

R&D Magazine

Vattenfall Research and Development Magazine • No 3, October 2010

THEME:
Sustainable
cities

Welcome to the

R&D Magazine

The Vattenfall R&D Magazine is a magazine about research and development within the Vattenfall Group. In each edition, we want to provide an overview of current R&D activities, and a deeper view of one specific theme. The purpose is to keep readers up to date on advances in this particular area.

The theme in this issue is Sustainable Cities. Vattenfall's concept Sustainable Cities was launched to help cities in their transition to a sustainable use of energy. We aim for long-term partnerships with cities and to help them make tailor-made plans for sustainability. This is achieved by improving energy efficiency on all levels, as well as by deploying sustainable energy sources. In this issue, you can read more about Vattenfall's work in the Sustainable Cities programme.

Lars Strömberg, Vice President of Group Research and Development and Agneta Rising, Vice President Environment, also provide an insight into the environmental aspects of the R&D processes. You can also read about the struggle to preserve the European eel.

As in previous issues, we also have the latest news briefing from several of the research programmes within Vattenfall R&D.

We hope you will enjoy reading the magazine!

Petra Sarközi is legally responsible for the R&D Magazine.

If you have any comments or questions about the R&D magazine, please contact rdmagazine@vattenfall.com

If you have any questions about the Sustainable Cities Programme, please contact Programme Manager Thomas Munch-Laursen: thomas.munch-laursen@vattenfall.com

Lars Strömberg, Vice President for Vattenfall Group R&D.
Petra Sarközi, responsible for communication of Vattenfall Group R&D.

Produced by Blomquist & Co. Cover picture Getty Images.
Photos by Colourbox, Getty Images and Vattenfalls photo archive.

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WHAT DOES VATTENFALL MEAN BY RESEARCH AND DEVELOPMENT AND WHY DO WE DO IT?

Vattenfall pursues research and development (R&D) as part of the business development of the Group. The aim is to meet the demands of customers, to reduce the environmental impact of our operations, to improve their efficiency and to contribute to our climate vision.

Vattenfall as an energy company and a system builder and operator has little or no competence in the manufacturing or production of technical equipment; instead we define our needs to the manufacturing market. Consequently, we do not develop new hardware or software products. Our ambition is to be an excellent user of technology that is mainly developed by others, notably equipment manufacturers, to provide our customers with clean electricity. To achieve this, we often work together with different suppliers, large and small, from the laboratory stage or in demonstration or pilot projects. In these projects, we develop know-how and provide the operator's perspective on, for example, the usability and maintainability of new systems.

Vattenfall's Group R&D programmes are organized in different areas:

- Renewables
- Operational efficiency
- Nuclear energy
- Energy efficiency
- Carbon capture and storage
- New technologies

Read more about Vattenfall R&D at www.vattenfall.com

Environmental concern - a motive force for development

Environmental aspects are an essential part of almost all R&D processes. History shows not only that environmental restrictions are fundamental for our business operations, but also that they constitute a strong motive force for development.



Lars Strömberg, Vice President of Group Research and Development

Environmental issues have partly to do with “hard requirements” which provide the basis for permits for our operations; these are relatively easy to measure and to clearly define. But our licence to operate also includes “softer” aspects like ideas and philosophies. Many groups in society have a say in the public discussion, and subjective opinions are not always in accordance with facts and scientific reports. Such aspects are usually more difficult for us to grasp and tackle successfully. It is, however, absolutely necessary for us to investigate and compile facts so that we stand on solid ground when running our business.



Agneta Rising, Vice President Environment

In our organisation, we have formed structures to ensure that qualified environmental expertise is involved from the very start in all R&D processes.

Six “Centres of Excellence” have been formed - on Air quality, Water protection, Soil protection, Chemical management, Sustainability and biomass, and Waste and by-products - as networks of experts from different countries and lines of business throughout the Vattenfall Group, including R&D. Their task is to ensure that Vattenfall stands at the forefront in knowledge, keeps ahead of legislation (particularly in the European

“Six “Centres of Excellence” have been formed - on Air quality, Water protection, Soil protection, Chemical management, Sustainability and biomass, and Waste and by-products”

Union) and is knowledgeable regarding current scientific research.

Another structure is our “Environmental R&D Centre”, which looks into new issues to determine how Vattenfall should work strategically with them and ensure that we have the necessary competence and tools to do so. This centre ensures that we have channels to experts, universities and other external parties in different countries for the benefit of the whole Group. ■

A struggle to preserve the European eel

Vattenfall has started to transport eels migrating down streams with the purpose to preserve the eels. In the last 25 years, the European eel population has decreased to only 1-5 per cent of its natural number and the eel is now on the EU red list for threatened fish species. Mostly this derives from changed weather conditions and unsustainable fishing - but in addition hydro power plants constitute a menace for the eels. At Vattenfall, it is therefore a high priority to save the eels.

The European eels are born to travel: after they are born in the Sargasso Sea off the North American coast, they follow the Gulf Stream all the way up to Europe and struggle upstream along rivers to find fresh water where they can grow up. After 5-20 years they perform this trip once more, but in the other direction: they follow the rivers down to the sea and then swim back to the Sargasso Sea to spawn. But the price of finding the right growing conditions is high; many eels are trapped on the way. To some extent this is due to hydro power stations in the Swedish rivers. The obstacle is the turbines. Smaller eels can get past alive but not the larger eels.

