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This publication describes the Swedish Energy Agency's support for research and innovation in the form of results and effects, and it presents future requirements for a sustainable energy system.

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Preface

Emissions of greenhouse gases and their impact on the Earth's climate probably represent one of the greatest challenges humans have ever faced. The transition to a green economy is the key to sustainable social development and is essential to our ability to manage climate change.

Radical changes are required of the energy system's actors, rules and technologies in order to meet the major social challenge posed by climate change. Research is a long-term investment and the factors for success are an integrated approach, collaboration and dialogue with the business community, academia and other public agencies.

Swedish energy research has already delivered several innovations and the transition from a fossil fuel-based energy system to a renewable energy system is well on the way. However, we are not there yet. Energy and climate issues are closely linked and the solutions to the challenge of climate change are largely energy-related. Greater ambition is required in the energy sector for the results to make a clear impression in society and on the climate.

'Swedish Energy Research' reports on a selection of initiatives, results and effects to which research and innovation in the energy sector have contributed. There is positive development and this has also boosted the Swedish business community and enhanced its international competitiveness. It also describes future research requirements to accelerate the development towards a sustainable energy system.

Rémy Kolessar
Head of the Department for Research and Innovation

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The Swedish energy research and innovation programme

The Swedish Energy Agency is the third largest state sponsor of research in Sweden. Every year, the Swedish Energy Agency distributes just over SEK 1 billion to research, development, demonstration, commercialisation and innovation initiatives. This contributes to meeting Sweden's energy and climate goals, implementing its long-term energy and climate policy and achieving a number of energy-related environmental policy goals.

Energy research and innovation is driven by society's need for a more sustainable energy system. The Swedish Energy Agency works strategically to prioritise and gain acceptance for its work with selected initiatives. This takes place in close cooperation with universities, the business community and the public sector. Research results contribute the knowledge and expertise that enable a sustainable energy system to be developed. They are also designed to contribute to the commercialisation and implementation of new products and services in both Sweden and other markets, and are converted into policy at various levels of society and lead to well-founded energy and climate policy decisions.

Energy research is part of long-term energy policy

One of the major global challenges is to create secure access to safe, sustainable, efficient energy. The issue of energy security is closely linked to that of climate change as fossil energy accounts for a large part of global energy use. Swedish energy policy aims to combine ecological sustainability, competitiveness and security of supply. Consequently, there is a strong link between energy policy, climate policy and environmental policy and this link requires balanced development as a secure energy supply also forms part of the basis for economic growth. Energy research and innovation play an important role in Swedish energy policy. Along with other instruments, research and innovation initiatives contribute and supply additional impetus to influencing the development of the energy system towards the established goals. Since the Swedish Energy Agency manages a number of policy instruments that aim to develop a more sustainable energy system, there are good opportunities to create synergies between different initiatives.

According to Government instructions, the task of the Swedish Energy Agency is to "...promote research and innovation in the form of a strategic initiative spanning the entire innovation system, in close cooperation with and as a supplement to other energy policy initiatives and other instruments aiming to achieve climate and energy goals and energy-related environmental policy goals".

Current energy policy is based on the Riksdag decision on a coherent Swedish climate and energy policy (Climate bill 2008/09:162). There are specific targets for reducing emissions of greenhouse gases, increasing the volume of renewable energy and enhancing the efficiency of energy use. The targets match Sweden's commitments in relation to EU climate and energy targets.

The Riksdag has also adopted the vision that Sweden will have a sustainable, resource-efficient energy supply without net emissions of greenhouse gases into the atmosphere by 2050.

For Swedish environmental policy, the overall generational goal is to be able to leave the next generation a society in which the major environmental problems have been solved. There are also sixteen environmental quality goals, some of which are directly linked to the energy sector.

SPECIFICATION OF THE RESEARCH POLICY GOALS:

- To build up the scientific and technical knowledge and expertise that are needed to apply new technologies and new services to enable the transition to a long-term sustainable energy system in Sweden in which ecological sustainability, competitiveness and security of supply are combined.
- To develop technologies and services that can be commercialised by the Swedish business community and thus contribute to sustainable growth and the transformation and development of the energy system both in Sweden and in other markets.
- To contribute to and benefit from international collaboration in the energy sector.

Various initiatives are contributing to transition

The research activities supported by the Swedish Energy Agency comprise large parts of the innovation system and include energy-oriented basic research, applied research (also called industrial research), experimental development, demonstration activities and commercialisation.

The Swedish Energy Agency distributes approximately SEK 1.3 billion per annum for research and innovation. The research is mainly organised in programmes. The number of programmes varies over time based on identified research needs. The majority of energy research projects are implemented within the framework of 55 research and innovation programmes. A number of projects are also implemented outside the programmes and supplement the research programmes. The Swedish Energy Agency currently finances approximately 1,100 projects.

Figure 1 Number of researchers/ postgraduate students funded by the Swedish Energy Agency, 2014

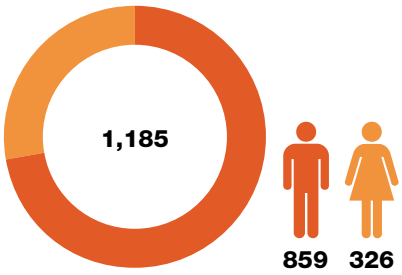
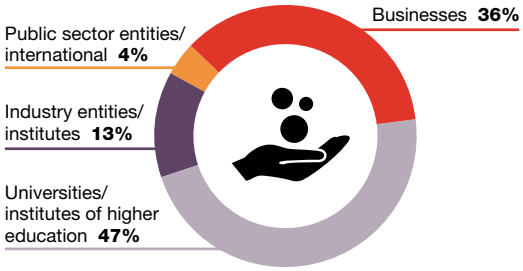


Figure 2 Research financed by the Swedish Energy Agency, according to recipient group, 2014, percent



Scientific excellence and quality are essential for a basic research project, and the initiative should represent a contribution to the transition of the energy system, whether the initiative is driven by curiosity or need. In a demonstration project, the primary focus is on application, its marketable quality, the potential for implementation and its contribution to the development of the energy system.

It is important to maintain a long-term approach in the development of research and innovation. Research and the development of expertise and knowledge often take a long time. There may subsequently be a delay of several years before new research findings, knowledge and innovations are applied or commercialised and implemented. It generally takes 10–30 years for new technology to proceed from the research and demonstration stage to introduction and use on a large scale.

Research and innovation activities take place at universities and institutes of higher education, in various industry and research institutes and in the business community. International networks in the Nordic region and the EU and the International Energy Agency (IEA) are also important for the exchange of knowledge and expertise.

Collaboration and co-financing – tools for relevance and quality

If societal change is to take place, it is essential for there to be collaboration between the various actors and sectors of society. Consequently, the Swedish Energy Agency works actively to collaborate with society at large. Co-financing and collaboration lead to higher academic quality and to benefits such as effects related to resources, expertise, learning, guidance and networks. Collaboration is an important element when the Swedish Energy Agency develops needs-related strategies for priority initiatives and new initiatives in the form of programmes, as well as when it assesses applications and ideas.

The Swedish Energy Agency uses several different forms of research programme to achieve collaboration, ensure relevance for different target groups and benefit society. Research programmes that are managed by the Swedish Energy Agency and are a result of the strategy work are the commonest form. Initiatives in the form of programmes also take place in direct collaboration with the business community and other actors. These are called collaboration programmes. In these programmes, the industry and the Swedish Energy Agency agree on the contents.

The Swedish Energy Agency is assisted on programmes by the Programme Council or external experts who assess applications on the basis of specific criteria. Different criteria are sometimes also weighted to compare applications. The assessments by the Programme Council and/or external experts are submitted as recommendations to the Swedish Energy Agency, which then makes decisions.

Competence Centres are another type of research programme that is mainly implemented in cooperation with the business community and where the initiatives are focused on a specific field that is of interest to the Swedish Energy Agency and the industry. The institute of higher education, the industry and the Swedish Energy Agency build up and finance the research environment jointly, each contributing a third.

Basic research at universities and institutes of higher education is often financed in full by state funds. The closer to implementation and marketing products (goods or services) or processes are, the stricter the requirements for co-financing are. The co-financing rate in 2014 was 45 percent. Co-financing allows state funds to function as levers and contribute to products and services being developed in collaboration with academia, the business community and the public sector.

Figure 3 Research financing, 2014, SEK million

Strategic innovation areas are the concern of several public agencies

Research programmes within the strategic innovation areas are another form of research programme. Strategic innovation programmes are similar to collaboration programmes but they offer better opportunities to include issues that span the areas of responsibility of several agencies. A total of 16 programmes are financed jointly by Vinnova[1], the Swedish Energy Agency and Formas[2].

The aim of the strategic innovation programmes is to create the conditions for sustainable solutions to global social challenges and international competitiveness by means of collaboration in areas that are of strategic importance to Sweden. Six examples of the programmes financed are presented on the following pages.

1 Vinnova is Sweden's innovation agency.
2 The Swedish Research Council Formas.

SMART BUILT ENVIRONMENT

The programme has a plan for how the urban development sector can contribute to Sweden's journey towards becoming a global pioneer, realising the new opportunities made possible by digitisation. The objective of the programme is to reduce the environmental impact of the construction sector, reduce planning and construction time, reduce total construction costs and make new business logic possible in the sector.

GRAPHENE

Graphene is a brand new material that is predicted to be able to meet innumerable challenges in several industries. Areas of application in which graphene is expected to contribute to solutions include health, clean and efficient energy and smart, green, integrated transportation.

The objective of the programme is for Sweden to become one of the ten leading countries in the world at using graphene to ensure industrial leadership. The programme is designed to help establish graphene as a new industry, boost knowledge transfer between industries and ensure Swedish graphene-based products reach the market.

BIOINNOVATION

Sustainable development requires a transition to a bio-based economy. The development of new bio-based materials, products and services is essential if we are to be able to meet the global challenge of climate change and maintain the long-term competitiveness of Swedish industry.

The vision for BioInnovation is for Sweden to have switched to a bio-based economy by 2050. The objective is to create the best possible conditions for increasing value added and competitiveness in the Swedish bio-based sector.

DRIVE SWEDEN

Innovative measures are essential to the vitality and growth of the cities of the future, and automated transport systems will change the principles for urban planning as well as for the development and use of future means of transport.

A combination of parallel developments in information and communication technology, policy, urban planning and self-driving vehicles means that Sweden can take the lead and make a marked contribution to sustainable growth. The Drive Sweden programme involves collaboration across industrial sectors with information and communication technology at its core and strong links to the automotive and construction sectors.

The vision of the programme is for Sweden to be positioned as the leader in automated transport systems. The area will be reinforced via cooperation, coordination and making use of all ongoing and planned initiatives.

RE:SOURCE

The RE:Source programme is a new strategic innovation programme for research and innovation related to sustainable resource and waste management. The vision is for Sweden to be the world leader at minimising and making use of waste. Improved waste management can help reduce the environmental problems of waste and the waste can become a resource for recycling materials and recovering energy. The programme aims to find solutions to three major societal challenges: a resource-efficient society, sustainable material supply and a sustainable energy system.
RE:Source is part-financed by the Swedish Energy Agency, Vinnova and Formas. Actors from the recycling and waste industry and the manufacturing industry, material producers, public agencies, municipalities and cities, universities, institutes of higher education and research institutes all work together in the programme.

SMART ELECTRONIC SYSTEMS

The importance of smart electronic systems, based on microelectronics and nanoelectronics, photonics, micromechanics, power electronics and integrated systems, is increasing dramatically in our society. The area is also the key to resolving the global challenges facing a future sustainable society, for example with new energy-efficient electronic systems.

We have a dynamic Swedish electronics industry and a high international academic level in this area. However, to stay at the top, Sweden needs to improve knowledge transfer and interaction in value chains, focus on important leading technical fields and guarantee the supply of expertise in the area.

The goal of the strategic innovation programme is for Sweden to be a world-leading industrial country in virtually all areas in which we depend on advanced information and communication technology for electronic components and systems by the year 2025.

The Swedish Energy Agency's strategic priorities

The Swedish Energy Agency works regularly on strategy and develops this work constantly. The cornerstones of the work are dialogue and collaboration with the actors in the innovation system based on energy and climate policy goals.

Constant changes are taking place in the world around us and the rate of development is very high in certain areas. At the same time, research activities need to be carried out with a long-term approach. Robust yet flexible strategies are essential to be able to work in this environment.

Basic data from a wide range of different reports, evaluations and analyses is used in the work. Contributions include reports from the thematic areas' development platforms consisting of a total of around 90 representatives of the various parts of society (business community, public sector and academia). The development platforms deliver advisory documentation to the Swedish Energy Agency. The strategies are regularly reviewed to ensure that their direction and focus are relevant.

The work of the Swedish Energy Agency is organised in thematic areas[3]:

Power systems and electricity generation: This area comprises renewable electricity generation technologies such as hydropower, wind power, solar power and marine energy, plus the transmission, distribution and use of electricity.

Bioenergy: This area comprises production and processing of biofuel (including waste) and its conversion into electricity, heat and cold.

Transport system: This area comprises enhancement of the energy and resource efficiency of the transport system, conversion of vehicles to use renewable fuels and production of renewable fuels.

Industry: This area comprises efficient energy use in processes and efficient exploitation of raw materials, input materials and surplus energy. It also includes increased use of renewable energy carriers and fuels and development of renewable and resource-efficient materials and products.

Buildings in the energy system: This area comprises buildings' total energy use throughout their life cycle and buildings' and users' interaction in districts or entire cities.

General energy system studies: This area analyses the energy system from the perspective of society. Policy, the economy, instruments and markets, plus the various actors operating within the system and their actions are all components about which more knowledge is needed.

Business development and commercialisation: This area comprises support for business development, commercialisation and the spread of new solutions.

International partnerships: This area comprises the Swedish Energy Agency's initiatives to promote Swedish research and innovation by means of international collaboration and work to promote the competitiveness of Swedish research and innovation in international markets.

3 The thematic areas were previously called: energy system studies, transport sector, fuel-based energy systems, buildings as energy systems, power systems and energy-intensive industry. There is a proposal to add another thematic area: sustainable society.

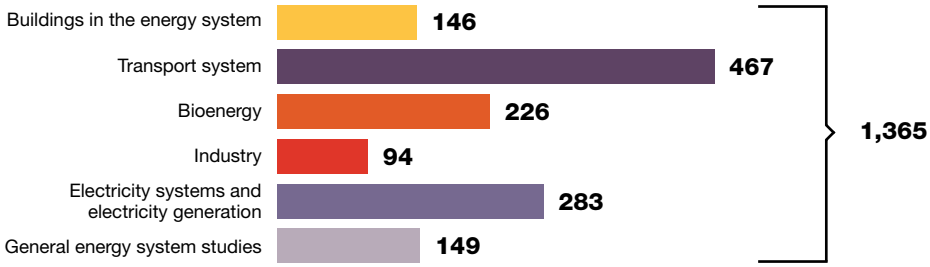
The Swedish Energy Agency's priority research fields up to 2016

The Swedish Energy Agency is currently pursuing a strategy that is valid up to the end of 2016 via five priority research fields, all of which are steeped in a system perspective that is extremely important for Sweden:

- a vehicle fleet independent of fossil fuels
- an energy system compatible with renewable electricity generation
- enhancement of the energy efficiency of buildings
- increased use of bioenergy
- enhancement of the energy efficiency of industry

These strategic priorities apply up to the end of 2016 and are intended to guide energy-related research and innovation initiatives. The next strategy for priority research and innovation initiatives in the energy sector concerns the period 2017–2020 and will be submitted to the Government at the end of 2015 via the report 'Helhetsyn är nyckeln' (A Holistic Approach is Key).

Figure 4 Research financing by the Swedish Energy Agency, 2014, SEK million



Climeon uses thermal power to make the world more energy-efficient

On a business trip, enthusiast and engineer Thomas Öström realised that something had to be done to manage global resources. He gave up his safe job in 2010 with the ambition of making a difference. Just five years later, Thomas' company Climeon has 15 employees, and two energy recovery power plants have already been sold to clients Viking Line and SSAB. The Swedish Energy Agency has supported Climeon throughout its journey.

Thomas Öström's commitment to the environment took shape during a business trip to Beijing in 2006. He reacted to the high volumes of exhaust gases filling the city. What struck him is that our lifestyle is unsustainable, and that something had to be done. Thomas came home and thought about where he should start. Aiming to learn more about environmentally friendly technologies, he started an environmental blog. He found a conversation partner in his neighbour Joachim Karthäuser, a chemist. They discussed what could be done with wind power, solar power and hydropower, but discovered that there was great development potential in thermal conversion. A significant part of the energy used by humans becomes waste heat that, if only better conversion methods were available, could be recovered. Neither Thomas nor Joachim were able to let go of this idea.

From patent to prototype

To make a long story short, the Eureka moment was when the two men realised that the solution to the problem of extracting maximum energy from heat of low temperature is to use a vacuum – or a low pressure process – which is counter-intuitive and against prior art. Their process pushed the efficiency of electricity generation towards the theoretical maximum. With their first patents and a sheaf of calculations in their hands, they held a meeting with the Swedish Energy Agency at the end of March 2011.

"For us, it was great to meet someone who had knowledge about similar projects and similar technology. We also knew that if we had the support of the Swedish Energy Agency, it would be easier to bring other financiers on board. However, they were doubtful at the Swedish Energy Agency. So they sent us to Professor Per Lundqvist at the Royal Institute of Technology (KTH)," says Thomas.

Per Lundqvist's review confirmed that Thomas' and Joachim's calculations were correct and concerned an untried solution with great potential. With this confirmation, the Swedish Energy Agency gave Climeon a development grant of SEK 850,000 to build a prototype.

Climeon's patented technology:
Climeon's patented technology bears similarities to ORC systems. This involves a carrier liquid circulating in a closed system. Waste heat causes the liquid in Climeon's power plant to gasify. The gas drives a turbine and an electric generator, and the gas is re-converted to liquid.

From prototype to demonstrator

When the prototype was working according to the calculations, the next step was to build a miniature 3 kW power plant to demonstrate the entire process. The Swedish Energy Agency also provided support for this. This time the grant was SEK 1 million. In connection with this grant, Climeon held a new share issue to raise further capital.

"In terms of development, we still had a long way to go. My approach was that, if we fail to achieve 10 percent efficiency, we will stop. However, after two years of work, in early February 2014, we achieved the necessary effect and set a world efficiency record at KTH," says Thomas, still enthusiastic after this moment of triumph.

"We really thought we had got somewhere. We went to the Swedish Energy Agency for the third time. What we wanted to do was to build a larger 100 kW power plant. We were granted SEK 3.5 million by the Swedish Energy Agency, and we held a new share issue to raise more capital for the company. The fact that the Swedish Energy Agency is supporting us is always like a stamp of quality," says Thomas.

“The Swedish Energy Agency keeps everything in order

2014 was a hectic year. To mass-produce the 100 kW power plant, a production plant was created. In November 2014, we had the first order, from the shipping company Viking Line. In December, Climeon submitted the final report for the Swedish Energy Agency's financing process. The final report, which takes some time to write, contains all the evidence showing that the 100 kW power plant works and performs well.

Thomas thinks that all start-ups need someone to report to. In their case, it was the Swedish Energy Agency.

