

Risønews



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Focus on
sustainable energy

Risø DTU
National Laboratory for Sustainable Energy

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Sustainable development meets current needs without impairing the ability of future generations to cover their needs. Can we achieve this? Yes, with a global effort, believes Risø's director

By Rolf Haugaard Nielsen
Science Journalist

"We must give future generations opportunities which are at least on a par with ours. However, it won't be on the same terms," says Henrik Bindslev.

One example is the world's dwindling oil reserves. "It is OK to use the oil. But only if we use the welfare that oil creates to improve the education of people around the globe and to develop new energy sources and resources so that our descendants can manage without oil. That is sustainability in practice."

Global access to electricity is vital in order to realise this vision. "Today 1.6 billion people live without electricity, which traps them in a state of poverty and illness. We, as humans, have a responsibility to break this vicious cycle."

Sustainable energy also involves security policies. In a few decades, Europe will need to import 70 per cent of its energy. "The certainty of such dependence is even now influencing our political aims in relation to Russia and countries in the Middle East."

The challenge is to combine today's needs while ensuring that man-made climate change does not impair living standards for future generations. "With the IPCC's report on the consequences of the greenhouse effect such as shortages of clean water, drought and flooding, the time has come to reduce the global emission of greenhouse gases."

Tomorrow's energy

In the short term, we need more wind power. "The additional price in relation to coal-fired power generation is modest, and up until 2020 the share of electricity production from wind turbines can be raised from 1 per cent to perhaps 16 per cent. Incorporating fluctuating energy sources into the supply systems will pose problems, which we are already aware of in Denmark. Armed with effective solutions, Danish industry can combine altruistic considerations with self-interest in the shape of an exciting commercial future."

One promising technology is electricity production using concentrated solar heating in large plants, which are now being built on a commercial scale in Spain and the US. The solar power plants can store surplus heat for the night-time hours in molten salt. "It is cheaper to store energy in the form of heat than as electrical power. Think of the price difference between a vacuum flask and the battery in your laptop."

Second-generation biofuels are part of the solution and are potentially sustainable because they are produced from plant residue. "The next step is bio refineries producing polymers, chemicals and fertilisers from the substances left after flour and biopetrol have been produced."

In 10 years' time, solar cells will be financially competitive, while in 50 years' time fusion energy is likely to be a key player in the global energy system. "Both sun, wind and fusion power plants can supply electrical power as well as hydrogen or synthetic fuels for transport."

How will populous countries such as India and China join in? And how can we support sustainable development in the poorest developing countries? "In the growth countries, we must help people to understand that sustainability offers economic rewards in the long term. Poor countries should be assisted so they can exploit local resources, for example via industries that manufacture wind turbines made from wood."

"We are one world community, and we are all dependent on each other to create mutual happiness," says Henrik Bindslev.

A necessary national laboratory

A national laboratory for sustainable energy is necessary for the Danish research and business communities to seize the opportunities in a rapidly growing and fast-changing world market

By Rolf Haugaard Nielsen
Science Journalist

Denmark is unlikely to again experience a wind turbine adventure where risk-taking blacksmiths and scientists achieved the impossible and commandeered the world market. On the other hand, we can forge a position for ourselves across the entire spectrum of sustainable energy technologies. "As a national laboratory, Risø is responsible for ensuring that Denmark does not miss out on any promising opportunities," says Henrik Bindslev, Director of Risø.

Take, for example, the large solar heating plants, which are hardly relevant here given the Danish climate. But worldwide, this technology is steaming ahead. "I have discussed it with solar power plant suppliers in the US, and we can play a role here. For example, the supports for the huge mirrors were heavy and susceptible to the effects of the wind. Thanks to our wind turbine research, we now possess unique expertise in aerodynamics and the manufacture of large, strong and lightweight structures. This is just one example of the opportunities open to far-sighted businesses."

Denmark can also promote the global spread of sustainable energy through the development of advanced technologies for treating residual biomass to enable the release of plant sugars for fermenting to ethanol. "In this context, it is obvious to collaborate with Brazil to utilise the enormous volumes of bagasse which are left after producing bioethanol from sugar cane."

"As a national laboratory, Risø can develop strategic activities in promising areas, preferably high-risk energy technologies that offer the chance of major breakthroughs. Tomorrow's winners can be polymer solar cells, which can open up promising commercial opportunities. If the cells can be produced sufficiently cheaply, it will be possible to roll out 10,000 sq m across the roof of a super-

market warehouse and replace the foils every few years."

Flexible energy systems

As the share of unstable energy sources such as wind and sun increases in the energy system, the need grows for buffers which can absorb surplus electricity and deliver it at peak times.

"The world needs flexible energy systems, where electricity supplies and transport go hand in hand," says Henrik Bindslev. "Plug-in hybrid cars and electric cars can come to play a central role. While cars are parked at people's workplaces, a computer purchases power for the return journey when the price is at its lowest. And if society needs electrical power, the batteries in the cars supply surplus electricity to the grid. Risø's SYSLAB aims to be an international pioneer and developer of tomorrow's energy systems."

Climate and developing countries

To halt the warming of the Earth's atmosphere, it is crucial that emissions of greenhouse gases are minimised in the growth countries in Asia and South America. "For example, China is implementing wind power and establishing its own wind power industry, offering fabulous opportunities for Danish subcontractors. Here, Risø is working with China's meteorological authorities on a wind atlas."

In relation to the poor developing countries, the Kyoto Protocol's CDM mechanisms should be used optimally with sound development projects that contribute to building up local know-how and employment. "In this context, we hold a strong card with the UNEP centre, which was recently awarded the Energy Globe Award for solar cell projects in rural areas in India."

"As a national laboratory, Risø DTU can develop strategic activities in promising areas, preferably high-risk energy technologies that offer the chance of major breakthroughs. DTU and Risø DTU has established a climate centre with free hands to promote sustainable development and strengthen Danish commercial interests," says Henrik Bindslev, Director of Risø.





New lodestars for wind power research

The wind turbines of tomorrow must be as reliable as the best passenger aircraft. And it must be possible to integrate them into the electricity system. However, a low price per kWh is no longer quite such a decisive factor

"More efficient wind turbines mean fewer wind turbines per wind farm thus reducing the requirement for raw materials. Higher efficiency can be achieved by using a spinner anemometer, an instrument mounted on the spinner of a wind turbine that measures wind speed and

wind direction. Today's wind turbines are short-sighted, so to say. They are not able to "see" sharply where the wind is coming from, and consequently they cannot turn directly into the wind and they lose power. A spinner

anemometer measures the wind direction very precisely, and can therefore help to ensure precise yawing. This may improve efficiency by 1-5 per cent," says Troels Friis Pedersen from the Wind Energy Department.

