# INVESTING IN RESEARCH FOR A SUSTAINABLE ENERGY FUTURE

## – A SWEDISH MODEL

# SWEDISH MODEL MAKES STRONG ENERGY RESEARCH STRONGER

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**EU leaders, and increasingly their counterparts around the globe, are calling for a transformation of the global economy, starting with the energy system, as part of efforts to counter climate change and to put the world on a sustainable path.**

In Sweden, energy research of strategic importance for the future has been organised into three research environments that receive government funding. **Bio4Energy, Chalmers Energy Initiative** and **STandUP for Energy** are initiatives that bring together leading research groups from six Swedish universities. The researchers, in turn, are collaborating with industrial stakeholders, research institutes and peers at other universities in Sweden and abroad. Together they develop efficient and sustainable energy systems.

To be sustainable, the societies of the future will require large amounts of renewable energy and smart electricity grids, as well as new vehicle technology. All of these developments constitute significant global challenges. Sweden has taken a comprehensive approach to these matters. Collaboration and long-term funding have enabled the search for technological solutions that will also be viable from a socio-economic and an environmental perspective.

The government's funding of Bio4Energy, Chalmers Energy Initiative and STandUP for Energy amounts to 24 million USD (€18.7 million) per year. A new working model and long-term funding allow the research environments to take a systemic approach and to raise strategic questions. They also pave the way for projects in which new technologies, products and services may be tested on a large scale.

## 3 ENERGY CHALLENGES

The Swedish government has identified three energy research areas of strategic importance:

1. Large-scale renewable electricity production and its integration into the electricity grid.
2. Electrical propulsion systems and hybrid vehicles.
3. Biorefinery: Sustainable and efficient biomass conversion for the purpose of making heat, power, biofuels and bio-based products.

## 3 CRITERIA

Government funded strategic research must:

1. Be of the highest international quality;
2. Contribute to meet major societal needs and solve important problems in society;
3. Be conducted in areas related to Swedish trade and industry.

## 3 RESEARCH INITIATIVES

Three research environments have been awarded government funding to conduct strategic energy research:

**Bio4Energy**
Umeå University, Luleå University of Technology and the Swedish University of Agricultural Sciences.

**Chalmers Energy Initiative**
Chalmers University of Technology.

**STandUP for Energy**
Uppsala University, the Royal Institute of Technology, the Swedish University of Agricultural Sciences in Uppsala and Luleå University of Technology.

Many industrial partners are also participating in various projects.
The Swedish Energy Agency is the government agency responsible.

# BIO4ENERGY – FROM SEED TO ADVANCED FUELS AND CHEMICALS

**“The pulp and paper industry has a clear interest in improving its processes. Its profits may be increased by including high-value by-products in their product range”.**

**In its niche of bioenergy and biorefinery, the research environment Bio4Energy in northern Sweden has taken a systems approach to tackling the energy challenge. Its 150 researchers design methods and tools for producing energy and bio-based products from forest-sourced raw materials or organic waste.**

"We develop methods for using the whole tree and apply system analysis to check that our methods are sustainable", says Stellan Marklund, Bio4Energy programme manager.

Bio4Energy strives to invent processes that are efficient in an economical, environmental and social sense, and are based on renewable raw materials. Wood or woody residues, as well as by-products from the pulp and paper industry, are turned into biofuels, bioenergy or value-added "green" chemicals.

What makes Bio4Energy's strength is the fact that its competence spans the entire biorefinery value chain, from designing the first tree seed, to end products such as advanced fuels and chemicals.

"We are working on many different levels and bring them together in different ways. Our competence spans everything from genetic engineering to the improvement of the wood quality, to the optimisation and transformation of the biomass into other products", according to the Umeå University professor Marklund.

Torrefaction, or roasting, is one technologically-advanced method for the pre-treatment of the raw material that makes it easier to store, transport and handle. The biomass is heated to 300 degrees Celsius in a reactor chamber void of oxygen. The product is a dense, brittle and hydrophobic pellet or briquette with excellent properties for bioenergy production.

"The volume is drastically reduced, and the material is easy to transport and store. I think this can be a useful technology in the third world as well. The material is water resistant and can be stored in moist conditions", said Marklund. He went onto applaud the long-term approach of the government-funded strategic initiatives.

BIO4ENERGY

"We have an eye to the future. Many of the processes that we are developing will become even more attractive with the rise of the oil price", he said with reference to the Earth's finite resources of fossil oil.

"The pulp and paper industry has a clear interest in improving its processes. Its profits may be increased by including high-value by-products in their product range".

**Researchers in industrial and plant biotechnology are collaborating in the research environment Bio4Energy with the aim of making biofuels and value-added "green" chemicals in an efficient and a sustainable way.**

The raw materials they use are sourced from the forest. Sugar molecules are extracted from woody cellulose to become building blocks in end products such as ethanol, butanol or succinic acid. The aim is to produce viable alternatives to fossil fuels, using renewable raw materials.

