Technical University of Denmark

Sustainable energy research at DTU

Energy systems integration for the transition to non-fossil energy systems

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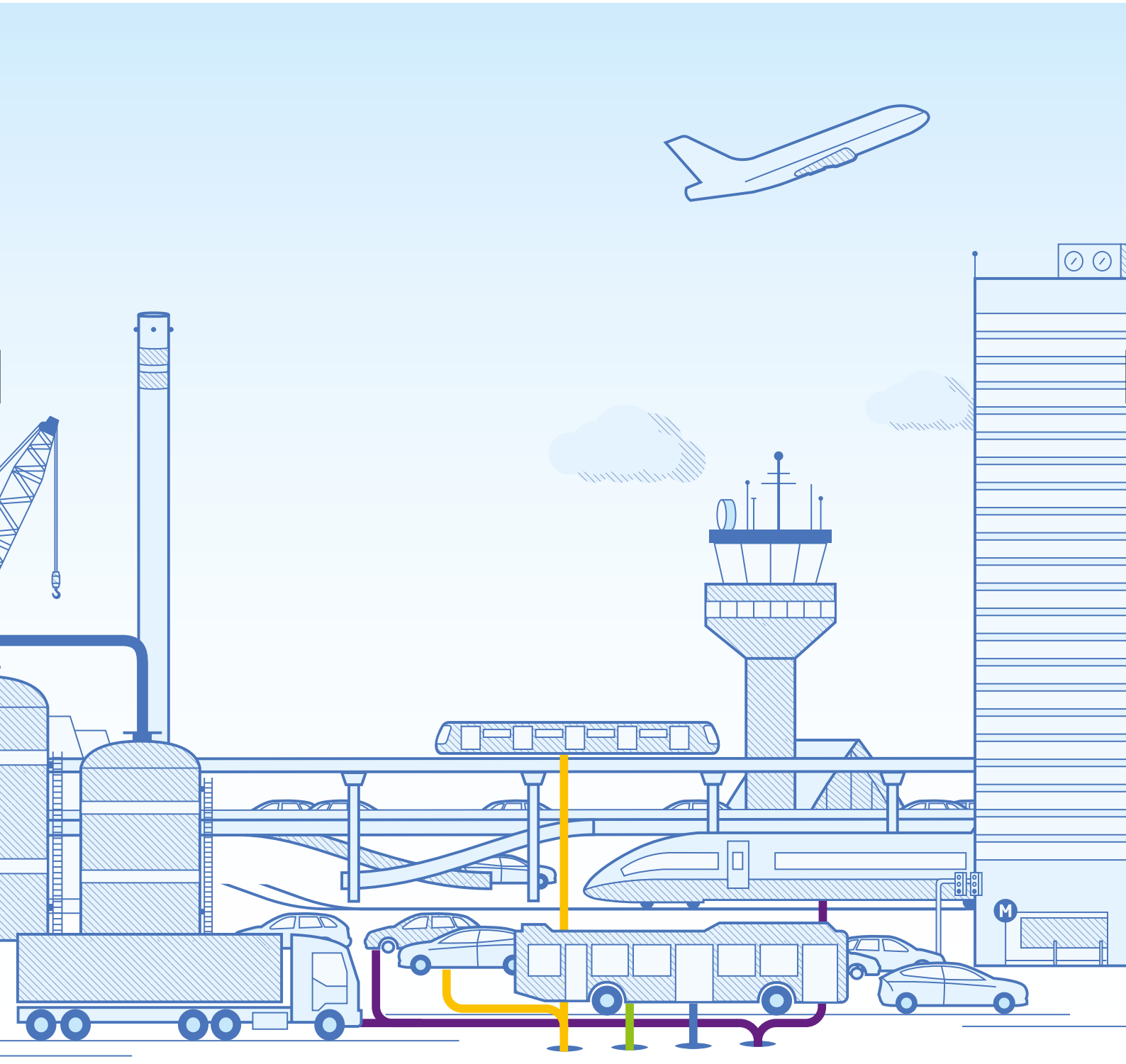
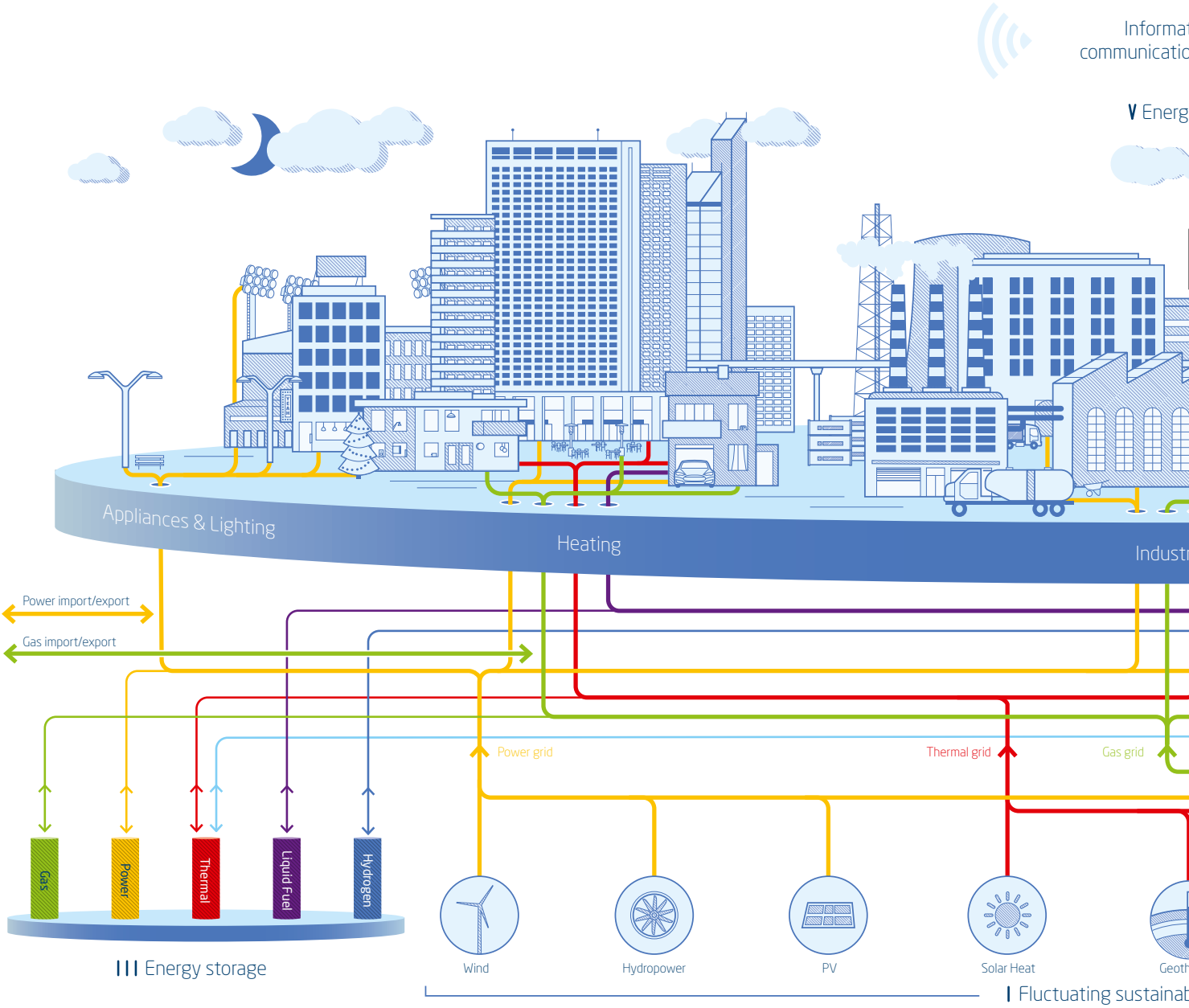