By Morten Andersen
Research Journalist

Every hour, a large wind turbine needs to be erected somewhere in Europe.

This is how Erik Lundtang Petersen, Head of the Wind Energy Department, illustrates the implications of the new EU targets. Add to this that the USA must install just as many turbines, while 50 or so factories in China have started producing wind turbines in 2007.

"Vestas Wind Systems, Siemens Wind Power and LM Glasfiber are still world-leading, but the competition, and thereby the challenges, has certainly intensified. It has added considerably to the R&D requirements," says Erik Lundtang Petersen.

"Right now the focus is on reliability. About half of the coming wind turbines in the EU will be offshore. It can prove extremely costly if an offshore turbine fails. Therefore, the wind turbines of tomorrow must match the best passenger aircraft for reliability. Moreover, there is increasing focus on developing solutions that integrate wind energy with the rest of the electricity system."

A seller's market

On the other hand, an old main objective is now less important: "Traditionally, the lodestars for scientists have involved reducing the price per produced kWh to make wind power more competitive in relation to other energy sources. This is obviously still desirable, but it is no longer the 'Golden Goal' of research," says Erik Lundtang Petersen, citing the fact that the kWh price has increased by 20 per cent in the past year: "This does not mean that research has gone wrong, but rather that we are seeing a seller's market. Everyone wants wind turbines, and



manufacturers are completely out of stock. Consequently, the price rises."

Shortage of raw materials

In fact, demand is so strong that manufacturers are having problems sourcing basic raw materials such as steel for the towers and plastic, glass and carbon fibre for the blades. And this in turn presents research with new challenges:

"There is a huge interest in wind turbines with a smaller need for materials. For example, if we succeed in developing a system that can quickly and safely regulate the angle of the blades in relation to wind speed and turbulence, it dispenses with the need for large volumes of materials. And we have come a long way already. We are also aware that the expectations of the outside world are great - almost frightening!"

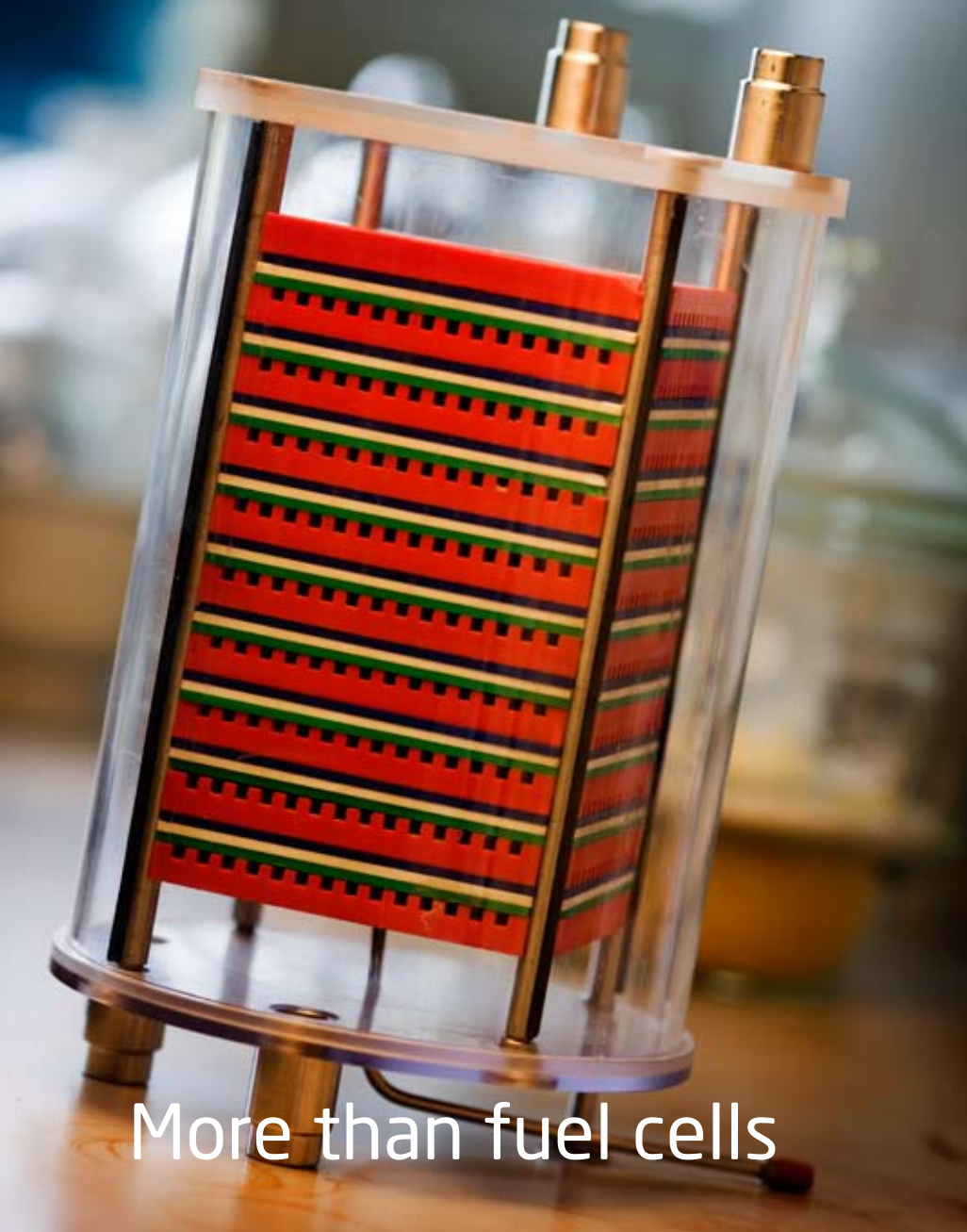
The biggest wind projects

Following the merger on 1 January 2007, there are now more than 180 scientists working with wind energy under the DTU umbrella, 130 of whom are at Risø.

Most recently, Risø has established a new blade-testing facility.

The Danish Council of Strategic Research supports the development of a new blade type with a flexible trailing edge. The blades are being developed by Vestas in collaboration with Risø.

The EU-subsidised project UpWind - the biggest R&D project which the EU has ever supported - aims to develop huge 8-10 MW wind turbines.