“The technology working is actually only a small part of things. A lot revolves around following your plan, what it will cost and what the customers will earn. The Swedish Energy Agency has a reporting method with a number of mandatory templates. This is an excellent way of keeping everything in order,” says Thomas.

Instead of 200 tonnes of fossil fuel

Viking Line has now installed Climeon's Ocean power plant on M/S Viking Grace. The system generates the incredible figure of almost 700,000 kWh of power from the waste heat from the fossil gas-powered ship. This means that Viking Line saves 200 tonnes of fuel a year. The company has also begun a partnership with SSAB to recover residual heat from its steel production.

"The technology feels amazing. We aren't doing anything magical or strange. We can recover ten percent of the waste energy without breaking any of the laws of thermodynamics with a process that is extremely optimised," says Thomas.

Climeon now has a conditional loan of SEK 14 million from the Swedish Energy Agency. The money will be used to develop three pre-commercial prototypes in different customer segments with the aim of obtaining feedback from customers and collecting operating data from the systems. The company is currently looking for customers with large quantities of waste heat, for example in the steel industry and the marine world.

On the recommendation of Climeon's lawyer, Thomas has stopped writing his environmental blog so that his patented ideas remain within the company. However, he is as much an engineer as an enthusiast. When asked where Climeon would be without the support of the Swedish Energy Agency, he replies without a moment's hesitation:
"I don't think we would be anywhere". ■

> ...without the support of the Swedish Energy Agency, he replies without a moment's hesitation:
>
> "I don't think we would be anywhere".

Facts in brief:

Start year: 2011
Headquarters: Stockholm
Business concept: Recovery of waste heat
Number of employees on start-up: 3
Product: Climeon Ocean™
Customer benefit: Waste heat converted to useful electric energy. Avoids CO^2 and heat emissions. Attractive pay-back times.
Number of employees, 2015: 15
Number of units sold, 2015: 2
Partners: Alfa Laval, Deprag, SLS, Dione, KTH, Lund University, Stockholm University
Examples of customers: Viking Line, SSAB
Market: Global
Net sales, 2014 (SEK thousand): 80

Power systems and electricity generation

Research into electricity systems and electricity generation comprises electricity generation from the renewable resources water, wind and sun, plus technology for power transmission and distribution. The cost of building new renewable electricity generation plants has continued to fall in recent years, which has resulted in rapid expansion. This positive development has taken place thanks to long-term research and development work that has ultimately contributed to creating jobs and new products.

The EU has established targets for each country's proportion of renewable energy by 2020. Sweden has committed to a target of 50 percent of total energy use being renewable. This target was already achieved in 2012, and in 2013 the proportion of renewable energy in Sweden was 52 percent. In 2013, renewable electricity accounted for 62 percent of total electricity use[4]. Future renewable energy targets will be affected by EU negotiations and climate change meetings.

The transition to a sustainable energy system entails major changes and research challenges in the area of electricity. The vision of the research activities into electricity systems is for Sweden to be internationally recognised for having a 100 percent sustainable electricity system and also for being a net exporter of electricity by 2050. This means that research is needed to develop new technologies and improve and enhance the efficiency of existing ones to make them more cost-efficient. The transformation of both the energy and electricity systems entails challenges. For example, electricity generation fluctuates greatly, creating an enhanced need for flexibility in the electricity system, in particular among consumers. The fluctuations create an enhanced need for storage.

It is important for technological developments to take place with due consideration for the environment and to meet society's need for an efficient, safe electricity system now and in the future.

4 Read more at www.energimyndigheten.se/energilaget.

Results and effects

For nearly fifteen years, the Swedish Energy Agency has supported research into how sound from wind turbines affects humans and our health. The research is being conducted at Halmstad University and at the University of Gothenburg. To date, more than one thousand people who live near wind turbines have been included in the studies. The studies have involved both quantitative sound measurements and qualitative interviews. The results show that very few people are disturbed by sound from wind turbines but that those who are disturbed experience a high level of disturbance. At the population level, therefore, sound from wind turbines presents no problem for human health. However, for some individuals it may entail major problems. Around 10 percent of the individuals included in the studies indicate that they are disturbed or very disturbed by sound from wind turbines and have symptoms such as headache or fatigue.

Great potential for development of solar cells

The cost of solar cells has fallen dramatically in recent years. This has contributed to the number of solar cells installed in Sweden having doubled for the fourth year in a row. Despite this, solar electricity still constitutes only a very small part of total electricity use in Sweden. In 2014, the proportion was 0.06 percent.

Sweden also has internationally competitive research into a wide range of different solar cell technologies, and several companies are offering new technologies for sale on the market. The Swedish Energy Agency has supported some of these companies through research and development initiatives in the field. One example is the research group at Ångström Solar Center. They have beaten the world efficiency record for CIGS thin-film solar cells several times, and the technology is now available on the market.

Midsummer AB is an example of a company in the solar cell industry that develops and sells production equipment for thin-film solar cells. They currently have around thirty employees. Another company, Exeger, has decided to focus on molecular solar cells. They are currently completing a solar cell factory in Stockholm. Both Midsummer AB and Exeger have received funding from the Swedish Energy Agency for their technology and business development.

The Swedish Energy Agency also supports research that develops new knowledge designed to facilitate the ongoing solar cell expansion. For example, the Swedish Energy Agency supported a project in which the company CIT Energy Management AB studied how different installation systems suit different conditions. The study covered around 100 existing solar cell systems. Experience from both installers and solar cell owners was compiled and fed back to the industry to enhance knowledge to ensure that solar cells are optimally installed.

THIN-FILM SOLAR CELLS REQUIRE LESS MATERIAL

CIGS solar cells consist of a few micrometres of thin film on a glass or steel surface. The light-absorbent layer is a mixture of copper (Cu), indium (In), gallium (Ga) and selenium (Se). CIGS solar cells belong to a group of solar cells that are called thin-film solar cells. As the cells are so thin, much less material is needed to make a thin-film solar cell than is needed to make a standard crystalline silicon solar cell.

MOLECULAR SOLAR CELLS OFFER NEW OPPORTUNITIES FOR BUILDING INTEGRATION.

Molecular solar cells are also called Grätzel solar cells after the Swiss researcher, Michael Grätzel, who is behind the technology. The solar cells contain a film of nanoparticles made of titanium dioxide which is dyed using a dye that makes the particles function like photosynthesis. Molecular solar cells can be made semi-transparent and coloured, creating exciting potential for integration in glass façades, for example. This type of solar cell is not as sensitive to the direction of solar radiation and is therefore suitable for exploiting diffuse sunlight.

Sweden has world-leading research in the field of marine energy.

Wave power is a largely unexploited renewable energy resource that has the potential to contribute to the energy policy goals of Sweden and Europe. However, the sea is a tough environment for power plants to survive in, which makes it more difficult to reach the commercialisation stage. Research and development are in progress and the technology has matured, with a number of concepts being tested at full scale.

Sweden has world-leading research in the field of marine energy. The research activities have resulted in the formation of a number of companies. The expertise of researchers also plays an important role in various projects in partnership with established development companies. CorPower Ocean AB is a Swedish development company that has developed a wave power plant that will soon be tested at sea at half scale. In partnership with KTH, during the development work they designed a new type of gear technology, a cascade gear that can convert rotary motion into linear motion and vice versa. The cascade gear has the potential for use in the transport sector, showing that innovations in one sector may also have value in another. CorPower Ocean AB, with a researcher in Norway, has also developed a new technology for controlling the motion of the wave buoy in relation to the waves. The major advantage of the new technology is that parts of the wave power plant can be reduced in size, which results in lower cost and extended service life. This makes the wave power plant competitive in relation to other wave power technologies.

Current research, development and demonstration activities

The research supported by the Swedish Energy Agency in this area is primarily conducted via various research programmes. In addition, the Swedish Energy Agency finances international research projects with other European countries to support international development in the area.

To disseminate results and coordinate the industry, the Swedish Energy Agency often arranges conferences linked to the various research programmes. One example of this is Solforum, which has been very appreciated and helped bridge the gap between academia and companies.

Below and on the next page is a description of a selection of current research, development and demonstration activities in the thematic area of electricity systems and electricity generation.

Silicon carbide contributes to reduced energy losses in industry

The EU has identified systems driven by electric motors as the product group in which the greatest energy efficiency gains can be achieved. Electric motors are used for purposes such as driving fans, pumps and compressors. The Swedish Energy Agency estimates that systems driven by electric motors account for approximately 70 percent of electricity consumption in Swedish industry and nearly 40 percent of total electricity consumption in Sweden. One way of enhancing the energy efficiency of these systems is to replace silicon with silicon carbide in various components. Silicon carbide also contributes to other benefits such as lighter products, the ability to tolerate higher temperatures and increased service life.

With Vinnova, the Swedish Energy Agency is supporting a research programme with the aim of accelerating the development of silicon carbide products. Projects carried out within the framework of the programme have shown that companies such as Alstom Power and Atlas Copco can use silicon carbide components to achieve 60–65 percent reductions in losses in power electronics compared with conventional technology.

New programmes for hydropower and marine energy

In the area of renewable electricity generation, new programmes have been started for both hydropower and marine energy. The programme 'Kraft och liv i vatten' (Power and life in water) aims to develop the knowledge and methods required to make hydropower more environmentally compatible in connection with operation and conversions. The programme is a partnership between the Swedish Energy Agency, the Swedish Agency for Marine and Water Management, the water supply agencies and a number of hydropower companies.

In the area of marine energy, the Swedish Energy Agency has recently launched a research programme focusing on wave and current power. The programme is designed to support technology development in the area and also contribute to knowledge about environmental impact and develop methods for installation, operation and maintenance. A recently started project in the programme is a partnership between CorPower Ocean AB, Ocean Harvesting Technologies AB and Waves4Power AB to design and develop a wave power system based on a combination of the three companies' technologies. Corporate partnerships are important as they increase the chances of commercialising concepts.

The electricity grids of the future require technology for the integration of renewable energy

Research focusing on issues relating to the design of the electricity grid of the future is managed by the Swedish Centre for Smart grids & Electric Storage (SweGRIDS). The long-term objective of the centre, in which industry actively participates, is to create the technology required for the integration of all forms of renewable electricity generation. The goal is for Europe to be climate-neutral and sustainable by 2050.

Challenges in the future

Renewable electricity generation technology has become increasingly competitive in recent years. To ensure that renewable electricity generation in the Swedish power system remains competitive in a future scenario with less nuclear power than today, there is a great need to develop all renewable electricity generation alternatives.

Hydropower may play an even more important role as a regulating power in the future. Among other things, this will require technical solutions to be developed to allow existing installations to be utilised efficiently, while also taking account of their environmental impact. In wind power, more knowledge and expertise are needed on how to reduce the impact of wind power on society and the environment and on the conditions for wind power in forests and cold climates. In solar power, urban planners and actors in the construction industry need better knowledge about how solar cells can be integrated in buildings. Grid companies need more knowledge about how the distribution of small-scale generation affects local grids. In wave power, the challenges involve increasing the reliability and survivability of wave power plants, while also reducing the cost of electricity generation. As the proportion of renewable electricity generation increases in the energy system, increased flexibility and storage will also be required in the electricity grid. Electricity is also expected to become more important, for example as electric vehicles become more common.

In this development, the Swedish Energy Agency aims to contribute to maintaining Sweden's position as a world-leading research nation in a number of areas. To continue to lead the way, we continuously review our strategies. The initiatives that the Swedish Energy Agency is now taking aim to increase the proportion of renewable electricity generation and build up an electricity market that contributes to efficient, safe development.

Bioenergy

Research and innovation in the thematic area of bioenergy comprise activities involving the production and processing of biofuels, the use of waste for energy recovery and conversion into electricity and heat. The Swedish Energy Agency has supported research and innovation in the area for many years. This has helped make fossil fuels almost completely replaceable with renewable alternatives for fuel-based electricity and heat generation.

The bioenergy area consists of many components that need to work together in terms of costs, energy and resource efficiency and environmental impact. The Swedish Energy Agency's research activities range from basic research to demonstration, and many projects are in applied research (also called industrial research). The projects are financed in full or in part by the Swedish Energy Agency and are usually carried out in close cooperation between forestry and agricultural companies, public agencies, energy companies, the manufacturing industry, institutions and institutes of higher education.

The close cooperation between the Swedish Energy Agency and market actors helps make the knowledge produced relevant for users with good opportunities to exploit and apply the results in practice in sustainable, competitive solutions.

Biomass is used as fuel for electricity and heat generation. It is also used to replace fossil fuels in industry, in fuel production and in other bio-based products. Energy recovery from biomass, bioenergy, is an important part of the transition to a sustainable energy system and is important for the achievement of climate goals.

Biofuels are a renewable resource and the biggest form of energy used for heating in Sweden. Resource efficiency can be enhanced by producing electricity in a cogeneration process in parallel with the use of biofuels for heat generation.

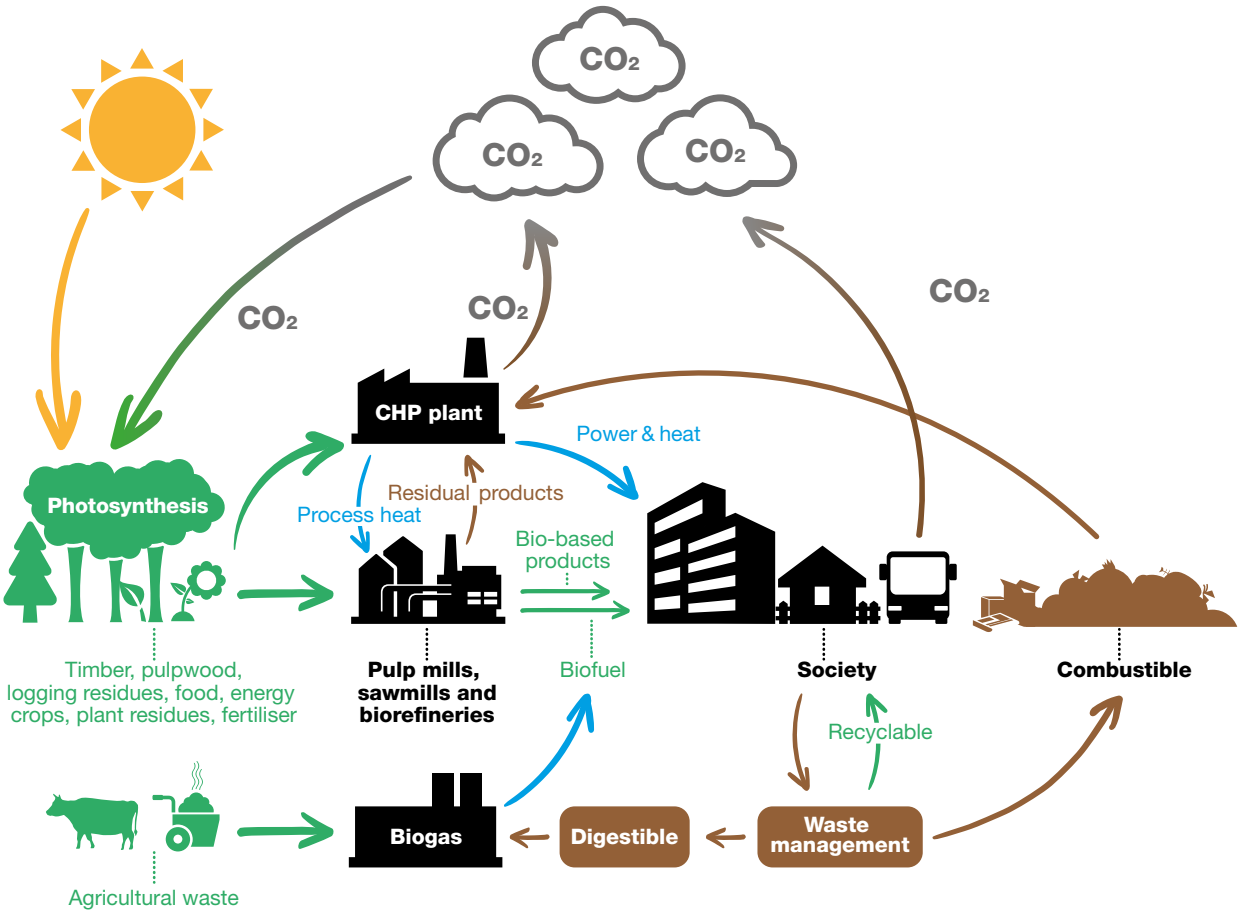
Residual materials from the forestry industry constitute an important fuel resource that can be supplemented with energy crops such as fast-growing deciduous trees and waste fuels. Domestic bioenergy produces social benefits such as employment, security of supply, rural development and some environmental benefits.

In 2013, 128 TWh (terawatt hours) of biofuel[5] was used in Sweden and the potential exists to increase the supply and use further by approximately 100 TWh[6].

5 14 TWh waste and peat was also used.

6 Assessment by the Fuel Development Platform based on SOU (Swedish government official reports) 2013:84 and Profu 2014. Biofuel scenarios – how much biofuel can we use in the Swedish energy system by 2030?

Illustration 1: Ecocycle of bioenergy

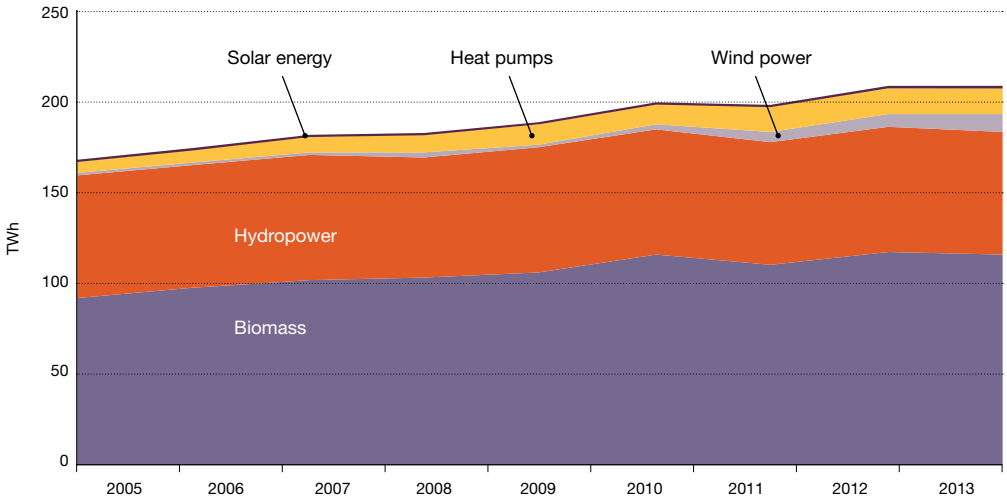


Biomass production needs to increase to meet future demand for energy and the expected stricter climate and environmental targets. Continued research and innovation are required throughout the biofuel chain to make bioenergy competitive with fossil alternatives. It is important in the research to ensure that increased use of biomass is also sustainable and resource-efficient. By means of its support for research and innovation, the Swedish Energy Agency is creating the conditions for the continued transition. Sweden is the leader in a number of bioenergy areas and can contribute knowledge and technology exports.

