcohols, gases or electricity. The greatest potential for energy efficiency improvement is found in vehicles used in urban traffic: by using electricity, energy use can be reduced significantly. The energy saving potential of vehicles used in long distance traffic is less. However, since heavy trucks mainly are responsible for the increase in traffic, even small improvements are significant.

There are two national research programmes dealing with issues related to vehicle development, and five national centres. The programmes and centres are closely linked in order to benefit from common working areas and overall synergy effects between them. They also share a common business intelligence monitoring and analysis element. The following are brief details of the programmes:

- The Strategic Vehicle Research and Innovation Initiative (FFI)
  This new programme was started at the beginning of 2009. It is split into five parts; Sustainable Production Technology, Vehicle Development, Transportation Efficiency, Vehicle and Traffic Safety, and Energy and Environment. The yearly budget is USD 100 million, half of which is government funding. About one third of the overall focus will be on safety, and two thirds on energy.

- Energy Systems in Road Vehicles
  This academic research programme is devoted to batteries, fuel cells and other components for vehicles using electricity as a means of improving energy efficiency. The Swedish Energy Agency administers the programme.
  The programme, which runs until the end of 2010, has a budget of about USD 12 million. To date, several PhD students in the field of hybrid vehicles and fuel cells have been trained, and a number of patents have been granted for new types of hybrid drive lines.

Volvo has started an electric city vehicle project with money from FFI. The aim of the project is to design, build prototypes and test a zero-emission commuter vehicle.

Swedish Hybrid Vehicle Centre (SHC)

The aim of this project is to establish an internationally competitive centre of excellence for hybrid electrical vehicle technology, facilitating education and research to meet industrial and societal needs in the area, and to form a natural framework for cooperation between industry and academia. Participating in the centre are: AB Volvo, Scania CV AB, Saab Automobile AB/GM Powertrain AB, Volvo Car Corporation AB, BAE Systems Hägglunds AB, Chalmers University of Technology, Lund University and the Royal Institute of Technology. The centre started in July 2006 and the budget for the first period, 2007 to 2010, is approximately USD 11 million.

HIGHLIGHT

– a success story where funding from The Swedish Energy Agency has played an important role

El-Forest – Half as heavy and twice as good

The world's first electric hybrid forwarder has many environmental advantages. It uses less fuel than conventional forwarders, causes less damage to the ground, and produces only half the quantity of CO_2 emissions. The new machine is at present in the trials stage, but it was by no means certain that its inventor, Lennart Lundström, would be able to get his unique forwarder to this stage.

Lennart Lundström grew up on a forestry estate in Sidensjö outside Örnsköldsvik, which had been in his family for 13 generations. As a boy, he worked in the forest with his father, cutting down trees by hand and using a horse to pull them home.

– It was about that time that forest machines started to appear, and I saw the damage that they did to the ground in the form of deep ruts, says Lennart Lundström.

His first idea was to invent a forwarder that would cause less damage to the ground. With an electric motor to drive each wheel, wheels could be controlled individually and following in line after each other. This was where the idea of electric operation came from, creating an entirely new concept for forwarders.

Fortunately, Örnsköldsvik has a number of engineering industries, and Lennart contacted Thordab, a family company that manufactures parts for heavy forestry machinery. Working together, they started to produce sketches of the new forwarder.

Lennart Lundström succeeded in obtaining financing from foundations, which enabled him to keep going while conditions were unfavourable. In addition, he had access to capital from felling in his own forests. Together with Thordab, the company of El-Forest was set up to construct the prototype.

When the prototype was ready, it was displayed at the Agency's annual Energiting conference in 2007. The Agency assisted with presentations, and helped to introduce the company to potential investors. One which was seriously interested was Volvo Technology Transfer, which lost no time in going in as a majority shareholder. Markets are now being opened up through Volvo's sales channels in Europe, Canada and South America.

– For many years, Volvo has had no forestry machinery in its range, so it's important that now, when we're starting to manufacture forwarders and harvesters again, we should go in for the most environmentally friendly technology. Series hybrid technology is a very interesting step towards plug in hybrids, says Per Wassén, investment manager at Volvo Technology Transfer.

At the same time, the Agency gave the company a loan of almost SEK 5 million to enable El Forest to be able to manufacture three forwarders for trials in different Swedish forest environments. The first forwarder was delivered in the spring of 2009 to Hamra, 100 km north of Mora. Lennart Hult, who is the purchasing and technology manager for Sveaskog, is particularly pleased with the low fuel consumption.

– Ordinary forwarders use about 11–13 litres of diesel fuel per hour, but this one doesn't seem to use more than half that, which very clearly means that it is taking an important step in the right direction towards reducing environmental impact.

Volvo Technology Transfer expects to start production of 20–40 machines per year in Örnsköldsvik over the next few years, gradually increasing production thereafter.

The fact that, after 15 years' thinking and work, this forwarder finally exists feels almost unreal for its inventor, Lennart Lundström.

– I sometimes have to pinch myself to be sure that I'm not dreaming. The forwarder has attracted an enormous amount of interest, for which I'm very glad.

According to Lennart, this is certainly not by chance, but due to stubbornness and an unusual combination of knowledge and experience. Lennart is a trained electrical engineer, having worked for many years for ASEA, which later became ABB, on the technical design of equipment, and was involved in obtaining five patents for the company.

– If I hadn't been an electrical engineer, I would never have dared to tackle this particular technology. And if I hadn't been so closely connected with forestry, I wouldn't have been so upset by the damage to the forests, says Lennart Lundström.

About 4000 forwarders are in use in Sweden which means that, when their use on the international level is also considered, they use a very large amount of fuel, which can be very substantially reduced. And the environmental benefits can be further increased if the technology can be used in other heavy machines such as wheel loaders or dumpers, which have varied loadings when lifting, carrying and discharging their loads. Lennart's vision is that future engines in these types of machines could run on ethanol, fuel cells or even solar cells.

When the forwarder was displayed for the first time at Elmia Wood, visitors were surprised not so much by the machine itself, as by the fact that it had taken 30 years before it appeared.

FACT: Forwarders

Forwarders lift timber from the ground and transport it to forest tracks. Ordinary forwarders have a large, heavy engine, to provide sufficient power to deal with the load peaks. The new forwarder has a small diesel engine that drives a generator that charges batteries. During load peaks, extra power is available to the motors from the batteries to assist the diesel engine, which can therefore run at a constant speed and so reduce emissions. Energy is also returned to the batteries when the machine rolls downhill; energy which would otherwise be wasted by being turned into heat by the brakes. This can reduce fuel consumption by 30 percent or perhaps 50 percent.

THEMATIC AREA

Energy-intensive Industry

Sweden's energy intensive industries generate a significant proportion of the country's export revenues. Although output has increased steadily for many years, extensive efficiency improvements at the same time have meant that the actual amount of energy used by the industries has remained more or less constant over the last 40 years. Nevertheless, there are still significant potentials for reducing the amount of energy used. Improving the efficiency of processes is a constant activity, helping to improve the competitiveness of companies operating in the global arena.

"Since the 1970s, Swedish industry has improved its production efficiency at about 2 percent per year. Although the total amount of energy used has remained more or less constant, the production value has more than doubled. Nevertheless, there is still a substantial potential for improvement."

In 2007, industry accounted for 39 percent of the country's final energy use. Of this energy quantity, 79 percent of the entire use of 156.6 TWh was used by the energy intensive sectors of pulp and paper, iron and steel, the chemical industry and the mining and minerals industry. Industry's main energy source is electricity, at 36 percent, followed by biofuels at 35 percent, fossil energy at 26 percent and district heating at 3 percent. These basic industries are characterised by high capital costs, which means that they are cautious when considering the introduction of entirely new technologies. It can therefore take some time before any new energy efficient technology has spread throughout an entire sector.

Scenario 2020

The expected scenario in 2020 can be described as follows:

Oil consumption in Sweden will be at its lowest level for several decades. Research, development, policy measures and rising energy prices have resulted in a reduction in the use of oil in several sectors of society. As a result of improvements in energy efficiency and a greater proportion of biofuels, industry as a whole has reduced its use of oil by 30 percent, to 13 TWh/year, compared with its value in 2007.