Energy systems integration for the transition to non-fossil energy systems

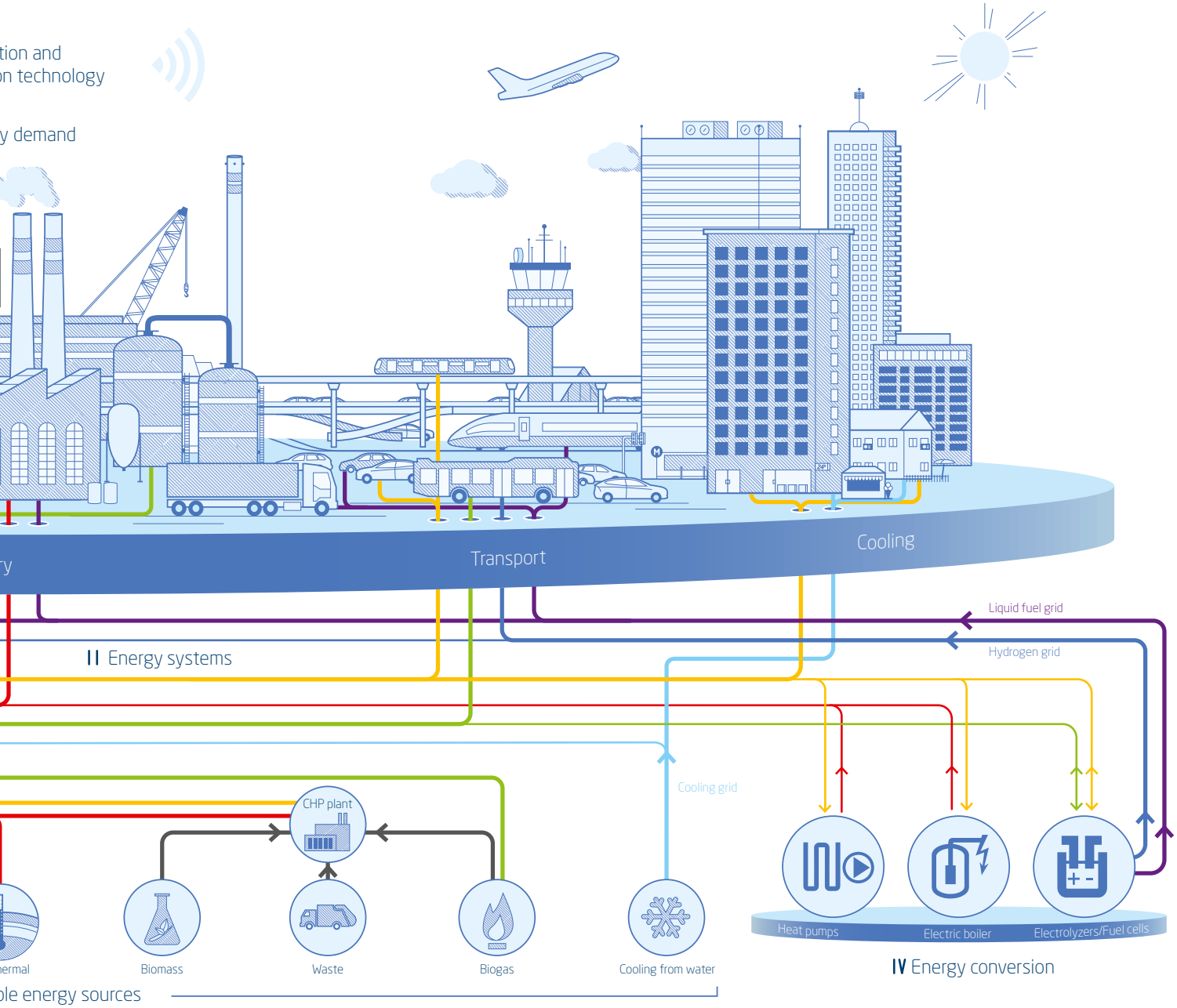


In the coming years, Denmark and other countries worldwide are set to increase their focus on transforming their energy supplies towards more sustainablew technologies. As part of this process, they can make extensive use of the knowledge generated by the Technical University of Denmark (DTU). The university is in the international vanguard of knowledge and research in the field of sustainable energy.

With as many as 1,000 employees spread across a large number of departments, the university possesses extensive expertise on a wide range of energy technologies and energy systems. Research is carried out in close cooperation with internationally leading institutions and experts.

Based on a wealth of core competencies, DTU takes a broad and holistic approach to energy research within both energy supply and consumption. Against this background, DTU identifies, presents and discusses new energy technologies, energy systems and energy consumption in buildings, the transport sector and for lighting purposes. The university also looks at challenges, opportunities and limitations.

This publication present a selection of the sustainable energy-related activities at DTU, which all point towards future sustainable energy systems where security of supply, climate concerns and new green economic growth go hand in hand.



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The great transformation

It is by now almost universally accepted that energy technology innovation is central to meeting climate change challenges while also supporting economic and energy security objectives. However, in the publication Energy Technology Perspectives 2015, the IEA Executive Director Maria van der Hoeven concludes that "the current pace of action is falling short of the aim of limiting climate change to a global temperature rise of 2° C". Hence, research, development and the demonstration of new sustainable energy technologies and systems are of paramount importance and urgency.

I strongly believe that addressing these issues will involve a massive increase in the utilization of sustainable energy like wind, solar and biomass. This transformation will not take place overnight, but take decades. For this reason, we must give high priority to efficiency improvements in the use of fossil fuels and in the end-use sector.

The EU has set specific targets for the development of renewable energy, and the Danish Parliament has adopted an energy plan with the goal that by 2050 all Danish energy consumption is supplied by sustainable energy technologies. Fortunately, the transformation does not conflict with the need for economic growth. On the contrary, it creates jobs because of the significant potential for producing and exporting sustainable energy technologies.

Denmark possesses considerable expertise within the field of sustainable energy technologies and systems. Much of this expertise is found at DTU, where approximately 1,000 staff members from many departments are conducting research into sustainable energy.

For DTU, it is very important that this research takes place in close cooperation with internationally leading institutions and experts. Furthermore, the DTU National Laboratory for Sustainable Energy is working to foster interdepartmental cooperation and synergies. The laboratory also aims to strengthen DTU's participation in international alliances and forums in the energy area. In other words, DTU is highly geared to providing the community with expert knowledge on how to launch the necessary green transformation.

Anders Bjarklev,
President

A world of knowledge about sustainable energy

DTU is in the international top league when it comes to knowledge about and research into sustainable energy, with specialists in sustainable energy technologies, energy systems as well as in the conversion and storage of energy. To this can be added expertise in policy analyses and recommendations, impact assessments and capacity buildin DTU therefore places considerable emphasis on taking a holistic view of the energy system. Installing an individual solar heating system on a building that is well-insulated and supplied with district heating may not necessarily be a good idea. And if a house-owner refrains from insulating his house properly because he has installed solar cells on the roof, the solution will not be optimal either. If we are to solve the great challenges we are facin g, it is not sufficient to undertake research in new energy technologies. It is equally important to improve energy efficiency on a broad front.

Overall, DTU possesses the core competencies and breadth of knowledge and engages in holistic thinking in energy research. Against this background, DTU is working to identify, present and discuss new energy technologies and systems as well as pointing out challenges, possibilities and limitations in this regard. Finally, I would like to stress that it is of paramount importance for DTU that our research is carried out in close collaboration with the best research teams in Europe and worldwide.

Hans Hvidtfeldt Larsen
Vice Dean, Head of DTU National Laboratory for Sustainable Energy

DTU news search: Energy production Solar energy

An uplifting story about plastic solar cells

An uplifting story about plastic solar cells Researchers at DTU catch the sunlight in solar cells made from ultra-thin layers of plastic which convert the light energy into power. The vision is to carry out mass production of vast quantities of plastic solar cells so efficiently that solar cells will contribute substantially to meeting the world's energy demand.

Plastic solar cells do not convert as much sunlight into electricity as conventional silicon-based solar cells. However, the production of plastic solar cells requires much less energy than the production of silicon cells. Moreover, the manufacturing process is faster and cheaper. The technology is commercially available today but costs have to be reduced even further to compete with the precipitous drop in the cost of silicon-based PV. Another big hurdle is durability.

Today's plastic solar cells only last for a couple of years. This means that it should either be easy and fast to replace them, and/or their durability must be increased. DTU is addressing both issues. The goal is to develop polymer cells that can last for ten years.

While attempting to increase durability, DTU researchers are also working to improve efficiency. Silicon cells convert 15–20 per cent of solar energy into electricity whereas polymer cells only have an effect of 2 per cent. The goal is to achieve 10 per cent for OPVs.

Partner: Mekoprint

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The mass production of vast quantities of plastic solar cells can contribute substantially to meeting world energy demands. ***Photo:*** DTU.

DTU news search: Physics Catalysis Solar energy Computer calculations Data analysis

Stepping up the hunt for materials to harvest solar energy

An intense hunt is underway for materials which have the capacity to transform sunlight into fuels.

The volume of material is overwhelming, so researchers need reliable methods to speed up their progress in the search. Researchers at DTU have now established such a method. Working with a database containing 2,400 materials whose crystal structures were known, the researchers found 25 interesting candidates, and closer analysis revealed that five of these could potentially be used to harvest solar energy.

Partners: MIT, Lawrence Berkeley National Laboratory

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Photocatalytic cells convert sunlight directly into hydrogen.
Photo: Torben Nielsen.

DTU news search: Energy production Energy storage Solar energy

Photocatalysis turns sunlight into hydrogen

Researchers at DTU are developing photocatalytic cells that convert sunlight directly into hydrogen. In such a device sunlight splits water into oxygen, protons, and electrons. The protons and electrons migrate across a membrane and recombine to form hydrogen atoms, while the oxygen is released from the cell.

Photocatalytic devices have been built in laboratories around the world, but the scientists still face tough challenges. The cells must be efficient with a solar-to-hydrogen efficiency between 5–15 % and they must also be cheap and robust.

The researchers improve the efficiency using their expertise in surface and interface science. One promising strategy is 2-photon devices, where the water-splitting electrode contains two layers, which absorb different wavelengths of the solar spectrum in order to boost the solar-to-hydrogen efficiency.

Project: Center for Individual Nanoparticle Functionality (CINF) is a centre of excellence for basic research funded by The Danish National Research Foundation.

Partners: Haldor Topsøe A/S, Caltech University, École polytechnique fédérale de Lausanne (EPFL).