"The eels that reach the Swedish coast are only a small part of the total," says Peter Stedt, communications officer at Vattenfall Hydropower. "Many eels stay in the Mediterranean, and some in the area around Britain, and since they are considered a delicacy many are caught due to fishing. But since the number of eels has decreased considerably, we decided to take actions".

This summer, Vattenfall therefore implemented the new method of collecting full-grown eels in Lake Vänern and simply transporting them downstream in a tank, past the power stations Olidan and Lilla Edet. After that the eels are



released back into Göta River and continue to the sea. Other methods to increase the migration of eels are also under development. At several power plants, activities to restore the natural migration routes for the eels have been carried out in consultation with the Swedish Board of Fisheries and the County Administrative Boards. For example, Vattenfall inaugurated two new migration routes for eels in the River Rolfså in spring 2010.

"The new detour at Bosgården power plant in the Rolfså leads the eels away from the dam and offers a safe way to pass the power station," Peter Stedt explains. "Other fish species, for example trout, also use this route."

A couple of studies conducted by the Board of Fisheries on when during the year the eels migrate and what routes they choose, research that Vattenfall has sponsored, have been helpful in planning these activities.

"There is also ongoing research on different ways to lead the eels away from

the turbines, working with for example light, sound and vibrations," says Anna Östlund, who is responsible for the environment and water rights at Vattenfall Hydropower South, "and at the University of Karlstad studies are underway on how to design the power plants to prevent eels from getting stuck in the intake grilles."

In 2009, the Swedish water authorities announced their decisions on the EU Water Framework Directive. For Vattenfall this entails major challenges in the coming decade to promote biodiversity in the rivers where power is produced.

"At Vattenfall we take environmental issues very seriously, and this is how our hydro power operations affect the environment," says Peter Stedt. "By constructing our power stations we destroyed the natural routes for the fish - so it's our responsibility to compensate for this.

Together with the Swedish Board of Fisheries and a couple of other Swedish power producers, Vattenfall has prepared a common action plan for the eels, including the target that, within five years 40 per cent of the potential eel production upstream the power stations shall survive the turbines. In the future this cooperation will continue the task of protecting the eels. ■

R&D, News in Brief



THERMAL TECHNOLOGY PROGRAMME

Storage of biomass

The storage of biomass can be associated with problems such as heat development with a risk of self-ignition, dry matter loss and the reduction of fuel quality. Such problems often lead to a loss of energy compared to the energy content at time of purchase. Microbial activity in the material stored may also have health and safety consequences.

Vattenfall has just started diploma work at The Swedish University of Agricultural Sciences (SLU). This work will result in guidelines for our heat and power plants on how to store large amounts of biomass in an optimal way.

There are also plans to perform full-scale storage trials of biomass at Idbäcken, Vattenfall's plant in Nyköping, Sweden. We are going to use fuels like wood chips and recycled wood chips in the storage trials.

Agricultural fuels

Vattenfall has recently finished a study of the R&D activities concerning agricultural fuels. The study also included the main important findings from the research programme on agricultural fuels run by Värmeforsk between 2006 and 2010.

Agricultural fuels such as willow or straw are becoming increasingly important in Vattenfall. In Denmark, straw has been used for many years and is now fired in the new Fynsværket unit 8 and at Amagerværket unit 1. In Poland, there is a requirement to use agricultural fuels in order to gain green certificates. Vattenfall is running a programme on willow plantations measuring up to 200 ha in the proximity of Warsaw. The co-combustion of different agricultural fuels is also taking place at both the Żerań and Siekierki plants. In Germany, Vattenfall is now setting up plantations of up to 150 ha of poplar for later use in the Berlin plants.



SUSTAINABLE CITIES PROGRAMME

Family shall test a climate-smart home

Vattenfall, Volvo Car Corporation and A-hus are cooperating to test climate-smart living in Sweden. A family with children is going to live in an energy-efficient house for six months. The unique project is called One Tonne Life because the purpose is to see if it is possible to live so that the carbon dioxide emissions for one year do not exceed one tonne per person.

Living on one tonne of carbon dioxide per person per year is a major challenge considering that the average figure in the world today is about seven tonnes. The players in the project believe that it is possible for the test family to approach one tonne of emissions without compromising their standard of living, if the correct technology, expertise and consistent behaviour are used. In order to show that this sustainable living is possible, different technologies for energy efficiency come together and are tested in a real life situation.

The well-insulated and energy-efficient wooden house, built by A-hus, is situated in Hässelby, outside Stockholm. Vattenfall will equip the house with smart technology that will measure the family's electricity consumption in real time and offer expertise for efficient energy use. The product Vattenfall will use to measure the family's energy consumption is called Energy Watch and will be launched on the market shortly.

The family will also be provided with an electric vehicle, a Volvo C30, which offers Volvo a great opportunity to study how an electric car fits in to the life patterns of a modern-day family. Vattenfall will also provide a charging pole to charge the electric car. The charging pole is connected to a charging station which can register travel data and provide information about electricity consumption and battery status.