The total use of energy by industry is approximately the same as during the previous decade. On average, specific energy use for any given product has fallen by 10–20 percent.

The increase in indigenous production of electricity has resulted in an increase in exports of electricity. Most of the electricity intensive industry sectors have been able to maintain their competitiveness during the 2010s.

Surplus low temperature thermal energy from the energy intensive industries is being increasingly used, particularly as district heating in southern Sweden, where waste heat streams at temperatures of 55 °C or above are fully utilised.

Recycling of materials from fibres, plastics, glass and steel has become increasingly important. Recovery units have been established in many places, which accept materials not only from private persons, but also from smaller companies.

Even today, several of the energy

intensive sectors continue to use large quantities of fossil energy. Regulations applicable to these companies have been progressively tightened up in order to achieve climate objectives. Carbon Capture and Storage (CCS) has been tested for several years, and is presented as an important means of reducing greenhouse gas emissions.

The regional distribution of the energy intensive industries is much the same as it was in 2010. The location of new industrial plants, such as biorefineries, has been determined not only by access to maritime transport, but also by the closeness to raw materials, rail links and markets for the products.

From 2020 to 2050

It is much more difficult to foresee likely developments between 2020 and 2050. World events over the last 40 years have largely been unforeseen, and it is likely that future developments will be equally dynamic. Nevertheless, some long term trends that are likely to affect the situation in 2050 are as follows:

Oil will still be playing a part in the world economy in 2050, but supplies will have been reduced. Just how the oil is used will be affected by several factors, of which priorities, acceptance and price are likely to be among the most important.

- The global demand for energy will be greater than today.
- Global trade will increase.
- Swedish energy intensive industries will continue to be developed towards knowledge intensive high technology niche products. Sweden accounts for only a small proportion of world production, and cannot compete with manufacture of bulk products.
- Electricity demand from the Swedish energy intensive industries will continue to be high, accompanied by high price sensitivity.
- Energy use in Swedish industry will be based on renewable energy sources and electricity (with the latter being increasingly produced from renewable sources) and some other fossil energy sources. The energy mix will continue to differ considerably between sectors.
- Improving the efficiency of energy use will still be an ongoing process in

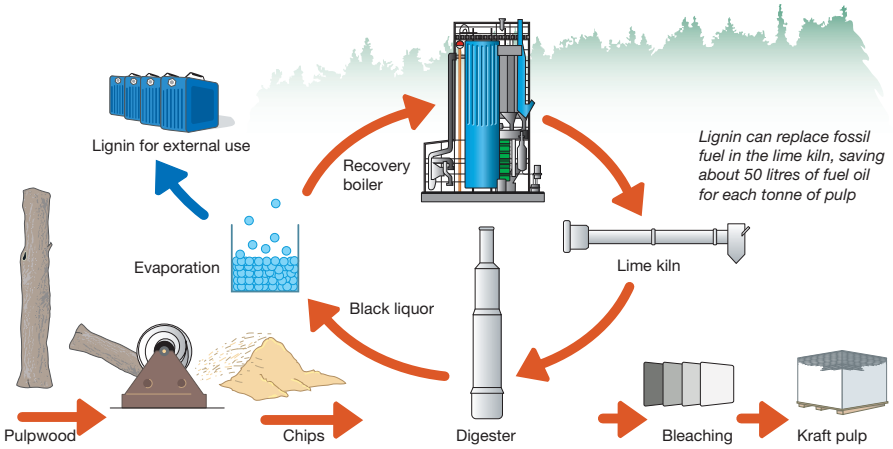
FACT: Research direction

Research is concentrated on problems and potentials such as:

- improving the efficiency of electricity use
- improving efficiency when using fossil or renewable fuels
- increasing industry's own supply of energy to its processes, by better utilisation of waste heat, by products and waste, as well as through own production of electricity
- supplying energy in the form of heat, fuels and electricity to nearby areas.

FIGURE 8: *More efficient pulp production through targeted extraction of lignin*

Lignin is a constituent of wood. Modifying the kraft process for extraction of lignin in solid form for use as a fuel has several benefits. It replaces the use of oil in certain process stages and increases the production of pulp. The new LignoBoost process is the result of ten years of research.



Swedish industry, constituting a base for maintaining or improving competitiveness.

- Swedish industry will develop and export energy efficient technology.

Challenges

The Swedish energy intensive industry is under constant pressure to change, with a number of factors being of particular importance. Markets, legislation, policy measures and other incentives play an important part at national, regional and global levels. The climate problem, renewability, availability and price of oil (and of other fossil raw materials), together with the associated global economic effects, are all factors that affect industry and society in various ways.

Improving the efficiencies of the use of materials and/or energy is an important means of meeting these challenges. The availability of biomass, and particularly of forest raw materials, affects many areas. Competition from other countries affects the competitiveness of the pulp and paper industry. The establishment of bio-refineries can have a beneficial economic effect, creating facilities in which several different products such as materials, energy products and chemicals can be produced. The climate problem is driving the iron and steel industry to develop more efficient processes with less environmental impact. The government has set a target of reducing present day use of Swedish natural gravel by 90 percent by 2020, which means that it must be replaced by some other mineral raw material for various applications. The petrochemical industry is interested in expanding its raw materials base to include renewable raw materials.

Process integration

Process integration is concerned with overall energy analyses, not only of the interaction between different parts of a process, but also of entire industrial processes. It involves mapping energy flows in factories, and identifies potentials for structuring and modifying industrial processes in order to make more efficient use of energy and to reduce environmental impact. Process integration methods are being applied in the pulp and paper industry, the iron and steel industry, the food processing industry and in other sectors.

Waste heat – a resource

The energy intensive industries produce considerable quantities of waste or residual energy. These energy streams have high flows, often at comparatively low temperatures. In several places in Sweden, process industries have for many years supplied district heating to the surrounding community. However, there is potential for using more of the waste heat for district heating purposes. Considerable quantities of energy could be beneficially used if district heating nets were opened to competition.

Cleaner iron production with less energy

LKAB in Luleå is involved in the major EU ULCOS (Ultra Low Carbon diOxide Steelmaking) project, the aim of which is to reduce carbon dioxide emissions from steel

production by 50 percent. Another steel industry project is concerned with improving the efficiency of the blast furnace process. Blast furnaces are technically complicated, with several chemical reactions taking place at high temperatures. The interaction between the crude iron and the slag is particularly important. Controlling the formation process of the slag and its final composition allows a cleaner crude iron to be produced with less energy. Slagging agents are traditionally loaded into the top of the furnace, but current research looks at the possibility of also injecting the slagging agent at a lower level in the furnace. This procedure has two advantages: different types of slagging agents can be used, customised for the respective zones in the furnace, and smoother, more stable and energy efficient operation is achieved.

Solid fuel production from lignin in black liquor

For several years, the Agency has supported research on improving the efficiency of pulp production. Work in the FRAM projects (Future Resource-Adapted pulp Mill) has developed a process to produce a solid fuel from lignin in kraft mills' black liquor. A development plant was inaugurated at Bäckhammar in 2007. The aim of these projects has been to produce the fuel as efficiently as possible, and to customise it for various applications. The fuel has been tested in a combined heat and power plant and in the lime kiln of a kraft mill, where it can be used to replace oil.

One benefit of lignin is that it can be recovered with a low moisture content, which gives improved efficiency. This technology is particularly attractive for pulp mills suffering from production limitations due to insufficient recovery boiler capacity. Lignin removal provides an opportunity to increase pulp production. The work has involved representatives from several stakeholders, ranging from pulp mill owners and equipment manufacturers to final users of the fuel. The Swedish production potential for lignin fuel is estimated as 5–10 TWh. The programme has been successful, and the patented process has been sold to Metsä.

HIGHLIGHT

– a success story where funding from The Swedish Energy Agency has played an important role

Sunpine – Renewable synthetic diesel fuel

With biodiesel oil having been developed from corn, rapeseed and palm oil, attention is now turning to other plant materials. The first large scale production of renewable diesel oil from tall oil was in Piteå.

One of the byproducts from the chemical pulp industry is tall oil, which can be used as the starting product for the production of renewable diesel oil, which is the motor fuel that is most needed.