Results and effects

Developments in bioenergy and the phasing out of fossil fuels have taken place gradually in small steps over a long period of time. This has contributed to making Sweden the world leader in several bioenergy areas today. Research and innovation support from the Swedish Energy Agency contributes to long-term expertise build-up and development, which in turn contributes to a strong business community and knowledge and technology exports. Thanks to bioenergy, the target of achieving 50 percent renewable energy by 2020 was achieved by 2013.

Figure 5 Renewable energy in Sweden, 2005–2013, TWh



	2005	2006	2007	2008	2009	2010	2011	2012	2013
Biomass	92	97	102	103	107	116	110	118	116
Hydropower	68	68	69	67	68	68	69	69	68
Wind power	1	1	1	2	3	4	6	7	9
Heat pumps	7	8	9	10	11	11	14	14	14
Solar energy	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Total	**168**	**174**	**181**	**182**	**189**	**199**	**199**	**208**	**207**

Sources: The Swedish Energy Agency and Eurostat

Biomass fuel now more cost-efficient and environmentally sustainable

Research and innovation activities supported by the Swedish Energy Agency have helped systems for harvesting forest fuel become increasingly cost-efficient and environmentally sustainable. Cultivation systems, plant material and technical solutions have been developed for energy forests (Salix sp.). For Sweden, the development of plant material and technical solutions has become an export product to countries wanting to reduce their dependence on gas and oil, for example Ukraine, Lithuania and Poland.

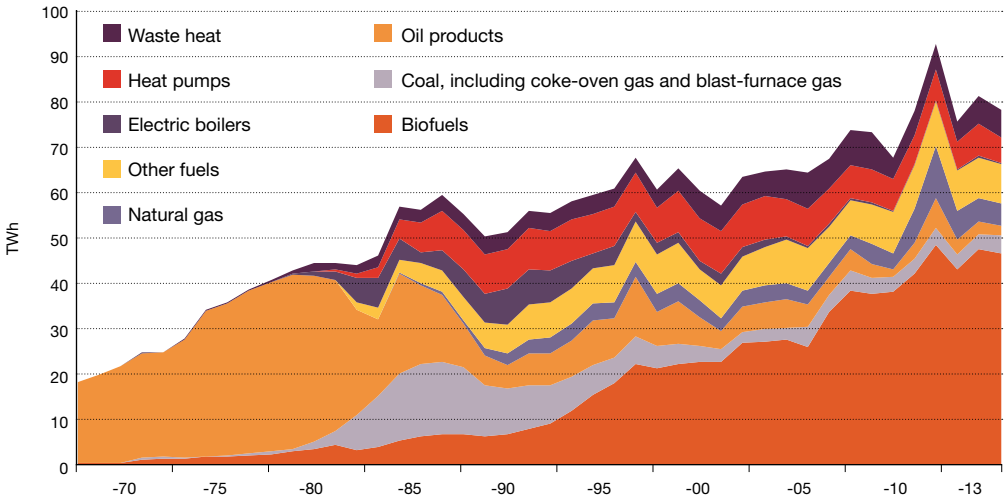
New ISO standard for assessment of the sustainability of bioenergy

Sustainability requirements are playing an increasing role in the bioenergy market. Long-term research supported by the Swedish Energy Agency has produced increasingly reliable documentation on how biomass fuels should be produced and used for Sweden to meet its national environmental targets. Multiannual international work with major contributions of Swedish expertise, including from researchers financed by the Swedish Energy Agency, resulted in 2015 in an ISO standard to help assess the sustainability of bioenergy systems.

Reduced corrosion with the use of solid biofuel

Coal and oil began to be replaced with biofuels in district heating systems and combined heat and power systems in the 1980s. This caused extensive corrosion problems in the plants. By gradual development of methods and materials for dealing with the problems, 90 percent of fossil fuels have been replaced. As a result of research and development partly financed by the Swedish Energy Agency, the state-owned company Vattenfall patented the ChlorOut method that is used commercially to reduce corrosion when using solid biofuel.

Figure 6 Energy supplied for district heating production, 1970–2014, TWh



Better opportunities for recovery of waste heat

In many industrial processes, heat is a by-product that is often not used. With research funding from the Swedish Energy Agency, Climeon is developing a new chemical process that converts heat into electricity in a low-pressure process. This development has been carried out in close cooperation with academia. The technology has demonstrated considerably better efficiency than previous commercial systems. This offers new opportunities for the recovery of waste heat from industries and new opportunities for the conversion of other low-grade heat.

Efficient energy recovery from waste

Waste incineration has increased dramatically in Sweden following the ban on the dumping of sorted flammable waste and organic waste and the introduction of a landfill tax. One of the reasons is the opportunity to convert waste fuel into both district heating and electricity. Supported by the Swedish Energy Agency, Sweden has become a world leader in energy recovery from waste thanks to developed flue-gas purification and incineration technology.

Technology and knowledge exports

China has a great need to replace coal with biomass. Sweden has both knowledge and experience. This creates great potential for Swedish companies to develop technology based on Swedish knowledge and to become established in the Chinese market. Success depends on long-term cooperation with the Chinese authorities, universities and business community. Chinese authorities have now decided to start construction of a combined heat and power plant with a bioenergy combine[7] based on Swedish technology[8] in Jilin Province in China. It will be the first Swedish-Chinese demonstration plant to be built. The partnership with China means a boost to Swedish research, which also offers the opportunity for technology development in Swedish plants.

7 A bioenergy combine and a biorefinery are plants in which several different yields, energy and other products are extracted in a resource-efficient, integrated manner from bio-materials. This may involve different combinations of electricity, heat, biofuels, pellets, chemicals and other products.

8 Developed by Biosteam AB.

Current research, development and demonstration activities

Research and innovation in the thematic area of bioenergy is designed to contribute to meeting future demand for electricity and heat supplies and to replacing fossil fuels in the energy and transport sectors with renewable fuels. Demand is to be met with a sustainable biofuel supply and resource-efficient use of waste flows. Developments in the area are taking place gradually over a long period of time. Current research, development and demonstration activities are presented on the following pages on the basis of seven research areas in the thematic area.

Meeting demand with efficient supply at a reasonable cost

Biofuels are primarily residual forest materials but they may also be agricultural products, energy crops, industrial by-products and waste.

The research aims to develop the biological and technical production processes for biomass for energy so that the expected increase in demand can be met by an efficient supply at reasonable costs and within the framework of both national environmental quality targets and international sustainability criteria. There is also a need for research into the future volume and quality of waste fuel.

New pest-resistant Salix species that are adapted to different climate and cultivation conditions are required. Current research is developing improved methods for plant cultivation, which will produce new species for an expanding market in Europe. Aspen and poplar are fast-growing bio-materials, and the research is focusing on efficient cultivation systems and supplying the market with suitable species.

In the area of biogas, research is in progress to enable new substrates for biogas production in addition to traditional substrates such as sewage treatment plant sludge, manure and food waste. The research is also focusing on producing more biogas from the substrate and new solutions for the food industry, paper industry and agriculture. The waste water from paper and pulp mills holds the potential for approximately 1 TWh per annum. The research is supplemented by investment support for new, innovative biogas technology.

Sustainability – an important aspect of bioenergy research

Current research aims to clarify long-term effects on the environment (soil, water and biodiversity), climate and forest production for various biofuel production systems, soils and regions. Public agencies will gain a more reliable basis for drawing up sustainability requirements and how biofuel production should be made environmentally sustainable. This knowledge is used in negotiations, for example in the EU and in international standardisation work. The research also aims to develop solutions for the management and utilisation of residual products from energy recovery (slag, ash, digestion residue, etc.) that present no risk to the environment or health.

Research into fuel refinement to boost energy density

The research into fuel refinement is studying whether raw fuel materials can be refined into pellets or briquettes. This is to boost the energy density in the fuel in order to enhance the efficiency of fuel transportation and to allow the fuel to be fired efficiently in a small-scale furnace. The conversion of bio-materials into pyrolysis oil or by means of torrefaction are other processes being studied.

More efficient plants for electricity and heat generation

The research into generation of heat and electricity is focusing on making the processes in biofuel-based and waste-based plants more cost-efficient and resource-efficient, for example by means of higher efficiency, fewer operational problems and increased, flexible production. The plants are adapted to use new fuel types, while emissions into the environment must be kept down.

Combined heat and power production is a resource-efficient way of generating heat for urban areas via district heating. Current research is contributing to making systems resource-efficient and cost-efficient, while new solutions for district heating users are being developed.

System studies in the thematic area of bioenergy

Bioenergy research via system studies may take a number of different directions. Using life cycle and energy balance analyses, the research produces information on the most resource-efficient and climate-efficient ways of producing and using biomass, including waste and biogas. The research also focuses on how different waste flows can best be used from the point of view of resources and the environment, and on the role of energy recovery from waste in a circular economy. Other studies reveal the link between various instruments and the development of the bioenergy market. New issues concern how different forms of sustainability criteria will affect bioenergy use and international trade, plus the role of bioenergy in a sustainable energy system.

Challenges in the future

Bioenergy has the potential to make a further contribution to the sustainable energy system. To achieve good economy and resource efficiency, the heat from combined heat and power and fuel production and other residual heat needs to be utilised, also in connection with increasing energy efficiency in buildings and alternative heating methods.

The costs need to fall at all stages from fuel production to use. Research and innovation are required to create the conditions for more fuel and electricity based on biomass, in addition to other policy instruments.

To accelerate developments, research results need to be efficiently converted into knowledge, processes, products and services. To create a knowledge base and further development in the area of research, results must be communicated to academia, industry and the public sector. The knowledge base is particularly important for the ability to draw up regulations in Sweden and the EU on matters such as the sustainability of bioenergy on a scientific basis.

Global standard for bioenergy was a Swedish success

In the rest of the world, the knowledge that bioenergy, produced in the right way, is much better for the environment than several other forms of energy is often not as widespread as in Sweden.

The new global standard for bioenergy sustainability issues is designed to facilitate such assessments. Sweden led the successful work and the secretariat for these issues was also located in Sweden.

The new standard for bioenergy means a common global framework for assessing the environmental, social and economic sustainability of all forms of bioenergy. This type of energy consists of biomass produced from plants via photosynthesis. The Swedish Standards Institute, SIS, led the Swedish work on this standard. SIS is responsible for bringing together national stakeholders in standardisation processes.

Lena Bruce, a business developer focusing on strategic analysis at Sveaskog and chair of the Swedish working group behind the bioenergy standard that was prepared over a period of five years with the participation of around 30 countries, can now take a sigh of relief.

"I am really pleased that we managed to achieve a dialogue between all the different parties. Initially, many of them just stood up for their own issues, but gradually they began to see the similarities and not the differences between each other's opinions. This allowed us to make the decisive breakthroughs," explains Lena Bruce.

Fast, broad analyses of proposals behind breakthrough

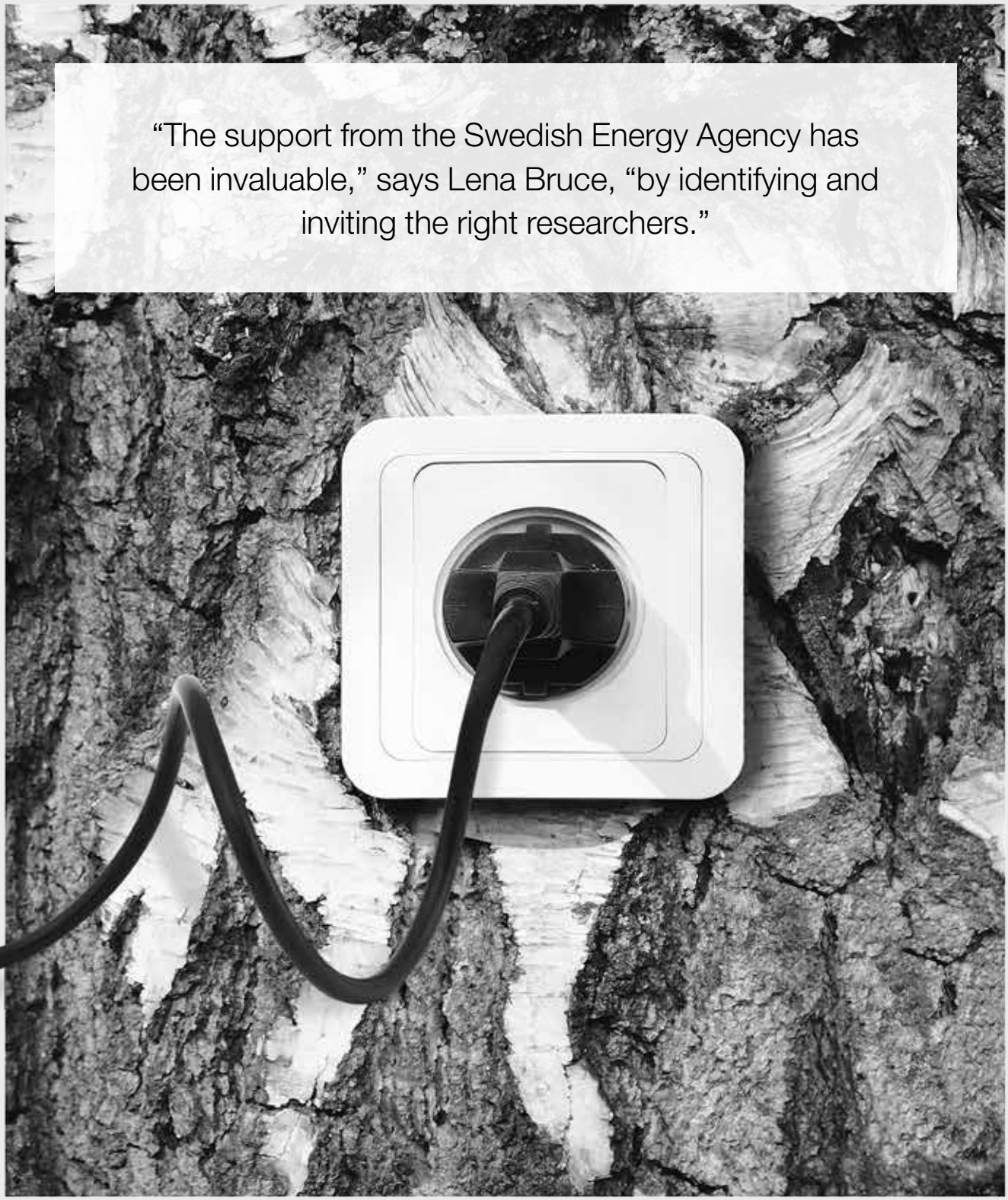
Lena Bruce says: "The support of the Swedish Energy Agency has been invaluable, by identifying and inviting the right researchers. These were initiatives that helped build up the necessary Swedish expertise to produce the environmental parts of the standard."

"The very opportunity to have a technical committee and a negotiation group composed of public agencies, private companies, trade organisations and researchers produced a unique advantage in the process. We were able to perform fast, broad analyses of the effects of various proposals in a Swedish context," says Lena Bruce.

The Swedish Energy Agency has financed research into the environmental sustainability of bioenergy for decades: how different forms of bioenergy affect soil, water and biodiversity and how the climate impact varies between different ways of producing and using biomass for energy.

Lena Bruce says that a major challenge for Sweden was guaranteeing that the new standard, formally called SS-ISO 13065:2015, took account of the special Nordic conditions for producing bioenergy. Otherwise it could have been disastrous for Swedish bioenergy production.

"It is particularly important for the standard to take into account the unique Nordic



“The support from the Swedish Energy Agency has been invaluable,” says Lena Bruce, “by identifying and inviting the right researchers.”

conditions for forests with rotation periods of 80 years. In warmer countries, the rotation period from seed to mature tree may be seven years," says Lena Bruce.

If, for example a climate assessment were only made for a short period of time, fast-growing trees would appear more climate-friendly as the carbon dioxide circulates faster in those systems. In that case, Nordic forest biomass could have appeared negative for the climate, which does not correspond to analyses over entire rotation periods. However, the new standard takes this into account.

New standard means better bioenergy for all

The expertise of the Swedish Energy Agency and the experts made it possible to argue in favour of formulations compatible with the knowledge about Swedish conditions, while they remained relevant for different international biofuels.

"The primary objective of the standard is to motivate producers to prepare transparent, objective information," continues Lena Bruce. This allows buyers to make better choices and countries and companies to understand that it is better for both the climate and business if they are more environmentally friendly and show that they are. For companies, it is a competitive advantage."

"The standard is a condition for Sveaskog to be able to compare itself with its competitors globally on the basis of the quality of the bioenergy created and how it affects the environment.

The state-owned company Sveaskog is Sweden's biggest forest owner with sales of SEK 6.2 billion in 2014 and nearly 700 employees nationwide.

Secretariat for sustainable aspects located in Sweden

In many places in the world, there is concern that the greater use of bioenergy will lead to the felling of forests that are an important tool in the reduction of the threat of climate change. However, Lena Bruce points out, for example, that the Swedish experience of active forestry in combination with protected areas and improved knowledge about how bioenergy can be extracted without affecting the nutrient balance has made bioenergy such an attractive form of energy in Sweden.

"This is the sort of knowledge we shared."

The many years of experience and specific knowledge about bioenergy was largely why Sweden shared the chairmanship and secretariat with Brazil for the part of the new standard that concerns environmental, economic and social aspects, which is a prestigious task for Sweden, according to

Hans Nordström, chair of the WG 3 working group.

"It was important for the right questions to be asked with the help of the international expert group, so that the standard can really be used rationally by countries and companies."

Hans Nordström also states that the Swedish Energy Agency and SIS were decisive in this process with their expertise, experience and good contacts in Sweden and abroad among important researchers, institutes, companies and public agencies.

"The process was committed and stimulating, and both the Swedish Energy Agency and SIS moved it forwards efficiently," he says.

A standard based on science

Gustaf Egnell, a researcher in forest science at the Swedish University of Agricultural Sciences, SLU, and one of the experts who participated in the standardisation work, explains that, without the support of the Swedish Energy Agency in the area of bioenergy over the years and the knowledge built up as a consequence, Swedish credibility would have been questioned.

"The work would have been more difficult and, in the worst case scenario, we would not have arrived at the finished standard," he says. Gustaf Egnell says that the words 'scientifically based' were heard with unusual frequency during the negotiations.

"The combination of experts from academia and experts from, for example, the Swedish Energy Agency is absolutely necessary to ensure that a standard like this has a scientific basis and is applicable in practice."

That is the next challenge.

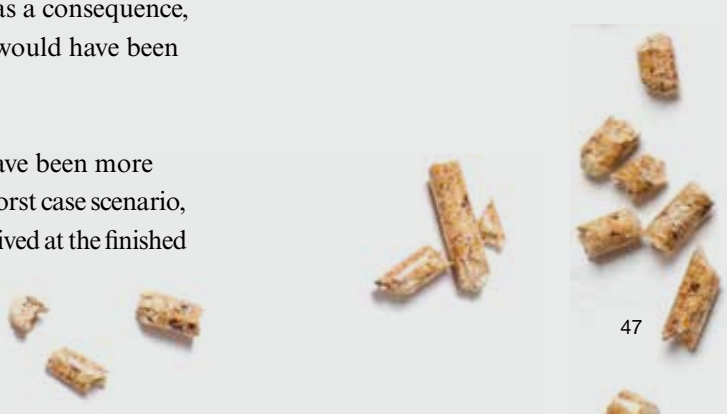
"This standard is different and versatile, and it will therefore need some help to be implemented internationally. I fervently hope that all those concerned will now jointly develop good ways of implementing it," says Hans Nordström.