"Enzymes and micro-organisms facilitate this transformation", says Leif Jönsson, head of the Bio4Energy Biochemical Platform.

"We have seen that even very small changes to the wood's chemical composition make it easier for enzymes to reach the cellulose. Subsequently, more sugar can be extracted from the same amount of wood, which increases profitability", according to the Umeå University professor.

A high sugar yield is a prerequisite for this type of production process to be efficient. Efficiency, in turn, is needed for the bio-based products to become a competitive alternative to their petrochemical counterparts.

**In northern Sweden, researchers and engineers are developing bioenergy solutions for the future.**

Woody residues from logging operations, such as stumps and bark, are turned into fuels and bioenergy in a single step, using gasification technology.

The product is a high-quality synthesis gas which, according to the Bio4Energy researcher Magnus Marklund, carries great promise.

"At this stage we are about to embark on a mapping exercise to define the different parts of the process", says Marklund who is the chief executive officer of the Sweden-based Energy Technology Centre at Piteå, a research foundation geared at bioenergy research and development, adding; "This will be followed by an industrialisation phase".

The technology could find several applications. The researchers are focusing on making biofuels, electricity and "green" specialty chemicals.

"One has to look at this from a systems perspective to be able to make optimal choices for the implementation and application of the process", Marklund said.

"To find the optimal solutions on a systems' level, process integration tools will play a central role. In this sense Bio4Energy is making a major contribution to our research" at the ETC, which has more of a technology focus.

***www.bio4energy.se***

# COMBINING RESEARCH OF KEY TECHNOLOGIES WITH THEIR SYSTEM IMPACT

**"We are trying to provide a mosaic of analyses and results, and when different perspectives are compared, we learn plenty".**

**Chalmers Energy Initiative encompasses all three areas identified by the Swedish government. Moreover, there is an expressed objective of understanding the societal consequences of technological advances, which has resulted in establishment of a fourth sub-area – Technology Impact Assessment.**

"It's advantageous to take the overall perspective; the challenges demand it," says ***Anders Ådahl, Director for the Energy Area of Advance at Chalmers, and the coordinator of the Chalmers Energy Initiative.*** "We combine in-depth research of key technologies with studies of their system impact."

**Upgrading biomass is one of the major focus areas of Chalmers Energy Initiative**. As an example, Chalmers has one of the world's largest research facilities for gasification, which produces nitrogen-free gas from biomass. The conversion of biomass to alternative fuels, green electricity or materials/chemicals entails considerable challenges for technological development throughout the production chain – from raw materials to end products – and for proper integration of the facilities into the energy system.

**Green electricity from wind power is another major focus area.** Large-scale integration of renewable electricity, with increasing portions of varied production, brings new challenges for the transmission grid in guaranteeing reliability and power quality.

Electrification of motor vehicles is increasing globally and leading automakers are putting substantial resources into meeting the market's expectations for safe, energy-efficient and economical automotive concepts. Chalmers Energy Initiative is taking on the challenge by conducting a broad range of projects in **electrical propulsion systems and hybrid vehicles.** The projects often have their base in established collaboration with the Swedish automotive industry.

"Present development is bringing together different research disciplines, various industrial sectors and industry and academia," says Anders Ådahl. "The need for interaction is increasing and collaborative programmes within Chalmers Energy Initiative are capturing the opportunities."

**"How can technological development, economics and politics interact so that new energy technology can be implemented in society? And at the same time, how can implementation of disadvantageous technologies be avoided?"**

"Understanding and seeing the big picture regarding the system effects of new technology is exceedingly complex, but nonetheless, is something we have to do," says ***Associate Professor Björn Sandén, at the Division of Environmental Systems Analysis at the Chalmers University of Technology.***

"Because many stakeholders need to participate in discussions on society's technology choices, we've decided to gather different types of analyses at a single location, and summarise the research briefly and clearly. This has resulted in a series of e-books that is constantly growing and evolving. The first book, Systems Perspectives on Biorefineries 2012, is available on the Web, and more than twenty researchers are currently working on the next book about opportunities and problems with electrically powered transports."

"What we're trying to do is provide a mosaic of analyses and results, and when different perspectives are compared, we learn plenty. We hope that this learning will eventually contribute to wiser decisions in trade and industry, and in politics."

**The details of the future designs of our motor vehicles are difficult to predict. But that there will be increased electrification is certain.** Broad research is being conducted at Chalmers in this area, both regarding storage methods and charging technology. And in the intelligent systems that tie together the whole.

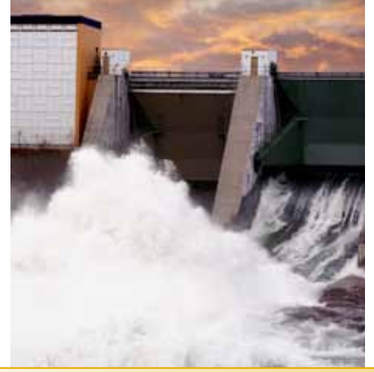
"We're looking both at the intelligence needed in the vehicles, and the intelligence necessary for connection to the surrounding infrastructure," says ***Bo Egardt, professor of control engineering at the Chalmers University of Technology.***

**There are many exciting examples here. What about a "thinking" electric hybrid car, for example?**
A car that detects when you are on your way to work, that knows you can charge the batteries once you arrive and that regulates consumption of electrical energy thereafter.