More than fuel cells

Fuel cells convert fuels directly into electricity at high levels of efficiency. Risø works with Topsoe Fuel Cell A/S to develop the so-called SOFC fuel cells. In addition to electricity, they also produce heat, which can be used for e.g. domestic heating. SOFC fuel cells are ex-

By Morten Andersen
Research Journalist

"For many years, the department has been heavily engaged in developing fuel cells in collaboration with Topsoe Fuel Cell. This will continue, but the strategy has always been to exploit the competences in other fields as well," says Søren Linderoth, Head of the Fuel Cells and Solid State Chemistry Department.

A new agreement has been signed with an energy industrial partner regarding research into electrolysis at high temperatures. Where a fuel cell produces electricity and heat as a result of a chemical reaction between oxygen and hydrogen, the opposite happens with electrolysis. For example, electricity from a wind turbine can, when assisted by Risø's

tremely flexible and can use e.g. natural gas or biofuels. The individual fuel cells produce a voltage of 1.5V, for which reason the cells are stacked to supply the 220V in the electricity grid.

high-temperature cells, be used to efficiently produce hydrogen or syngas from water and CO₂ with oxygen as a useful by-product.

"Popularly speaking, electrolysis is a fuel cell in reverse. This is therefore a perfectly obvious place to apply our knowledge," says Søren Linderoth.

Getting electrolysis rolling

It was the industrial partner that contacted Risø: "It was primarily our R&D competences, of course, which attracted them, but the fact that we have shown that we can collaborate with industry was also important. They were looking for a partner who could help to get things rolling if ideas proved to hold potential," says Søren Linderoth.

Risø's long-term involvement with fuel cells must be utilised in relevant areas. Most recently, an agreement has been signed with an energy giant on electrolysis research

"The broad profile we have built up has for a long time been part of our strategy. Flue gas treatment and removing nitrogen oxide filters from the exhausts of diesel vehicles are both areas in which competences from fuel cell research can be applied. Moreover, we have established contact with companies which are interested in electrolysis."

Still fired up about fuel cells

Even though advances are being made in other fields of research, our collaboration with Topsoe Fuel Cell to develop fuel cells is still our primary activity:

"At the moment, we have ten employees from the company working here, but they will be leaving later this year when Topsoe Fuel Cell's new factory in Lyngby starts production. However, this does not mean that our efforts, amounting to about 50 man-years, will be scaled down," says Søren Linderoth, and explains:

"You don't discontinue the research just because industrial production has started. On the contrary, it becomes even more important. The fuel cells which have been developed still need to be optimised, and the next generations of fuel cells need developing."

A task which Søren Linderoth is greatly looking forward to:

"Over the past couple of years, we have gone to greater lengths to produce fuel cells than we would have wished – and gone further than we are actually suited for. We had to, as the company does not yet have the capacity itself. Now we can fully concentrate on R&D."

Holistic approach to bioenergy

Agriculture hand in hand with bioenergy, controlling carbon conversion, increased biomass production, the right plants for tomorrow's climate, converting residues to bio-fuels, polymers and chemicals. Risø's Biosystems Department is putting together the jigsaw

By Rolf Haugaard Nielsen
Science Journalist

Biofuels made from plant-derived materials and organic waste can reduce emissions of greenhouse gases from both power plants and cars. But how will large-scale production of bioenergy affect soil fertility, the landscape and the groundwater? Which crops provide the most suitable biomass? How can the plants be optimised to thrive in tomorrow's warmer climate? And once the grain is sent for milling, how do we then convert the straw, chip, energy crops and manure as efficiently as possible into solid fuel, biogas, bioethanol, hydrogen and synthetic fuels? Can we take the next step with biorefineries that utilise the final residues for producing polymers, chemicals and fertilisers?

Holistic thinking! This is the keyword at Risø's Biosystems Department, which now includes energy research at DTU Biosys as well as the gasification group at DTU, which is working with the pyrolysis of coke and biomass to produce synthesis gas for converting into synfuels, e.g. DME. "With 86 employees, of whom 50 are directly engaged with bio-energy, we cover everything from sustainability analyses to projects with private companies," says Head of Department Kim Pilegaard.

Climate, cycles and biomass

Knowledge of plant physiology and the biological cycles in agriculture and forestry, for example carbon exchange between the soil and the atmosphere, is the starting point for assessing how a warmer climate will affect biodiversity and biomass production. The research must also provide an answer to whether we can simply remove straw from the fields for energy production, or whether carbon needs to be fed back and in which form. Tests in the climate chambers at RERAF resemble the predicted climate in 2075 and

show how plants such as rape and barley will react to warmer weather and increased levels of CO₂ and ozone in the air.

Other experiments focus on the potential of energy crops such as lucerne or legumes, which fix nitrogen from the air, and which can therefore be cultivated using less artificial fertiliser and less energy than for maize and corn. A new possibility is cultivating the sea lettuce algae, which produces four times more biomass than plants.

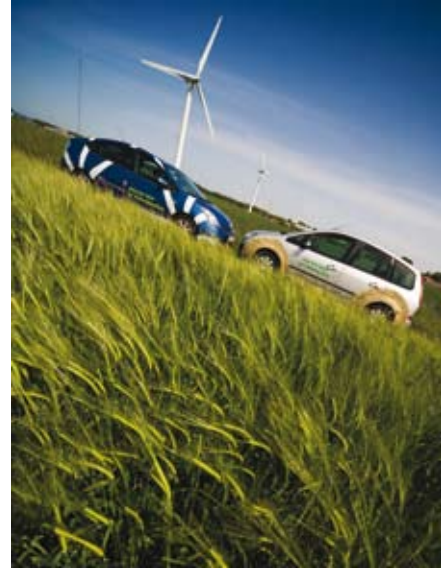
Second-generation biofuels

The department covers all processes involved in the development of second-generation bioethanol; from pre-treatment, where the straw is opened via the breakdown of lignin, through to the release of plant sugars from cellulose and hemicellulose and final fermentation.

In the MaxiFuel test plant, the co-production of bioethanol, biogas and hydrogen is being studied. The advantage of this combination is that each process exploits the residual products of the other processes, reducing the prices of both biogas and bioethanol. All that's left is lignin. The company Biogasol is commercialising the concept and has, together with Pacific Ethanol, been paid DKK 125 million by the US Department of Energy to build a demonstration facility in the USA.