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DTU news search: Solar energy

The Economics of Large-scale Solar Power

When you introduce a new energy source, such as Concentrated Solar Power (CSP) plants, you need to consider the consequences for the entire energy system. A simple return on investment (ROI) calculation will say that CSP is too costly at the moment. However, the technology should be seen in a broader perspective. The two leading renewable power supply technologies, wind power and traditional solar cell units, are both characterized by relatively large fluctuations. This makes CSP an attractive addition. The current facilities already have some storage capacity, allowing energy production from daytime to be used during the night. The HYSOL project looks at hybrid systems, in which this flexibility is enhanced further through biogas-driven turbines. HYSOL presents a range of possibilities for introducing CSP in various scenarios in a manner which makes the technology economically viable.

Project: HYSOL project (HYbrid SOLar) under the 7th EU framework program.

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DTU news search: Solar energy Computer calculations

Predict solar resources

DTU researchers have developed the necessary tools for forecasting the output from PV systems on an hour-to-hour basis a few days in advance.

In Denmark, the operator community is known as "Sol 300" because their facilities have sprung from a policy decision a few years ago to establish 300 PV systems. Since then, many private households have also invested in PV systems during a period when a beneficial government subsidy scheme was in place. These developments have increased solar power generation in Denmark to 1.5 per cent of total power generation.

During the summer, production can rise as high as 3.7 per cent. This is still a small enough share for power system operators to manage using current back-up reserves. However, as the installed capacity is increasing, it will very soon become vital to forecast solar power.

Typically, solar power generation is high during the summer, while wind generation is high during the autumn and winter, which makes it desirable to mix the two sources. However, forecasting will be crucial. DTU Wind and DMI are developing complex meteorological forecasting models, as well as a component which translates the weather forecasts in a way that predicts the future output from a given solar power system.

1.5%

Share of solar power of Denmark's total power generation.

During the summer, production can rise as high as

3.7%

The simplicity of the algorithms is a considerable asset. While it takes up to four hours of computer time to run the calculations for the entire meteorological model, it will only take seconds to obtain the solar output results. This makes the solutions highly operational.

Partners: DMI, PV system owners.

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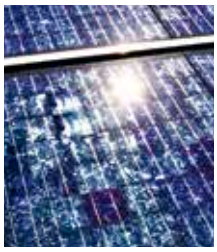
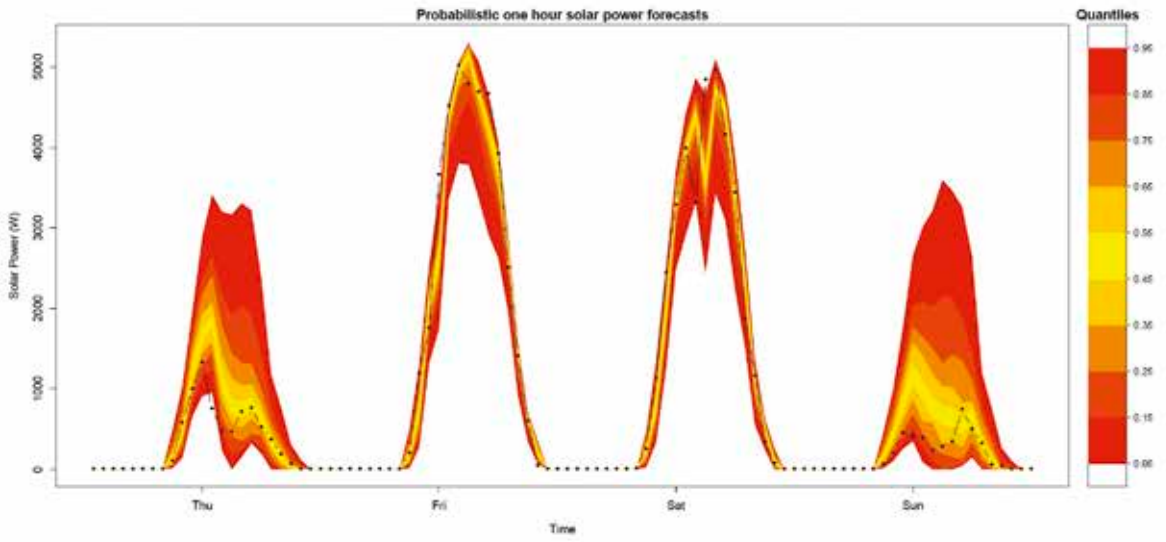


DTU researchers have developed the necessary tools for forecasting the output from PV systems.
Photo: Torben Nielsen.
Graph: Peder Bacher.



DTU news search: Energy Electrochemistry Energy production Energy storage Solar energy Physics Catalysis Micro and nanotechnology

On the way to an artificial leaf

The process of using light, water and air to create fuel is also called artificial photosynthesis because it mimics the method which plants use to convert energy from sunlight into sugar, the plants' fuel. The researchers utilize a "tandem design" in which the combined energy of two visible photons (light energy particles) provides the energy needed for water splitting. The water splitting process proceeds faster with the tandem design.

The challenge of making a tandem structure is that it comprises two different materials that have to be in close contact. This can only be done if the distance from atom to atom in both materials is the same. Otherwise it will be difficult to make the two structures connect. It corresponds to assembling LEGO bricks from two different manufacturers. If the distance between the studs on the two types of bricks is different, you cannot press them together.
It has been found that silicon, which has been used for water splitting for many years, and the composite material gallium nitride phosphide (GaPN) can be used. The two materials are thus well suited for merging in a tandem structure. The main research activity of the project is to optimize the production process for GaPN on silicon. This could be the route to an artificial leaf with a rather high efficiency.

Sponsor: The Danish Council for Independent Research (DFF) has granted funding of DKK 2.5m to the project.

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DTU's Høvsøre Test Site. ***Photo:*** DTU.

DTU news search: Wind energy

Test centres for large wind turbines

DTU operates three wind turbine test sites in Denmark: DTU Risø Campus, Høvsøre Test Site for Large Wind Turbines at Lemvig, and Test Centre Østerild at Thisted. The test centres' locations and facilities allow the wind turbine industry to carry out R&D and tests of prototype wind turbines and new wind turbine technology. All the test stands at Østerild have been rented out to EDF Enérgies Nouvelles, Vestas Wind Systems A/S, Siemens Wind Power and Envision Energy.

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DTU news search: Wind energy

Faster production of long high-quality offshore wind turbine blades

The cost level of offshore wind must be reduced further in order to compete with other energy sources. A new project – OptiMadeBlade – aims to optimize the production of blades in order to save several million euros on the price of an offshore wind farm.

The blades make up approximately 10 per cent of the cost of an average offshore wind turbine. A large part of the costs are related to materials and manufacturing. By leaving established principles of blade production and optimize the manufacturing process, a new project aims to develop methods that will result in the faster production of long offshore wind turbine blades.

The new concept involves a sophisticated and streamlined production process that will optimize the cycle time of production and help to keep costs down. At the same time, the method will help to ensure that the blades are manufactured to a high quality.

Partners: LM Wind Power A/S, Fiberline Composites A/S, Eltronic A/S, Aalborg University.

Sponsor: Innovation Fund Denmark (15m DKK).

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DTU news search: Wind energy

Wind energy is competitive

A number of technological advances have paved the way for wind power—an industry which currently employs more than 800,000 people worldwide. The advances include larger wind turbines, lighter materials and far more efficient wind turbines. This means that wind energy generated in areas with good wind conditions, e.g. coastal areas, can now compete with fossil fuel-based energy. In DTU International Energy Report 2014—Wind Energy, DTU points out that there are a number of barriers to wind energy that must be overcome for Denmark to meet its target of 50 per cent wind energy by 2050.

The report also recommends that the authorities focus more on setting up stable framework conditions for the sector to achieve a sufficiently higher share of wind energy: "Adapting our energy systems to accommodate large volumes of fluctuating wind power remains a challenge. It may be necessary to store electricity on a large scale if we are to achieve the target," says Vice Dean Hans Hvidtfeldt Larsen, from DTU National Laboratory for Sustainable Energy.

In addition, the electricity generated by offshore wind turbines must be made cheaper, as this holds the largest growth potential. Producers are well on the way to reducing costs by 40 per cent by 2020, but—according to the report—the industry must also work towards the mass production of wind turbines and increased recycling of end-of-life wind turbines. Highly skilled employees in the wind turbine industry are in short supply, so targeted initiatives are required within the fields of education and research.

Report: DTU International Energy Report 2014: Wind Energy—drivers and barriers for higher shares of wind in the global power generation mix.

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It is vital that the foundations of offshore wind turbines can withstand extreme waves. ***Photo:*** Torben Nielsen.

DTU news search: Wind energy
Computer calculations

Extreme waves and offshore wind turbines

Extreme waves occur during storms, and offshore wind turbines are required to withstand "the 50-year wave", which is the largest wave which statistically occurs only once in the course of 50 years. In the new DeRisk project, it is the loads—that is, how much force the foundations must be able to handle that is in focus. Over the past fifteen years, a number of advanced calculation models for waves have been developed at DTU and DHI. It has attracted considerable attention internationally, and led to good contacts in research and between players in the offshore wind industry. In DeRisk, the next step involves combining the models into a rational design approach that can be utilized in the practical design process. This is achieved through GPU-enabled wave computations, physical model tests and advanced load models for the wind turbine structures. DeRisk lasts for four years and involves nine partners.

Partners: DTU Wind Energy, DTU Mechanical Engineering, DTU Compute, DHI, University of Oxford, University of Stavanger, DONG Energy, Statkraft and Statoil.

Sponsor: Innovation Fund Denmark (DKK 20m).