OCEAN ENERGY PROGRAMME

Wavebob in tank testing campaign

One of Vattenfall's partners, the Irish company Wavebob, has performed basin tests this summer. Vattenfall participated in the basin tests, which were realized in order to study the survivability and generating capacity of the Wavebob and learn more about this technological solution.

The tests were conducted in a laboratory environment in Wageningen in the Netherlands and Nantes in France. Two Wavebob models were tested in the Netherlands, a simplified and scaled-down survival model and a larger production model. The survival model was exposed to several extreme sea states in the laboratory's test tank and various survival strategies were investigated. The production model was tested in various types of wave climate in order to measure its functionality and output. In France, a production model was tested for a range of operational sea states.

All in all, the tank tests were successful and the observations increased the understanding of the Wavebob device. Before the tests the expected output was first calculated and the tests are being used to verify that the calculations are correct. A lot of data on the power absorption behaviour of the Wavebob device was recorded and further understanding will be gained during the analysis of the data.

Wavebob's wave power plant is a ring-shaped buoy whose centre is linked to a large vertical underwater structure. The two units move with respect to each other in the swell. A hydraulic system transforms these movements into electricity.



WIND POWER PROGRAMME

Self-healing of cracks in concrete

Vattenfall is involved in a project dealing with the self-healing of cracks in concrete. Theoretically, cracks can be sealed by the substances migrating from the concrete itself, so-called self-healing takes place. In cooperation with Skanska and Lund Institute of Technology, Vattenfall is studying the effect of self-healing on the chloride ingress in concrete in marine environments.

Cracks in concrete foundations subjected to severe environmental conditions, for instance marine environments, must be injected if their width exceeds a certain maximum value. The injection is performed in order to obstruct the ingress of the aggressive substances into the concrete and protect the reinforcement bars against corrosion. The maximum permissible crack width is regulated by the structural codes and standards and is normally set to 0.2 mm, sometimes even lower. The crack width in a concrete structure is controlled by means of reinforcement. The narrower the cracks, the higher the amount of reinforcement. An increased amount of reinforcement leads to increased construction costs. The injections also increase construction costs.

The results of the project may influence the design of the concrete foundations for wind power plants in marine environments, and lead to the more economic design of the structures. The project will be completed in the beginning of the 2011 when we will also have the preliminary test results.



E-MOBILITY PROGRAMME

Experiences from real life tests of Volvo V70 plug-in hybrids

Together with Volvo Cars, ETC (Energy Technology Centre) and the Swedish Energy Agency, Vattenfall is developing and testing plug-in hybrid electric vehicles. Two prototypes of Volvo V70 plug-in hybrids were used by 16 families in Gothenburg, Sweden from December 2009 to May 2010. The families used the cars in their everyday lives over a period of several weeks. The test project is unique since it is one of the first times that private individuals have had the possibility to use a plug-in hybrid vehicle as their own private car. The purpose of the real-life test is to see how plug-in hybrid vehicles can work as a family car and to examine their environmental impact. The test driving will continue in Gothenburg and Stockholm until the turn of the year 2010/2011.

Summaries of the experience gained from the first test period show that the test drivers used the electric power mainly in city traffic while they changed to the combustion engine on the public highways. All in all, 39.5% of the driving distances were covered using electric power. Charging was mainly carried out at home or at work. None of the test drivers used the charging poles in public places for charging. Most of the drivers think it is easy to handle charging, it becomes a daily routine. Many of the Volvo test drivers point out the positive influence on the local environment; the cars are silent and have no exhaust fumes when driving on electricity.



CCS PROGRAMME


Chemical Looping Pilot plant for more efficient CO₂ capture

A new 1 MWth Chemical Looping Combustion (CLC) pilot plant for the combustion of conventional pulverized coal has been built and is being taken into operation in Darmstadt, Germany. "The commissioning of the 1 MWth CLC pilot is progressing very well and we are able to operate the start-up burner from the process control system", says Dr. Ströhle who is technical coordinator at the test facility of the EU-sponsored ÉCLAIR project, in which Vattenfall is participating together with Alstom, Air Liquide, C.S.I.C (Instituto de Carboquímica, Spain), SINTEF, Darmstadt University of Technology, and Chalmers University of Technology. The pilot plant is the first approach to demonstrating the novel chemical looping combustion principle in a complete auto-thermal reactor system. Commissioning will continue for the rest of the year and the test programme will start in February 2011.

The purpose of the EU-funded project ÉCLAIR (Emission Free Chemical Looping Coal Combustion Process) is to develop CLC for coal combustion with more efficient CO₂ capture than the technologies tested in pilot plants today. In the chemical looping process, the CO₂ separation from nitrogen is achieved without using the cryogenic air separation units necessary in the Oxyfuel technology, or any chemical absorption units. The CLC process may reduce the additional fuel consumption to approximately 6% compared to about 20% for the Oxyfuel technology. The additional fuel is necessary due to the energy required for CO₂ separation and compression. CLC aims to reduce the CO₂ avoidance cost to about 10-15 €/ton CO₂.

Vattenfall has been strongly pushing this promising technology for many years. After the tests made in the ÉCLAIR project, validation on a larger industrial scale would be needed before the technique can be introduced on a full production scale.