Facts in brief:

Name: SS-ISO 13065:2015

Countries involved: 35

Swedish organisations and companies involved: 11



Transport system

Sweden has a national goal of having a vehicle fleet that is independent of fossil fuels by 2030. To achieve this goal, the transport sector has to switch to renewable fuels. It is also necessary for vehicles to become more energy-efficient and for the transport system as a whole to become sustainable. Heavy investment in research, development and demonstration activities in the transport sector are needed to achieve the goal.

The Swedish Energy Agency contributes nearly SEK 0.5 billion a year in research funding for around 300 transport-related projects. The funding has contributed to results including demonstration systems for renewable fuels, the development of energy-efficient city buses and the demonstration of more energy-efficient goods transportation.

The Swedish Energy Agency invests in research to develop renewable fuels, energy-efficient vehicles and vessels and energy-efficient, sustainable transport solutions. This includes research into the transport system and how we use it.

Together with other public agencies, the business community and academia, the Swedish Energy Agency plays an important role in contributing to achieving national goals and targets and a sustainable transport system.

The Swedish Energy Agency estimates that a number of policy instruments will be needed for the transport sector to become more sustainable. Policy instruments can be extremely effective. In Norway, tax relief for environmentally-friendly vehicles has led to a total of 50,000 electric cars being registered (spring 2015), which has contributed in turn to Norway being the first country in Europe to have the average emissions from new cars below 100 g carbon dioxide per kilometre. EU emission standards have a strong impact on the automotive industry's transition to more energy-efficient vehicles. These limit carbon dioxide emissions to an average of 95 g per kilometre for passenger cars and 147 g per kilometre for light goods vehicles by 2021. EU Directives concerning renewable fuels, for example the Renewables Directive and the Fuel Quality Directive, have a strong impact on developments by creating the frameworks for which biofuels and raw materials are funded in national funding systems.

Results and effects

Since its launch in 1998, the Swedish Energy Agency has funded a large number of projects in both academia and industry with the objective of producing renewable fuels and energy-efficient vehicles. One of the results of the Swedish Energy Agency's investment in renewable fuels has been a demonstration project, GoBiGas, in which biomass is gasified to create methane that is distributed via the natural gas network in the Gothenburg area.

The Swedish Energy Agency's long-term investment in research in the area of more energy-efficient vehicles has resulted, for example, in fully electric buses serving central Gothenburg routes today. The following pages contain a description of a selection of the projects funded by the Swedish Energy Agency.

Demonstration plant for renewable fuels

For the production of fuel from biomass to leave the test stage, the technology needs to be demonstrated on a scale that is large enough to provide a clear image of fuel quality, operating finances, yields and availability. One such example is the GoBiGas demonstration project in Gothenburg, which is co-funded by the Swedish Energy Agency. The project involves forest raw materials being gasified to form synthesis gas that is converted into methane in a catalytic process. The methane is distributed via the existing natural gas network, allowing efficient distribution of the gas to fuel stations for gas-powered vehicles.

The GoBiGas project consists of two stages. The first stage is the demonstration plant, with possible gas production of 20 MW. This was opened in March 2014. A second stage, with a production target of 80–100 MW gas, depends on the technology and finances allowing a commercial plant to be built.

THREE SYNTHETIC FUELS

There are currently three fuels that can be produced via gasification that the Swedish Energy Agency considers interesting. These are methane, methanol and dimethyl ether (DME).

Methane is produced via a catalytic process called methanisation.

Methanol is produced via a catalytic process at high pressure and can also be converted into petrol.

Dimethyl ether (DME) can be produced directly via synthesis gas by means of a catalytic process, but can also be produced through the dehydration of methanol. DME is a gas but it becomes liquid at relatively low pressure and has properties that resemble those of LPG. DME is an interesting diesel fuel with a high cetane number.

Clear advances in the development of energy-efficient city buses and passenger cars

The Swedish Energy Agency's research funding has helped AB Volvo develop fully electric buses. The buses use 60–80 percent less energy than diesel buses. They are silent, emission-free and powered by electricity generated by wind power and hydropower.

The first bus in the development chain was a hybrid bus that was developed with the support of the Swedish Energy Agency and launched in 2010. The next stage of development was a plug-in hybrid bus, which has been tested on route 60 in Gothenburg since 2012. The fully electric buses were launched in 2015. They have a larger battery than the hybrid buses and are charged at the termini. Electric operation offers passengers many comfort features, for example indoor boarding and the expansion of local public transport in noise-sensitive areas. The electric buses used on regular routes are a result of the ElectriCity partnership, in which new solutions for future sustainable, attractive public transport are developed, tested and demonstrated. In addition to the buses themselves, the partnership also involves developing and testing new bus stop solutions, traffic management systems, safety concepts and energy supplies. Electrically powered public transport opens up new opportunities for how cities and urban areas can be planned, for example with exhaust-free bus stops indoors.

Via its research funding, the Swedish Energy Agency has helped Scania develop hybrid buses in which the combustion engine is prepared for operation with biodiesel. Sales of these buses were launched in 2014. The hybrid system is able to produce fuel savings of 20–25 percent, depending on operating conditions. With a biodiesel engine, this means a reduction in carbon dioxide emissions of 60–65 percent.

The Swedish Energy Agency has also co-funded a number of Volvo Cars' research projects in the area of more energy-efficient vehicles. This has helped Volvo Cars reduce the average emissions of carbon dioxide in its new car sales considerably in recent years by means of more efficient combustion engines. For example, in recent years, Volvo Cars has produced a brand new scalable engine generation for its entire range of models based on the knowledge produced via the research funded by the Swedish Energy Agency. The Swedish Energy Agency's activities involving light electric vehicles have also resulted in Volvo Cars and Vattenfall AB deciding to form a joint company, V2 Plug-in-Hybrid Vehicle Partnership, to commercialize plug-in hybrid vehicles.

During summer 2014, the Swedish Energy Agency made it possible for the public to hire 20 electric cars on Gotland via the Elbilslandet Gotland project. The project involved the construction of 20 charging stations on the island so that hirers could charge the cars while visiting various destinations. Approximately 1,400 people are estimated to have driven the project's electric cars during the project period. This project can be compared with the fact that, at the end of 2014, there were fewer than 2,000 electric cars in total in Sweden.

Surveys were used to document user experience and log driving and charging patterns. Eight out of ten of those who hired electric cars on Gotland had never driven an electric car before, showing that the car hire market is a good opportunity to reach potential new electric car users.

As many as 96 percent of those who hired an electric car via the project said that they could imagine hiring one again, and just as many would recommend others to do the same. The project was very successful and increased knowledge about and acceptance of electric cars. This led to a continuation of the project up to the end of 2016.

DIFFERENT TYPES OF ELECTRIC VEHICLE

A **hybrid vehicle** has both a combustion engine, one or more electric motors and a battery. The combustion engine can be run on a conventional fuel or a renewable fuel. During braking, the batteries are charged via the generator and, when the vehicle accelerates, the stored energy is reused.

A **plug-in hybrid vehicle** has both a combustion engine, one or more electric motors and a battery. The battery can be charged from the electric grid, with the result that short journeys can be made without needing to use the combustion engine.

A fully **electric vehicle** has no combustion engine and has a large battery that is charged from the electric grid.

Demonstration of more energy-efficient goods transportation

The 'En trave till' (One stack more) project (ETT project) is a demonstration project for more energy-efficient forest transportation. By increasing the weight and making the vehicles longer, they are able to transport more timber. The project has shown that carriers' energy consumption can decrease by up to 20 percent. The results have aroused great national and international interest, even outside the forestry industry. The most obvious result was the decision by Finland to permit a maximum total weight of 76 tonnes for trucks from 1 October 2013. This is largely based on results from the ETT project. If today's 2,000 conventional 60-tonne timber trucks were replaced by larger trucks, the number of vehicles could decrease to 1,300 and fuel consumption could decrease by 45 million litres of diesel every year.

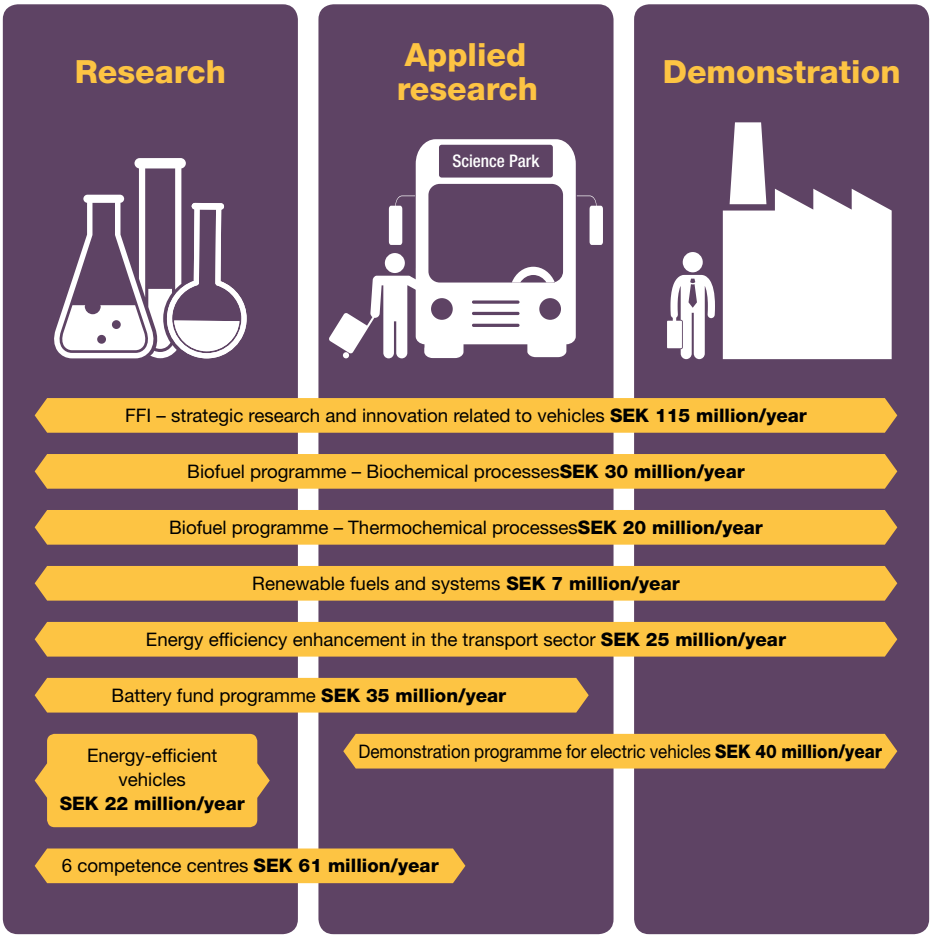

SCA SKOG
Lång last
SVETRUCK

Current research, development and demonstration activities

The Swedish Energy Agency's transport research is mainly conducted in programmes and at various competence centres. A competence centre is a research centre in which academia, companies and the Swedish Energy Agency share the funding.

The fact that there are initiatives for the entire chain from basic research to demonstration activities helps build up scientific and technical knowledge, plus the expertise needed to apply new technologies and new services.

Illustration 2: The Swedish Energy Agency's transport-related research programmes



The Swedish Energy Agency's transport research is conducted in close cooperation with other agencies, the Swedish automotive industry, institutions and universities. Among other things, the Swedish Energy Agency is involved in the Forum for Transport Innovation, Transam, which is a forum for public agencies that support transport research, and several international partnerships such as the Nordic Platform for Energy & Transport.

The following pages contain a description of the Swedish Energy Agency's priority research, development and demonstration initiatives in the area of transport.

Research, development and demonstration activities for the transition to renewable fuels

The Swedish Energy Agency funds research, development and demonstration activities related to production technologies for renewable fuels. Reducing climate impacting gases and increasing the security of supply are two strong driving forces for the replacement of fossil-based fuels with renewable alternatives.

In order to proceed rapidly with the transition to renewable fuels, it is necessary to have biofuels that can be used in existing vehicles. In the short term, the Swedish Energy Agency's activities are therefore directed at biofuels with molecules identical to petrol or diesel, also called drop-in fuels. Fuels from lignin are the main focus of this development. This involves converting lignin from pulp mill lye and other sources into a renewable raw material that can, in turn, be converted into renewable fuels in a conventional refinery. One driving force is that many pulp mills are interested in having a large quantity of lignin removed from their process to allow them to increase capacity. There is potential to use several million tonnes of lignin from Swedish pulp mills for biofuels. The Swedish Energy Agency has funded several projects to develop the techniques needed and is planning large-scale initiatives in the years to come in order to enable commercialisation of the technology.

Parallel to its investment in drop-in fuels, the Swedish Energy Agency is funding research into ethanol from cellulose and fuels produced via gasification. These investments have a longer-term perspective and require major changes in the vehicle fleet and infrastructure.

Energy-efficient vehicles and vessels are needed to reach targets

However transportation takes place and whichever fuels are used, vehicles and boats need to be energy-efficient and resource-efficient. This is necessary both to reach climate targets and to manage limited resources.

The Swedish Energy Agency funds initiatives in the area of electric and hybrid vehicles. The reason for this is that the Swedish Energy Agency sees this as energy-efficient technology that will make it possible to make the transition to a vehicle fleet independent of fossil fuels by 2030.
Below is a list of specific initiatives in this area:

- The demonstration programme for electric vehicles focuses on charging and the infrastructure for electric vehicles, plus user behaviour. Started in 2011, continues until 2017.

- Svenskt Hybridfordonscentrum (Swedish Hybrid Vehicle Centre – SHC), a national competence centre for the research into and development of electric and hybrid vehicles. Started in 2007, continues until 2019.

- The Swedish Energy Agency is participating with the Swedish Transport Administration and Vinnova in a pre-commercial procurement of electric road systems (ERS). The procurement is now in a demonstration phase. Two consortia producing technology for transferring electrical energy to vehicles in motion will be evaluated in 2015–2018. The result will create a knowledge base for deciding whether it is possible to proceed with the technology to dramatically reduce fossil fuel consumption in heavy transport. The demonstration will take place in Gävle and south of Arlanda Airport.

Electric vehicles are subject to rapid technical development. The range of batteries is improving and the material costs are falling. However, combustion engines will continue to constitute a central component in the transport sector, primarily for long-distance goods transportation. In the short term, research is required to further increase the energy efficiency of combustion engines. In the longer term, initiatives are required to convert the transport system to using renewable fuels. Consequently, it is also important to develop combustion engines for renewable fuels. To meet these needs, the Swedish Energy Agency has started new initiatives at competence centres in the areas of combustion engines and catalysis.

Sweden's strong international position in the heavy automotive industry means that the development of vehicles and combustion engines is also of great economic importance to the country. As a result, it is important for Swedish vehicle makers to be able to develop energy-efficient, competitive vehicles. To be competitive in this area and to take the lead in terms of energy-efficient, safe vehicles, the Swedish Government and the automotive industry began a cooperation programme in 2009 on strategic research and innovation related to vehicles (FFI). FFI is funded by the Government and the automotive industry and includes joint research, development and innovation activities, with the focus on climate, the environment and safety.

The initiative involves research and development for approximately SEK 1 billion per annum, half of which consists of public funds. There are currently five programme areas and strategic initiatives. The Swedish Energy Agency administers the energy and environment sub-programme, one of the Swedish Energy Agency's biggest research programmes.

Energy-efficient, sustainable transport solutions

The Swedish Energy Agency sees an increased need for research and demonstration in the area of energy-efficient, sustainable transport solutions. Consequently, the Swedish Energy Agency has decided that the research programme on energy efficiency enhancement in the transport sector will continue during the period 2014-2017 with a budget of SEK 100 million. The programme supports research into various energy-efficient transport solutions such as transfer of goods to the most energy-efficient means of transport, energy-efficient shipping, energy efficiency enhancement of transport in urban areas and energy efficiency enhancement of transport by influencing behaviour.

The area of sustainable transport solutions is managed by several public agencies in Sweden. Consequently, it is important to take stock of and develop cooperation in this area.


CHALMERS
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Science park
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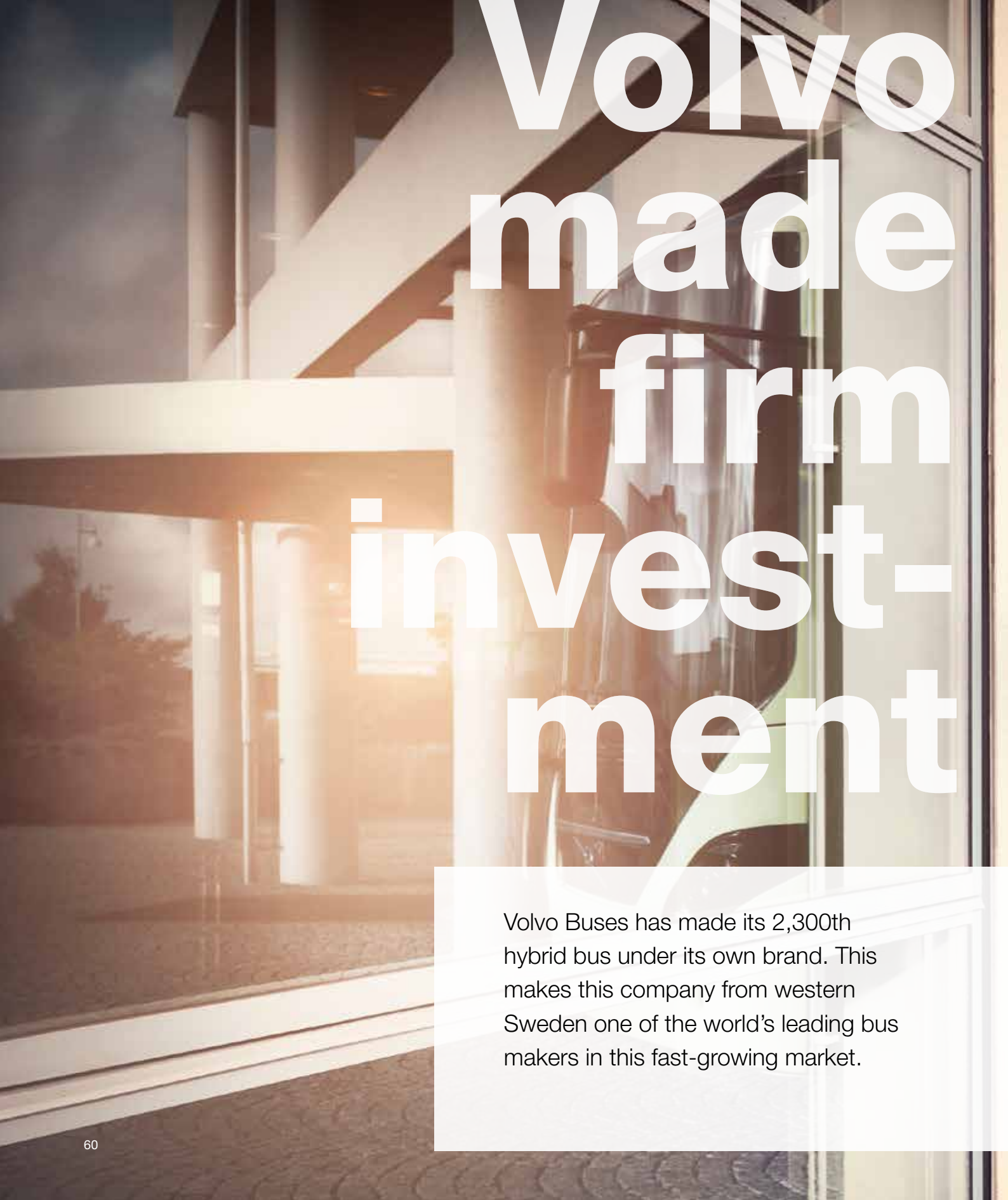
Challenges in the future

Both globally and in Sweden, the transport sector is likely to grow. A large part of the growth will be in goods transportation. The strong position of the Swedish heavy automotive industry in the world market means that it is well placed to exert international influence. Consequently, it is important for Sweden to continue to drive research into energy-efficient vehicles and renewable fuels. The research into fuels must be balanced between fuels that can be used in the current vehicle fleet and fuels that are suitable for a future vehicle fleet with even stricter requirements for energy efficiency and resource efficiency.