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DTU news search: Wind energy

WindScanner infrastructures for Europe

Wind energy researchers and businesses across Europe will soon be able to use a new experimental research infrastructure for wind scanning, WindScanner.eu. "Users will tell us which wind turbines and turbulence aspects they are interested in, and the WindScanner.eu consortium will then assist researchers and industry in designing optimal scan patterns and field tests accordingly," explains Torben Mikkelsen, Professor at DTU Wind Energy, adding: "This way, users from research institutions, universities and the wind industry are relieved of quite a lot of the previous work with tall mast installations, and can focus their efforts on the scientific and technological aspects of the wind conditions."

The institute's researchers have developed two sets of space and time coordinated laser-based wind scanners, each set consisting of three synchronized scanners which are able to remotely measure wind speeds and directions in huge volumes of airflow. When data from three scanners are combined, the investigators will obtain 2D scanned maps of the three wind components. In 2009, a grant from the Danish National Research Council allowed DTU Wind Energy to establish a national infrastructure, WindScanner.dk. The facility allows for the experimental evaluation of hypotheses and numerical modelling of natural wind and turbulence properties in the atmospheric boundary layer where wind turbines operate.

Currently, a preparatory phase project under the EU's Seventh Framework Programme (FP7) led by DTU Wind Energy is envisioned to make the infrastructure available to researchers and companies across the continent. The project was admitted to the European Strategy Forum on Research Infrastructures (ESFRI) Road Map 2010 to be developed into a joint European renewable energy research infrastructure. Nine research institutions from seven European countries are taking part in the project consortium. The plan is to launch WindScanner.eu in spring 2016. The facility already has several showcases, e.g. a joint project with the innovative French company Nenuphar on horizontal axis wind turbines for deep-water floating offshore parks.

The WindScanner.eu e-Science Platform will comprise a collection of web-based tools accessible for the scientific community and represent a single point of entry for users where they can acquire necessary knowledge about the technology, have a chance to run it, use the acquired measurements and other data, and communicate and collaborate with peers. The WindScanner Central Hub will be responsible for its development and implementation.

Partners: Eight European energy research institutions from Norway, Germany, Spain, Holland, Greece, and Portugal.

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DTU has developed laser-based wind scanners which are able to remotely measure wind speed and directions.
Photo: Torben Nielsen.

Removing barriers for the production of biogas

The Danish Government's energy plan includes a fourfold increase in the production of biogas. DTU's research project BioChain provides tools that contribute to achieving this target. Bioenergy production and the reduction of greenhouse gases depend on the composition of the biomass and its handling from agricultural, household and industrial sources to biogas production. The project identifies barriers to production, and proposes actions to remove these obstacles. All stages are analysed—from biomass production and harvest, transport, pre-treatment, biogas production, transport, energy conversion, and the end-use of residues.

Partners: University of Southern Denmark, Uni-versity of Copenhagen, Aarhus University, SEGES P/S.

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DTU news search: Bioenergy Energy production

An innovative and technical approach to biorefineries

The extraction of high-value compounds from seaweed or agricultural waste products is an important part of the novel biorefinery concept. ***Photo:*** Colourbox.

Biorefineries can convert low-value biomasses into liquid fuels, fuel pellets, biogas, fodder, fertilizers, food ingredients, and in-demand high-value chemicals, while generating very little waste. Biorefining is a sustainable technology, providing the feedstock biomasses are agricultural waste products such as straw, stalks, potato pulp, sugarcane bagasse or empty fruit bunches. In the refinery, the biomass is broken down by enzymes into its monomeric constituents for fermentation or—as a new strategy—into defined structural elements that can be used directly after separation.

DTU focuses on the enzymatic conversion and separation steps, and addresses novel processes for biorefineries in both laboratory experiments and in a pilot plant facility capable of processing kilogrammes of biomass. One example of a tough technical challenge is the silica content of straw, which is increasingly used for biorefining. Silica is problematic in industrial processes as it deposits on filters and blocks process equipment, often causing system failure. In particular, the silica content is high in rice straw, which is the biggest agricultural waste product on Earth.

In collaboration with industrial partners, the researchers are investigating how to remove silica from biomass feedstocks. Traditionally, much of the research has focused on wheat straw, which is used in Denmark to produce bioethanol. However, in recent years several new possible resources have been studied.

One example is seaweed, which is easy to break down into its constituents. Seaweed is interesting because the macro algae are rich in hydrocolloids which are used to substitute fats in food. The extraction of such high-value compounds from seaweed or agricultural waste products is an important part of the novel biorefinery concept.

Project: Biomass for the 21st Century.

Partners: University of Copenhagen, A.P. Moller Maersk, DONG Energy, Haldor Topsoe, MAN Diesel & Turbo, Novozymes.

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DTU news search: Bioenergy Energy production

Biomass-to-energy takes clever combustion

One of the challenges in the combustion of straw and wood is to prevent the formation of corrosive ash deposits in the process equipment. Optimizing the conversion processes requires knowledge of a range of sub-processes, from shredding methods, firing, heating, pyrolysis, the evaporation and condensation of salts and other inorganic and potentially corrosive compounds to the formation and reduction of harmful compounds. DTU keeps expanding the fundamental understanding of the high-temperature processes in order to be able to apply the knowledge industrially. The formation of nitrogen oxides (NO_x) is an example. Many of the sub-processes that lead to the creation of NO_x remain the same whether you burn natural gas, coal, oil, biomass or waste. Further, the creation of NO_x is independent of the process, which can vary from large burners in power or cement processes to medium-size equipment such as industrial or marine boilers to small-scale wood stoves.

Partners: FLSmidth, Babcock & Wilcox Vølund, DONG Energy, B&W Energy, HWAM, Rockwool, and Haldor Topsoe.

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DTU news search: Bioenergy

Enzymes for second-generation bio-fuels

In Denmark, Novozymes is the leading expert when it comes to selecting the most suitable enzymes for turning straw and other agricultural and forestry waste materials into liquid energy sources. DTU researchers then try to understand how this enzyme works in order to suggest optimization, either through modifications of the enzyme itself or the process. Also, the researchers look at other enzymes which might assist in the process. Pre-treatment tests can be performed at a DTU's Risø campus. Currently, DTU is involved in a large joint industry project, Biomass for the 21st Century. Here, one of the objectives is to investigate processes that convert lignin into a liquid substance which resembles crude oil. The product might replace bunker oil for container ships. Besides the advantage of being renewable, the product is also environmentally benign due to its low sulphur content.

Partners: A.P. Moller Maersk, DONG Energy, Haldor Topsoe, MAN Diesel & Turbo, Novozymes, and the University of Copenhagen.

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Pre-treatment tests on enzymes at DTU.
Photo: Torben Nielsen.

DTU Chemical Engineering has test facilities for the very small-scale analysis of a few milligrams in the laboratory to full-scale work on several tonnes of material. ***Photo:*** Torben Nielsen.

DTU news search: Bioenergy Fuel cells

More fuel from same amount of biomass

Project SYNFUEL combines electrolysis with biomass gasification in order to produce more biofuels from the same quantity of biomass. Biomass is converted by gasification. This produces syngas, which can be further converted to methane or liquid fuel for use in the transport sector. If hydrogen is added to syngas, the amount of methane or biofuel could be significantly increased. In the project, DTU conducts research into making electrolysis cells stronger, and into boosting the production capacity of each cell, so the process can become more efficient and profitable.

Partners: Aalborg University, Chalmers University of Technology (Sweden), Massachusetts Institute of Technology (MIT), Northwestern University (USA), Chinese Academy of Science, TU Berlin (Germany) and the University of Lyon (France), Haldor Topsoe, AVL, DONG Energy, and Energinet.dk.

Sponsor: Innovation Fund Denmark (DKK 17m).

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DTU news search: Wind energy Systems analysis Mathematical analysis

Easier to connect cables between wind turbines

Offshore wind turbines are connected to each other by cables. The cables can be connected in a myriad of ways, and to optimize the planning process, DONG Energy entered into collaboration with DTU to develop a tool which functions as an add-on program to Excel and saves DONG a lot of time. In a matter of just a few hours, it is possible to determine the most suitable connection.

Partners: DONG Energy.

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Algae biorefineries convert wastewater into biofuels and high-value chemicals

Wastewater can serve as a nutrient source for micro algae that can be used to produce liquid biofuels, biogas, and fertilizers. Researchers at DTU are developing methods to extract high-value chemicals from the algae before they are used to produce biofuels. These chemicals can then be used to produce pharmaceuticals, cosmetics, pigments, and bioplastics. To make algae biorefineries economically viable, it is crucial to match each wastewater stream with the right algae. At DTU, the first matchmaking is carried out by microtiter screening, in which many algae species are tested against wastewater from a particular stream. Thereafter, the microplate screening results are validated in larger laboratory experiments. The researchers are also involved in the operation of a pilot plant photobioreactor that maximizes the amount of sunlight the algae receive and hence their growth.

Project: Cooperation with the Municipality of Kalundborg and Novozymes.

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Laboratory-scale photo bioreactor.
Photo: Torben Nielsen.

DTU news search: Wind energy

Giant wind turbines in Østerild a tourist attraction

Giant wind turbines in Østerild are a tourist attraction.
Photo: DTU.