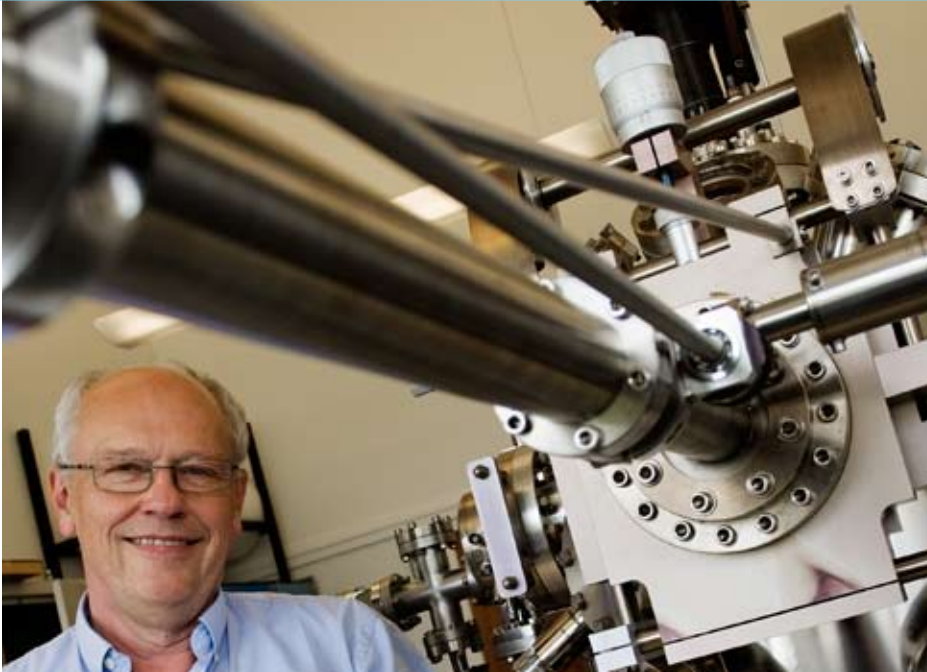
Another strategy aims to produce bioethanol at a power station where the lignin is incinerated, supplying energy for the other steps in the process. This will, in addition to bioethanol, produce animal feed and fertiliser. DONG is to test the concept at a power station in Kalundborg at the Inbicon demonstration facility, which has cost DKK 300 million.

"As a research department, we can certainly work with both DONG and Biogasol, even though they are competitors," says Kim Pilegaard.



Top: Foods must not be used for energy purposes; research activities are focusing on lignocellulosic raw materials, such as straw. Centre: Biomass for energy can be used to protect and conserve sensitive natural areas. Below: "In the RERAF greenhouse, all the parameters which are relevant for climate experiments with plants can be controlled. The six unique climate chambers at Risø DTU are currently being used for an experiment to reveal what happens with the genes when plants adapt to new climatic conditions," says Senior Scientist Teis Mikkelsen.

Plasma research to benefit industry



Plasma research is a hot topic and the basis of CO₂-free energy production

Poul Kerff Michelsen explains why it is natural to place long-term, strategic fusion research at a national laboratory rather than integrating it into a university department. Risø is a bridgehead for Danish industry becoming a supplier to the ITER experimental reactor. Actually, Danish plasma research is seeing various spin-

By Pia Jørnø
Science Journalist

Plasma research is a hot topic in more than one sense: Not just because plasma experiments are conducted at several thousand deg. Celsius, but also because plasma research is attracting considerable international attention as most of it involves fusion energy. It offers a sustainable solution to the energy and climatic problems which the world currently faces. The fusion fuel is extracted from seawater, and the fusion energy emits no CO₂ or other greenhouse gases.

Plasma research going well at Risø

"For many years, Risø has been the only place in Denmark conducting research into fusion energy; and it is Risø which represents Denmark in EURATOM, the international collaboration on fusion energy," says Poul Kerff Michelsen, Senior Scientist at the Optics and Plasma Research Department.

Poul Kerff Michelsen explains that it will be several decades before fusion energy is sufficiently developed to produce energy on a large scale. It is natural to place long-term, strategic fusion research at a national laboratory rather than integrating it with a university department that has to focus on a broader field of research as a basis for teaching. "Risø also participates in teaching

offs: With the CHP plants in Ringsted and Haslev, Risø is well on its way to developing a plasma-based plant which can clean the so-called NO_x gases – environmentally damaging nitrogen compounds – from the flue gases of straw-fired power plants.

activities at the Technical University of Denmark (DTU), and has done so for many years, offering a course in plasma physics and also supervision for BSc, MSc and PhD students," adds Poul Kerff Michelsen, who is delighted that Risø's new status as a DTU unit has led to closer and more independent contact with the students.

Benefiting Danish industry

Risø's team of almost 20 fusion scientists and technicians travels abroad when it needs to conduct experiments, because the several-million-degree-hot fusion plasmas can only be formed at large and expensive experimental plants which are situated in e.g. Germany, the UK and France. One might be tempted to ask why Denmark has to be involved in fusion research at all.

Poul Kerff Michelsen has a good answer to this: "Risø has some extremely competent and internationally recognised scientists working within this field. For example, on several occasions we have developed and supplied measuring equipment to the foreign fusion facilities, and we also expect to supply to the ITER experimental facility, which according to plan will be completed by 2017, and which represents the next key step towards fusion energy. Furthermore, we are a bridgehead for Danish industry becoming a supplier to the ITER experimental reactor. ITER will involve

Plasma technology for industry

The plasma types which Risø scientists use for industrial applications, such as cleaning flue gases from straw-firing, are called low-temperature plasmas. 'Low-temperature' is slightly misleading, as these plasmas are ten to twenty thousand degrees hot. They are called low-temperature plasmas because they are significantly cooler than fusion plasmas.

In addition to NO_x cleaning, low-temperature plasma scientists are also in the process of developing methods for surface treatment using plasma. For example, the large components in a wind turbine blade have to be roughened before they can be effectively glued together. Up until now, this has been done by sanding the surfaces, but using the plasma method offers the prospect of an easier process, where all the blade parts can be roughened in just a few minutes. Promising results have already been achieved in the laboratory.

industrial contracts totalling EUR 4 billion for supplying materials, IT, cooling technology, mechanical constructions, buildings etc."

A third good reason for investing in Danish plasma research is that it has begun to produce interesting spin-offs – in the shape of new technology for Danish energy companies. In collaboration with the CHP plants in Ringsted and Haslev, Risø is, for example, well on its way to developing a plasma-based plant which can clean the so-called NO_x gases – environmentally damaging nitrogen compounds – from the flue gases of straw-fired power plants.