Sweden is the EU member state that has had the strongest trend towards urbanisation since 2005. Sweden is currently being urbanised as the population in urban areas continues to grow, primarily via in-migration and an increased birth rate, while the population of rural areas remains almost unchanged. The population is growing primarily in the three metropolitan counties, which may result in greater impact on the infrastructure in the areas in which transport is growing and being concentrated. However, there are indications that the dominant position of motor traffic in the transport systems of cities is changing. In areas subject to densification, heavy demands are being placed on the infrastructure and there is a great need to find ways of using the infrastructure more efficiently, for example by means of different transport solutions. Digitisation and a connected society may also entail major consequences for the transport system. For example, the introduction of self-driving vehicles may have major consequences. Research into how to make the transition to sustainable transport solutions and communities and how different means of transport interact will be important in the future. In this context, research into behavioural aspects will also be important.



Volvo made firm invest-ment

Volvo Buses has made its 2,300th hybrid bus under its own brand. This makes this company from western Sweden one of the world's leading bus makers in this fast-growing market.

“Our success has depended greatly on the Swedish Energy Agency's assistance with research and development. We have worked together from the start, since 2006,” says Niklas Gustavsson, Head of Sustainability & Public Affairs at Volvo Group.

Volvo's decision in 2011 to switch production of city buses from diesel to hybrid powertrains was seen by many as a serious risk.

But today there are few people who think the investment was a mistake.

“If you are one of the world's biggest bus makers and if you want to continue to be, you sometimes have to make such a decision fast when the market is in the process of changing dramatically. If we want to continue to be the leader, I mean,” says Niklas Gustavsson on his mobile when he has time on the airport bus for a chat.

Partnership between companies and the state behind success

In such cases, when the risk is massive, it is particularly important to have competent partners with supplementary knowledge and access to their own networks. That increases the chance of succeeding with new innovations.

“We need the state, in the form of agencies such as the Swedish Energy Agency, Vinnova and the Swedish Transport Administration, and various companies to work together on research and development when the challenges and the risks are big. We need this partnership if Volvo is to remain the market leader in 50 years’ time,” says Niklas Gustavsson, adding that Volvo Buses has around 7,000 employees worldwide.

The model has been shown to work well over a long period of time.

One of many examples of a Volvo Buses project funded by the Swedish Energy Agency is the plug-in hybrid bus project in 2010–2012, which resulted in the first plug-in hybrid bus. The Swedish Energy Agency contributed SEK 18 million.

It is all about retaining this top-level research in Sweden.

The Swedish Energy Agency supports the development of ElectriCity

As early as 2007, the Swedish Energy Agency granted Volvo Buses funding for three projects with the aim of developing competitive hybrid buses for urban transport. Volvo Buses’ current position as the leader in hybrid technology for heavy vehicles is partly a result of these projects.

“With the Swedish Energy Agency's expertise and financial support for research and development, we have been able to develop many of the components necessary to build good hybrid vehicles. These include electric powertrains, batteries and charging equipment, plus entire systems.”

Niklas Gustavsson emphasises the importance of demonstrating how the new sustainable bus systems work in reality for potential customers such as cities. ElectriCity is one such a pilot project. It is in progress now in Gothenburg and the Swedish Energy Agency is supporting its development.

“When new street environments can be planned with greater density as a consequence of reduced noise and emissions, an entirely new approach to urban development is possible. It is also possible to drive indoors,” says Lars-Bertil Ekman, CEO of Göteborgs Stadshus AB, who would like to see more electric buses on the city's streets.

Facts in brief:

Explanation of a plug-in hybrid:
A vehicle that has both hybrid and electric modes.

Emissions reduction for plug-in hybrid compared with diesel: 80%

Reduction in fuel consumption for plug-in hybrid compared with diesel: 20–30%

Repayment period per plug-in hybrid bus: 5 years

Industry

Developments in Swedish industry are extremely important in the transition to a sustainable energy system. More efficient energy use and new resource-efficient products and services are examples of developments on which the Swedish Energy Agency is focusing. These initiatives are designed to benefit Swedish industry and create the basis for international collaboration. The initiatives are also designed to boost Swedish competence centres that contribute to industrial development in energy efficiency enhancement and greater use of renewable energy and renewable raw materials in industrial processes.

In 2013, Swedish industry accounted for approximately 38 percent, 144 TWh, of Sweden's final energy consumption. The pulp and paper industry, iron and steel industry, the chemicals industry and the timber industry account for three-quarters of total energy consumption.

Energy consumption in industry has been relatively constant since 1970, despite increased production. This is the result of both energy efficiency enhancements and a gradual transition from oil to electricity and biofuels. There is great potential to further enhance the efficiency of energy consumption and increase the use of renewable energy carriers in industrial processes. This can be done by developing techniques, products, services and systems. The potential for energy efficiency enhancement lies both in individual companies and in partnerships between companies and other actors in society. Research into system issues and business ownership is therefore increasingly needed to cope with the transition to a sustainable energy system. There is also a clear need for technology development to radically reduce energy use and emissions of greenhouse gases. For example, the development of new resource-efficient products can lead to more efficient use of natural resources and energy throughout the manufacturing chain. Materials made from renewable raw materials can create new business opportunities for Swedish companies and help boost the competitiveness of Swedish industry.

Results and effects

For a long time, the Swedish Energy Agency's research activities have focused on energy efficiency enhancement and the increased use of renewable energy and renewable raw materials in industrial processes. The activities are implemented in special research programmes directed towards the iron and steel industry and the pulp and paper industry. A broader industrial programme includes other less energy-intensive sectors and issues affecting all parts of the system.

In both the iron and steel industry and the pulp and paper industry, great efforts have been made to enhance energy efficiency in their processes. Several projects, for example, have involved reducing energy consumption in blast furnaces. Attempts have also been made to use biomass in blast furnaces instead of coal and coke.

These efforts may lead to both actual improvements at companies and a general build-up of knowledge in society.

More efficient energy consumption when baking bread

The SP Food and Bioscience research institute showed in a project that bakeries can maintain the same quality for many bakery products by replacing conventional oven technology with microwave and infrared technology. Initial small-scale tests showed that energy consumption can decrease by up to 60 percent. This reduction would be equivalent to at least 1.1 TWh a year if the technology were used to bake all bread in Sweden. The technology is also applicable to other bakery products, with even higher potential for energy efficiency enhancement. The project is now continuing in a demonstration phase involving several bakery companies.

Materials and product development in pulp mills

Lignin is one of several components of wood and plants. The Swedish Energy Agency has funded the Lignofuel project with approximately SEK 23 million. In the project, the research institute Innventia studied the possibility of using lignin as fuel. If it is broken down into smaller molecules, the lignin can be converted into a liquid bio-oil. The oil has the potential for conversion into different types of products such as chemicals, biofuels and carbon fibre. Full-scale experiments have been carried out in a Finnish pulp mill. The technology allows the pulp and paper industry to expand and renew its product portfolio and increase its production capacity in current processes. There is potential to use several million tonnes of lignin from Swedish pulp mills for new products.

Useful build-up of knowledge about membrane processes

Distillation is a key component of oil refineries. Membrane processes are predicted to play the same role in the biorefineries of the future.

Membrane processes are already established separation technologies in as widely different applications as the purification of oily water and the production of lactose-free milk. To be able to isolate specific compounds in the complex and often diluted process solutions in biorefineries, the challenge now lies in developing energy-efficient and cost-efficient processes.

The Swedish Energy Agency has funded several projects in the membrane group at the Department of Chemical Engineering at Lund University. The group has 40 years of research experience in membrane processes. In partnership with a number of membrane manufacturers, they are now researching membrane processes adapted to different applications in biorefineries.

Current research, development and demonstration activities

The research and innovation initiatives in industry are focused primarily on the energy-intensive sectors and are primarily in three areas:

- efficient energy use
- materials and products
- systems and business ownership.

The Swedish Energy Agency currently funds one broad industrial programme and two sector programmes directed at the pulp and paper industry and the iron and steel industry. Several programmes and projects focus on the production of biofuels, which is clearly linked to industry and industrial processes and systems. In addition, several programmes with industrial relevance are funded within the framework for the joint initiative in strategic innovation areas along with Vinnova and Formas.

Efficient energy use

Within the framework of efficient energy use, initiatives are taken to improve processes and technologies. These include development of existing processes and development of entirely new resource-efficient processes. Efficient energy use may also be secondary. This means that the industrial manufacturing process need not be more efficient but the product produced contributes to reducing energy consumption when it is used.

The Swedish Energy Agency funds the Royal Institute of Technology with approximately SEK 4 million for the IronArc project, which concerns a new method for the energy-efficient production of iron. The aim of the project is to evaluate the potential for a new method of iron production. The project will involve calculations of how the IronArc method can be scaled up to a plant with the capacity for 500,000 tonnes of pig iron a year. The project contributes to metallurgical knowledge and is important for the industry's future ability to reduce the use of fossil energy carriers and raw materials.

The OPTIR (optimised energy use of heating furnaces with radar imaging) will develop new calculation methods to be able to use radar-based measurement technology in furnaces. In steel works, energy losses can occur in heating furnaces because steel ingots are heated more than necessary or when the furnaces are started and stopped. Losses can be reduced if better and more reliable measurement methods are developed. The project may lead to energy efficiency enhancement through the optimisation of the heating of steel ingots via fewer production stops, better utilisation of heating furnaces and greater understanding of the process.

The aim of the project is to investigate the potential for energy efficiency enhancement and the opportunities for realising this potential throughout the production cycle, from metal production to recycling. The aluminium industry uses approximately 3 TWh of energy every year, and parts of production are very energy-intensive. In primary aluminium production, energy accounts for 30–40 percent of costs. Energy efficiency enhancement would therefore lead to both increased competitiveness and reduced emissions of greenhouse gases.

A need for renewable, resource-efficient materials and products

To meet energy and climate policy targets, there is a dramatically increased need for renewable, resource-efficient materials and products. Sweden has the advantage of having a good supply of raw forest materials that can replace raw fossil materials. Research in resource efficiency has great potential. This involves developing and implementing new technologies, reducing waste throughout the value chain and also increasing the use of the products that have been produced.

Energy efficiency enhancement can take place in several parts of the chain by means of the additive production of products (3D printing). A new material will be developed in a project related to resource-efficient production of new high-performance durable materials. This project is supported by the Swedish Energy Agency with approximately SEK 4 million. By producing the product additively, building up the components step-by-step in a form close to the final form, several subsequent energy-intensive steps such as rolling, forging and milling can be avoided. The method also allows cavities to be created in the components, which reduces both the total material consumption as well as the weight of the product. The special properties of the material mean that the components are more durable and do not need to be replaced or reground as frequently. This also results in energy efficiency enhancements at the user level.

The Swedish Energy Agency is supporting the research institute Innventia with SEK 7.5 million to implement a project on carbonised lignin products for energy-saving applications. The project aims to develop two highly processed applications for lignin from pulp mills: structural carbon fibres for motor vehicle applications and activated carbon fibres for advanced adsorption that can be used for hydrogen storage and gas purification. Bio-based carbon fibre can replace fossil-based carbon fibre. At the same time, less energy is used in the production of the material compared to conventional carbon fibre. The cost of lignin-based carbon fibre is calculated to be lower than that of conventional carbon fibre. This makes it possible for it to be used more in the automotive industry, which would lead to new cars having lower weights and thus lower fuel consumption.

Research into systems and business ownership

Research is conducted into systems and business ownership within the framework of all programmes, above all through the development of methods and tools that can be used for evaluation and as decision-making support ahead of new investments, for example. However, there is a need to increase the initiatives in this area. For example, this may involve collaboration between different companies and sectors or interaction between the public sector, companies and consumers.

The Swedish Energy Agency has funded three projects that are investigating various aspects of how energy use can be made more efficient by geographically close industries forming clusters.

The projects are being implemented with companies in the industrial cluster in Stenungsund and the three projects are collaborating to allow each other's results to be pooled. One of the projects involves investigation of the best use of surplus heat: via internal heat recovery in the industry or by exporting the heat. The two other projects are investigating aspects linked to district heating markets and sustainability issues.

The separation and storage of carbon dioxide (carbon capture and storage, CCS) may be part of the solution to achieving Swedish climate targets. This method will reduce carbon dioxide emissions from the industrial sectors which would otherwise find it difficult to radically reduce emissions by 2050. Several projects are in progress in this area to develop energy-efficient and cost-efficient separation technologies.

Challenges in the future

The Swedish Energy Agency sees an increased need for system studies to create a holistic approach to the conversion of the energy system. Digitisation in society is creating new conditions, while the complexity of systems and the volume of information are growing. New business models are being developed in the wake of digitisation. Stricter sustainability requirements are affecting the conditions for industry, but also offer new business opportunities and scope for innovations.

In recent years, additive production (3D printing) has changed the conditions for the manufacturing industry. How it will affect energy use and energy efficiency remains to be seen. Research initiatives in the area will be needed.

New knowledge and technological solutions are needed to allow renewable energy sources and raw materials to be introduced in more industrial processes and thus reduce emissions of greenhouse gases. This may take place by increasing the use of biomass in production, and a supplementary measure may be capturing and storing carbon dioxide. It is primarily a challenge for the cement and iron and steel industries to reduce fossil fuel based carbon dioxide emissions. Research and innovation will therefore be needed to develop new processes, technologies and systems.

Sweden has good access to renewable raw materials from its forests. Some of the current forest and chemicals industries may be developed into biorefineries with a range of bio-based products such as carbon fibre, chemicals and biofuels. Demonstrated production is normally required to evaluate a new technology or an innovation. It is relatively cheap to develop materials and processes on a laboratory scale, but scaling them up to the pilot and demonstration scale involves the costs being greatly multiplied. Government funding can make a big difference and help reduce companies' risks.

The potential to enhance the efficiency of industrial energy use remains high and will also contribute to enhancing the competitiveness of industry. This applies to the development of both established technologies and innovative new solutions. To achieve radical changes, the incremental improvements will need to be supplemented by radical technological advances. With these sweeping technological changes, Government funds can be decisive.


LOMOLOGIC

From invention to world-class product – with research support from the Swedish Energy Agency

With smart cutting technology, the Swedish company Tomologic is setting a new world standard for industrial cutting machines. The Swedish Energy Agency supported the company through the critical development phases. Customers are now lining up for a system that both produces less waste and saves energy by means of reduced material flows.

As a 15-year-old, Magnus Norberg Ohlsson stood on the factory floor as a cutting machine operator. He was already thinking about how to reduce the large piles of waste. When Magnus began at KTH a few years later, he had the solution within his reach. It was based on computer data processing capacity. In his last year at KTH, he founded Tomologic with a team that believed in his ideas.

Until today, around 30 percent of every sheet of metal was waste. The main reason for this is that there is a safety distance between parts so that the heat produced in the cutting process does not affect their shape. The simple idea behind Tomologic's cluster technology is to use computing power to calculate the optimum location of the parts to be cut out. With their Optimizer service, parts are clustered in groups, which halves the quantity of waste metal. The material saving is generally ten percent. In a world market that processes 845 million tonnes of steel a year, this amounts to large sums of money. And not just in material savings. The transport savings are huge too.

The Swedish Energy Agency, important from the start

After having written a business plan, Magnus and his companions began to look for support and co-financiers to develop the service and the company. With a development grant of SEK 4 million, the Swedish Energy Agency became one of the most important financiers of the company in 2010. In particular, because the grant could be used to employ more people and retain them throughout the development process.

"For us, this financial support was extremely important. We were able to use it to employ more people to implement a demonstration project," says Josefin Nordström, who has been involved since the start and now works as marketing and sales manager.

Standard on a new level

Josefin Nordström says that what makes Tomologic's Optimizer unique is the combination of Magnus' experience from the factory floor and the employees' ability to transform factory-based visions, combined with research, to write algorithms for the service. This means their ability to write the recipe for how the parts are to be placed and cut to ensure the right production conditions.

"It is complex software. Compared with the optimisation software that was the previous standard, we have moved to a new level," says Magnus Norberg Ohlsson.

Customer benefits include:

• Significant material savings and increased resource efficiency of approximately 10 percent as a result of maximum material utilisation.
• The software can be used without investments in new software and hardware.
• Shortened cutting times of approximately 13 percent thanks to dynamic clustering and optimised cutting paths.
• Reduced material flows and thus reduced energy consumption.

Financial support from the Swedish Energy Agency is always conditional, and this was the case for Tomologic as well. At the conclusion of the demonstration project, Magnus and Josefin travelled to one of the partner companies that were involved in the development work on the service. There they held a demonstration for invited delegates from the Swedish Energy Agency. It then became clear that the knowledge-based system was not just a vision. It was a fully functioning innovation on a standard factory floor.

Partnership with a world-leading cutting machine company

Several of the world's biggest manufacturers of cutting machines were soon interested in a partnership with Tomologic and negotiations began. Since 2012, they have had a commercial partnership with the Swiss company Bystronic. For them it was about being the first to offer the service, which makes their machines more attractive and their customers more profitable.

An innovation company is always at the leading edge of developments. In the case of Tomologic, a cloud service is also involved. Cloud services have become more common for us Swedes, and the same is true in industry. Abroad, it is clear that Sweden is some way ahead. However, there are now a growing number of companies that understand the value of reducing waste and energy consumption using the Optimizer cloud service.

"Without the Swedish Energy Agency, we would never have been where we are today. However, the focus now is on getting the market interested. Many people think our product is too good to be true, with gains in all parts of the chain," says Josefin Nordström.

Clear value for all

At management level, the figures speak for themselves: Tomologic's Optimizer saves huge sums of money. However, at the cutting machines, the operators are suddenly challenged. The software is so advanced that no human can match its ability to make fast, precise calculations.

Tomologic is currently in the phase in which the Swedish Energy Agency's conditional loan is very useful. The capital is currently being used to strengthen the organisation commercially. This is partly to continue the development of existing algorithms, boost the test infrastructure and patents and meet requirements and changes within the framework of the customer project preceding the global project launch.