Sustainable cities is about challenging conservative thinking



Cities are becoming more and more aware of their impact on the environment and are working hard to minimize it. By gathering its collective knowledge, Vattenfall can be a partner for cities in their transition to become more sustainable and use energy more efficiently.



Thomas Munch-Laursen,
R&D Programme Manager
Sustainable Cities



Anders Johnson,
Head of Business Development
Programme Sustainable Cities

“Within the Sustainable Cities R&D programme all this is covered by six different sub-programmes; Metering technologies, Product-related energy services, Distributed generation, District cooling, Solar energy and Geothermal energy.”

Urban areas are rapidly becoming the new main consumers of energy. At the same time, the debate about carbon dioxide emissions and the greenhouse effect is becoming more intense and many cities are working hard to reduce their carbon footprints. As cities are becoming increasingly aware of their energy consumption they strive to minimize their impact on the climate, for example through reducing energy consumption in new and existing buildings, making sure that the energy comes from sustainable sources, and ensuring that the energy is produced and distributed in an efficient way. Energy systems could be a complex puzzle to solve. Many technical solutions are available and technical development is progressing fast from a city planner's perspective. How to best leverage the different available solutions to create an energy system that suits the city's energy needs, balanced with budgetary issues, is a challenge.

Vattenfall's Sustainable Cities

Programme is conducted both from a Research and Development (R&D) perspective and a Business Development (BD) perspective in close cooperation. The concept was launched to work along with cities in their transition to a sustainable use of energy. Understanding the cities need of new energy efficient solutions, and the different challenges each city is facing, Vattenfall seeks to work close to the city stakeholders and in several cases enter into long-term partnerships with the cities. By gathering Vattenfall's collective knowledge and actively seeking more knowledge in the areas not yet covered, Vattenfall looks at the whole society and offers a systematic approach for energy sustainability. The aim for the Sustainable Cities Programme is to secure that Vattenfall's offerings meet the market needs of sustainable and efficient energy solutions and improve the customer satisfaction. R&D creates the technical platform and gathers new technologies and concepts, while BD is focused on city partnerships and to develop new business opportunities in the emerging market place.

A city's energy system comprises of different kinds of generation, both large and small-scale, distribution and different type of customers segments,

mainly divided into transports, industries and buildings. At Vattenfall, issues relating to the transport sector are handled by the E-mobility R&D programme, while issues relating to distribution are dealt with by the Smart Grids programme, and small-scale generation and means of increasing energy efficiency adapted for different kinds of customers belong to Sustainable Cities. Together, Vattenfall covers a city's entire energy system and enables a systematic approach when co-operating with cities striving for sustainability.

When striving to make a city sustainable and designing for the future, it is essential to take into account that different buildings have different needs. For a residential building in Madrid it might, for example, be beneficial to use solar panels to produce heat and electricity, while an office building in Berlin might be able to use district heating for both heat and cooling, or to pick it up from the bedrock using a small-scale geothermal system. Ultimately, however, the best way of achieving sustainability is to reduce the waste of energy, for example by adding additional insulation, making sure new buildings are constructed in an energy-efficient way or simply by visualizing the consumption so that everyone can get an understanding of and direct feedback on their initiatives to reduce energy consumption.

Within the Sustainable Cities R&D programme all this is covered by six different sub-programmes; Metering technologies, Product-related energy services, Distributed generation, District cooling, Solar energy and Geothermal energy. Currently, Vattenfall is running 26 different long- and short-term projects within these sub-programmes. An example of a long-term project is the evaluation of the potential for geothermal energy in Vattenfall's existing markets and an example of a short-term project is the study of heat pumps and heat storage that is being conducted in Germany.

Creating a sustainable city may sound technical, and it is to some extent, but it is primarily about challenging conservative thinking and proving that new technologies can work in existing complex energy systems. ■



PRODUCT RELATED ENERGY SERVICES

The light source of the future

Within the scope of the R&D programme Sustainable Cities, Vattenfall has begun collaborating with the research and development company LightLab. The aim of the project is to develop the light source of the future; the next-generation eco-bulb with high energy efficiency and with no use of mercury.

Conventional light bulbs are extremely inefficient, only 5% of the energy they use is transformed into light, and after a decision by the EU the use of conventional light bulbs is being phased out all over Europe. The energy saving potential is huge; in offices and official buildings lighting alone can account for almost 25% of the total electricity consumption and a total saving in the EU of 40 TWh is expected. However, this places high demands on the development of alternatives fulfilling high environmental standards. The most commonly used low-energy lamps contain mercury, and are therefore considered by some people to be a greater environmental threat than the conventional lamps. But the company LightLab has developed a technology for producing lamps that use very little energy and do not contain mercury.

LightLab is a Clean Tech company that develops lighting technologies with high environmental performance and energy efficiency. Their vision is to develop light sources with maximum environmental performance, combined with attractive lighting properties. The company uses a new patented technology to produce bulbs that can produce light in an energy-efficient way and without the use of mercury or other environmentally-harmful materials. This lamp will be the first product to use technology developed by the company itself.