– There is an enormous demand for renewable fuels. We could build many production plants for diesel fuel from tall oil: unfortunately, it's the availability of the raw tall oil that sets limits, says Lars Stigsson, environmental entrepreneur and owner of KIRAM, the company that started the project.

Lars Stigsson has been involved in research in the pulp industry for many years, working during the 1990s on the NovaCell project to remove sulphur from the manufacture of wood pulp. This taught him much about tall oil, which he realised would be of value as a biobased motor fuel if only the sulphur could be removed.

KIRAM joined forces with the petroleum industry, which was also facing the problem of removing sulphur from its raw materials. He applied to the Swedish Energy Agency for funding for a desulphurisation pilot project and for pilot scale tests.

– The financial support from the Agency was particularly important at the start of the project. The fact that we were able to present an entire working package subsequently attracted large investors, and was the reason why production was able to start so quickly, says Lars Stigsson.

With increasing emphasis on the importance of tackling the climate problem in the 2000s, interest in biobased fuels increased correspondingly. What is now usually referred to as the first generation of biofuels – ethanol, produced from corn, sugar beet and other edible crops – has been increasingly called into question. Attention is now turning to what are known as second-generation fuels, ranging from forest by-products to straw and biowaste, having much lower specific greenhouse gas emissions. A smaller quantity of raw materials produces a greater quantity of energy, while also having a much better life cycle performance.

At that stage, the know-how, the raw materials and an interested market began to come together. What was missing was a factory and funding. In 2006, Lars Stigsson broke the tall oil project away from KIRAM and started the Sunpine AB company, working full time on the plans to build a tall oil diesel fuel plant in Piteå. The tall oil will be bought from pulp mills in the area to deliver an output, when the plant is in operation, of 100 000 m^3 of synthetic tall oil diesel fuel per year.

This will be a win/win situation, with the pulp mills, which are today suffering from the general recession, receiving better revenue for a waste product, while the country benefits

from indigenously produced renewable diesel fuel that has not required extra cultivation. The additional quantity of fuel will meet the needs of 100 000 diesel cars driving 10 000 km per year.

To meet the necessary storage requirements for tall oil, Sunpine elected to build the plant in the Piteå oil harbour, where large storage tanks are already available. Now, in the final stages of the work, the company is cooperating with the Preem refinery in Gothenburg, as desulphurisation of petroleum and tall oil involves similar processes.

The investment in Piteå is in the order of SEK 300 million, which is beyond the reach of Sunpine's capital. Several companies have shown their interest, through readiness to invest. Today, Södra, Sveaskog and Preem have each invested SEK 50 million, which have become available to Sunpine as capital.

– The current financial crisis struck just as we were about to look for loans. It complicated matters somewhat, but everything has now been resolved. This is a sector with a future that many believe in, says Lars Stigsson.

The plant is planned for completion during the first half of 2010, with production starting immediately. At the same time, Preem's facility for hydrogenisation of raw tall oil diesel fuel will be ready in Gothenburg. The fact that Preen is prepared to make this investment in the middle of a period of financial uncertainty is due both to EU requirements and pressure from consumers for more environmentally sourced fuels. These are business such as transport companies, bus operators and taxi fleets, says Sören Eriksson, who is responsible for product development aspects at Preem.

The new EU directives, specifying the use of 10 percent of biobased fuels in all motor fuels, have marked out part of the route to reduce greenhouse gas emissions.

– We want to go further, and include up to 30 percent of tall oil in diesel fuel, and we're the first company in Europe with this process, says Sören Eriksson.

The facility that is being built will be flexible, able to accept many different types of fatty acids. Tall oil may be the first raw material, but Sören Eriksson can see several other raw materials that may become relevant. One of these is the inedible, but oil rich, jatropha fruit, which grows on bushes that can survive on poor soil in many parts of the world.

It's exciting and challenging work that faces us. The fact that it doesn't need any new infrastructure or new vehicles means that drivers can simply fill up as usual, but with a reduced final impact on the environment, says Sören Eriksson.

THEMATIC AREA

Biomass in Energy Systems

Bioenergy is important for Sweden, both for energy supplies to industry and for electricity and heat production in the country's extensive district heating systems. However, there is increasing competition for land, biomass and energy, with the result that these assets must be used as efficiently as possible. The sector needs to be further developed. Sweden's major comparative advantages are its large areas of forests, agriculture and peat bogs, coupled with an established bioenergy industry, in-depth knowledge and strong research groups.

Important in continued development

Important elements in continued development include:

- Increased safe, efficient, sustainable and competitive production of biofuels.
- More efficient use of resources, including the use of waste products, for the production of electricity, heating/cooling, motor fuels and other products, in such ways as via biocombinates.
- Replacing oil with bioenergy in the transport sector, in industry and in the heating sector.
- Meeting national environmental requirements and international sustainability criteria through the use of bioenergy.

Several reports have concluded that it is possible to almost double the Swedish supply of biomass. The 120 TWh produced in 2007 is likely to increase by several tens of TWh in a few decades. Provided that suitable measures are taken, the supply is estimated to have nearly doubled by 2050, to 230 TWh. More efficient forestry should make it possible to increase the production of forest energy from, mainly as by-products from forestry and the forest industry, while agriculture can deliver crops such as Salix, energy grass, hybrid aspen, grains, oilseeds, and various by-products from the foodstuffs chain.

The Agency's vision is that bioenergy should have achieved a dominant position in Sweden by 2020, and should also by then be expanding into other countries. Sweden will meet its commitments under the EU climate package in respect of its use of renewable energy by 2020 by using a further 25–30 TWh of solid biofuels and waste for energy supply to district heating and CHP, to industry and for individual heating systems. Most of this is expected to come from the forest, although the amount supplied by agriculture will also increase. Indigenous biomass will be used for the production of motor fuels, of which about 2 TWh will come from ligno-cellulose, and a certain amount of biobased motor fuels will be imported. Electricity from renewable sources, biofuels and energy technology will be exported to other EU countries. Easily accessible biomass, such as forest felling residues and trimmings and bioproducts are already being used: more fuel chains need to be developed in order to permit overall expansion.

Energy from forest, field, residues, waste and biogas

The competition for biomass is expected to increase. The vision is that fuels from the forest should increase by 20–30 TWh, with an additional 6–8 TWh from agriculture by such means as optimisation of the entire fuel chain by growers and end users together. Harvesting systems for energy crops must be less weather dependent. The use of waste as a fuel must be optimised in order to apply its potential in the most sustainable manner. Biogas production must be increased, while peat needs to be harvested in a manner appropriate to environmental and climate considerations.

The following R&D work is needed. If a greater range of bioenergy from forestry and agriculture is to be brought to the market, production systems need to be improved so that they are productive, energy efficient and appropriate to their environments. For the forestry sector, this means an ability to be able to harvest felling residues, stumps or entire small trees, and to increase production through appropriate use of fertilisers and other forestry practice. In agriculture, improvements are needed in all stages of the production of Salix and other energy crops or waste products. Processes for the production of biogas must be improved.