Polymers for sustainable energy production

By Pia Jørnø
Science journalist

"Our aim is to produce efficient and durable polymer solar cells," says Peter Sommer-Larsen, who heads Risø's Polymers for Energy Technology Programme.

The polymer solar cells developed by Risø have a considerably lower energy efficiency than the so-called first-generation solar cells. "First-generation solar cells can transform 20 per cent of solar energy to electricity. As things stand at present, the energy efficiency of polymer solar cells is only about 2 per cent, but we are hoping to raise it to 5-6 per cent," explains Peter Sommer-Larsen.

The lower energy efficiency is more than offset by the fact that the polymer solar cells are expected to be radically cheaper and easier to manufacture than first-generation cells. "At manufacturing speeds of one-to-two square metres of polymer solar cells per second, it will be possible to produce just as many square metres of polymer solar cells in an hour as a traditional solar cell factory makes in a whole year," says Peter Sommer-Larsen, while also acknowledging that a lot of research is required before this goal has been reached.

Interplay with Danish industry

Within the next year or so, the research group, led by Frederik Krebs, expects to be able to produce large areas of polymer solar cells quickly and cheaply. Development is taking place in collaboration with a Danish printing house as a printing process is being used to manufacture the polymer solar cells.

Polymers for sustainable energy production. Cheap polymer solar cells. This offers excellent business potential for industry, with exports to large parts of the world

"Research into polymer solar cells is strategic research, where we interact with the outside world – in this case with Danish enterprises. The collaboration in the research phase is giving the companies involved an excellent foundation for developing polymer solar cells into a solid business," says Peter Sommer-Larsen.

"Moreover, we have excellent resources and equipment for conducting research into polymer solar cells as we have been researching materials and polymers for many years here at Risø," adds the Programme Manager.

Biodegradable biopolymers

Risø's polymer programme is also involved in the development of biopolymers, i.e. polymers developed from various biological raw materials. Biopolymers are also biodegradable – they can be composted. This research is, of course, not directly targeted at energy technology, but it ties in, in a big way, with sustainability and reducing greenhouse gases!

"The raw materials include polylactic acids made from maize. Moreover, a group led by David Plackett is researching the possibility of making polymer film from hemicellulose, which is a by-product from the refining of bioethanol from straw," says Peter Sommer-Larsen. Here too, Risø is collaborating with industry.

However, polymer solar cells are by far the biggest research initiative in the polymer programme – seventeen of the programme's

30 employees are working within this area. "It is a huge interdisciplinary task which requires expertise in physics, chemistry, process technology and business development. We are looking forward to taking the project to the next phase, so a polymer solar cell production line can be established, as I am convinced that the technology has the necessary potential," says Peter Sommer-Larsen.



The solar hat is the first time that polymer solar cells have been integrated into a product. Here, the sun charges a battery that powers a small radio. The production of 2,100 solar cells at a printing company is, among other things, an exercise in taking Risø's knowledge and realising it in practice out in the business sector.

The solar cell group expects a lot of the recently acquired Solar Coating Machine, which can produce solar cells in long rolls by means of the roll-to-roll process.

Three generations of solar cells

First-generation solar cells are manufactured from pure silicon crystals, so-called silicon wafers. These boast an energy efficiency of 20 per cent and last 20-30 years, but they are expensive and resource-demanding to produce.

Second-generation solar cells are produced from so-called amorphous silicon or other semiconductor materials. (In an amorphous material, the atoms are not arranged in a crystal structure, but are randomly organised as in a fluid. For example, ordinary glazing is an amorphous material).

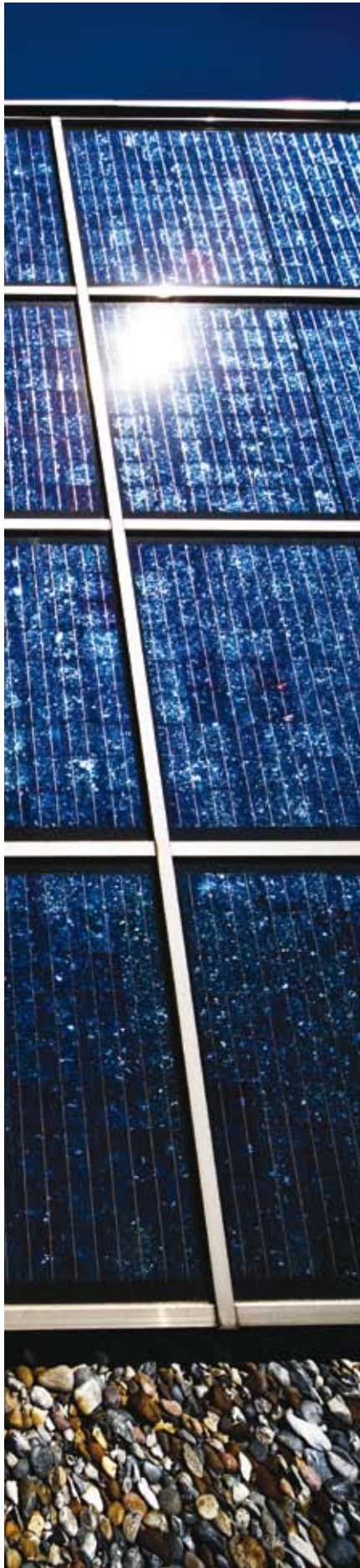
Second-generation solar cells have an energy efficiency of 8-10 per cent and can probably last for many years and are cheaper than the first-generation cells.

Third-generation solar cells cover other, newer types of solar cells, including Risø's polymer solar cells. They have a lower efficiency (2-5 per cent) than the first and second-generation cells, the best last for only a year or so, but it will be possible to produce them far more easily and cheaply.



Climate panel looks at renewable energy

The UN climate panel, IPCC, has just decided to prepare a special report on renewable energy. The report, which will be published in 2010, carries a high priority at Risø



By Morten Andersen
Research Journalist

When the UN's climate panel, IPCC (Intergovernmental Panel on Climate Change), published its fourth assessment report in 2007, it attracted considerable attention. At a meeting in Hungary in early April, the panel agreed to kick off the work on a fifth report, which will be published in 2013-2014. At the same time, it was decided to prepare a special report on renewable energy. This report, which will be published in 2010, will, among other things, look at how large volumes of renewable energy can be integrated into the present energy system.