After performing a technical analysis of the technology that LightLab uses, Vattenfall became interested in supporting the company in its work to develop a commercial lamp. The purpose of the collaboration is to provide the resources needed to develop a prototype of the lamp that meets market demands and customer needs. Vattenfall's role in the collaboration project will be to test the prototypes from a user's perspective and to contribute knowledge about the energy market. Lars Strömberg, Vice President of Group Research and Development at Vattenfall, explains why Vattenfall is joining forces with LightLab:

"Vattenfall's Research and Development wants to promote the development of energy-efficient products that meets the environmental requirements of tomorrow. LightLab's light bulbs have, in our opinion, the potential to achieve substantial energy savings in lighting."

The basic principles behind the technology are field emissions and cathodoluminescence. Instead of using a warm cathode, LightLab's bulb contains a cold cathode which does not require the use of heavy metals. The cold cathode has more advantages; since the cathode does not have to warm up the lamp glows at full capacity from the moment the light goes on, and in addition the lamp can also be used in environments where heat radiation is undesirable.

LightLab's bulbs are produced without the use of heavy metals and require less energy than regular light bulbs, even lower than low-energy bulbs. They are also temperature-independent and not sensitive to cold weather. Studies have shown that the technology works, and the latest years of development have both improved the energy efficiency and the light flow. The focus is now on optimizing the lifetime,

making the components smaller and improving the energy efficiency further. The lamp is considered to have great potential since conventional lamps are being phased out not only in Europe but also in Australia and some states in the USA, and since the energy-saving bulbs of today are only permitted due to an exception from the ban on using heavy metals. The prime competitor for the lamp is the LED-lamp, based on light diodes and developed by Philips. But tests have shown that the light from LightLab's lamp is more pleasant due to better colour reproduction. ■



THE TECHNOLOGY:

A flow of electrons is generated inside a cold carbon cathode in the centre of the lamp, and thereafter emitted outwards towards a glass chimney. The glass is coated with a luminescent powder and a thin layer of aluminium and when the electrons strike this surface light is produced.

METERING TECHNOLOGIES

Making electricity consumption visible

Energy management systems including visualization of energy consumption are important parts in designing the sustainable energy system of tomorrow. By visualizing energy consumption consumers will become active parts of an energy system that can contribute to a much more efficient use of resources.

Traditionally, the generation of electricity has been adapted to the prevailing consumption needs. With a large proportion of renewable energy sources, which mostly involves intermittent generation that varies over time, consumption in the future has to be continuously adapted to the available amount of electricity.

"We develop solutions for the visualization of consumption as well as energy management systems and home automation. The possibility to visualize energy consumption - and in the future also the instantaneous electricity price - will provide a tool for consumers for the more efficient use of

resources. Furthermore, steering and control of energy consumption will give additional value to our customers," says Tetyana Bogdanova, manager for sub programme "Metering technology and related services.

"Solutions based on smart metering and energy management systems at customers' premises can shift load from peak time as well as help to reduce overall consumption. Remote steering and control of electricity and heat consumers will open further potential for energy efficient living," says Bogdanova.

"An example is BeAware, an EU project that develops equipment and solutions to visualize real-time



consumption data from individual electrical appliances to, for example, an Iphone or Ipod. At Vattenfall, we are conducting laboratory tests and live demonstrations in order to get a deeper understanding of the concept

Vattenfall will start tests in customers' homes where the electricity consumption from seven major home appliances will be measured and displayed in an Iphone.



The possibility to visualize the energy consumption will provide a tool for consumers for the more efficient use of resources.

Vattenfall in Germany has installed "Energie Controlling Online" (ECO) to customers such as Citibank and Lufthansa. ECO offers solutions and services that can visualize the consumption of electricity, heat and water via for example the Internet or iPhones.

and to evaluate if this could be a suitable product for Vattenfall," explains project manager Monica Löf.

In Finland, tests based on the BeAware concept are already being conducted with real customers. Starting in November 2010, five households in Stockholm will be part of another test within BeAware. The electricity consumption from seven major home appliances will be measured and displayed either in an iPhone or projected in the home with a Watt-lite Twist torch. These tests and live system demonstrations provide important information on user

behaviour as well as information on the interaction with the existing smart-metering infrastructure and IT security issues.

Vattenfall is also further developing online energy controlling solutions for commercial and industrial customers. In Germany, there is already a successful commercial product called "Energie Controlling Online" (ECO) that has been delivered to, for example, Citibank and Lufthansa. ECO offers solutions and services that can visualize the consumption of electricity, heat and water by providing raw-data values every quarter of an hour via the Internet, iPhones or, for example, mobile telephones.

The effect of energy-efficiency improvements can quickly be checked with this online monitoring tool.

Other projects and project plans include Smart Office and Smart Home concepts. The ambition is to combine competences from Sustainable Cities' R&D and Business Development programmes, while incorporating knowledge on distributed renewable energy generation, smart grids and energy storage as well as energy management issues from throughout Vattenfall. ■

GEOTHERMAL ENERGY

Making use of a giant energy source deep under ground

Hidden under the Earth's surface, some two to four kilometres down in the bedrock, there is a source of energy that is extensive, sustainable and clean: geothermal energy. There is great potential for geothermal energy in Europe and Vattenfall is now evaluating the possibilities concerning how heat and power from the subsurface can be used in the future.