Environment, sustainability, resource effectivity

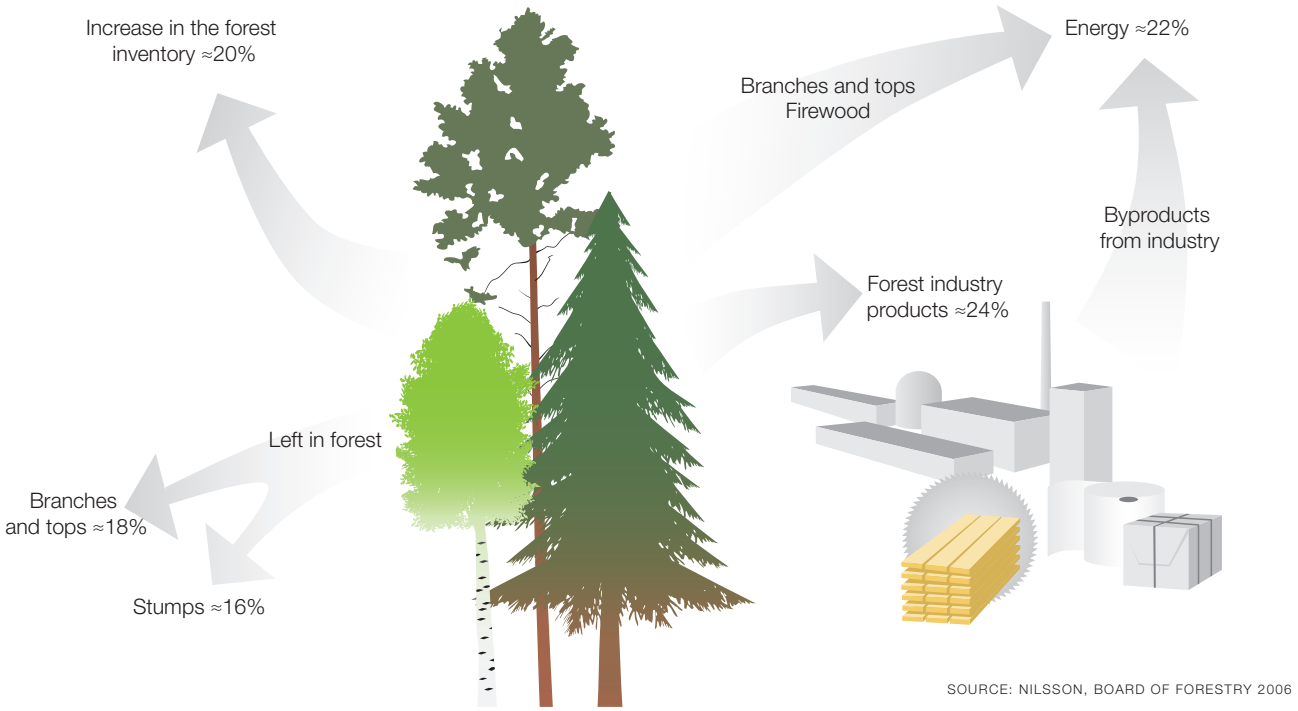
Greater production of bioenergy increases the risk of environmental objective conflicts. Consideration needs to be taken to both national and international rules and guidelines concerning sustainability and the environment. The Agency's vision is that production and use of Swedish bioenergy should meet national environmental objectives and should comply with EU sustainability criteria. To do so requires clear environmental guidelines for the production and harvest of all types of biofuels, meeting local and regional conditions. In order to minimise environmental objective conflicts, guidelines must be based on the values that society attaches

Efficient Biomass

The More Efficient Forest Fuels System is developing and improving production methods for small trees, branches and tops and stumps. An important step is to develop means of integrated harvesting of traditional timber for industrial purposes and for biomass for energy. Transport and logistics need to be improved for more efficient use of resources and cost efficiency. It is important to develop efficient means of long distance transport in order to be able to supply regions having high usage of biofuels from remote production facilities. Solutions involving the use of rail traffic are of particular interest.

Measuring moisture content

A system involving Near Infra-Red technology (NIR) has been developed for the measurement of moisture ratios, thus improving the weighing and measuring of biofuels. It is now in the process of being implemented by heating plants. Procedures for standardised NIR measurements have been developed, with the aim of providing a better basis for contracts between fuel suppliers and purchasers. On line NIR measurements have also been developed for controlling biofuel boilers, with promising results.



SOURCE: NILSSON, BOARD OF FORESTRY 2006

A large proportion of forest biomass is already used for energy production, although the potential is considerably greater.

Climate neutrality

Energy from biomassare generally largely climate neutral. The energy input to produce the fuels is small in relation to the energy in the actual biomass itself. Fuels with a short cycle time provide a rapid balance between absorption and emission of carbon dioxide. Fuels from the forest have a longer carbon cycle time: if felling residues are burnt as fuel, their carbon dioxide is emitted 10–20 years sooner than if they had been left to decompose in the forest, although there is ultimately a balance over a somewhat longer period.

to the necessary balances. The environmental added values of energy crops that take several years to grow must be considered and quantified. Heating plants using bioenergy must meet EU emission requirements.

The vision presupposes research and development in several areas. We need to describe the environmental consequences of various ways of producing bioenergy, and to turn this knowledge into the guidelines, which in turn need methods for striking a balance between environmental objectives. Methods of regional planning are needed in order to reduce the total environmental impact and to avoid sub-optimisation. The positive environmental effects of energy crops must also be quantified and utilized. Combustion technologies must be improved, so that even small plants meet EU emission requirements, even when burning high ash fuels or logs. Health effects of smoke from modern log fired boilers or stoves need to be further investigated.

Handling and upgrading bioenergy

The expected development is that large scale production systems for pellets will dominate, and production will increase. Exports of bioenergy and bio sourced electricity will increase, while the production of pellets from sawdust will be quality assured and standardised.

The vision is that more of raw materials such as branches and tops, stumps, straw, peat and agricultural residues will be used as feedstock for large scale pellets production, producing an end product of a quality to meet customer requirements. Farmers will be producing and upgrading energy crops, while agriculture fuels and residues will be converted in both small scale and large scale operations. Waste will be processed to increase its suitability for such purposes as electricity production. Various stages of pretreatment can result in intermediate products that facilitate both the physical supply and the trading of products.

All this requires the following research

A) *Felling residues are a by-product of forestry. Methods for recovering them need to be improved. Research is improving our knowledge of the environmental effects of extraction of felling residues.*

B *and* **C)** *Nature conservation is important in Swedish forestry, and must be considered when removing biofuels.*

D) *Cleaning and thinning are important for forestry care, but we need to find more efficient systems if small trees are to become an economically efficient type of energy.*

and development. The production cost of large scale upgrading must be reduced by 10 percent. New processing and upgrading methods must be developed, concentrating on process control and quality assurance of the upgraded fuels. Primary processing methods must be developed to optimise fuel qualities for different methods of conversion. There is a need to demonstrate methods of large scale production of pellets from straw fuels/residues from the agricultural sector, together with production systems for small scale upgrading suited to various local conditions. Methods of pretreatment of biomass, and storage without loss of substance, should be developed.

Use of bioenergy

The importance of bioenergy for heat production in plants having a fuel input not exceeding 10 MW is increasing. Competition for bioenergy that are more easily burnt, such as high quality pellets, means that they are used primarily in domestic

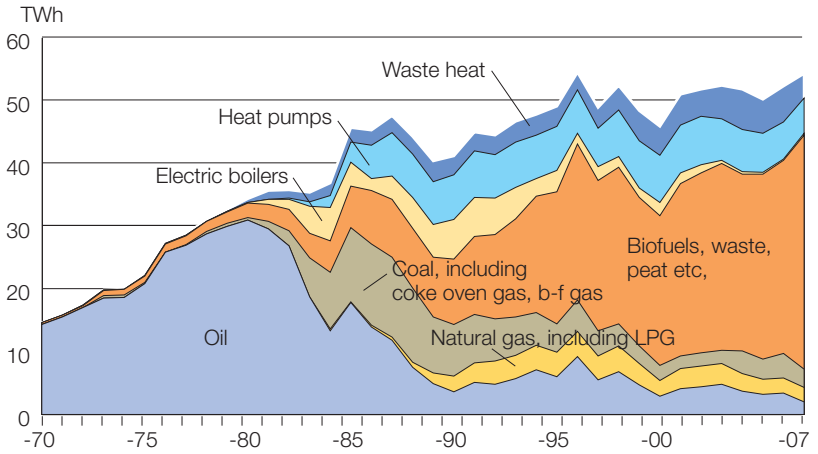
Sustainability criteria

The EU Renewable Energy Directive specifies that biofuels must meet the Directive's sustainability criteria. This applies at present only to liquid biofuels, but rules for all biofuels are expected. The criteria concentrate on greenhouse gas balances in a life cycle perspective, and on biodiversity. For many years, Sweden has been investigating how the use of bioenergy can be compatible with the dozen or so of national environmental targets that are affected, but this work needs to be further intensified in order to investigate how biofuel production affects the carbon balance and greenhouse gas flows of ecosystems.