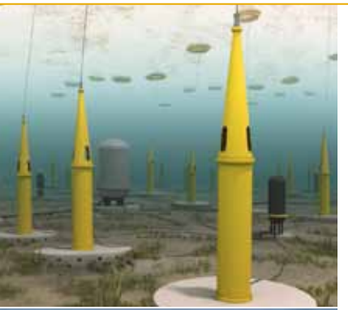
"We already know that many drivers often travel the same routes. Our idea is to equip the cars with intelligent computer systems, connected to mobile networks, navigation systems and the like, so that the energy reserve is utilised in the best possible manner. The result is higher energy efficiency and lower losses."

# NEW FORMS OF INTERACTION, ALL ORIENTED TO ELECTRICITY

**"We've gathered many of the most skilled researchers in Sweden and collaborate with the country's largest companies in the energy sector".**



STandUP for ENERGY



**STandUP for Energy is a collaborative programme between Uppsala University, which is the coordinator, the Royal Institute of Technology in Stockholm, the Swedish University of Agricultural Sciences and the Luleå University of Technology.**
"We've gathered many of the most skilled researchers in Sweden and collaborate with the country's largest companies in the energy sector," says ***Professor Kristina Edström, who is the coordinator for the entire programme.***

**STandUP for Energy covers many areas, all oriented to electricity.**
Within renewable electricity production for example, there are initiatives in biomass and flowing water, as well as solar, wind and wave power.

Professor Edström's special interest is in battery research, which is essential for the further development of electric cars and hybrid technology for larger vehicles such as buses. Batteries can also be used as backup power for electricity grids and to regulate renewable electricity production. Much in the field of sustainable energy supply is interrelated in one way or the other. Bringing together knowledge from various disciplines is something that Professor Edström sees as one of the most important effects of the strategic collaboration.

"It promotes research that hasn't been possible before. We have innovation researchers looking at how people regulate their energy consumption with smart electricity grids. We have psychologists analysing how people make rational decisions regarding the electricity market, for example. And we have technically oriented researchers who know everything there is to know about how smart electricity grids are built up. Exciting new knowledge is being generated in the interaction between disciplines."

Other examples are projects in both large-scale and small-scale hydroelectric power, always related to a wider energy-systems perspective.

"All new forms of interaction produce exciting synergic effects," says Professor Edström. "These in turn create stronger research environments, which can really make a difference."

**For Europe to achieve its climate goals, intermittent production of electricity from wind power, solar power and hydropower must be addressed.** This has made smart electricity grids a truly hot area of research.

***Professor Lars Nordström at the Royal Institute of Technology*** is doing research in self-healing electricity grids, one of the first clear indications that smart electricity grids are now a reality.

"Fewer and shorter power outages may not seem like the world's coolest vision for the future," says Professor Nordström. "But it's exceedingly important in our everyday lives. And the concrete technical benefits for operations are such that power companies want to move forward with this right away."

Self-healing electricity grids are based on intelligent automation systems that measure and remedy power outages. The systems automatically reconnect the power via operable parts of the electricity grid when there are disturbances. This is a broad field of research that is gathering many different disciplines. Professor Nordström's department works with IT systems and the actual control regulation.

"But here we have to mention an important reservation. However intelligent and automated we can make the systems, there must always be power lines in place for making the reconnections."

**Biomasses are also expected to gain increased significance for the production of electricity.**
***At the Swedish University of Agricultural Sciences, Professor Per-Anders Hansson's*** research group is working with system studies of how and when different types of bioenergy are best used for renewable electricity production.

**Hydroelectric power is a renewable energy source with global capabilities to reduce poverty and increase growth.**
In this area, even small-scale hydroelectric power has major potential. But to make it work, three requirements must be fulfilled.

**"Small-scale hydroelectric power must be environmentally accepted, efficient and inexpensive," says *Professor Staffan Lundström, from the Luleå University of Technology*.**
"If it isn't, it's better to invest in another alternative."

This is why his research in environmentally friendly, small-scale hydroelectric power is so important. A unique all-encompassing perspective has been taken here. Not the least, it is important to take consideration to fauna passage, with fish migration being the most important aspect. Professor Lundström and his research group, along with a group in Uppsala, are analysing two different concepts for optimising.

"We're looking both at a system with ponds and one without. As far as I know, no one else in the world is comparing all three aspects – cost, efficiency and the environment."

BIO4ENERGY

CHALMERS ENERGY INITIATIVE
LARGE STRATEGIC RESEARCH PROGRAMME

STandUP for ENERGY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