Within the R&D Programme

Sustainable Cities, the sub-programme Geothermal Energy started just before the summer. The task of the sub-programme is to gain knowledge about different geothermal technologies and the possibilities for Vattenfall to utilize and apply geothermal energy to city environments and new or existing district heating systems. The interest in geothermal energy is slowly but steadily awakening, one reason being that if utilized in the right way, it could bring lots of advantages.

"The benefits of this energy source are several," says Peter Wilén, manager of the Geothermal Energy sub-programme. "Apart from a great environ-

mental performance, it is renewable, the production costs are low and it is well suited for base load purposes in an energy system due to a stable supply and no dependency of weather conditions."

Geothermal energy is energy in the form of existing heat below the Earth's surface that can be used to either warm up, cool down or generate electricity. Despite its benefits, however, there are a number of obstacles to overcome before geothermal energy can become a commercial reality and contribute to European energy supply to a larger extent.

One obvious obstacle is the depth.

To get down to water with usable temperatures, holes of up to four kilometres (depending on geological conditions, temperature gradient and on what technique is used) have to be drilled. Vast geological studies have to be conducted to determine areas suitable for geothermal operations. This means large initial costs when building geothermal sites. This in turn means that, with few exceptions, geothermal energy and electricity generation in Europe is currently not economically viable. In Germany, government subsidies make the energy source commercially interesting. For a wider use of deep geothermal energy, the





Hot water geysers show the immense amount of geothermal energy stored under ground.

EGS-technology, (Engineered or Enhanced Geothermal Systems) is promising. By using fracture technology, heat sources can be utilized at depth less dependent of natural flow conditions than the conventional technology. The EGS- technology is well known today but needs to be further developed in various geological environments. The first plant though, is running in Soultz in northern France.

Geothermal energy can also be extracted from the shallower ground under the subsurface. In those systems combinations with heat pumps are common. Systems for both heating and cooling can use the subsurface both as

heat source and cooling source. Shallow systems are commercial viable in many countries today but the heating and cooling applications needs to be further developed and promoted.

"We are conducting studies to identify the potential and to find suitable geothermal projects for us to run. The countries that we are studying are Germany, Poland, the Netherlands and Denmark - all of them with good, although slightly different, conditions for geothermal energy," says Peter Wilén.

One concrete example of a possible Vattenfall project with commercial potential is to provide a new urban district in Warsaw with geothermal energy. The city itself has analysed the conditions

and Vattenfall is currently utilizing the joint competencies and skills within the company to find ways of applying geothermal energy in the new district heating system that will be built in the new parts of Warsaw.

The geothermal area is not new for Vattenfall. Since 2003, Vattenfall has been running a geothermal pilot plant in Neustadt-Glewe in Germany, providing valuable knowledge and geothermal competence. In addition to the Warsaw project, the new sub-programme is also actively investigating the possibilities for geothermal heating and cooling, and a bit further down the road, electricity generation. ■



SOLAR ENERGY

Sunny times for solar power

Despite a growing number of large installations, solar power generation is today characterised by hundreds of thousands of decentralised small scale systems on private and commercial rooftops. However, solar technologies for large-scale generation are now being evaluated as a significant part of Europe's future energy mix. Is this increasingly 'hot' industry something for Vattenfall to consider?

SOLAR POWER COMPRISES TWO MAIN TECHNOLOGIES:

- Photovoltaics (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect.
- Solar thermal energy (STE) is a technology for harnessing solar energy for heat generation.

Few utilities in the world operate solar power as a sizable fraction of their generation mix today. The Solar sub-programme within the Group R&D programme Sustainable Cities endeavours to assess how the rapid development and growth of this industry will affect Vattenfall's core business of selling electricity and heat. Following the resulting market assessment, the solar sub-programme will also seek to identify what role Vattenfall can play in the medium to long term in order to participate effectively with solar power as part of its portfolio of services and generation capacity.

Conservative forecasts by the International Energy Agency (IEA) say that photovoltaic power generation can provide 5% of global electricity generation in 2030, and 11% in 2050. Solar energy technologies in general, including solar thermal, could provide up to 20%.

However, in Germany 5% of the conventional generation nameplate capacity has already been reached through added solar capacity, and under the National Action Plan for the EU RES Directive (Renewable Energy Source) the government has set a binding target of 52 GWp (Giga Watt peak) installed capacity by 2020, increasing solar PV's share to 10%. For this to be achieved, annual newly-installed capacity would only need to be 3.8 GWp; forecasts for 2010 estimate 8 GWp will be installed.

"The technical potential of solar power is immense, so it is important for Vattenfall to keep track of the development in this area. By 2020 it is foreseen that 70% of Europeans will be able to access solar energy at a lower price than retail energy from the grid, which as a pan-European organisation is something we are considering

in our long term strategies," says Richard Lawless, the Solar sub-programme manager.

Solar photovoltaic technology still be considered as an emerging technology that is not yet competitive without subsidies. This is changing rapidly, however, with solar-generated power in southern climates now achieving retail grid parity. In Germany, subsidies are set to converge with retail electricity prices by 2014, and will most likely be completely phased out within ten years. Irrespective of this, based on these government-supported feed-in tariffs, investments in solar systems still generate an attractive financial return.