Improved production of pellets

Current research cooperation with the pellets industry is aimed at improving the efficiency of production processes and ensuring a high quality of the pellet fuels. If future increasing demand is to be met, it will be necessary successfully to produce pellets from a wider range of raw materials than from sawdust alone. An important development in this work has been the use of NIR applications for monitoring the raw material properties (mainly moisture ratio), and the ability to control the pelletising process to suit the measured properties, as well as for measuring properties of the output pellets. NIR instruments are now being introduced in various parts of the Swedish pellets industry.

FIGURE 9: *Two thirds of district heating is supplied by biofuels, an example of successful joint action of research and policy measures.*



SOURCE: ENERGY IN SWEDEN, 2008

Efficient biomass fuels

Efficient biomass fuels are those that provide the most energy output in proportion to the work input. Bioenergy is normally very energy efficient. The efficiency depends on how the biomass is produced and how it is used. The input of energy needed to produce and transport the fuel must be compared with the energy content of the end product. Biomass from forest and short rotation crops such as Salix are examples of energy efficient biomass fuels, delivering about twenty times more energy than required for their production and transport.

boilers and stoves. More difficult bioenergy are used in larger plants where problems caused by such effects as higher ash content, poorer mechanical properties and varying moisture ratios, can be more easily dealt with.

The Agency's vision is that the use of fossil fuels for heating should be phased out, and that electrically direct heated houses should be converted to the use of biofuels or heat pumps. This will increase the small scale use of pellets by about 5 TWh. Pellet firing systems for domestic applications must require a minimum of attention. About ten efficient CHP plants, with heat outputs of less than 5 MW, will be commissioned.

Realising the above requires the following R&D work. Innovative systems for conversion of houses from direct electric heating must be developed, together with heating combinations involving the use of solar heating. The target is to ensure that at least 50 percent of directly electrically heated houses can be converted. Development of new bioenergy fired boilers and stoves must ensure that the products meet the strictest EU emission requirements. Efficient CHP technology for thermal outputs of less than 5 MW (using a range of technologies and biofuels) must be developed, as must small local heating plants suitable for use with difficult grades of fuel.

Stumps – a sustainable energy resource

The stumps of trees represent a fuel resource that is almost entirely unutilised. At present, it is unclear whether it is environmentally acceptable to harvest stumps on a large scale, and research is ongoing to see in which aspects it effects the biodiversity and on carbon and plant nutrient balances in forest areas. Material to provide a basis for more extensive environmental analysis will be available by 2010. The work is intended to develop recommendations for environmentally acceptable stumps harvesting, and how the associated ground disturbances should best be avoided.

System perspective and market

Increased international competition for bioenergy turns the spotlight on the question of supply, while fuel prices are rising. This provides a potential for export of upgraded bioenergy and other products. The vision for 2020 is that biomass for energy should be used where they deliver the greatest climate and supply benefits, with efficient use of resources at all stages. Society needs the necessary knowledge and skills to facilitate effective policy measures and optimum solutions. Accepted quality assurance systems will ensure that bioenergy from a wide range of raw materials can be used for various purposes.

The necessary R&D work is as follows. Bioenergy potentials and limitations, in relation to the overall climate and environ-

mental work, need to be ascertained. Rational/optimal strategies for land use and processes for the production of bioenergy, foodstuffs and industrial raw materials need to be developed. The effects of national and international policy measures need to be clarified, through such means as international cooperation in this field. Decision makers need to be given the necessary knowledge of policy measures and incentives to ensure that development proceeds in the correct direction without sub optimisations.

Ongoing priority working areas

A lot of development is already in progress. Continued R&D input is needed in order to move forward and to improve the economics and overall performance of bioenergy. The various parts of the system need to be developed in step with each other, with a sufficient width of approach.

The following areas have priority of importance:

- Improved cost and resource efficiency, with several fuel chains reaching the market
- Determination of guidelines for meeting environmental requirements, sustainability and specific environmental targets
- The development of a broader raw materials base for primary processing, and the development of fuel quality suitable for different purposes
- Efficient conversion methods, suited to new fuels.

Bio-combinate for effecient use of the biomass resource

The Skellefteå bio-combinate Storuman is a second-generation bioenergy combinate. It produces electricity and district heating, and also dries raw material for the production of pellets, which provides a heat sink for electricity production in the summer when the demand for district heating is low. More such combined services plants will be needed in the future, producing various combinations of electricity, heat, cooling, steam, pellets, motor fuels, chemicals, animal feeds and biogas.

The plant is the result of several years' R&D work, in which the Agency has been involved. The system is at present being verified, and is expected to show a higher overall efficiency than that of earlier plants. A commercial platform – Green Exergy AB – has recently been established, with the aim of launching the technology on various markets. The Agency is now monitoring progress in order to see whether this model is suitable for general application in respect of commercialisation of Swedish energy technology and know how.

Different forms of energy from biomass

- Pellets are processed biofuels that have been ground, dried and pressed. They differ from chips in that they are dry, which has made them suitable for small scale firing in relatively easily converted oil fired or coal fired boilers. The pellets are then ground into powder.
- Returned timber, also known as returned timber chips, consists of (for example) salvaged demolition timber and waste from building sites, turned into wood chips. This fuel is often burnt in larger boilers together with forest chips.
- There is considerable discussion on how peat should be classified. Although the EU emissions trading scheme classifies peat as a fossil fuel, the IPCC climate panel does not do so. Sweden regards peat as a slowly renewable fuel. Electricity produced from peat is entitled to green certificates in the Swedish electricity certificate system.
- Digesting biological waste produces biogas which, after cleaning, can be used as a motor fuel. Biogas can also be used in CHP plants.
- Technologies for producing ethanol and gas from wood or other lignocellulose materials, and for producing motor fuels by gasification of black liquor, are being developed.
- There are now almost 600 district heating systems in the country.

HIGHLIGHT

– a success story where funding from The Swedish Energy Agency has played an important role

Biomass – contributes to Swedish energy

Sweden has invested considerable sums of money in order to reduce the use of oil and replace it with bioenergy. Large district heating systems, employment considerations and climate effects have all helped to smooth the path for a fuel that was previously regarded almost as a joke.

In the middle of the 1970s Sweden's dependence on fossil fuels began substantially to decline, largely as result of the oil crisis. Basing energy systems on imported oil was simply regarded as unsustainable, and environmental considerations also began to make themselves known. The country elected to develop Swedish fuelsources and reduce emissions. Funding, subsidies and taxes have been used to encourage the use of biomass and reduce the use of coal and oil. Kent Nyström, managing director of the Swedish Bio Energy Association (Svebio), describes the factors assisting the increase in the use of bioenergy in Sweden:

– We have plentiful bioenergy assets and no fossil fuels. Being a small country makes it easier to introduce system wide changes. With a pro active policy, we have been able to establish a strong domestic market, he says.

Since the beginning of the 1970s, Sweden's carbon dioxide emissions have fallen steadily. This is partly due to the substantial energy contribution from nuclear power. However, biomass for energy is being used in significant quantities, in parallel with the expansion of district heating.

By 1980, the government had invested SEK 1300 million in 600 projects for solid fuels firing, including a large number of wood chip, peat and bark boilers. There was also substantial investment in research, prototype plants and demonstration plants. Peat attracted greater attention, and forest waste now began to be regarded as an energy resource.

In 1981, the Oil Replacement Fund introduced new funding for technology, including the use of biofuels and peat. According to Lars Tegnér, who has worked with various public authorities on fuel based energy conversion processes, the subsidies for the use of peat were not fully successful as a policy measure.

– Nevertheless, they opened up a market for biofuels by bringing together sellers and purchasers. Public funding helped to get the process started, he explains.

The prices of coal and oil fell again around the middle of the 1980s, thus reducing interest in indigenous fuels, although there was still a need for new electricity production capacity. Climate considerations also started to come up onto the political agenda.Large scale district heating systems have provided a heat sink for combined heat and power production, thus obtaining more energy in total from the fuel. In the same year that the carbon dioxide tax was introduced in 1991. Parliament approved SEK 1000 million investment support for combined heat and power production, and SEK 625 million for developing biofuels.

These are biomass for energy

Biomass are raw material, or refined products derived from biomass.