"I believe that this product is of huge value for all of industry. In the current situation, material savings represent the most specific savings available," says Magnus Norberg-Ohlsson.

Optimizer – technology that reduces waste

Tomologic's Optimizer is web-based software that uses algorithms to provide the manufacturing industry's cutting machines with optimised cutting plans. This allows material waste to be reduced by up to 50 percent.

Facts in brief:

Start year: 2009
Number of employees on start-up: 5
Business concept: To reduce material waste in the manufacturing industry
Product: 'Optimizer' optimisation service
Customer benefit: Reduces material waste in the manufacturing industry
Number of employees, 2015: 17
Headquarters: Stockholm
Partners: Bystronic (Switzerland)
Examples of customers: CH Industry AB (Sweden), AL-Cut AG (Switzerland), Catalytic Combustion Corp (USA)
Market: Global
Net sales, 2014 (SEK thousand): 2,641

"This allows
material waste to be reduced by
up to 50 percent."

Buildings in the energy system

More efficient energy use in the buildings sector is an important part of the conversion of the energy system. Buildings account for nearly 40 percent of total energy consumption in Sweden. There is a need for knowledge in many different areas. The Swedish Energy Agency supports research and innovation activities in both new and existing buildings. Existing buildings present the greatest challenge as many of today's buildings will still be with us far into the future. This long time frame also means that it is important for new buildings to be more energy-efficient than they currently are.

The housing and service sector accounts for approximately 40 percent of Sweden's total energy consumption. The climate impact of buildings has decreased considerably since the 1990s. However, the impact of the construction process on the climate remains high and represents a large proportion of the construction and property sector's total carbon dioxide emissions, calculated on the full life of buildings, from production to phase-out and final management.

The sector involves many actors with different roles, responsibilities and competencies, from large construction companies to individual property owners and households. There is a need for knowledge in many different areas and the needs may vary greatly from situation to situation. The entire energy chain needs to be taken into consideration at the same time, from natural resources to delivered energy services. The behaviour of end energy consumers also needs to be taken into account. Research and development interact with a number of other policy instruments to achieve energy efficiency enhancements in buildings.

Results and effects

Swedish industry's strong position in refrigeration and heat pump technology, an electric cord that visualises energy consumption in an educational manner, analyses that are used by public agencies when reporting on Government commissions and the effect of light on health and performance are a few examples of results of initiatives by the Swedish Energy Agency.

In evaluations, major coherent programme initiatives in the area of construction have been shown to result in good achievement of goals for the development of collaboration methods between the business community, universities and public agencies. The ambitions for disseminating results are also extensive in this area. Projects have generally succeeded well in reaching their target groups with results.

Pilot projects in buildings of cultural and historical value created practice

The results of initiatives relating to energy efficiency enhancement in buildings of cultural and historical value have led to an increase in knowledge in the sector among public agencies, administrators, consultants, etc. When the programme in this sub-area was initiated eight years ago, energy-efficient solutions such as heat pumps and dehumidifiers were more or less banned in buildings of cultural and historical value. Pilot projects in the programme have paved the way and their results are now the practice. The European standard for selecting heating systems in churches, which was developed with the support of the 'Spara och bevara' (Save and preserve) research programme, is now used both within the Church and by Swedish public agencies.

Strong Swedish position in refrigeration and heat pumps

The Swedish Energy Agency's research, development and innovation activities in the area of resource-efficient refrigeration and heat pump systems has helped contribute to the strong international position of Swedish industry and research institutions within refrigeration and heat pump technology.

Lighting affects behaviour, well-being and performance

Technological developments have been very fast in the area of lighting in the past decade. From filament lamps to low-energy lamps to today's LED lamps, which provide good light quality at a low cost. Against this background, the lighting research programme has contributed to the conversion from filament lamps to LED lamps. The programme has also succeeded in building up expertise in the areas of energy-efficient lighting solutions, behaviour, acceptance and how performance and health are affected by light. The programme has made it possible for other research environments that did not previously work on energy efficiency enhancement to add this aspect to their research, an effect that is very positive. In the areas of lighting and light and health, Sweden has stood out worldwide with good results in studies of the health aspects of light intake and performance linked to the daily dose of light.

Energy, IT and design are linked

For many years, the Swedish Energy Agency has supported research and development projects to generate greater knowledge about people's different attitudes and energy habits in housing, at work and in leisure time in our increasingly mobile daily lives. Support has also been granted for projects in the area of how design and IT solutions affect the driving forces behind and the obstacles to more sustainable energy use. Like water, power flows through The Pac, the cord that shows the energy that connected units are using and is a very specific example of a result of the programme. The Power Aware Cord prototype aroused great attention and gained great international success. In 2010, it was named one of the 50 best innovations in the world by Time Magazine. The Pac has now been launched on the market.

Important documentation for Government commissions

The Swedish Energy Agency has financed research carried out partially in an international context into energy use and climate impact from the construction stage, including so-called built-in energy. These results formed important documentation in the Swedish National Board of Housing, Building and Planning's report for a Government commission on the level of knowledge and the need for continued research and other initiatives in the area. In a similar manner, both behaviour and obstacle analyses from the 'Förnybar energi för alla' (Renewable energy for all) research project were used in 2015 as documentation and as a part of the report on the agency's work on commission one of the spending authorisation document. This concerned information activities to promote the development of microproduction of electricity from renewable energy sources.

Current research, development and demonstration activities

The vision for the Swedish Energy Agency's work in the area is to achieve resource-efficient and energy-efficient buildings. To achieve this vision, collaboration is essential, among other things between municipalities, the business community and academia. The challenges faced by buildings concern not only Sweden. Consequently, the Swedish Energy Agency participates in several international partnerships concerning research and development initiatives in the area.

In the area of buildings, there is a need for integrated research perspectives and an interdisciplinary approach. Technical research is combined with research in social and behavioural science. Projects are carried out that study and develop the interaction between buildings' technical and architectural designs, building services engineering components and energy supply systems. Other important elements involve combining this with users' and other actors' motivations, knowledge and incentives for energy efficiency enhancement.

Energy efficiency enhancement of the Million Homes Programme

Several current projects deal with how energy management measures can be implemented in existing buildings, especially in the Million Homes Programme. For the Million Homes Programme, energy efficiency enhancement is only part of the challenge of socially, economically and ecologically sustainable development. To refurbish older residential areas, including Million Homes Programme areas, initiatives are being implemented to develop package solutions and innovative system solutions for energy measures along with other valuable improvements for the housing.

Low-energy houses and nearly zero energy buildings

Research initiatives are being implemented to promote the development of robust technology specially adapted to the construction of new low-energy houses and nearly zero-energy buildings (nZEBs). These include research, development and demonstration activities concerning structural engineering, window systems, superinsulating wall systems and combinations of efficient ventilation and heating systems. Initiatives for the technical installations also need to focus in particular on the users.

Interdisciplinary approach throughout the construction process

To achieve a resource-efficient, sustainable built environment, initiatives are implemented involving interaction between technology research, urban planning research and architecture research. Decisions made by architects and municipalities in the construction process, from comprehensive plans to detailed development plans and building permits, have long-lasting impacts. Initiatives are prioritised in all phases, from comprehensive planning down to building design and recovery, including issues such as the use of solar energy in architecture.

Research is conducted to study the construction process and the actors involved from an energy perspective. The construction process consists of different phases: concept, planning, design, construction, delivery for management and use, and finally demolition. In the phases of the construction process, different actors are responsible for managing different elements. Consequently, there is a challenge and a need to research and develop energy-relevant methods and processes for construction.

One focus is on energy consumption during the construction phase. New knowledge is being gained on how choices of construction materials and construction systems, the design of buildings and structural components can contribute to more energy-efficient, climate-efficient buildings from a life cycle perspective.

Research into people's homes and daily lives

Initiatives related to so-called 'Living labs' supplement a situation where simulations and small-scale experiments are unable to produce new knowledge. They accelerate the introduction of new technology and reduce the lead time between research results and market introduction. New partnerships are encouraged and risk can be reduced and distributed between several actors.

Challenges in the future

The greater part of the properties in Sweden are existing buildings, many with a great need for renovation. For the Million Homes Programme, energy efficiency enhancement is only part of the challenge of socially, economically and ecologically sustainable development. Initiatives to enhance the efficiency of energy use in buildings are needed via research, development and innovation and via other instruments.

The buildings of the future are one of the cornerstones in the creation of flexible energy systems in which large-scale production and storage interact with locally generated and stored electricity. The creation of such integration requires new research into and knowledge about behaviour as well as flexible new products and services in and around the built environment.

The Swedish Energy Agency is already seeing examples of buildings being not just consumers of energy but also small-scale electricity generators. For example, solar energy is well suited for generation of electricity on or near buildings. Flexible buildings are also required to create a more flexible energy system in Sweden which is able to cope with more intermittent power from sources such as solar and wind energy.

As new buildings become more and more energy-efficient, the importance of energy consumption in other phases of the life cycle of buildings increases. The choice of materials, energy consumption in the construction phase and material recovery and final management become increasingly important.

To meet the energy efficiency enhancement challenges of the future, initiatives are needed in construction research, innovation and demonstration.

General energy system studies

New actors, new technology and new connections are creating new conditions for energy policy and future scenarios. People are an important component of the energy system, not least our ability to introduce and manage the energy technology solutions that are part of the transition. The focus of general energy system studies is on the big picture, general system issues and how the system relates to the world around it.

The reason for the system perspective is that all technologies can be seen as interconnected parts that form a whole. The energy system and its actors are affected by taxes, laws, rules and events in the wider world. Everything is linked. Consequently, it is not enough to look for answers to one question at a time as that does not make it possible to arrive at a coherent understanding of the system. If, instead, questions are asked with a holistic approach, it is possible to develop versatile knowledge about how the system works and its conditions. Interdisciplinary studies are therefore encouraged to achieve a sustainable energy system.

Research in the area of general energy system studies has an established role in Swedish energy research. The old general energy system studies research programme has existed since the first energy policy programme started in 1975. During the 40 years in which Swedish energy research has been conducted, the area's main responsibility, focus and scope have all changed. Energy system issues have become increasingly important as a result of the energy policy decisions made in recent years. Energy system issues have also started to increasingly concern the issue of climate. That makes them both EU issues and a global concern.

In energy system studies, basic research, investigatory research and policy-based research are all conducted on the basis of a number of different disciplines, either individually or in interdisciplinary constellations. It is also possible to fund research in the area over a broad spectrum. It is important to have both research with a critical approach and research into how the energy system relates to other societal systems and political areas.

As there is a growing need for long-term sustainable management of the earth's resources, the energy system plays a central role in societal development. Energy system studies that produce knowledge about the conditions and means of climate policy are needed to drive the international climate policy process forwards. Energy system studies also involve analysis of the inherent importance of energy research and show how research and other energy policy tools relate to each other.

Results and effects

The thematic area of general energy system studies has had two objectives: to ensure expertise for future requirements and to create direct benefit for decision makers.

Ensuring expertise for future requirements

Research funding has allowed people to develop their expertise in issues of relevance to energy policy goals and targets, not just for now but also for future requirements. 70 theses have been written and approved in the Energy Systems graduate school. The doctoral theses supported via the graduate school have concerned a number of topics, for example:

- actors related to the first low-energy houses
- divisions and partnerships between district heating companies in the Stockholm area
- systemic effects of energy efficiency enhancement in houses heated with district heating
- municipal planners' ideas of sustainable travel
- households' use of electrical appliances
- biogas as a renewable fuel.

Creating direct benefit for decision makers

These energy PhD students represent knowledge capital that has worked in society for a long time and continues to work. By 2015, roughly half of these PhDs have stayed at universities and institutes of higher education, where they continue with new research projects. The other half have taken employment in other parts of the Swedish energy system: the Swedish Energy Agency, energy consultancy companies, research centres, research councils, trade organisations, other public agencies, other private and state-owned companies and one non-profit organisation. The expertise supplied in this way is part of the conversion of the energy system.

The research has also generated direct benefit in the form of documentation for decision makers at national and municipal levels and in private companies. For example, theses from the graduate school have been used in Government commissions of inquiry on energy issues. Support for large and small individual projects has accounted for the majority of projects in the second objective of the thematic area: to create direct benefit for decision makers. Energy system studies often have clear policy relevance, for example via the 'Vägval energi' (Energy Routing), LETS2050 and NEPP research programmes.

'Vägval energi' was a research programme led by the Royal Swedish Academy of Engineering Sciences in 2008-2009. It was funded by the Swedish Energy Agency, Formas, Swedenergy, the Confederation of Swedish Enterprise and Åforsk. The final report indicated five routes ahead: prioritising energy efficiency enhancement, investing in measures that produce the most climate benefit, investing in electric cars, continuing to use nuclear power and preparing for a warmer climate.

LETS 2050 (Governing transitions towards low-carbon energy and transport systems for 2050) was a large, four-year research programme that was co-financed by the Swedish Energy Agency, the Swedish Environmental Protection Agency, Vinnova and the Swedish Transport Administration in 2009–2013. The subject of the research programme was moving towards zero emissions by 2050 and it tackled the major issues of climate change in a long-term perspective, technical development, social motivation, political management and future scenarios as strategic tools. The programme ended with a summary publication: 'I ljuset av framtiden' (In the Light of the Future).

NEPP (North European Power Perspectives) is a coherent, multidisciplinary research project on the development of electricity systems and the electricity market in Sweden, the Nordic region and Europe in the time frames to 2020, 2030 and 2050. The research is conducted by around ten highly qualified researchers and analysts. NEPP is funded by the electricity companies, Svenska kraftnät, the Swedish Energy Agency and the Confederation of Swedish Enterprise.

Current research, development and demonstration activities

There are currently two main focuses in general energy system studies: the Energy Systems graduate school and Strategic Energy System Research. The overall aims are to create new long-term expertise for the energy system and for the research to benefit decision makers at different levels.

Both the Energy Systems graduate school and Strategic Energy System Research are the result of reorganisation in 2014 and more institutes of higher education may now bid to participate. Unlike the old general energy system studies support programme, international climate policy is part of Strategic Energy System Research, and SEK 20 million has been earmarked for electricity market research. The total budget up to 2018 is approximately SEK 50 million per annum on average. The funding therefore accounts for approximately three percent of the Swedish Energy Agency's annual research budget.

The Energy Systems graduate school contributes to interdisciplinary expertise supply

The Energy Systems graduate school contributes to the supply of expertise in interdisciplinary energy system research and general energy research.
The programme supports doctoral projects that are organised in interdisciplinary groups. This means that doctoral candidates with different backgrounds from different institutes of higher education work together. The doctoral candidates have several supervisors. To ensure that the projects are interdisciplinary, the main supervisor is at the student's own institution and there are secondary supervisors at other institutions.

Strategic energy system studies at national and international levels

Strategic energy system research is designed to contribute to:

- the development of new knowledge of good scientific quality, including the synthesis and communication of existing knowledge
- the preparation of a scientific basis for expedient energy and climate policy
- building expertise in the energy system, electricity market and climate research areas.

Strategic Energy System Research has a budget of SEK 130 million, which is distributed over the years 2014-2018. The projects in the programme are linked to several research areas and they relate in different ways to the challenges associated with a sustainable energy system. Both new holders of PhDs and experienced researchers are funded throughout the research programme. The researchers often work together in large national and international groups. Here are a few examples:

- *From hours to decades – how will variations in load and production affect the composition of the future electricity systems of Sweden and Europe?*
  The project focuses on energy systems with a high proportion of electricity generation from solar and wind power, which may be conceivable after 2020.

- *National challenges for the industrialisation of energy technology in global innovation systems.* The project aims to investigate how Sweden can create domestic industrial innovation based on research and development of new energy technology in areas with a limited domestic market but with significant global potential.

- *International climate policy after Paris: Targets for carbon dioxide and other greenhouse gases.*
  The project studies international climate policy and is based on the outcome of the COP21 climate conference in Paris. The focus of the project is on issues concerning balancing the reductions of emissions of short-lived substances with an impact on climate against long-lived greenhouse gases.

Challenges in the future

In energy system studies, research into the role and mode of operation of the Swedish energy system will continue to be important in the future. The energy system is affected by the general development of society, which affects the actors in the energy system. This may be about changes of ownership, new business models in established energy companies or the formation of new companies. It may be about households becoming generators when solar cells are installed on the roof or adapting their energy consumption as a result of direct information from electricity meters. Such changes in roles create new conditions for the spread of new technology.

Energy policy is an important topic for study in itself. Critical research into targets and decision-making processes at international, national and local levels can provide assistance in decision-making processes. Energy policy involves a concentration of the underlying synergies and target conflicts into questions of balance and choice of direction that may have long-term effects as a consequence of the often long technical service lives.

The formation of energy policy is assisted by prospective studies involving model development and scenario descriptions. Models that describe how sub-systems affect each other and that make it possible to assess the outcome of a change in any part require more method development in order to produce solid knowledge-based tools that enhance system understanding. For example, Sweden's old nuclear power can be replaced by new nuclear power, renewable electric power, energy efficiency enhancement or a combination of these options.

Scenarios can be modelled on a scale from thought-provoking to conservative. Radical scenarios can stimulate innovation in both technology and policy. Realism is also required. Swedish energy policy cannot affect everything, particularly not international development. How can developments be made robust, despite the uncertainty in the surrounding world?

Business development and commercialisation

The transition to a sustainable energy system is creating growing global demand for new technology and new services. There is great potential for Swedish energy research to meet this demand. Success depends on Swedish technology and knowledge being commercialised. Economic growth, export opportunities and jobs will be created at the same time. Support for business development, commercialisation and the spread of new energy technology is important if this is to be achieved.

For companies with innovations at the early stage of development, it is a challenge to find capital from private market actors. This applies in particular in the energy sector and to innovations with capital-intensive development, long development and commercialisation periods and high risk associated with technology. In addition, this type of company operates on markets that are subject to stimulus measures and regulations. Venture capital goes instead to other areas where the risks are more predictable.

Consequently, Government funding in these phases is essential to the conversion of the energy system and the simultaneous development of new business than may lead to jobs, increased growth and higher export revenue.

The Swedish Energy Agency helps young companies launch new products and services on the market and funds companies until their innovation has reached a level of maturity at which private actors are prepared to step in and finance and drive continued development. The Swedish Energy Agency's funding for business development and commercialisation goes to projects in which the commercial potential is considered to be high and the projects are considered to have significant impact on the conversion of the energy system.

A significant success factor for the Swedish Energy Agency's initiatives is its broad range of expertise across the entire energy sector and all phases of the innovation system. There is also valuable collaboration with other public agencies, academia, the business community and private financiers.

Results and effects

The Swedish Energy Agency's model for funding research and the development and commercialisation of innovative Swedish energy technology has contributed in several cases to growth companies having succeeded in launching products and services on a market or attracting private capital to finance their continued growth. Here are some examples.

Reported revenue

One indication of the effect of the Swedish Energy Agency's business development support is when companies report revenue as a result of the business development projects funded by the Swedish Energy Agency. For 2014, 16 companies reported revenue totalling SEK 15 million (SEK 12 million in 2013). In addition, SEK 1 million in licence income and cost savings was reported.