The leading industrial countries have indeed understood the potential of solar energy. In Germany, for example, there is already an ambitious programme and considerable subsidies for solar power. In 2004, a number of cities, such as Berlin, Bonn and Wiesbaden, began to map the technical potential of optimally-inclined and oriented roof space. Now, more than 150 municipalities in Germany have assessed the technical potential of solar power in the areas under their governance, using new mapping technologies that allow for the rapid assessment of city landscapes with respect to roof-mounted solar power.

Vattenfall in the Netherlands has

invested in an innovative project called Almere Sun Island. The project was started by Nuon and the municipality of Almere and completed in the summer of 2010. It consists of an island covered with 7 000 m² of solar collectors. Water is heated in the solar collectors by the sun's rays and then pumped directly into the local district-heating network of the new residential area Noorderplassen-West. The solar island will supply 10 per cent of the district's annual heating needs.

In a proactive step, Vattenfall Europe New Energy, with the support of Vattenfall Power Consultant, has been leading the assessment of Vattenfall's own roof space with respect to the integration of solar power. So far, several megawatts of potential capacity have been evaluated, albeit with a wide variation in the suitability of sites.

"Vattenfall has been active in the field of solar power for nearly 20 years. The Solar sub-programme intends to benefit from, and bring together, the internal international experience and knowledge across Vattenfall. Among other investigations we have started a general study of solar thermal energy for assisted district heating in order to explore the main economic drivers behind this technology and concept," says Richard Lawless. ■



Germany has an ambitious programme for small-scale solar energy generation.

DISTRIBUTED GENERATION

Renaissance for distributed generation

In the wake of industrialization, there has long been a gradual expansion of large-scale generation sources. The development of suitable technologies and the increasing demand for more renewable generation, however, has led to an opposite trend that could mean a true renaissance for distributed generation.

The concept of distributed generation is not new. Before the era of electrification, starting in the beginning of the 20th century, small-scale power sources like water or wind mills were often the heart of small factories and workshops.

“Now we are looking at the potential for distributed generation in a modern densely-populated city environment. The ambition is to find sustainable solutions that can reduce energy demand, save costs and curb emissions,” says Dr. Jürgen Helmig, sub-programme manager for Distributed Generation.

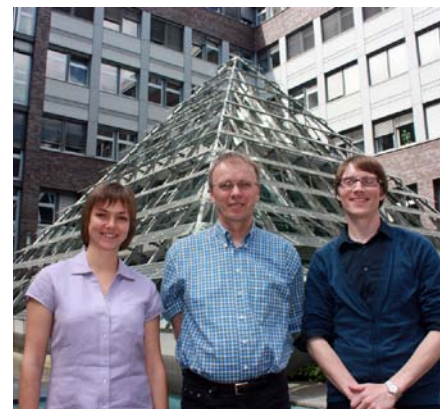
The main focus is on all types of distributed generation in the range lower than 5 MW, including combined heat and power production systems (CHP), as well as single heat and single power generation systems close to the customer’s site.

A first overview of distributed generation technologies, for example internal combustion (IC) engines, fuel cells, stirling engines, micro gas turbines and small-scale wind power generators has been conducted within the sub-pro-

gramme. Now a more comprehensive market study of distributed generation technologies is being considered. Heat pumps represent a typical distributed generation technology that is already widely used in some regions, for example the Nordic countries. A project and market study on heat pumps and heat storage solutions in Germany is now running on behalf of Business Unit Heat Germany.

“The purpose of the project is to compare stand-alone heat pumps that follow the heat demand directly, with centrally-steered heat pumps that optimally use cheap electricity and store the heat until it is demanded,” says Jürgen Helmig.

Another area of focus is the Organic Rankine Cycle (ORC) technology and Vattenfall is investigating the various products available on the market. A very interesting aspect here is the installation of an ORC module at existing heat plants in order to generate electricity by using hot water from the base-load boiler to drive the process.



Sustainable Cities Sub-programme managers based in Berlin: Dr Jürgen Helmig (in the middle, Distributed Generation), Tetyana Bogdanova (left, Metering Technologies), and Richard Lawless (Solar Power)

Other ongoing projects are for example investigations on “Heat pumps and solar thermal energy” (University of Lund, Sweden), “Green heat in Warsaw” and “PROkleineKraft”, a pilot project that will demonstrate the technical and financial feasibility of the business idea “the virtual power plant”. ■

“The purpose of the project is to compare stand-alone heat pumps that follow directly the heat demand, with centrally steered heat pumps that optimally use cheap electricity and store the heat until it is demanded.”



Architectural model with solar panels and windmill power generator.

COOLING SYSTEMS

A growing cool business

With more energy efficient buildings and perhaps a warmer climate in the future, the demand for heating is expected to decrease while cooling solutions in office premises, homes and other buildings might become a growing business.





A new range of absorption chillers and ventilation convectors can provide both heating and cooling in private homes and offices.

There are a number of solutions for cooling. Traditional cooling often implies electricity-driven compressor cooling. This means small, cheap and easy-to-fit installations but strains the electricity system, especially in the summer. However, other sustainable solutions are available.

By using cold water, cold air or snow, or by using "free" energy, such as surplus heat or solar energy, it is also possible to produce cooling. For example, absorption chillers use the energy in hot water to produce cooling, mostly the heat in water-based heating systems. Groundwater cooling uses water from an underground aquifer to produce cooling in the summer and heating in the winter. It is even possible to produce cooling by using solar energy.