- Chipped felling residues from forestry and by-products such as sawdust, bark and black liquors from the pulp industry are important bienergy.
- Cultivated willow (Salix) crops are used in the same way as forest felling residues, although to a much lesser extent. Other agricultural fuels are straw and reed canary grass. Some grain are also used for ethanol production.
- Pellets are processed woody biomass that have been ground, dried and pressed. They are especially suitable for small scale boilers.

Continues on next page.

The next important milestone in terms of state support occurred in 2003, with the introduction of the electricity certificate system. Electricity suppliers must be able to provide a certain proportion of electricity from renewable sources, and are required to purchase certificates to a corresponding value, which supports the producers of renewable electricity.

– New CHP production represents a substantial step forward for meeting the government's targets of more electricity from renewable sources, says Lena Sommestad, managing director of the Swedish District Heating Association.

Over the period 2003-2008, Parliament has approved almost SEK 2000 million for climate investments, known as Klimp funding. This has been aimed at local authorities, companies and private persons, for investments intended to reduce climate impact. In 2007, more than half of the applications were for district heating. Klimp made it possible to try the use of new technology.

The CHP sector now expects to more than double its electricity production by 2015, as new and expanded district heating systems come on line. Swedish district heating has an annual turnover of SEK 25 000 million, and employs 30 000 people, making it an important part of the Swedish economy. Large scale combustion of bio in 1991. presents many challenges, both environmental and technical. When it was realised in the 1980s that branches and tops could be a potential bioenergy resource, it was not known at the time how this use would affect the ecology of the forests. What would be the effect on the next generation of growth and would it reduce biological diversity? This provided a signal for the start of extensive investigations.

– These investigations grew into a completely new area of research, financed mainly by the Swedish Energy Agency, and later also by Nutek and Vattenfall, recalls Anna Lundborg, working with bioenergy at Swedish Energy Agency.

In 2008, the National Board of Forestry updated its recommendations on the harvesting of forest fuels in an environmentally responsible manner, including the return of ash to the forests. The Board, the Swedish Environment Protection Agency and the scientists have constantly conducted a dialogue, with the result that there is much shared knowledge and scientific results, facilitating the use of biofuels.

– We have leading edge competence, able to provide expert decision making material and assessments to public authorities. This is particularly useful now, in the light of the EU draft proposal for a directive concerning the use of more renewable energy and criteria for sustainable bio energy, says Anna Lundborg.

These are biomass for energy

- Chiped demolition timber and waste from building sites are often burnt in larger boilers together with forest chips.
- Sweden regards peat as a slowly renewable fuel. Electricity produced from peat is entitled to green certificates in the Swedish electricity certificate system.
- Biogas from waste can be used in CHP plants or, after cleaning, used as a motor fuel.
- Technologies for producing motor ethanol and gas from lignocellulose materials, and for producing motor fuels by gasification of black liquor, are being developed.

THEMATIC AREA

The Power System

The use of electricity will continue to increase world-wide, partly because a change from other forms of energy carriers to electricity. Electrification has played an important part in the development of our modern society, and will do so for the developing countries, as well as other rapidly growing economies.

The Swedish electricity system produces almost 150 TWh of electricity per year, based on hydro power and nuclear power, which together provide about 90 percent of production. The remaining production comes from fossil-fueled and biofuled capacity and from wind power. At present, wind power delivers about 2 TWh, but it is the Government's objective that wind power production should be expanded to 30 TWh per year by 2020. Wind power will be the renewable energy source playing a dominant part in conversion of the energy system, and thus contributing both nationally and globally to reduced emissions of green-house gases, as a result of Sweden being expected to become a net exporter of electricity.

Today, Swedish electricity production is responsible for only modest carbon dioxide emissions, as it is based on hydro power and nuclear power production, together with the CHP plants which, largely, burn biofuels or waste. As most of the hydro power is produced in northern Sweden, while most of the power is used in the south of the country, the backbone of the Swedish grid is a transmission system running from north to south.
The power system theme area includes research into the renewables of wind power, solar electricity, wave power and the development and modernisation of hydro power and CHP production. Important areas for the new production technologies include reducing the costs of electricity and reducing environmental impact, while also developing simple and cost-effective connections to the country's power grid with maintained reliability, safety and electricity quality. To this end, research into the transmission and distribution systems is concentrated primarily on intelligent networks, i.e. management, supervision etc. In addition to the common problem areas, each electricity production method has its own important areas, such as the need to develop methods of facilitating establish-ment of wind power production in difficult areas, such as offshore, in cold climates or in forest areas.

Sweden has a strong industrial presence in electric power, both in production and transmission. Most of the country's products in this sector are exported. As industry is normally involved in research at an early stage, the work often results in practical application/commercialisation.

Wind power

How can large amounts of wind power be integrated into the power system? This is being investigated from market and technical perspectives in some of the projects in the Vindforsk research program. Studies have shown that it is not primarily

the physical potentials for wind power production that limit its expansion, but factors such as the planning process, suitable tie points for grid connection and technical problems. One study concludes that 510 TWh/year could be produced in onshore plants and 46 TWh/year offshore.

Technical problems for integrating wind power include system stability and the capacity of the system to deal with varying power inputs and problems of high-frequency transients. Offshore wind farms have experienced transformer and generator failures, the underlying reasons for which are not fully understood. One possible explanation is that the failures have been caused by high-frequency oscillations in the power grid. Switching of common vacuum circuit-breakers can give rise to transient overvoltages. Models of electrical systems with detailed modelling of circuit-breakers in the system have been developed. If the realistic potential for wind power integration is to be fully exploited, there is a need to investigate performance in difficult locations, such as in cold-climate or forested areas. Establishment in cold-climate areas requires, for example, development of methods of de-icing or preventing the build-up of ice on rotor blades, and means of detecting and measuring ice formation.

Solar cells

An alternative type of solar cell produces electricity with the help of a dye. Cells of this type, known as Grätzel solar cells after the name of their discoverer, consist of a transparent and porous nanocrystal (titanium dioxide) covered with a thin film of the light-absorbing dye. The pores are then filled with an electrolyte which completes the circuit. The big advantage of Grätzel cells is that their production cost can be much lower than that of traditional solar cells based on crystalline silicon. The technology is now approaching the commercialisation stage, with several companies setting up both pilot-scale and

Solar cells

The entire world need for electricity could be met by covering only 5 percent of the area of the Sahara with present-day solar cells. The major challenge is to make solar cells costcompetitive, which is why work is concentrated on producing cheaper and more efficient cells. An interesting example is presented by the Swedish company of Midsummer AB, which combines its expertise in the manufacture of CD/DVDs with CIGS thin-film solar cells, and is developing a manufacturing process for these cells that is intended to reduce production costs.

The photovoltaic solar cells on the roof of Hovet sports arena in Stockholm are flexible thin-film modules of amorphous silicon, which are integrated in the roofing membrane. The system supports the illumination for the adjacent Globen arena.

Silicon Carbide

The properties of silicon carbide make it suitable for the production of energy-efficient and high-temperature electronic devices. In order to realise this potential, the Agency has supported work along the entire development chain for several years, from conception of the material to advancement of power electronic devices. There is now a growing industry as a result of state support. Power electronic devices made from silicon carbide are seen as an important element in the development of electric hybrid vehicles and pure electric vehicles. Other important applications include motor control and power transmission.

full-scale production lines. Sweden is involved in this development through a joint project between Uppsala University, the Royal Institute of Technology and Swerea IVF in Mölndal. The university is conducting fundamental research into new dyes and electrolytes, and producing and characterising new cells. This research group is among world leaders in the sector. The fundamental research is complemented by the manufacture of modules and development of the production process by Swerea IVF, with the long-term objective of manufacturing cost-effective solar cells for large-scale electricity production.

Ocean energy systems

Wave power

A wave energy converter concept, Seabased, is being tested offshore outside Lysekil, a village on the west coast. The prototype, which has been developed at Uppsala University, consists of a generator which is placed on the sea bed, with one end of its moving element connected by a line to a buoy on the surface, and the other end connected to a spring which is secured to the base of the unit. The moving part of the generator is a piston, which is pulled up and down in the stator by the buoy, thus inducing a voltage in the stator windings. The generator is protected from severe weather, as it is on the sea bed, while mechanical elements are simple and can withstand high loads. A six m diameter doughnut-shaped buoy has shown itself to be particularly suitable for extracting maximum lift from wave motion. The generator of the Lysekil unit will be of the order of 10–20 kW, but a scaled-up version, with an output of 50 kW, will be tested in very severe weather conditions and a high tidal range at a test facility in Scotland during 2009.