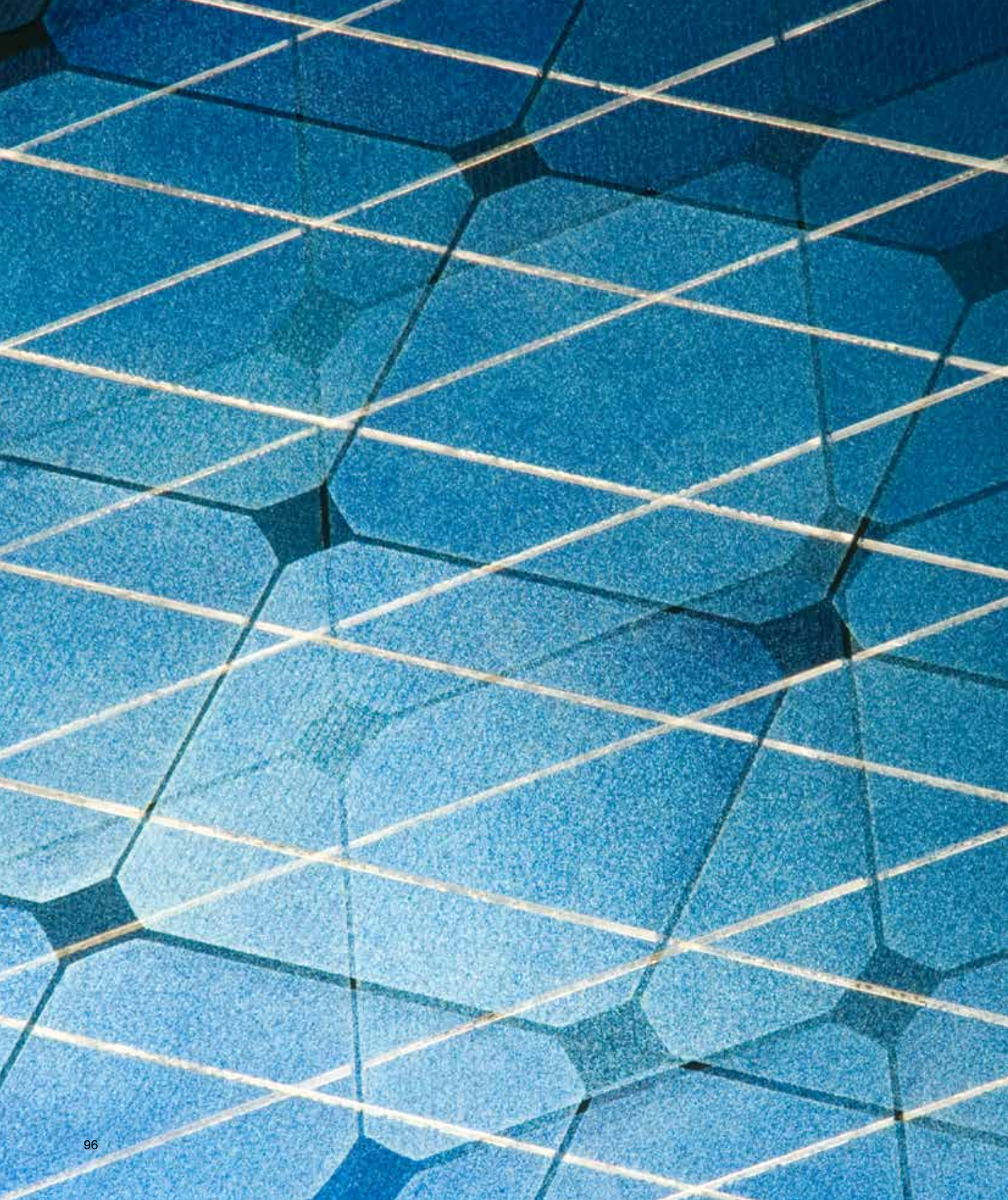
Listing of PowerCell Sweden AB

One way in which companies gain access to the private capital market is by being listed on stock exchanges. Several of the companies that have received business development funding from the Swedish Energy Agency have received private capital by being listed afterwards. One of these companies is PowerCell Sweden AB, which developed efficient fuel cell technology that converts diesel into electricity. In 2014, PowerCell was listed on First North, Nasdaq's market for small companies in the expansion phase. PowerCell is one of four companies in the Swedish Energy Agency's business development portfolio that has been listed on a stock exchange or other exchange. The other three are Arc Aroma Pure AB, Heliospectra AB and Insplorion AB.

Commercial sales from Climeon AB

Climeon AB has developed a new method for extracting electricity from residual heat. Climeon's technology is based on a new type of chemical motor that converts hot water into electricity in a low-pressure process. The method is considerably more efficient than other existing products.

Climeon received funding from the Swedish Energy Agency at various stages to develop and commercialise its technology. The 'Från teknologi till affärsverksamhet' (From Technology to Business Operations) project ended in 2014, and Viking Line and SSAB are now the first commercial users of the innovation.



The company's technology is designed to produce electricity from heat at low temperatures with small temperature differences. It is possible to produce profitable electricity from heat down to 80 degrees. The company is considered to have the potential to capture large market shares. On a global scale, this could mean an annual increase in electricity supply of up to 23 TWh.

The process was developed in close cooperation with the Royal Institute of Technology, Stockholm University, Chalmers Industriteknik and the Faculty of Engineering at Lund University with funding from the Swedish Energy Agency. Climeon received approximately SEK 20 million in funding in the form of grants for four technology verification and development projects and loans for a business development project. The two success factors were stamina and the funding being granted in stages.

Expected effects

Below are three examples of companies that received business development support at an early stage and the commercial potential of which is considered to be high, while the projects may have an important impact on the transition to a sustainable energy system.

Sol Voltaics manufactures high-efficiency nanowires

Solar panels constructed with nanowires are a new technology that may mean a breakthrough for the production of high-efficiency solar cells at competitive prices. Sol Voltaics has developed nanowires that have proven high efficiency and low production costs. The nanowires can considerably improve the efficiency of silicon-based solar cells. The company's business concept is to produce and sell materials to existing producers of solar cell modules. The module producers who use the product will increase the efficiency of their existing silicon solar cells and improve the efficiency of the average modules from approximately 15 percent to approximately 30 percent.

During the project period, Sol Voltaics has moved from being a research project to a commercially oriented company. The long-term goal for Sol Voltaics is for technological developments to lead to large-scale Swedish industrial production of nanowire film for more efficient solar cells for the global market. The project is currently considered to have very good potential to be commercially successful.

Exeger makes the best indoor solar cell in the world

Exeger has developed a brand new solar cell based on dye-sensitised solar cells[9] (DSC) and is currently building the world's biggest factory for production of DSC in central Stockholm. In 2014, the company completed a production line with capacity to produce 20,000 square metres of solar cells annually. The production line was further extended in 2015. Exeger's solar cell is the world's best indoor solar cell and if, for example, it is integrated in the case of a tablet, it can constantly charge the battery under standard office lighting.

Tomologic reduces waste in cutting machines

Tomologic offers technology to control cutting machines in industry to reduce waste considerably. The company offers the manufacturing industry an online-based optimisation system for industrial cutting processes.

Tomologic has grown fast. It won the prestigious Venture Cup in 2010. The Swedish Energy Agency was involved in the jury work. After having received funding from the Swedish Energy Agency, the company now has sales in six countries. According to its calculations, it has the potential to make savings of approximately 4,875 TWh per annum. Plus approximately 10 percent material savings.

Economic effects since 2005

- Around 80 companies have been granted funding of approximately SEK 600 million, an average of SEK 7.4 million per company.

- The funding has entailed private co-financing of an additional approximately SEK 800 million, producing a co-financing rate of 58 percent. Many companies have also attracted other private capital to finance other parts of their operations in addition to the project for which the Swedish Energy Agency has granted funding.

- Four of the companies have been listed on the stock exchange with a total market value of approximately SEK 1 billion in October 2015.

- Three of the companies have been purchased by industrial actors.

- The six companies with the highest value in the portfolio have a total combined market value of over SEK 3 billion.

9 Dye-sensitised solar cells are solar cells in which light is absorbed by a dye, as opposed to a semiconductor in other solar cells.

FUNDING FOR BUSINESS DEVELOPMENT

As of 2015, the Swedish Energy Agency's funding for business development projects has been designed as a grant with limited royalties that are paid to the Swedish Energy Agency.

- The royalty commitment is linked to the funding recipient's income statement and amounts to three percent of net sales.
- After a royalty-free period of three years, the commitment applies for ten years or until 120 percent of the grant has been paid in royalties.
- The greater part of business development funding was previously paid out as loans with a repayment commitment based on revenue from the results of the project.

Role of the Swedish Energy Agency

The role of the Swedish Energy Agency is to supplement the market. This means that projects that are unable to gain full funding from private market actors on account of high risk and long lead times from research and development to commercialisation are granted funding.

The task of business development activities is to identify companies with the potential to implement their business plan, successfully commercialise their technology and thus contribute to the conversion of the energy system.

The Swedish Energy Agency's business development and commercialisation work is based on funding that is repaid in the event of commercial success and is offered to projects in which the utilisation of the project aims to produce financial business advantages that are largely linked to the applicant. As a condition of funding, the Swedish Energy Agency requires activities and measures to create companies that are attractive to private financiers and to facilitate commercialisation. The Swedish Energy Agency also actively offers support to companies after they have been granted funding in order that they can develop into successful growth companies.

The role of the Swedish Energy Agency as an expert agency means that it has a high level of expertise in most areas concerning energy issues in society. The holistic approach and contacts that the Swedish Energy Agency has in relation to the energy system and its actors is one of the reasons it is able to contribute well to companies' development and success.

Figure 7 Cumulative lending of business development funding, 2005–2014, SEK thousand

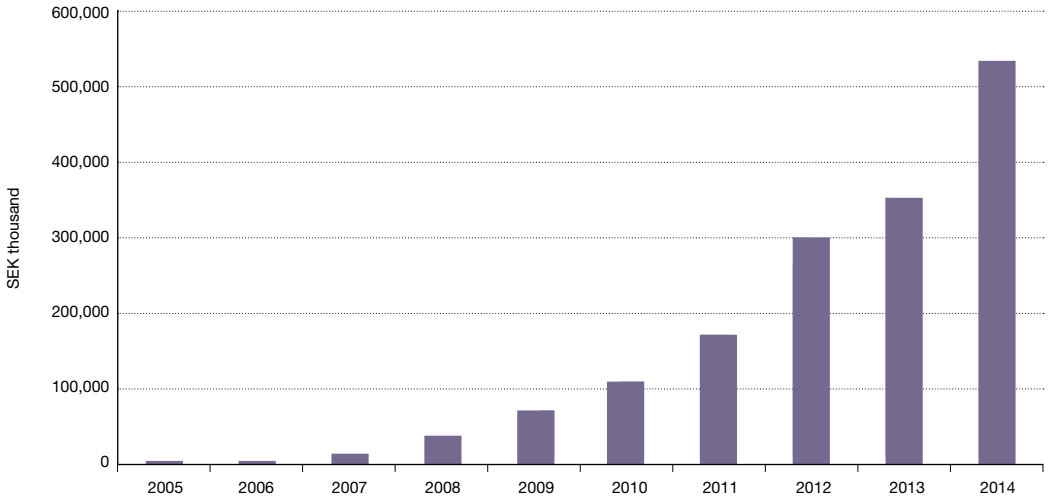
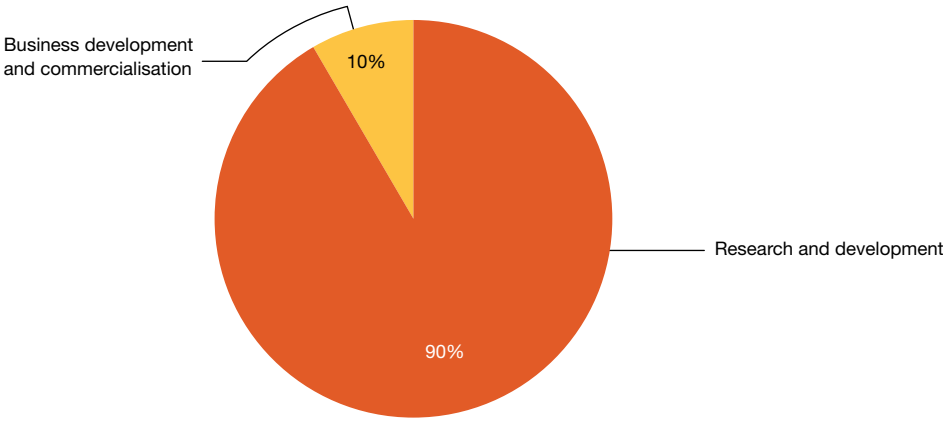


Figure 8 Proportion of business development funding in relation to total energy research funding paid out by the Swedish Energy Agency, 2010–2014, percent



On average, inquiries about business development support are received from around a hundred companies every year, one tenth of which receive support after a thorough evaluation process. The evaluation process is broad and comprises areas including technology, the company and its market, and finance and law. This is done to gain an overall picture of the potential for commercialisation.

The Swedish Energy Agency's work with portfolio companies

With a portfolio of 68 active companies, there are great opportunities to allow companies to generally benefit from each other's knowledge and networks. For this reason, the Swedish Energy Agency carries out portfolio development, which involves viewing the strengths and weaknesses of companies from a business development perspective, in order to then help them further.

Most of the companies have their main market outside Sweden, which means that the Swedish Energy Agency can use its global networks to reduce the risk for portfolio companies when they launch their products or services internationally. Consequently, the Swedish Energy Agency has performed an analysis of the companies in the portfolio and used this to create a number of different internationalisation programmes. The programmes are directed at Germany, the USA and the UK. All are based on the portfolio companies' structure and needs. The programmes are organised with a number of modules and the aim is to create contacts with potential investors, partners and customers in the companies' target markets. Approximately 20 companies from the portfolio are involved.

Challenges in the future

As long as there is a lack of venture capital[10] in the energy sector, the Swedish Energy Agency's business development funding will continue to be necessary to commercialise and spread innovations.

External equity capital for a company's early phases of development is a significant source of financing for the commercialisation of innovations. The situation has developed so that investments in growth companies, in the form of external equity capital, have been shifted to later phases. At the same time, investments in companies' early phases of development have become fewer and fewer. If this development continues, there is expected to be an increased shortage of venture capital for the development of companies that cannot be financed with Swedish Government funding on account of restrictive government funding rules but are still considered to be in a phase of development that is too early for private financiers.

The Swedish Government is planning specific venture capital initiatives, including for the energy sector. The initiatives are designed to correct the development whereby investments have been shifted to the expansion phase. The Swedish Energy Agency considers this to be an important supplement to the Government business development funding that the Government funding rules permit.

10 Venture capital is external equity capital or risk capital that is invested in companies' early phases of development.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International research partnerships

International research partnerships allow Swedish researchers and companies to obtain knowledge from other countries. At the same time, they gain new platforms for their own activities. In this way, international partnerships lead to an exchange of Swedish research funds. The Swedish Energy Agency invests in international partnerships in the energy sector at several levels in research, innovation and demonstration.

International research partnerships in the energy sector contribute to enhancing and developing Swedish energy and climate policy. It is important for Swedish universities and institutes of higher education, the business community and the public sector to make international contacts. This allows Swedish knowledge, expertise and experience in different areas to inspire more people and be disseminated further. At the same time, Swedish actors can be inspired and acquire experience, knowledge and expertise from others. Activities that are carried out in an international arena also contribute to faster development, dissemination of solutions and higher efficiency. For example, the activities may be shared points of view to contribute to the formulation of EU initiatives or the preparation of common guidelines that are used in several countries.

International partnerships are increasingly necessary

International partnerships are becoming increasingly necessary and important to meet the global challenges associated with the development of a sustainable energy system. The Swedish Energy Agency is involved in partnerships at several different levels and in different constellations, depending on the type of partnership. The Swedish Energy Agency's staff represent Sweden on international committees and participate in coordination and strategy work. The Swedish Energy Agency also disseminates knowledge about international projects and calls for proposals to Swedish stakeholders, for example via the National Contact Point for Horizon 2020, and supports Swedish actors' participation by means of planning grants and part-financing of partnership projects, for example via calls for proposals with Vinnova.

In bilateral contexts, it is important to have public agency representation and active commitment and exchange at the policy level among other things to create legitimacy and trust in the partnership. The Swedish Energy Agency's involvement in delegation trips usually involves the planning of seminars and its own lectures.

Nordic energy research collaboration

Nordic Energy Research (NER) is the financing institution for energy research within the framework of the Nordic Council of Ministers, an intergovernmental body involving Sweden, Denmark, Finland, Norway and Iceland. NER supports areas of energy research that are of common interest to the Nordic stakeholders. These are partly the countries that contribute funds and partly the researchers who apply for funds for collaboration projects. NER funds and coordinates research, and provides administrative expertise, networking and advice. To be granted funding, the proposed projects must comprise representatives of at least three Nordic countries.

Energy research partnerships within the EU

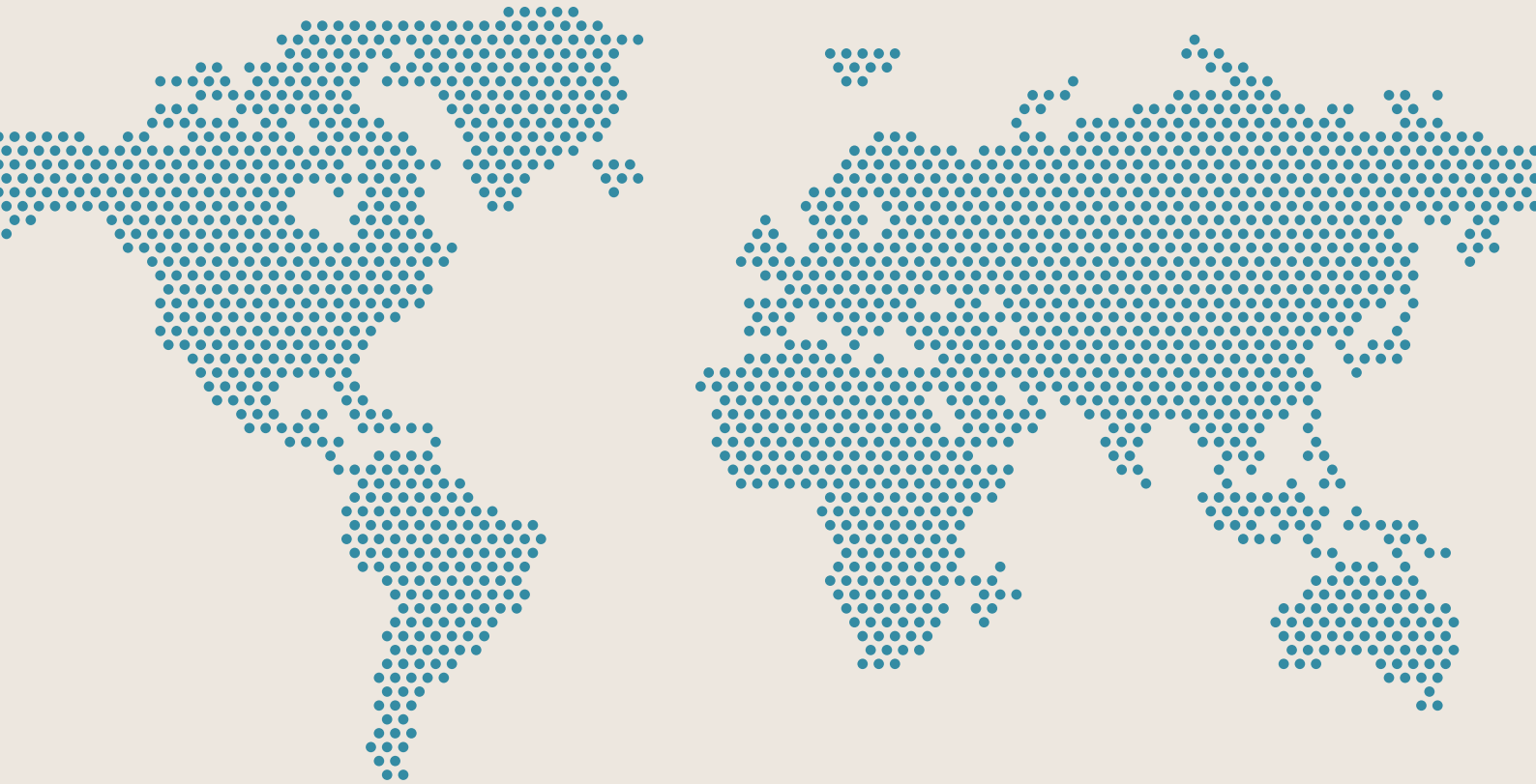
Strategic Energy Technology Plan (SET plan)

The European Strategic Energy Technology Plan (SET plan) aims to boost research and innovation in the energy sector to enhance the competitiveness of sustainable energy. The strategic plan applies primarily to renewable energy and technology with low carbon dioxide emissions and further development of technology for energy efficiency enhancement. A great deal of input from industry is required to realise the roadmap within the SET plan.