"The special report will look at how quickly we can realistically expect to introduce the different types of renewable energy, and how we can do it in a way which is financially sensible and defensible in relation to the security of supply," explains Hans Larsen, Head of the Systems Analysis Department:

"It is possible to envisage a situation at the end of the century in which renewable energy dominates. However, it is not just the long time-frame that is interesting. We need to take a close look at how we are going to get there," says Hans Larsen, who participated at the meeting in Hungary.

CO₂ capture part of the package

Together with several other scientists at Risø, Hans Larsen has been contributing over the years to the IPCC reports, among other things as a member of the IPCC Bureau.

"There is no simple solution. We have to look

Globally, three central challenges to the energy systems of the future are emerging: They must strengthen the security of supply – also in the developing countries. They must ensure reduced emissions of greenhouse gasses to halt climate change. They must contribute to fighting poverty. Risø contributes to solving these chal-

at all the options. There is considerable and financially attractive potential in energy savings and higher efficiencies. Then, there is renewable energy efficiency improvements – but for many of the technologies it will take many years before they are ready to play a bigger role. Finally, the power plants can be made more efficient. This includes capturing CO₂ at the coal-fired plants and storing it underground. This might well be a necessary solution to ensure that CO₂ emissions top in 2020 and then start to fall," says Hans Larsen.

Long haul most important

The next couple of years will be an extremely busy time for the department's employees due to the coming Climate Summit in Copenhagen in December next year. For example, DTU's new climate technology programme is holding a number of international workshops. The first – about future energy systems – is being held on 19-20 November 2008 in connection with the publication of Risø Energy Report 7.

"We are working with two objectives. First, it's obvious that we need to produce new research results. However, if we can also help the technologies onto the market, then we have accomplished something which is even better," says the Head of Department, emphasising that the Copenhagen Summit is a step in the right direction:

"Recently, energy and climate have been attracting a lot of attention, but for us it has been an important issue for several years. We see the inevitable long haul in the coming years as being the most important."

lenges by conducting research into energy policies and energy systems with particular focus on environmental and climatic consequences. And Risø is contributing to developing and implementing new and efficient methods to strengthen the energy supply to poor areas in the developing countries.

Climate panel reports

The UN climate panel, IPCC, is organised into three working groups which each write a report on the scientific basis for the global future climate changes, the possibilities of adapting to the changes and the possibilities for influencing the changes respectively.

The three reports are normally published at about the same time, and together form the basis for the climate panel's synthesis report, of which so far four have been published – most recently in 2007. The fifth assessment report is, as mentioned above, expected to be published in 2013-2014. In addition, the IPCC regularly publishes reports on particularly important topics.



No energy without materials

Within the past couple of years, the Wind Energy Department has developed a design for a new trailing edge for wind turbine blades. Using compressed air, the trailing edge of the turbine blade can be moved up and down, making it possible to control the load on the blade. Through collaboration with the Materials Research Department, a manufacturing process has been developed, and the first prototype has confirmed the operating principle.

The Materials Research Department has developed the process technology, which DTU students have used to manufacture the super-light carbon fibre body for one of DTU's eco-cars. The body is designed as a self-supporting sandwich construction of very thin carbon fibre layers, and made by means of resin infusion technology. The picture shows one of the front wheel housings with the hole for the wheel. This hydrogen-powered car participated in the Shell Eco Marathon in the south of France in May 2008 and set a new Nordic record with a performance corresponding to 2,328 km per litre of petrol.

Effective materials are needed for sustainable energy production

By Pia Jørnø
Science Journalist

"Without materials – no energy." This is how Dorte Juul Jensen, Head of Risø's Materials Research Department, summarises the importance of materials in energy-producing technologies.

"To extract as much energy as possible from the wind, the sun, biomass etc., it is crucial to do research on materials. Take, for example, wind turbines. Their growth in size depends on materials," she says.

Strategic materials research within selected areas

The department optimises materials with a view to achieving the most efficient sustainable energy technologies. Optimisation involves using the most suitable yet at the same time cheapest possible materials. And developing the fastest and simplest processing procedures when energy components and plants have to be made from these materials.

The department has selected five focus areas (see box), which are all important for the further development of sustainable energy. "There is a lot happening in the area at the moment, and we need to keep our fingers

on the pulse. On the other hand, we cannot embrace everything. We have to devote considerable efforts to the selected focus areas in order to be at the forefront nationally and internationally," says Dorte Juul Jensen, adding that Risø has a long tradition of conducting strategic research within selected, relatively narrow areas.

"This type of research is well-suited for a national laboratory, where a main aim is to develop new applications, while a university department, for example, has to cover research more broadly for the sake of the education programmes."

Basic research important

At the same time, the department emphasises the importance of fundamental research. "This tradition goes right back to when Niels Bohr and others founded Risø. And it is still extremely important to combine basic research and technology; otherwise we cannot remain at the forefront of developments. We must have a 'bubble layer', where we explore new possibilities, some of which can be developed into completely new applications in say ten years' time," says Dorte Juul Jensen.

One of the department's five focus areas, superconducting materials for wind turbi-

nes, beautifully exemplifies this: "For many years, Risø has studied superconductivity, and we have several internationally recognised scientists in this area. Basic research within superconductivity is now paying off, as we are in the process of developing superconductors for wind turbine generators. The increasing size of turbines poses a problem because more and more of the gearboxes are failing – so a direct-driven generator with superconductors will be a big step forward," says Dorte Juul Jensen, who however doesn't expect to see superconducting generators on the market for at least another ten years.

The Materials Research Department's five focus areas

- Strong and lightweight materials for wind turbines
- Strong and lightweight materials for land, sea and air transport
- Materials for hydrogen systems and storage
- Superconducting materials for wind turbines
- Materials for fusion reactors

Risø's Radiation Research Department is a key part of Denmark's emergency preparedness against the spread of radioactive substances. Now, the cyclotron and research into radioactive pharmaceuticals at the Hevesy Laboratory is strengthening an already active research environment in radioecology and radiation physics

Tomorrow's radiation research

By Rolf Haugaard Nielsen
Science Journalist

Radiation was one of the very first fields of research to be established at Risø. Today, the Radiation Research Department is still a key part of Denmark's emergency preparedness in the event of an accident at a nuclear power plant in one of our neighbouring countries. Radioecological research gives scientists the possibility of describing how radioactive

A special day

Benny Majborn has worked at the Radiation Research Department since 1971. It was a notable day when, on 26 April 1986, scientists discovered the pollution from Chernobyl before the Russian authorities had informed the outside world about the catastrophe, and were able to quickly form an overview of the situation in Denmark. Another important task was carrying out a nationwide mapping of radon in homes and studying radon's penetration from the soil in the 1980s and 90s.