"We are trying to develop sustainable solutions for comfort cooling and process cooling which are practically applicable, adjusted to local conditions on the market and adaptable to local conditions. At the moment we are primarily looking at different solutions for heat-driven cooling," says Anne-Marie Sjöbohm, sub-programme manager for Cooling Systems.

A promising project for district cooling based on district heating is running in Berlin. The project is evaluating the

"We are planning for a market introduction in 2011-2012. The first commercial installations in offices and hotels have already started."

possibility to offer a competitive concept for a standardized cooling system.

"We are testing prototypes of modular absorption chillers for offices and households. They are operated by hot water from Vattenfall combined heat and power plants and can be used with the existing heating infrastructure in houses. The new range has a capacity from 50-160 kW each and can be combined in modules to provide 50-320 kW. We will be able to offer a convenient combined heat and cooling solution that can compete in terms of costs with traditional compressor chillers," says project manager Roland Hellmer.

"We are planning for an extensive market introduction in 2011-2012. The first commercial installations in offices and hotels have already started. The main target group is naturally our existing heat customers in the

office segment, hotels and residential districts, as well as in private homes to whom we could offer a new product in the summer when the demand for heat is normally low," says Roland Hellmer.

Another project for cooling from district heating is also running in Warsaw. The project is using results from the German project and is now looking at customer behaviour in order to develop a profitable business solution.

Other cooling projects are looking at the possibility to use district-heating driven heat exchange systems for cooling (Uppsala) and are comparing traditional cooling systems with district cooling (Amsterdam). ■



Vattenfall in Berlin has developed a solution with modular absorption chillers for offices and households. The absorption chillers are operated by hot water from Vattenfall combined heat and power plants.

ANOTHER PERSPECTIVE

How to make Amsterdam a Sustainable City



Amsterdam

All around Europe, the process of transiting cities to carbon-neutral communities has begun. At the Amsterdam Climate and Energy Office, energy strategies are being developed with a focus on reducing energy consumption in existing buildings in Amsterdam. Jannis van Zanten, working at this office, gives us an insight in this ambitious process.

Amsterdam, with its 750 000

inhabitants (1.4 million if the suburbs are included), is the largest city and official capital of the Netherlands. Climate and energy are prioritized issues for the city and the goal for climate reduction is 40% by 2025 compared to 1990's level. In the energy strategy of the city, called Different Energy, the focus lies on four different "transition pathways": Buildings, Clean transports, Port and industry and Sustainable energy. In the Climate and Energy Office of Amsterdam, 15-20 people work with renewable-energy matters and to develop energy strategies and CO₂-reduction strategies for Amsterdam. Jannis van Zanten's main focus is on buildings and sustainable energy.

"Amsterdam has 400 000 houses and a large amount of office space - 8 million square metres. We don't have that much industry in Amsterdam so we have a different focus than, for example, Rotterdam with its enormous industrial area."

To improve the climate performance of the buildings the city applies the "trias energetica": First, energy consumption in new and existing buildings is reduced due to improved insulation and renovation. Secondly, efforts are made to ensure that the energy used comes from sustainable sources like the wind, the sun or biomass. Step three is to develop the energy systems to make

sure that the energy originated from carbon sources is produced and distributed in an efficient way - for example by connecting buildings to district heating from power plants fuelled with fossil fuels and waste.

"The main responsibility for climate action lies with the city, because we have set the goals for carbon reduction in the city. But we need everybody in the city to cooperate and work together with us to achieve success: energy companies, housing companies, the citizens and everyone else."

Today, about 50 000 houses (10%) are connected to the district-heating network, but this number is growing by 5 000 houses each year. This is due to a close cooperation between NUON and the city, who have together set a partnership goal of 100 000 connected houses in 2025 and 200 000 (50%) in 2040. For the future heating system, van Zanten believes in switching to biomass and connecting all the Amsterdam carbon power plants to the heat grid, and also adding hot-cold storage and geothermal heat to the energy system. "Maybe CCS is an option for power plants," Jannis says, "but it is also very expensive and I don't think it will be an alternative for the long run. In Amsterdam, we don't focus on CCS, or on nuclear power."

NUON has also started two district-cooling networks in Amsterdam but it

is hard to make them financially viable. The city and NUON are thinking of co-operating on cooling in the same way as on district heating to increase the use of this sustainable cooling method.

Amsterdam is also looking for ways to expand today's generation of electricity from renewable resources by developing wind power and, in a longer perspective, solar power and geothermal energy. These are the local energy sources that the city of Amsterdam believes will be of importance in a longer perspective.

"First we will develop windmills," says Jannis van Zanten, "and work in wind projects mainly on land - offshore wind is also important but at a national level. Second, in a longer perspective, we will increase the use of solar PV system, on roofs and on every surface that we don't use. This will start in approximately 10 years, today solar PVs are too expensive but we expect a lot from this technology in the future."

When asked what he considers to be the greatest challenge for the future, van Zanten answers: "How to reduce the use of energy in the existing city, how to make the existing 400 000 houses less energy consuming. This is a difficult matter because of the many players included in the game, but it is necessary; the available amount of sustainable energy in the future will be much less than today's cheap fossil fuels." ■