Marine currents

Sweden also has potential for electrical production from constant marine currents, both offshore and in rivers. So far, a very slow speed experimental permanent-magnet generator (5 kW) has been developed: the next step is to build a turbine and generator for testing in a real marine environment.

The doughnut-shaped buoy in the wave energy converter tested offshore Lysekil.

Combined heat and power production

Research and development in this area is concentrated on improving efficiency, reducing costs and tackling corrosion problems associated with the production of electricity from biofuels. The favourable conditions for CHP production from biofuels has meant that interest has increased in converting smaller boilers to CHP production.

The results from many years of research into corrosion mechanisms by the HTC and KME material research programmes have meant that the industry now sees good prospects for taking a step forward through higher steam data from biofuel firing. A new research programme will start in 2009, bringing together and filling in those gaps in knowledge which remain before the final objective of building a full-scale demonstration facility in 2015, having at least two percentage points higher electricity production efficiency than that of present-day plants.

A new four-year programme period was started up in the Swedish Thermal Engineering Research Association's basic programme in 2008. The most important elements of the programme are development and dissemination of knowledge, coupled with improving the efficiency of existing combustion plants. The Swedish Energy Agency has brought together representatives from various sectors of industry to work in the field of carbon capture and storage, to form a new joint research programme in 2009.

Combined heat and power

CHP and district heating plants in Sweden have undergone substantial changes over the last two decades. During the 1980s, the majority of the fuel used for heat and power production was of fossil origin. After 1991, with the introduction of the carbon dioxide tax and together with result from R&D, the proportion of biomass used for heat production has risen steadily from 25 percent in 1990 to 69 percent in 2007. The proportion of renewable fuels used for power production has increased from 35 percent in 2001 to 65 percent in 2007. This has been accompanied by a 45 percent increase in electricity production, from 9.4 TWh to 13.6 TWh, equivalent to 6 percent of total electricity production in 2001 and 9.4 percent in 2007.

HIGHLIGHT

– a success story where funding from The Swedish Energy Agency has played an important role

A major leap forward

State support for a power transmission project based on the use of new DC technology provided the starting signal for a development which revolutionised the expansion of future power systems and provides new potentials for renewable energy sources.

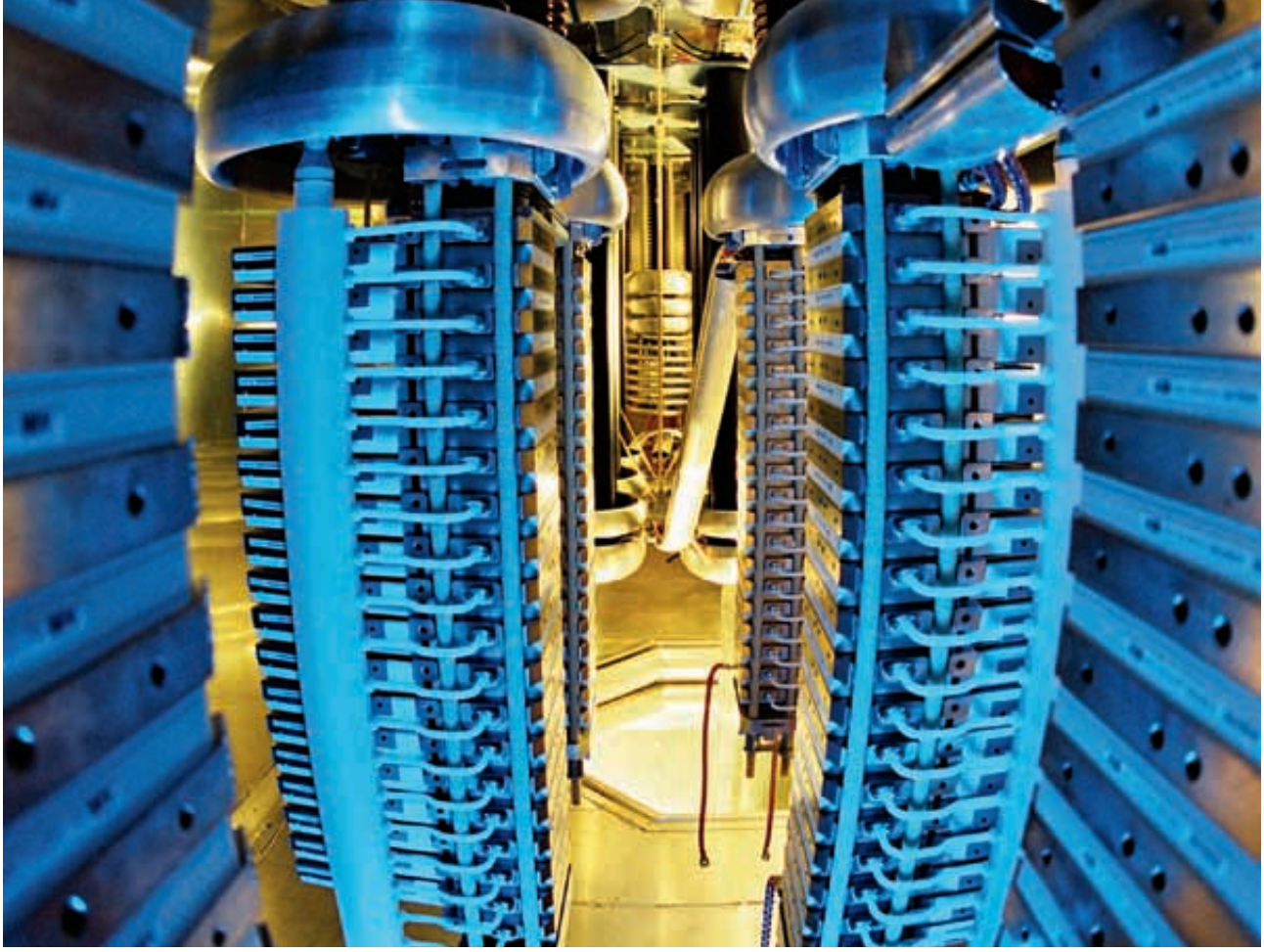
The local electricity distribution system on the island Gotland in the Baltic sea required reinforcement when wind power began to be expanded on the island during the 1990s. The choice lay between expanding the existing 70 kV AC system or using a technology that had not previously been bought, but which in theory offered clear advantages. An additional consideration was the fact that construction of a traditional overhead line system would encounter planning problems, while burying AC cables would cost about ten times as much.

Developed by ABB, the new technology was known as HVDC Light, and was intended for the transmission of moderate powers using high-voltage DC, and specially designed for operation over long distances of underwater or underground cables. The use of DC allowed the power flows in the cables to be controlled, thus improving the electricity quality in the AC networks, which was an important aspect when carrying electricity from wind power plants. The system had been developed by ABB in Ludvika and tested in 1997 in a pilot facility, with converter stations at the Hällsjön power station and at Grängesberg, connected by 10 km of overhead lines.

As HVDC Light was a new technology, it was more expensive than proven technology and thus presented too great an economic risk for the purchaser or manufacturer to accept alone. As the technology was unproven, there was also a certain element of technical risk in the project. Vattenfall's Stig Göthe, head of research at the time, recalls the agonies of making a decision on investment in an expensive unproven technology:

– I could feel the pressure. On the one hand, we wanted proven technology in order to provide the best for the island's electricity customers and for wind power in the south of the island, while on the other hand we wanted to ensure that development of the new technology didn't move elsewhere, thus keeping employment opportunities in the country, he explains.

At the end of 1997 ABB, Gotlands Energi AB through Vattenfall, and Nutek (Nutek was restructured in 1998, with establishment of the Swedish Energy Agency) had reached agreement on the construction of a power line between the wind power plants at Näs in the south of the island and Visby, and to share the risk. The agreement was a world first for power transmission using the new application of high-voltage DC. Two 70 kilometre 80 kV cables, carrying 50 MW, would be buried in the Gotland limestone. The total investment amounted to about SEK 150 million, for a technology that had never previously been used commercially. Shortly after reaching the agreement, the new Swedish Energy Agency formally took over responsibility from Nutek, and approved a grant of SEK 40 million for the project.