The work is to be based on the targets established for emissions of greenhouse gases, renewable energy and energy efficiency for 2020 and 2050. New technology is required to meet the targets. Therefore, the strategy for increased coordination between EU member states contains a new approach for research and development in the energy sector.

The EU Commission and industrial actors have launched seven industrial initiatives to bring together the research and innovation initiatives in wind power, bioenergy, smart grids, smart cities, solar energy, carbon capture and storage (CCS) and nuclear power. Sweden has decided to participate in the areas of wind power, bioenergy, smart grids and smart cities. The initiatives are financed via the Horizon 2020 framework programme and other common structures such as NER300[11], the European Investment Bank, EU member states and the business community.

11 NER300 is an EU programme for funding innovative low-carbon demonstration projects. The funds come from the sales of emission allowances.



Horizon 2020 – the EU framework programme for research and innovation

Horizon 2020 is the EU's new framework programme for research and innovation for 2014–2020. It is the world's biggest research and innovation programme with a budget of nearly EUR 80 billion. The programme is divided into three strategic objectives: Excellent Science, Industrial Leadership and Societal Challenges.

Societal Challenges contains the Secure, Clean and Efficient Energy programme, which aims to support the implementation and development of energy policy in the EU. The programme provides support for research, development, innovation and demonstration. It also provides support for more market-related measures such as policy development, capacity building and behavioural change. The programme also offers access to various types of support. In Horizon 2020, Swedish representatives are most active in research partnerships in combined heat and power, bioenergy, solar energy, marine energy, wind power, transport, smart grids and smart cities and communities.

The Swedish Energy Agency promotes increased international participation in various ways. One is by supporting applicants to prepare their applications for cooperation programmes in the EU such as Horizon 2020.

Partnership programmes concentrate resources

The European partnership programmes entail agreements between the EU Commission, EU member states and/or industry. The programmes aim to create public private partnerships and to concentrate resources for research and innovation in important industrial areas. The partnership programmes involve important financing opportunities. However, they also require the active participation of Swedish research funding bodies. The public partnership programmes are financed partly by the Horizon 2020 framework programme and partly by participating member states' national budgets for research and innovation.

In the industrial partnerships, companies have made financial commitments to participate. There are two partnership programmes in the energy sector and Sweden is involved in both: Biobased Industries and Fuel Cells and Hydrogen.

The Swedish Energy Agency participates in various research programmes that are supported by the EU Commission: ERA-net, ERA-net+ and ERA-net COFUND. The programmes aim to enhance collaboration between different research funding bodies and boost international collaboration. In these programmes, the participating countries are responsible for most of the funding. There is collaboration between research funding bodies in order to open up national programmes. ERA stands for European Research Area, and Net reflects the fact that different research funding bodies are collaborating. The aim is to enhance European cooperation on research and development to be able to open up national programmes for the participation of researchers from other countries in the long term. Consequently, cooperation may contribute to coordination gains from European research and development initiatives.

KIC InnoEnergy, an initiative for innovation and technology

KIC (Knowledge & Innovation Community) InnoEnergy is an initiative from the European Institute of Innovation and Technology. The aim of KIC InnoEnergy is to create new technology and applied innovation in sustainable energy. Another aim is to facilitate the transition from concept to product, from laboratory to market and from student to entrepreneur.

The objective of calls for proposals in KIC InnoEnergy is to support projects that supplement basic research such as the development of products, processes and services with commercial value. The projects must also have a positive impact on society such as reduced energy costs, more secure supply to energy and reduced emissions of greenhouse gases. KIC InnoEnergy Sverige AB is responsible for the thematic area of smart grids and electrical energy storage.

Funds for KIC InnoEnergy come from 27 co-owners and around 100 partners. The Swedish co-owners include the Royal Institute of Technology, Uppsala University, ABB and Vattenfall with a number of partners. The Swedish Energy Agency contributed funds upon formation of the Swedish part of the partnership.

Global multilateral partnerships

International Energy Agency (IEA)

The IEA, which is an independent body within the Organisation for Economic Co-operation and Development (OECD), has four focus areas: security of supply, economic development, environmental awareness and enhanced cooperation with non-member countries. The IEA's research partnerships, so-called implementing agreements, include both the IEA's member countries and partner countries such as China, India and Russia. Participation is voluntary. Sweden is an IEA member and is very active in IEA cooperation. Sweden is involved in 23 of a total of 39 research partnerships.

A research project on solar energy in urban planning is being carried out in the IEA's research programme on solar heating and solar cooling. The project has led to recommended guidelines for architects on integrating installations for solar heating and power in buildings. The guidelines are intended for use in communication with clients, public agencies, construction companies and urban planners. Recommended guidelines have also been drawn up for producers and developers of solar power and heating products. In addition, there is a website on innovative solar energy products for integration in buildings and another website that shows inspiring examples of buildings with integrated solar energy systems from various countries.

Clean Energy Ministerial (CEM)

The CEM partnership started in connection with the Copenhagen climate conference in 2009. The aim of CEM is to strengthen policy dialogue and exchange of experience between the countries involved in the partnership, partly to accelerate the development and spread of sustainable energy solutions. The CEM work entails concrete initiatives in different technology areas or other important areas of initiative. The Swedish Energy Agency participates, among other things, in a network for smart grids, the International Smart Grid Action Network (ISGAN).

ISGAN contributes to the more rapid development and spread of smart grid solutions. The international exchange of experience in the network is motivated in particular by the fact that several countries are developing national plans for expansion of robust, flexible grids.

The Swedish actors have a prominent position in ISGAN. Among other things, this has led to the bilateral partnership with India on microgrids.

Bilateral research and innovation partnerships

Sweden has several agreements with other countries on bilateral research and innovation cooperation in energy-related projects. A central precondition is that they must come under the framework of the Swedish Energy Agency's priority areas. Cooperation enhances ongoing or planned national initiatives, for example partnerships that increase Swedish actors' access to research and innovation-related infrastructure in other countries.

What distinguishes bilateral partnerships is that government actors need to be involved in the projects to launch the partnerships. A particular challenge of these partnerships is presented by the differences in terms of structures, planning and decisions between Sweden and the partner country. This becomes particularly noticeable in large projects with several participants.

The following are examples of bilateral partnerships:

- International collaboration for environmental innovations – energy in China (ISMEK) is a call for proposals that was implemented jointly with Vinnova to promote innovations in the area of environmental technology.

- Indian-Swedish Innovations' Accelerator works to develop innovative new energy technology in India and Sweden. The programme promotes technology transfer and facilitates contact between Indian stakeholders and innovative Swedish companies. The Swedish Energy Agency works in the programme with Business Sweden and the Confederation of Indian Industry. The results of Swedish research and innovation initiatives in the form of energy technology and energy systems are disseminated via the programme. The results are further developed to suit Indian conditions.

- Indonesian-Swedish Initiative for Smart Energy Solutions (INSISTs) is a partnership with the Indonesian National Energy Council which also involves Gadjah Mada University and SP, the Technical Research Institute of Sweden. INSISTs acts as the basis for knowledge and network exchange, while Swedish environmental technology solutions are tested and developed to suit the Indonesian market.

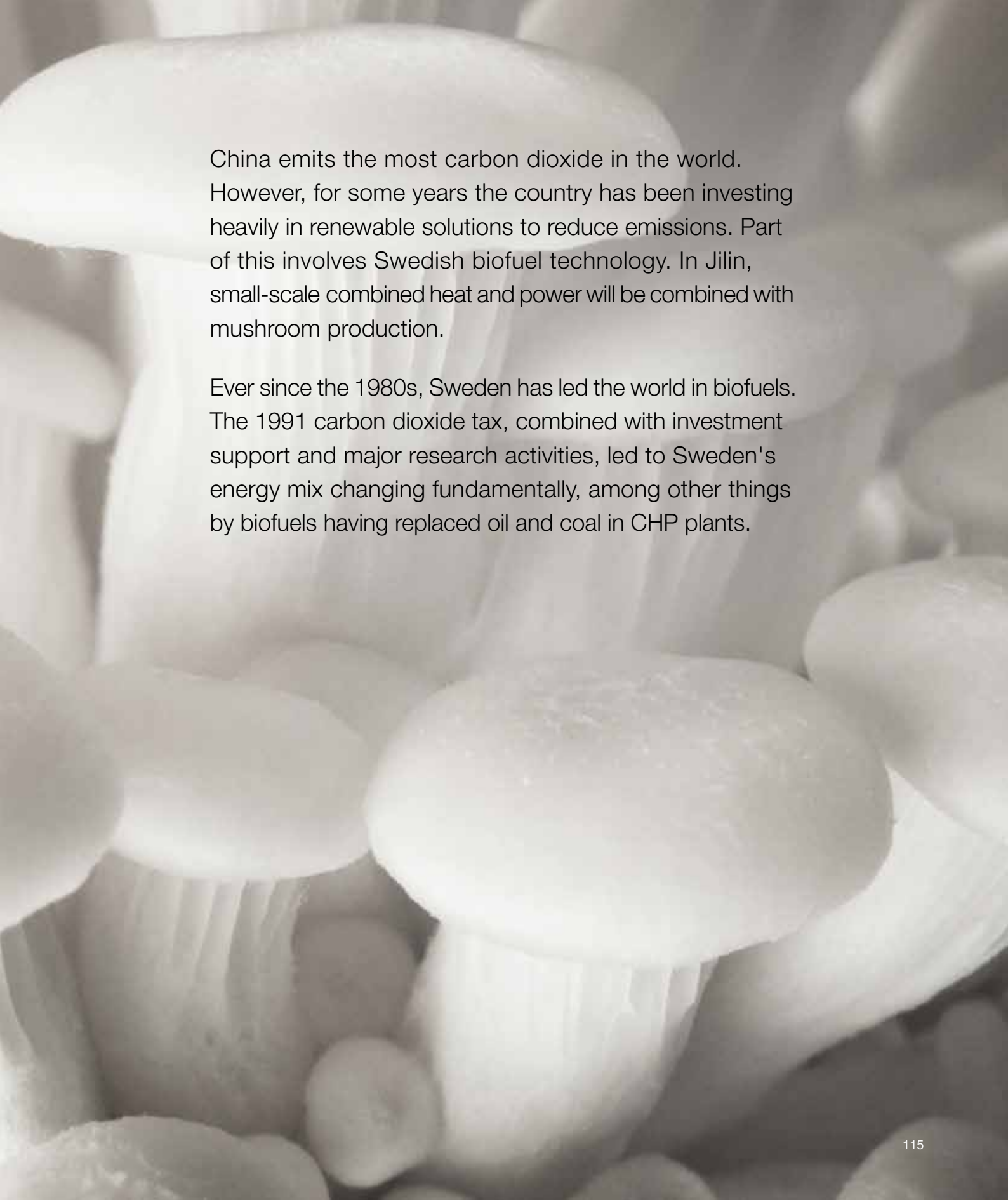
In the future, the world's emerging economies such as India, Indonesia and China, will play an increasingly important role in the global economy. They therefore also have growing importance for the competitiveness of Swedish companies. Bilateral partnerships give Swedish companies opportunities to better understand and develop their offerings to meet the needs of emerging markets. Bilateral partnerships are therefore a means of channelling results from Swedish energy research and innovation out to a wider market. At the same time, the partnerships make it possible to acquire knowledge and experience from other countries.

Standardisation at the international level

Standardisation work is important for the spread of new technologies and methods on international markets. Thanks to the efforts of Swedish experts, a new international ISO standard on the sustainability of bioenergy (ISO 13065) has been adopted. The Swedish Energy Agency's long-term research funding contributed to the solid documentation that was needed to complete the standardisation process.

The work on sustainable bio-based products in the European standardisation body (CEN) was based on the ISO process. This is a positive signal for any continued work on sustainability criteria for solid biofuels under CEN.

Swedish biofuel technology in China reduces emissions and enhances knowledge



China emits the most carbon dioxide in the world. However, for some years the country has been investing heavily in renewable solutions to reduce emissions. Part of this involves Swedish biofuel technology. In Jilin, small-scale combined heat and power will be combined with mushroom production.

Ever since the 1980s, Sweden has led the world in biofuels. The 1991 carbon dioxide tax, combined with investment support and major research activities, led to Sweden's energy mix changing fundamentally, among other things by biofuels having replaced oil and coal in CHP plants.

CHP plants have great potential – also in China

In 1996, Skellefteå Kraft opened the world's first bioenergy combine in Hedenbyn. The plant produces district heating and power, but the steam in the process is sent on to an adjacent pellet factory. It is used to dry the pellets and then enters a low-pressure turbine to generate more power.

Biofuels can be used in many ways. When the researcher Shaojun Xiong, of the Swedish University of Agricultural Sciences (SLU) in Umeå, was at a seminar in China in 2004, he met senior representatives of the Chinese Energy Ministry and told them about Sweden's investments in solid biofuels.

"I explained that Sweden received 16 percent of its energy supplies from biofuels (ed.: 34 percent in 2015) and they thought I was lying. But they were very interested in knowing more."

During that time, a process began that, in a few years, will result in a demonstration plant for a solid biofuel combine in the province of Jilin in north-eastern China. There have been many long processes along the way: industrial, political, economic and research-related. A formal cooperation agreement between Sweden and China was signed in 2011. For Sweden and the Swedish Energy Agency, it has been important to support collaboration between universities and the business community on this type of international research project in order to build local platforms in other markets.

Mushroom factory produces fuel for the plant

In the demonstration plant, combined heat and power production will be combined with a mushroom factory, part of a major industry in China.

"The mushrooms are cultivated in a cellulose substrate consisting of sawdust, bark and chips. When the mushrooms have been harvested, this waste is dumped in the natural environment. We saw the opportunity to use it as fuel instead and reuse some of the residual heat in mushroom production," says Lars Atterhem, CEO of Biosteam.

Lars is one of the enthusiasts behind Skellefteå Kraft's investments in bioenergy combines. However, since 2011, he has had his own company and has been one of the driving forces in the Swedish-Chinese partnership.

"The demo plant increases energy efficiency, reduces emissions and solves a waste problem. District heating plants are only used in the winter in China, so this allows the plant to be used all year round, thus making it more economical," he says, continuing:

"But it's not enough simply to take Swedish technology and go to China. The solutions have to be adapted and developed to suit local conditions."

The raw material used in bioenergy combines in Sweden is mainly pure wood products. The mushroom waste in the demonstration plant, on the other hand, is damp and contaminated and must be treated correctly so that it can be used optimally.

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This is one of the challenges in the research project 'To develop high energy efficiency and small-scale bio-energy combine', which SLU is managing with funding from bodies such as the Swedish Energy Agency and Vinnova.

"There are many challenges with so-called ash-rich fuels. The main problems that have to be solved concern emissions, corrosion, sintering and the high concentrations of ash formed during combustion. However, we have tried to find a number of technical solutions in partnership with Umeå University and Luleå University of Technology. It is necessary to dry and refine the raw material and to optimise the temperature in the boiler," says Shaojun Xiong, who is managing the project at SLU.

Collaboration that leads to innovation

The research project is designed to produce knowledge that will support the demonstration plant and benefit Swedish plants. This is an example of how collaboration between academia and industry leads to innovations and contributes to Swedish competitiveness.

Another important element of the project is the collaboration processes built up between public agencies, researchers and companies, including ABB.

According to Lars Atterhem, three components are required for this type of complex international project: research, the industrial and business part and political support.

"Of course, the Swedish Energy Agency is important as it funds a great deal of research. They also represent Sweden internationally in various contexts to commercialise Swedish bioenergy technology, which is also important," says Lars Atterhem.

Sweden can learn much from the project

The project is about more than just exporting existing technology to China. Sweden is also learning a great deal in the form of knowledge and applications. For example, how we should use complicated raw materials such as biomass from short rotation coppice and agriculture by-products in our domestic CHP generation.

The project may also be beneficial in many other parts of the world. A significant part of the research involves generating knowledge that paves the way for export opportunities for Swedish environmental technology.

"This type of industrial research package is fully applicable in other parts of the world as well, for example India, Africa and south-east Asia. It opens up new business opportunities for Swedish companies," states Lars Atterhem.

The planned start of construction of the demonstration plant in Jilin is autumn 2016. It will then take just under two years until the bio-combinate can be commissioned with the new technical solutions developed in the research project. During this period, the Chinese staff will also be trained in the new technology. The training will be planned and implemented under Swedish management.

Facts in brief:

Partners: Biosteam AB, Valutec AB, Greensteam AB, ABB, Fundaco, SCA, Swedish University of Agricultural Sciences, Umeå University and Luleå University of Technology.

Planned start of construction of the project: Autumn 2016.

Expected volume generated per annum: 38 GWh power and 118 GWh heat.

A sustainable energy system benefits society

The Swedish Energy Agency works for a sustainable energy system combining ecological sustainability, competitiveness and security of supply. We develop and communicate knowledge about more efficient energy use and other energy issues to households, businesses and public agencies. We support research, innovation and demonstration activities in the energy sector. We participate in international partnerships to meet climate targets and manage various policy instruments such as the electricity certificate system and the trade in emission allowances. We also prepare national analyses and forecasts, plus Sweden's official statistics in the area of energy.

'Swedish Energy Research' is a publication that describes the situation for research, development and demonstration activities for the period 2010–2015. It reports on a selection of initiatives, results and effects to which research, development and demonstration activities, business development and commercialisation in the energy sector have contributed. The publication also describes future needs for research to achieve a sustainable energy system.

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