Since the opening of the National Test Centre for Wind Turbines in Østerild in autumn 2012, the area has developed into a real tourist attraction. The highest wind turbine is a Vestas 8 MW turbine, which rises 222 metres from the ground to the blade tip in the top position.

There are many visitors on both weekdays and at weekends, and the huge turbines fascinate them. A visitor centre, where visitors can learn more about wind turbines and wind energy, opens in 2016.

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DTU news search: Ships and offshore constructions Wind energy

Mobile robots to turn giant wind turbines into profitable energy source of the future

Within a few years, the cast-iron structures which bear the components of large offshore wind turbines will grow dramatically in size and weight. This will make it impossible to bring the elements into the processing machines. A new project, InnoMill, will develop mobile robot processing units, which can easily be placed on the components themselves. As a result, production will be more flexible and cheaper, and thus cut a good chunk of the production costs. This can be achieved without compromising the high precision required by the wind turbine industry.

Partners: The project is headed by the DAMRC research centre; the other partners are DTU, CNC Onsite ApS, Global Castings A/S, Ide-Pro Engineering & Software A/S, Aarhus University, Bila A/S.

Sponsor: Innovation Fund Denmark (DKK 13m).

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DTU news search: Energy production Power stations Electricity supply

ITER fusion research project

Nuclear fusion of the hydrogen isotopes deuterium and tritium into helium holds the promise of providing the world with an almost unlimited energy source, but from a technical point of view fusion energy is extremely challenging. The hydrogen fuel must be heated to 200 million degrees C in order to form burning plasma that heats itself once the fusion processes have been started. To achieve this in a reactor, the hydrogen plasma must be contained by a magnetic field and never touch the reactor walls, which would cool it.

The world's largest fusion experiment, ITER, is under construction in France. Experiments may start in 2020 according to the present plan, and the first ignition of the plasma is scheduled for 2027. By then, ITER should be able to produce a fusion power of 500 MW, which is ten times the power that is needed to heat the fuel. In 2014, DTU was selected to design a diagnostic system for ITER.

The design will be ready in 2019. The DTU physicists are also investigating turbulence and the associated transport in fusion plasmas in order to develop a predictive model that can simulate turbulence and transport in the edge region of the plasma in the ITER experiment and future reactors.

Danish activities in fusion energy research are coordinated by the Plasma Physics and Fusion Energy (PPFE) Section at DTU Physics.

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The EUROfusion collaboration includes 29 research organizations and universities from 26 European countries including CRPP, EPFL, Lausanne, Switzerland; Max Planck Institute for Plasma Physics, Garching, Germany; JET, Culham, UK etc.

A further collaboration is managed through SDC (Sino-Danish Center for Education and Research): Institute for Plasma Physics, Chinese Academy of Sciences, Hefei, China. Other collaborations are through ITER and EUROfusion with research institutions in the USA, Russia, India, Japan, and the Republic of Korea.

Concrete projects encompass:
A diagnostic for the ITER experiment: Low Field Side Collective Thomson Scattering (F4E-FPA-393).
Partners: Instituto Superior Técnico (IST), Portugal.
Contact: Søren Bang Korsholm,
Senior Scientist, DTU Physics,
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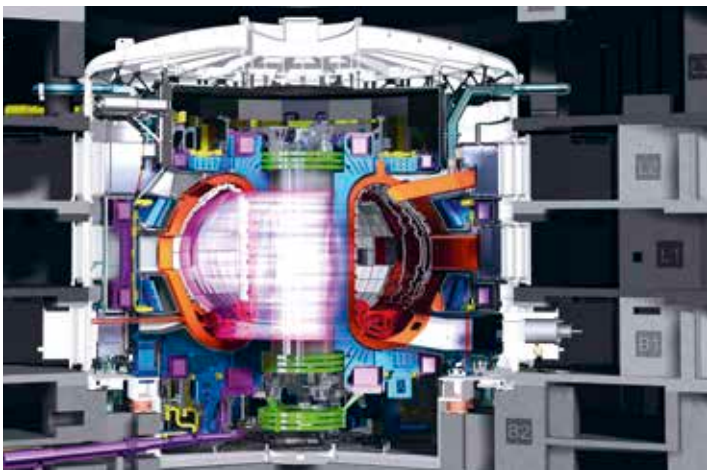
Fast ion and collective Thomson scattering (CTS) at the ASDEX Upgrade tokamak (IPP Garching, Germany).
Partners: EUROfusion.
Contact: Stefan Kragh Nielsen,
Senior Scientist, DTU Physics,
Phone: +45 4677 4534, ***Mail:*** skni@fysik.dtu.dk

Turbulence and transport in magnetically confined toroidal devices.
Partners: EUROfusion.
Contact: Jens Juul Rasmussen,
Professor, DTU Physics,
Phone: +45 2538 4537, ***Mail:*** jjra@fysik.dtu.dk

Web: www.fysik.dtu.dk/english/Research/PPFE



DTU researchers have developed a diagnostic system for ITER. ***Photo:*** ITER.

DTU news search: Bioenergy Fuel cells

More fuel from same amount of biomass

Project SYNFUEL combines electrolysis with biomass gasification in order to produce more biofuels from the same quantity of biomass. Biomass is converted by gasification. This produces syngas, which can be further converted to methane or liquid fuel for use in the transport sector. If hydrogen is added to syngas, the amount of methane or biofuel could be significantly increased. In the project, DTU conducts research into making electrolysis cells stronger, and into boosting the production capacity of each cell, so the process can become more efficient and profitable.

Partners: Aalborg University, Chalmers University of Technology (Sweden), Massachusetts Institute of Technology (MIT), Northwestern University (USA), Chinese Academy of Science, TU Berlin (Germany) and the University of Lyon (France), Haldor Topsoe, AVL, DONG Energy, and Energinet.dk.

Sponsor: Innovation Fund Denmark (DKK 17m).

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DTU news search: Energy systems Electricity supply

The end of power distribution as we know it

A European project, IDE4L (pronounced "Ideal"), is designing the next-generation distribution system able to handle decentralized production. "We want to create a system in which real-time and automated information is exchanged between all parties in a power system. For instance, price signals can induce modifications in both power production and consumption in a way that contributes to the stability of the overall system," says Lea L. Lohse, Innovation Manager at the Center for Electric Power and Energy (CEE), DTU Electrical Engineering.

The Danish island Bornholm was chosen for the demonstration. Bornholm has a 50 per cent share of renewable power. Most of it comes from wind parks.

The project has also investigated decentralized production from photovoltaic units. Further, the project included aggregator-induced flexibility in consumption, primarily by shifting the charging of electric cars and heat pump electricity consumption to suitable hours. Maintaining overall power stability is the main target, but it is also necessary to take local challenges into account.

"For instance, we have observed in a previous project, Eco-Grid, that consumers situated at the far end of the power feeder string may experience larger-than-average fluctuations in power quality caused by heat pumps and photovoltaic units in households closer to the source," says Lea L. Lohse.

Partners: Østkraft, The Danish Energy Association, Rheinisch-Westfaelische Technische Hochschule Aachen, Universidad Carlos III de Madrid, A2A Reti Elettriche, Unión Fenosa Distribución, Tampere University of Technology, Kungliga Tekniska Högskolan, Institut de Recerca de'l Energia de Catalunya, Telvent Energia.

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Web: ide4l.eu

IDE4L project website.
Photo: Torben Nielsen.

DTU news search: Energy systems Power supply

Cities can run on renewable energy in 2025

Cities can run on renewable energy in 2025.
Photo: Henrik Madsen.

"CITIES" is the largest Danish research project related to Smart Cities. The aim of the project is to develop methodologies and ICT solutions for establishing realistic, concrete and integrated energy systems for cities. CITIES will pioneer the research into fully integrated city energy systems, and hence establish a realistic and concrete pathway to ultimately achieving independence from fossil fuels in 2025 by harnessing the latent flexibility of the energy systems in cities through intelligence, integration and planning.

Project: CITIES (Centre for IT-intelligent Energy Systems in cities). Funded by the Danish Council for Strategic Research. A collaboration between a wide range of national and international partners in academia, industry and the public and private parts of the energy sector.

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Web: www.smart-cities-centre.org

DTU news search: Energy systems

A neighbourhood of energy flexibility

On a windy afternoon with lots of wind power available, heat pumps spring to life, and electric cars are charged. As the wind later calms, charging is paused and instead of heat pumps, the local district heating system steps in to provide cheap heating.

The example illustrates the mind-set behind EnergyLab Nordhavn. The project aims to demonstrate how electricity and heating, energy-efficient buildings and electric transport can be integrated into an intelligent energy system. Headed by DTU, the full-scale lab unites research, the relevant authorities, and private companies within energy supply, engineering consultancy, and device manufacturing. "The integration of the different sources of energy and the flexible consumption will be unique, not just in a Danish context but also internationally," says Christoffer Greisen, DTU.

Over the coming 50 years, new housing for 40,000 people and a similar number of workplaces will be built in Nordhavn, Copenhagen. The EnergyLab is aligned with the City of Copenhagen's ambition to become the world's first CO_2-neutral capital. The project works with PowerLabDK, a facility at DTU in Lyngby where suggested solutions can be tested virtually in advance. The main focus is to ensure that new solutions can be handled smoothly by the power system, explains Christoffer Greisen: "To make the system operational, we need to build on price signals."