The picture shows the heart of a HVDC Light station – the IGBT valves – where the alternative current (AC) is rectified to direct current (DC) or DC converted to AC.

For ABB, the order from Vattenfall represented a breakthrough. The company now had a demonstration installation to show to new potential customers, and has subsequently sold an average of one HVDC Light installation per year. Over a decade, HVDC Light has grown into a market worth about SEK 4000 million, and providing many jobs mainly in Sweden.

Technical development has continued, reducing the price and improving the technology. ABB has recently introduced UHVDC (ultra-high voltage DC) for transmitting large quantities of power over long distances.

The climate threat and the need to ensure security of power supplies necessitate the construction of renewable energy facilities. By 2020, 20 percent of EU energy production is required to come from renewable energy sources. Solar power and wind power are those forms of energy production that are increasing the most rapidly world-wide. In the EU, total installed capacity of wind power increased by 18 percent in 2007. Sweden plans to expand its wind power production from about 2 TWh to 30 TWh by 2020. Wind power farms are sited in windy areas, often a long way from existing electricity distribution systems. Power supply from them is uneven, as the wind is not constant, which affects the quality and stability of power on the AC grid.

VSC HVDC (which is the common name for the new generation of HVDC) is important in this context, as it provides new means of transferring small to modest quantities of electricity over long distances via small underground or underwater cables. The power flow can also be controlled to produce a smooth flow, which cannot be done on the AC grid.

Programmes at The Swedish Energy Agency 2008

Energy system studies

1 General Energy Systems Studies
2 International Climate Policy
3 Energy Systems Program (post-graduate school)
4 Nordic Energy Research Program

(Bio)energy incl. Combined Heat and Power

5 Sustainable biomass production and plant breeding
6 Increasing the efficiency of forest bioenergy systems
7 Wood Pellet Production Technology Platform
8 Environmentally friendly use of non-coal ashes
9 Centre for Waste Refinery
10 CECOST - Centre for Combustion Science and Technology.
11 Business sector research program for energy utilities
12 Artificial photosynthesis
13 Värmeforsk's Basic Programme
14 Värmeforsk's Programme: Forest Industry
15 Värmeforsk's Programme: Crops from field to energy production
16 National RD&D programme within the field of energy gases
17 TURBO POWER – Thermal Turbo-machines for Electricity Production

Transport sector

18 Program on Black-liquor Gasification
19 Swedish Hybrid Centre
20 Centre of Internal Combustion Engine Research Opus
21 Program on Ethanol production
22 The Vehicle Research Programme
23 Energy systems in Road Vehicles

Electricity Production

24 Vindforsk III – Wind Power Research Program
25 Centre for Renewable Electricity Conversion
26 Swedish Hydropower Centre, SVC
27 Environmental Issues in Hydropower
28 Program on Solar Photovoltaic
29 Centre of Excellence in Electric Power Engineering EKC2
30 The ELEKTRA programme to promote a long-term build-up of expertise in electric power engineering

Industry

31 Process Integration
32 Metallurgical collaborative research and energy efficiency
33 The Steel Industry's Research Program
34 Energy Efficient Casting Technologies
35 Mineral Processing Research Program

Built Environment

36 Energy Efficiency in Cultural Buildings
37 Energy, ICT and Design
38 Energy efficient lighting
39 ELAN – Electricity Usage in Everyday Life
40 Small-scale biomass combustion systems
41 Energy efficiency in refrigeration and heat pump systems
42 CERBOF - the Centre for Energy and Resource Efficient Construction and Facilities management

More information

Energy research on the web

The Swedish Energy Agency's web site, www.energimyndigheten.se, includes an English-language section called Energy research, with basic information on the various research fields. Information on news and calls for research applications can be found in the Swedish-language versions of the site. There is also information on, and links to, the various research programmes.

Forskning.se is a web site (mainly in Swedish, but with English summaries) that provides information on research and research findings in Sweden. It includes general information on Swedish research, news, links to all research funding sources, detailed information for journalists and presentations of various research results.

Energy Research Newsletter (In Swedish)

Would you like an e-mail subscription to the latest news on energy research? The Swedish Energy Agency publishes a newsletter (at present only in Swedish) aimed specifically at those parties interested in performing energy research. It contains news and information on current calls for proposals, events and conferences. Subscribe to it via the Agency's swedish web site http://www.energimyndigheten.se/sv/Press/Prenumerera/Nyhetsbrev/Nyhetsbrev-energiforskning/.

Brochures

You can find studies, reports, reviews and other written material on our web site. Much of this material can be downloaded or linked from the respective theme areas and research programmes. Some can be ordered from the Agency's publications service.

Links

Some research financing organisations with web sites in English:

The Swedish Energy Agency *www.energimyndigheten.se*
The Swedish Research Council (Vetenskapsrådet) *www.vr.se*
The Swedish Governmental Agency for Innovation Systems (Vinnova) *www.vinnova.se*
The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS) *www.formas.se*
Mistra *www.mistra.org*

Research programmes etc.

The Swedish Wind Energy Research Association *www.vindenergi.org*
Research into Grätzel solar cells *www.moleculardevices.se*
The Ångström Laboratory *www.angstrom.uu.se*
CECOST *www.cecost.lth.se*
KME *www.elforsk.se/kme/index.html*
Electric Power Centre of Excellence at the Royal Institute of Technology *www.comp.ee.kth.s*e

The Swedish Hydropower Centre *www.svc.nu*
The National Research Agenda for the Swedish Forest-based Sector *www.nra-sweden.se*

Competence Centers

CERC: *www.tfd.chalmers.se/CERC/*
KCFP: *www.vok.lth.se/index.php?id=147*
KCK: *www.kck.chalmers.se*
CICERO: *www.cicero.kth.se*
HTC: *www.htc.chalmers.se*
EKC2: *www.comp.ee.kth.se*
SHC: *www.chalmers.se/hosted/shc-en*

International links

Nordic energy research *www.nordicenergy.net*
IEA *www.iea-sverige.org* or *www.iea.org*
ERA-NET Bioenergy *www.eranetbioenergy.net*
IEA-Bioenergy *www.ieabioenergy.com*

Sector organisations etc.

The Swedish Association of Electrical Utilities *www.elforsk.se*
The Swedish District Heating Association *www.svenskfjarrvarme.se*
Research into heat pumps *www.effsys2.se*
The Forestry Research Institute of Sweden *www.skogforsk.se*
The Thermal Engineering Research Association *www.varmeforsk.se*
Innventia *www.innventia.com*

Other public authorities concerned with energy-related matters

National Road Administration *www.vagverket.se*
Swedish Environmental Protection Agency *www.naturvardsverket.se*
The National Board of Housing, Building and Planning *www.boverket.se*
The Swedish Consumer Agency *www.konsumentverket.se*
Central Services Office for the Government *www.regeringen.se*
Swedish Forest Agency *www.skogsstyrelsen.se*

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An efficient and environmentally friendly energy supply system

The Swedish Energy Agency aims at achieving a safe, reliable, environmentally friendly and efficient energy system in Sweden and internationally. The Agency works to improve the effectiveness of energy markets, with a greater element of renewable energy. It also exercises surveillance of the electricity distribution companies and is responsible for the country's strategic energy preparedness for crisis situations.

An important part of the Agency's work is the financing of research, development and demonstration activities in the energy sector. It supports a large number of research and development programmes in conjunction with universities, institutes of technology and industry.

Swedish Energy Research 2009 provides a brief, easily accessible overview of the Swedish energy research programme. The aims of the programme are to create knowledge and skills, as needed in order to commercialise the results and contribute to development of the energy system. Much of the work is carried out through about 40 research programmes in six thematic areas: energy system analysis, the building as an energy system, the transport sector, energy-intensive industries, biomass in energy systems and the power system.

Swedish Energy Research 2009 describes the overall direction of research, with examples of current research, and results to date within various thematic areas and highlights.

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