In the Hevesy Laboratory, Risø conducts research into biomedical trace substances and radioactive pharmaceuticals. The laboratory has a small production of these pharmaceuticals for Danish hospitals, in ad-

dition to which it also develops new pharmaceuticals. Concurrently with these activities, research into isotope production, new marking methods and radiopharmacy is conducted.

substances are spread by the wind and water and are absorbed in the biological systems. In a worst-case scenario, they can end up in our foods if an accident occurs at a nuclear power plant in a neighbouring country.

Together with DTU Nanotech, we are trying to smuggle the pharmaceutical into the tumours using liposomes, which are small hollow lipid balls," says Lars Martiny, who heads the Hevesy Laboratory.

Early diagnosis of Alzheimer's disease is a new area of research involving collaboration with GE Healthcare. Here, radioactive trace substances are coupled to a substance that attaches to the protein clumps that accumulate in the brain, even in the early stages of the disease. Clinical trials are being conducted at Rigshospitalet's Memory Disorders Research Unit in the autumn.

In recent years, the research has taken a completely new turn with the cyclotron at the Hevesy Laboratory manufacturing isotopes for hospital PET scanners and for medical research. "We have created an exciting milieu around the cyclotron, which also supports research into radiation physics and radioecology," says Benny Majborn, who has just stepped down as Head of Department after 37 years in the department.

Dosimetry with OSL

Risø has for many years been leading the way within research into dosimetry. For example, Risø has developed equipment based on Optically Stimulated Luminescence (OSL), which can be used for both dosimetry and dating. For medical applications, scientists work with very small dosimeters, which are placed at the end of optic fibres and inserted into the body. This makes it possible to follow the course of radiation treatment online, and verify that the optimum dose is being delivered to the tumour.

The isotopes are used particularly for cancer diagnosis. From a research point of view, focus is on radionuclide therapy where, instead of using harmless markers, hard-hitting isotopes are used, which are released directly into the tumour. "We are focusing especially on isotopes that release their entire radiation dose into the cancer cell with minimal damage of the surrounding tissue.

Measuring individual isotopes

In radioecological research, new methods are being developed for measuring radioactivity based on mass spectrometry (ICP-MS). "The sensitivity is markedly better than for radiometric methods, and we can distinguish between different isotopes of e.g. plutonium. This makes it easier to trace the source of, for example, pollution," says Benny Majborn. Another challenge is terror preparedness against dirty bombs. Here, scientists focus on models depicting the spread of radioactive substances via the atmosphere.

"However, establishing the Hevesy Laboratory has probably been the most important event during my time at the department," says Benny Majborn. "In doing that, we are living up to Risø's original objective - using nuclear physics discoveries for the benefit of society. The inauguration in 2005 was attended by thirteen members of the Hevesy family; even though they had been living abroad for many years, they felt a strong connection with Denmark. It was wonderful to witness their delight at the Hevesy name being linked to a laboratory at Risø which is continuing the work started by George Hevesy and Niels Bohr."



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50th anniversary



By Leif Sønnerberg Petersen
Senior Advisor, Risø DTU

Friday 6 June 2008 marked the 50th anniversary of Risø. This was celebrated on 4 June with Dr Haldor Topsøe, one of the founders of Risø, as one of the key speakers. He described why Denmark needed an institution like Risø. Back then, it was question of jumping on the bandwagon in the development of nuclear power for electricity production. Haldor Topsøe was, together with the Professors Niels Bohr, J.C. Jacobsen and Torkild Bjerge, a member of the Atomic Energy Commission, which was appointed in 1954. "With Risø, we wanted to create a place for nuclear research and for developing the technology to build nuclear power plants. However, Danish industry was unwilling to play a part," said Haldor Topsøe. Consequently, the nuclear power adventure ended more modestly, with producing fuel rods for reactors. "Risø was a fantastic gift to Danish society, but no one really wanted it. This was the start of Risø changing into a broadly based national laboratory. Risø became a hotel for innovation and new research. I believe Risø can look forward to a promising future, and industry will, to an ever increasing

On the occasion of its 50th anniversary, Risø has published a book with twelve accounts of Risø's history and activities, edited by Morten Jastrup: 'Energy for the future - with Risø from nuclear power to sustainable energy'. The book (in Danish) can be downloaded at risoe.dtu.dk. Printed copies of the book can be ordered by contacting Inga Hjerring on tel. +45 4677 4000 or at inga.hjerring@risoe.dk. An English version of the book will be available in the near future. The celebratory speeches were transmitted live and can be downloaded on demand at risoe.dtu.dk

extent, come to appreciate Risø as a valuable gift," concluded Haldor Topsøe.

Henrik Bindslev, Director of Risø, drew parallels between Risø's early days and the present situation. Back then, it was all about energy supplies. First nuclear power, then security of supply as a result of failing oil deliveries following the Yom Kippur war in 1973. Now Risø is a National Laboratory for Sustainable Energy, focusing on the challenge of creating tomorrow's sustainable energy systems.

Rector of DTU, Lars Pallesen, hailed Risø's successes: "No other Danish research institution has been managed as well as Risø. It is a pleasure to see a line-up of former directors here today, who can all be proud of their efforts." And Rector could announce that Henrik Bindslev is now no longer just acting director, but can add his name to the list of full directors. "The merger now enables Risø to strengthen its profile even further and to specialise its activities in the interests of society. Risø must always play a central role, and DTU, a large technical university, will provide an additional platform for Risø to become even better," said Lars Pallesen.

Jørgen M. Clausen, Danfoss A/S, was the last Chairman of Risø's Board of Governors before the merger with DTU in 2007. He remembered his first board meeting: "I was telephoned and asked to show up an hour earlier than planned. The reason was an analysis from FORCE Technology which showed initial signs of corrosion in the reactor. My first decision as Chairman of the Board was therefore to shut down the reactor," said Jørgen M. Clausen, and continued: "Risø will now help to develop bil-

Risø's Niels Bohr Auditorium was filled to capacity when Risø's 50th anniversary was celebrated on 4 June.

lion-kroner mass-production industries within sustainable industry. Risø has done it with wind energy, and can also do it in other areas. We are heading for a new energy revolution, where the challenge will be to provide energy to 8 billion people in a new and sustainable way; new technology will be the foundation. Risø must be involved."