For instance, a high level of wind power production will result in a low electricity price, which again will trigger consumption and consequently a lower demand for district heating. However, this is far from a trivial task as the price structures of the various energy sources are not well integrated today.

Partners: City of Copenhagen, HOFOR, DONG Energy, By&Havn, ABB, Balslev, CleanCharge, METRO THERM, Glen Dimplex, among others.

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Web: energylabnordhavn.dk

Nordhavn in Copenhagen will become a smart city with the help of DTU's EnergyLab Nordhavn. ***Photo:*** Torben Nielsen.

District heating can be smarter in the future. ***Photo:*** Colourbox.

DTU news search: Energy systems

Next generation of district heating

Loss is unavoidable in district heating, and the output temperature as warm water leaves the plant needs to be set at a high enough level to ensure the required minimum temperature when remote consumers tap their heat. "Current operating temperatures are largely set from experience-based estimates, and with a large safety margin. This leaves a huge potential for savings through computerized operation," says Henrik Madsen, DTU. "Prediction based on actual sensor measurements in the system will allow the operator to move significantly closer to the optimal temperature. We have demonstrated that this will reduce transmission loses by 10–20 per cent. This is worth millions of euros," Henrik Madsen notes, adding: "We have also shown that you don't need a fine-masked system with lots of sensors. In an average city, just five to six sensors strategically placed will be sufficient."

Partners: 45 national and international academic, industry and public partners (see website).

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DTU news search: Energy systems Electricity supply

Comeback of a power stability device

In order to integrate fluctuating power production from wind, photovoltaic cells and other renewable energy sources, the old-fashioned synchronous condensers seem to be very useful again in updated versions which DTU is developing together with Siemens. Most of the renewable generators will be connected to the grid by electronic power converters, which cause protection and control difficulties during disturbances. The synchronous condensers offer a solution to this challenge, as synchronous condensers can supply current during system faults. The focus at DTU is being able to control the condensers and their interaction with the system. The project is scheduled to last until 2018.

Partner: Siemens Denmark.

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A new model for life cycle assessments (LCA) of electricity systems shows that significant reductions in CO_2 emissions can be achieved by 2030.
Photo: Colourbox.

100%

Sustainable energy is the goal for Danish energy policy in 2050. This pose challenges for the power grid.

The DTU International Energy Report 2015 analyses how extensive integration of energy infrastructures can enhance the sustainability, flexibility, stability and efficiency of the 100% sustainable energy system.

Download the report at www.natlab.dtu.dk/english/Energy_Reports

DTU news search: Energy systems Energy production Electricity supply

Environmental impacts of future low-carbon electricity systems

DTU has developed a model for life cycle assessments (LCA) of electricity systems. The model shows that significant reductions in CO_2 emissions can be achieved by 2030, but at a price, for example the depletion of abiotic resources such as steel for wind turbines and increased air pollution from biomass incineration. In Denmark, some of the biomass required in tomorrow's electricity system can be met by straw, but removing straw may also lead to soil carbon depletion and the increased use of fertilizers. In a low-carbon scenario, substantial amounts of wood are likely be imported. This may result in deforestation elsewhere. Furthermore, wood pellet production and transport may increase CO_2 emissions in other countries. Therefore, the greenhouse gas emissions from imported biomass may counterbalance the local savings from phasing out the fossil fuels.

Project: Environmental impacts of future low-carbon electricity systems: Detailed life cycle assessment of a Danish case study.

Partners: Energinet.dk.

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DTU news search: Energy storage

Energy storage options for future sustainable energy systems

When large quantities of fluctuating renewable energy—such as solar and wind energy—have to be incorporated into the energy system, there may be a need for energy storage capacity. This is because electricity from renewable energy technologies is not necessarily produced in step with demand. Energy storage may therefore be one of the means of realizing the Danish Government's goal of fossil-free energy supplies by 2050.

Energy storage technologies are used to store energy in the form of thermal, electrical, chemical, kinetic or potential energy, and energy storage technologies and systems provide storage services at timescales from seconds to years. The DTU International Energy report Energy storage options for future sustainable energy systems analyses energy storage in a broad perspective with the aim of stimulating R&D in energy storage technologies and their integration in energy systems.

"If the ambitious EU and Danish goals of using renewable energy as a means of reducing greenhouse gas emissions are to be achieved, there will a need for serious investments in energy storage as one of the cornerstones of future sustainable energy systems. As the report was presented, we clearly felt, both within the EU and in Denmark, that there is intense interest in advancing technologies for energy storage," says Hans Hvidtfeldt Larsen, Vice Dean and Head of DTU National Laboratory for Sustainable Energy.

"Apart from pumped-storage hydroelectricity, which is a mature technology, a great deal of research and development work remains to be done in this area. I sincerely hope we manage to do this within the next 20 years," concludes Hans Hvidtfeldt Larsen.

Report: DTU International Energy Report 2013 – Energy storage options for future sustainable energy systems.

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Geothermal heat is delivered directly from the underground to the district heating grid. ***Photo:*** Torben Nielsen.

DTU news search: Energy storage
Energy production

Geothermal seasonal storage

Renewable energy and waste incineration often produce excess heat during the summer in Denmark. This heat can be used in district heating systems in winter provided seasonal storage is available. Heat production from sandstone aquifers at geothermal plants may be combined with the seasonal storage of excess heat from other sources in the aquifers at depths of 1–2 km. DTU is investigating the effects of storing hot water for months in different types of sandstone with the aim of defining sandstones in Denmark with the potential for geothermal seasonal storage.

Project: Heat Storage in Hot Aquifers (HeHo).

Partners: GEUS, BRMG, Vilnius University, and Danish Geothermal District Heating.

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DTU news search: Energy storage Energy Efficiency

The next generation of battery materials will be found using supercomputers

Metal-air batteries (MAB) are promising candidates to take over from lithium-ion. Instead of the traditional trial-and-error experimental strategies, DTU researchers will develop algorithms for the supercomputers for predicting possible materials and subsequently testing them.

Sponsor: The Villum Foundation (DKK 7m).

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DTU news search: Energy storage

How to store solar energy for the cold, dark months

To use solar heat for space heating and hot water efficiently, we need to be able to save it. A new way to store heat is in large salt hydrate stores based on sodium acetate. When heated to melting point, the salt hydrate can store heat without losing it unlike conventional water heat stores, which means heat from the sun can be used all year round.

Project: The "salt project" COMTES, Compact Thermal Energy Storage is partly funded by the EU's Seventh Framework Programme.

Partners: Graz University of Technology in Austria, Kingspan in Northern Ireland and Nilan A/S in Denmark.

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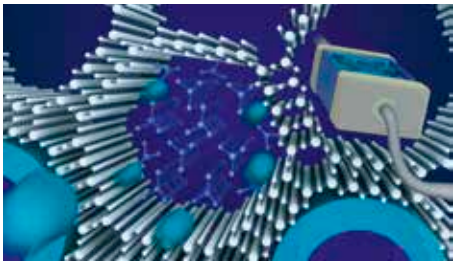

Schematics of the new battery material: lithium borohydride (LiBH4) is confined inside the nanopores of mesoporous silica scaffold (the rod-like structures). The lithium ions are shown in blue. ***Illustration:*** DTU.

1-2km

At these depths in earth's crust you can store excess heat in aquifers.

Wind energy can be stored in houses. ***Photo:*** Torben Nielsen

DTU news search: Energy storage Data analysis IT systems

Our houses can store wind power

Energy can be stored in buildings at times when the sun and wind generate more energy than we need. Using new frequent energy measurement data from houses, this can be done automatically and intelligently. Floors, walls, ceilings and furniture in living rooms and offices have the ability to retain heat for a while after the heating has been switched off. Using houses as energy storage has been made possible by energy meters which provide data on house energy consumption at short intervals. Using price-based control strategies, this storage can be charged when the price of electricity is low and discharged when the price is high. This price-based control forms the basis for using house-related storage to balance power consumption with the produced wind power, so that houses are used to store excess wind power.

Partners: Grundfos, Enfor, and Dong Energy.
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DTU news search: Energy storage Materials

High-performance lithium batteries

Researchers at DTU have discovered a new material which is a good solid conductor of lithium ions. This could lead to batteries with better durability, lower weight and higher safety. By confining lithium borohydride to the (tiny) nanopores of (nanocrystalline) mesoporous silica scaffold, researchers are able to show that the lithium ionic conductivity can be increased by a factor of more than 1,000 compared to the bulk material.

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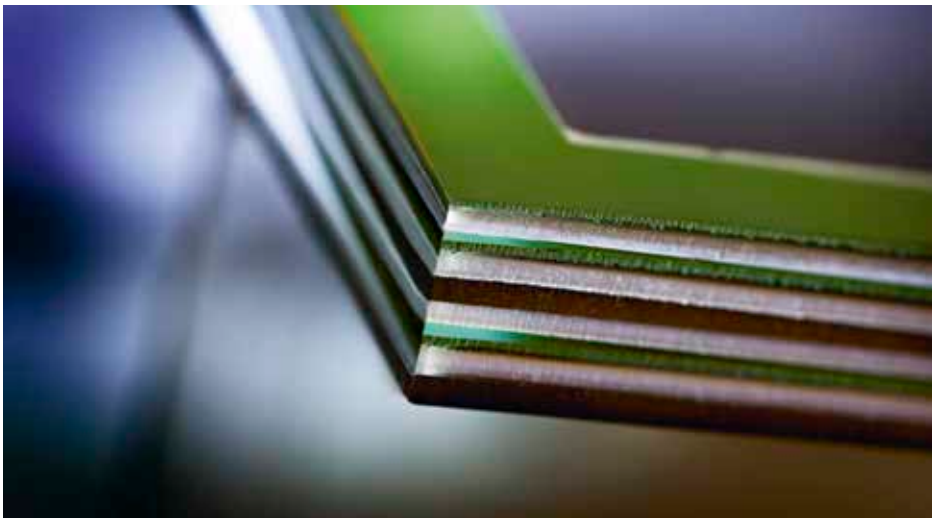
DTU news search: Fuel cells Energy storage

From electricity to fuel and chemicals



A Solid Oxide Electrolysis Cell (SOEC) consists of thin layers of advanced ceramics.
Photo: Torben Nielsen.

An electrolysis cell uses electricity to split, e.g., water molecules into hydrogen and oxygen. In this way, electrical energy is transformed into chemically bound energy in the hydrogen molecules. A Solid Oxide Electrolysis Cell (SOEC) consists of thin layers of advanced ceramics (and for certain types also metals) and operates at relatively high temperatures (700–1000 °C), which makes it highly efficient. The two electrolysis products, hydrogen and oxygen, are formed on each side of the cell.

SOECs can be used to produce hydrogen from surplus electricity generated by, e.g., wind turbines. The hydrogen can be stored and – using a fuel cell – reconverted into electricity again when demand returns. In other words, it allows the storage of electricity when production exceeds demand.

An SOEC can also electrolyse carbon dioxide (CO_2) to carbon monoxide (CO). If water is electrolysed at the same time, a mixture of hydrogen and CO is produced. This mixture, called syngas, is the starting point of a large number of syntheses of hydrocarbons in the chemical industry. In this way, liquid transport fuels can be produced synthetically. If the electricity is generated by wind turbines or solar cells, the use of the fuel is CO_2-neutral. In collaboration with industrial partners, DTU is developing the technology for various applications.

Sponsors: Energinet.dk and the EU's Seventh Framework Programme (FP7).

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DTU news search: Fuel cells Electrochemistry Electricity supply Energy production Energy storage Energy efficiency Energy systems

Standardization of research in hydrogen and fuel cell energy systems

Standardization is of great importance to the large-scale commercialization of fuel cell products. The purpose of the EU project "Solid Oxide Cell Testing, Safety and Quality Assurance" (SOCTESQA) is to facilitate the large-scale commercialization of solid oxide fuel cell products in Europe in the near future.

Partners: DLR, Germany; CEA, France; ENEA, Italy; EIFER, Germany; JRC, EU; NTU, Singapore.

Sponsor: Supported by the EU's Seventh Framework Programme.

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DTU news search: Fuel cells Energy production Physics Catalysis Micro and nanotechnology Nanoparticles

New catalyst paves the way for eco-friendly fuel

Polymer electrolyte membrane fuel cells (PEMFCs) hold promise as a potentially zero-emission alternative source of power for automotive vehicles, but they are costly due to the need for platinum catalysts. A new alloy of platinum with yttrium is a good alternative. The catalyst must be in nanoparticulate form, and this has been created at DTU. The next challenge is the development of a chemical synthesis method that allows for the production of the catalyst in large quantities.

Partners: SLAC National Laboratory, USA. Published in Nature Chemistry.

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DTU news search: Energy efficiency

Using waste heat as a resource

Often waste heat from industrial processes is of low temperature and hence of low quality. An organic Rankine cycle (ORC) unit is a suitable technology for converting such waste heat into electricity. Other heat sources appropriate for ORC units include geothermal heat, solar heat, biomass combustion and exhaust gases from combustion engines. In an ORC unit, the heat is used to evaporate a fluid at elevated pressure. The vapour is expanded to low pressure in a turbine, which drives an electric generator. After the expansion the working fluid is condensed into liquid form by rejecting heat to the ambient. The working fluid is an organic compound selected to have the properties desired for a given heat source. The research at DTU focuses on the design and modelling of ORC units for various applications. Numerical analyses as well as experimental test are conducted.

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A micro-scale ORC unit with a reciprocating expander.
Photo: Torben Nielsen

Heat pumps for high-efficient heat supply

Heat pumps may be applicable for high-efficient heat supply in an energy system based on renewable energy sources such as solar and wind with minimal use of thermal power stations based on fossil fuels. However, in the current, modern energy system, state-of-the-art heat pumps are not competitive with optimized combined heat and power production. The focus of the research is the best possible heat supply system in current and future energy systems, including working media, integration of heat demands and sources and thermal energy storage.

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DTU news search: Fuel cells Energy systems Eletricity supply

Demonstration of fuel cell systems for combined heat and power

The ene.field project is the largest demonstration of fuel cell systems for combined heat and power for individual buildings in Europe. Fuel cell systems will be installed 800 residential households, schools and institutions in Denmark and eleven other European countries. By learning the practical implications of installing, operating and supporting fuel cell systems with real customers, ene.field will demonstrate the environmental and economic imperative of fuel cell systems, and lay the foundations for market exploitation.

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DTU news search: Fuel cells

Alternatives to platinum catalyst in polymer fuel cells

Polymer fuel cells (PEMFC) use platinum as a catalyst material. Platinum is more expensive than gold. The project NonPrecious aims to develop active catalysts which are based on more common and inexpensive materials. Recently, researchers at DTU have found a new structure of iron and carbon with promising catalytic properties and high stability. This and other alternative catalyst materials will be developed in the project in collaboration between Danish universities and the Danish fuel cell industry.

Partners: Universities: University of Copenhagen, Institut National de la Recherche Scientifique (INRS), Canada, Guangxi University (GXU), China. Industry: Danish Power Systems, IRD fuel cells.
Sponsor: Innovation Fund Denmark (DKK 16m).

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DTU news search: Physics Catalysis Nanoparticles Micro and nanotechnology Energy production Energy storage

Decentralized methanol production moves a step closer

DTU researchers have found new catalysts that catalyse the formation of methanol from carbon dioxide and hydrogen with a similar efficiency to conventional catalysts. Conventional methanol catalysts suffer from a competing side-reaction that produces carbon monoxide. To create the proper reaction conditions and limit the influence of the side-reaction, large facilities are required. The new catalysts open up for the possibility of minimizing the competing reaction and increasing the methanol output at low pressures and thus facilitating the decentralized production of methanol.

Sponsor: Danish Council for Independent Research (DKK 2.6m).

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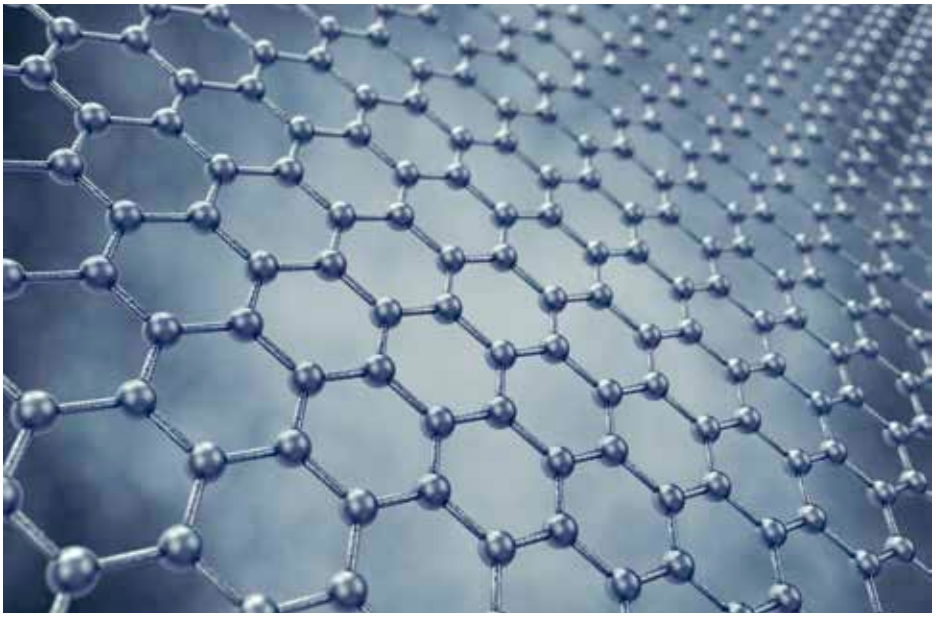
DTU news search: Physics Fuel cells Micro and nanotechnology

Efficient and sustainable catalysts for power production

Fuel cells are not being used on a large scale because of the high cost of catalysts. The most common fuel cell catalysts are expensive metals such as platinum.



Designing and synthesizing "graphene hybrids" as a platform for enzymes and then using them as electrode materials in new biofuel cells is quite new. ***Picture:*** Dreamstime.

Fuel cells are not being used on a large scale because of the high cost of catalysts. The most common fuel cell catalysts are expensive metals such as platinum.

In a new project, DTU researchers will replace expensive metals with renewable and sustainable alternative catalysts. The development of new catalysts with high activity and stability holds great potential, but also poses considerable challenges. The researchers will develop biocatalysts for biofuel cells, where both the catalysts and the fuel, such as glucose, are sustainable.