Centre, Haldor Topsøe, one of Risø's founding fathers. Right, Jørgen M. Clausen, President and CEO of Danfoss A/S and the last Chairman of Risø's Board of Governors before the merger with DTU. Left, Director of Risø, Henrik Bindslev.



CO₂ emissions must be reduced – DTU is finding the solutions

The world community only has a short time in which to tackle the climate problems –



DTU is taking up the challenge

By Leif Sønderberg Petersen
Senior Advisor, Risø DTU

In its fourth assessment report, the UN's climate panel gave the world community only 10-20 years to ensure that CO₂ emissions will peak. This will take fast and effective solutions. Consequently, DTU has gathered Danish and international resources in a large-scale research programme called DTU Climate Change Technologies. The initiative will lead to concrete partnerships between universities, businesses and the authorities to accelerate the use of efficient energy technologies and energy systems so we quickly find ways of reducing CO₂ emissions.

DTU Climate Change Technologies strengthens the foundation for developing and implementing climate technology solutions. Solutions which on the one hand can reduce CO₂ emissions and on the other ensure society's production and welfare under changed climatic conditions.

Workshops and conferences

Through a series of workshops and conferences, DTU is focusing on climate and energy technologies that either exist or which can be developed and quickly implemented. The

workshops and conferences must foster and strengthen collaboration between universities, businesses and the authorities and lead to specific development projects and partnerships.

In all, eight workshops, two scientific conferences and a concluding high-level conference will be held between June 2008 and September 2009. The subjects for the workshops and conferences are different energy technologies, climate adaptation and technologies for climate monitoring in Greenland. Each workshop will produce two-to-four recommendations in a brief report. At a final conference in September 2009, the recommendations will be summarised and put into perspective. Each workshop must outline strategies and partnerships for research institutions, private businesses and public administrations. In the workshop series, recommendations will be developed as to how research, business as well as regulation and administration can be coordinated to create greater innovation power and market progress than is possible for the individual players on their own.

Read more about DTU Climate Change Technologies at www.dtu.dk/klima.

Workshops, conferences and reports under the auspices of Risø

Event	Title	Date	Venue	Responsible
Workshop	Future energy systems	19-20 November 2008	DTU Lyngby	Head of Department Hans Larsen, Risø DTU
Risø Energy Report 7	Future low-carbon energy systems	19 November 2008	DTU Lyngby The report provides input for the Future energy systems workshop and will be published at the workshop	Head of Department Hans Larsen and Senior Advisor Leif Sønderberg Petersen, Risø DTU
Workshop	Sustainable energies	14-15 January 2009	DTU Lyngby	Director Henrik Bindlev, Risø DTU
Workshop	Transportation - sustainable energy in the transport sector and planning	17-18 March 2009	DTU Lyngby	Head of Department Hans Larsen, Risø DTU
Science conference	Risø International Energy Conference 2009	14-16 September 2009	Risø DTU	Head of Department Hans Larsen, Risø DTU



In the autumn semester 2008, Risø is offering three courses that focus on sustainable energy. At the same time, a new business-oriented elite study programme on fuel cells and hydrogen is starting up

Risø welcomes students

By Marianne Ryde
Communications Officer, Risø DTU

A bright and open student environment is currently taking shape in connection with Risø's Information Service Department. In September, the doors will open to 15-25 students, about half of whom are from abroad. They will be transported to Risø in buses to participate in three courses which will constitute the first part of the MSc programme on sustainable energy which Risø is offering in collaboration with several departments at DTU Lyngby.

- **Energy resources, markets and policies**

Starting from economic theories, this course gives students a basic understanding of the challenges faced by the energy sector, both in Denmark and internationally. Students will be given an introduction to the market conditions, financial and political terms on which energy production takes place. Course manager, Senior Scientist Stine Grenaa Jensen says:

"We aim to show the students how markets and public regulations influence our energy system. They need to understand that it is not sufficient to focus solely on optimisation of technical operation to improve the system."

- **Modelling and analysis of sustainable energy systems**

In future, energy will come from several different sources, including renewable energy, which by nature varies considerably in terms of output. Therefore, it is necessary to design the energy systems carefully to ensure a stable flow where both operating

economy, fuel consumption and emissions are under control. On this course, which will be run by Senior Scientist Peter Meibom, students learn about the mathematic formulas used to calculate such models, and they will be expected to set up small energy system models themselves.

"Students must learn to understand the connection between different parts of the energy systems and how it is possible to set up and implement mathematical models in this respect," says Peter Meibom.

- **Sustainability assessment of energy conversion and use**

The third course involves energy resources and technologies and their impact on the environment - focusing on bioenergy. Students will learn about different sustainability concepts and methods for analysing environmental impacts. And they will consider both the social, agricultural and climatic aspects of different energy sources.

"Students will use the methods in a three-week project of their own choice which might, for example, be entitled: 'What is the most effective application for biomass in the Danish energy system from a financial, environmental and energy-efficiency point of view?' Or: 'Conduct a life-cycle analysis of different fuels for transport'," says Professor Hanne Østergård, who is responsible for the course.

- **Elite study programme in fuel cells and hydrogen**

From autumn 2009, three new elite study programmes are starting at DTU. One of them, Fuel Cells and Hydrogen, will take place at Risø with Topsoe Fuel Cell as an industrial partner.

The elite study programme is a tailor-made two-year programme where keen students with average marks of at least 10 in their BSc exam can go further than is normally possible in the course of an MSc programme.

The elite study programme Fuel Cells and Hydrogen is being offered in collaboration with the physics and chemistry lines of specialisation, and consists of advanced academic courses and a Final project lasting almost a full year (50 ECTS points), and which is written in collaboration with Topsoe Fuel Cell.

"Elite study programmes can either be traditional academic programmes or business-oriented programmes. Risø opted for the latter, because we already work closely with Topsøe, and business partnerships are one of Risø's fortes," says Head of Programme Luise Theil Kuhn.

The elite study programme also includes a study trip abroad, for example to an international summer school or conference. Furthermore, students are also allocated a tutor who follows their studies closely, assisting with individual study plans.

RisøNews brings news about research, technology, innovation and educational activities at Risø DTU. The magazine is published twice a year and is sent to public authorities, businesses, the media, educational institutions, libraries, Risø staff etc.

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Technical University of Denmark
Frederiksborgvej 399
PO Box 49, DK-4000 Roskilde

Telephone +45 46 77 46 77 (main no.)
+45 46 77 40 21 (editorial)

Email risoe@risoe.dk

Fax +45 46 77 40 13

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