The biocatalysts will be based on the new material, graphene, combined with nature's own catalytic enzymes. Enzymes quickly denature outside their natural surroundings, but a new form of graphene—nanoporous graphene—can improve enzyme stability. Designing and synthesizing "graphene hybrids" as a platform for enzymes and using them as electrode materials in new biofuel cells is quite new.
The research group is headed by Jingdong Zhang, who has been granted DKK 6.5m by the Danish Council for Independent Research's so-called YDUN-programme for talented researchers in Denmark.

Partners: University of Potsdam, Germany, and Danish Power Systems.

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Magnetic heat pumps

The project "Efficient Novel Magnetocaloric Heat Pumps" (ENOVHEAT) will investigate the use of magnetocaloric materials as the active component in a heat pump. Such magnetic heat pumps will have a very high energy efficiency, and the use of harmful gases found in conventional heat pumps is avoided.

Sponsor: Innovation Fund Denmark (DKK 18.9m).

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DTU news search: Physics Image analysis Lasers Light sources Micro and nanotechnology Energy storage Energy production

DTU's industry portal benefits Danish energy research

DTU's Imaging Industry Portal facilitates Danish companies' access to the two coming facilities in Lund in Sweden, the European spallation neutron source (ESS) and the synchrotron MAX IV Laboratory. This has led to the creation of the strategic alliance CINEMA, with many stakeholders from the Danish energy sector.

Sponsor: CINEMA: Innovation Fund Denmark (DKK 23m). Industry Portal: Capital Region.

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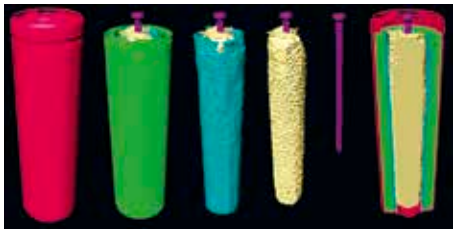

3D imaging of a battery. ***Picture:*** DTU.

DTU news search: Bioenergy Energy storage Biotechnology Biochemistry

Efficient conversion of syngas to liquid fuels

When biomass is heated to extremely high temperatures, it is converted to syngas which cannot be stored and thus must be used immediately. Furthermore, it is not compatible with the gas grid, nor can it be used for the energy-consuming transportation sector. Therefore, it needs to be converted into liquid biofuel. Existing conversion processes are relatively expensive, and a significant percentage of the energy content of the synthesis gas is lost. The SYNFERON project will provide a solution to this using an improved gasification technology that will produce a higher quality synthesis gas, followed by fermentation of synthesis gas to biofuels with microorganisms producing alcohols or methane. The ultimate goal is a complete design, which will include high-efficiency biomass gasification, cost-efficient fermentation processes, advanced product separation and purification technologies with low energy consumption, process analysis, optimization and comparison with competing technologies on the market. The project is a solid, interdisciplinary project drawing on considerable expertise from both academia and industry.

Partners: Danish Gas Technology Centre, Aquaporin A/S, Biosystems APS, Agnion Energy GmbH, Iowa State University.

Sponsor: Innovation Fund Denmark (DKK 17m).

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New, efficient route from biomass to liquid fuels for transport.
Photo: Colourbox.

DTU news search: Bioenergy Power storage

Pioneers in biomass conversion

The DTU researchers are engaged in two different biomass gasification technologies. One is a two-step process involving both pyrolysis and gasification. The process results in both high purity gas and high conversion efficiency. However, it is only suitable for wood and wood pellets. Currently other types of biomass is only used as a supplementary fuel at power plants. However DTU has demonstrated that close to total biomass fueling at a pilot plant by the company "Pyroneer", owned by DONG Energy In cooperation with a private company, Danish Fluid Bed Technology, the group also develops Fluid Bed technology, which allows the use of a variety of biomass fuels like straw, various types of biological waste and possibly even sewage.

Partners: Danish Fluid Bed Technology, DONG Energy.

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DTU news search: Energy efficiency

Climate protection through better insulation

Space heating accounts for 40 per cent of Denmark's total energy consumption. In particular, older houses generally hold considerable potential for energy retrofitting. It is not always straightforward to improve the energy efficiency of old town houses as many are subject to restrictions aimed at preserving their architecture. This counts out the possibility of exterior insulation. Instead, DTU is engaged in R&D projects with insulation manufacturers and various housing sector stakeholders on alternative methods. Key elements are internal insulation and replacing old windows with new windows to match the original architecture but with up-to-date energy specifications. However, it is important to exercise care with respect to causing problems with damp which damages buildings and is harmful to human health. DTU is developing reliable guidelines which state the conditions under which internal insulation will be the right choice.

Partners: Insulation manufacturers, housing associations and other building sector stakeholders.

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DTU's Embrace house, where one part is an unheated atrium, which can make life in the city a little greener.

DTU news search: Building design Building construction Construction materials Indoor climate

Building tomorrow's homes

In the Solar Decathlon competition, students compete to build the best energy-plus house which must also be affordable and well-designed. DTU participated in 2014, and was awarded eighth place overall with the Embrace house – a two-person urban house designed to be built on top of existing high-rise buildings.

In Solar Decathlon, the houses are assessed on ten different parameters: Energy efficiency, Architecture, Communication and social awareness, Sustainability, Engineering and construction, Electrical energy balance, Comfort conditions, Innovation, House functioning, as well as Urban design, transportation and affordability. The participants also have to consider the surrounding community which the house is to become part of, and the lifestyle of its occupants – now and in future. Embrace did particularly well in the category Sustainability as well as Urban design, transportation and affordability, being awarded fourth and sixth places, respectively.

Partners: Solar Decathlon Competition,
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DTU news search: Energy efficiency

Low-energy building ventilation

The key parameter for lower energy consumption from building ventilation is pressure loss. The greater the pressure loss, the more power is needed to keep the system running. One important concept here is dynamic pressure control which ensures that the system only operates with the minimal pressure necessary which saves energy.
The concept exists, but it is expensive to have technicians program and test algorithms that respond quickly and smoothly to pressure changes in every new ventilation installation. It is therefore necessary to develop a new plug-and-play device for the purpose. A second measure is diffuse ventilation ceilings. Certain topological changes can improve the ability of acoustics ceilings to function as air distributors in the room, which again corresponds to a lower pressure loss. Thirdly, ventilation flow control with aerodynamic drop dampers built into the ventilation systems have also proven effective at reducing the pressure loss.

Partners: Leanvent Aps, Saint-Gobain Nordic.
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DTU news search: Building design Indoor climate

Better insulation of old buildings

The interdisciplinary development area ReBuild at DTU is participating in a research project which aims to gather knowledge and experience on the internal post-insulation of buildings constructed before 1945. The project is set to run for five years, and its ultimate aim is to produce clear recommendations on the best way to retrofit old buildings with insulation.

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Older houses generally hold considerable potential for energy retrofitting.
Photo: Colourbox.

40%
of Denmarks energy consumption are used for space heating.

DTU news search: Energy efficiency | Energy systems

Energy-savings puzzle in perspective

Should savings be realized from electricity or space heating? The research project SAVE E analyses the decision-making behaviour that governs how households and businesses choose where and how to save energy. Based on the analyses, the project will examine how economic instruments and other regulation can be organized to support a development where energy-efficient solutions can phase out our dependence on fossil fuels. The goal is to develop models that can be used in energy policy to encourage and enable people to invest in more energy-efficient solutions. Only by adapting regulation to the behaviour that drives investments in energy savings will it be possible to promote the use of energy-efficient solutions in Denmark.

Partners: Eleven universities, public authorities and businesses.

Sponsor: Innovation Fund Denmark (DKK 17m).

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DTU news search: Energy efficiency | Energy storage | Energy production

Sensors that acquire energy on their own

DTU researchers are working on the idea that computer-controlled sensors right down to nano size can collect, process and pass on data in a distributed network. By collecting data from the physical environment, they can warn against adverse environmental impacts and natural disasters. The sensors acquire energy directly from their surroundings, for instance by receiving energy directly from vibrations in the rooms, from temperature differences near windows, or from radio waves. The sensors conduct measurements at regular intervals. The rest of the time they are in hibernation mode and store the harvested energy locally.

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DTU news search: Energy efficiency

Efficient lighting innovation

DOLL (Danish Outdoor Lighting Lab) is a joint effort between DTU, the Municipality of Albertslund and Gate21. The main focus of DOLL is energy-efficient LED applications in street lighting. According to EU calculations, European cities will have 2.3 billion street-lights and similar light sources by 2020. In Albertslund, the local authority has dedicated a large area for the full-scale use of innovative outdoor lighting. It has been named the DOLL Living Lab.

Furthermore, DTU has created the DOLL Virtual Lab in which businesses, architects and researchers can simulate their ideas. And finally, the DOLL Quality Lab offers businesses a place where they can have their light sources tested and certified. "We are delighted to have seen a huge level of interest from industry. This is perhaps the key reason why we have been able to achieve our goal of a fully equipped and functional lab in such a short period of time," says Jakob Munkgaard Andersen, Head of DOLL Quality Lab, DTU Fotonik.

Since the inauguration in January 2014 of the quality lab, which is situated at DTU's Risø campus, the focus has been to accommodate the needs of users in the industry. "Strong industry participation is what is driving all of DOLL, and we are beginning to see how joint industry projects create new ideas for research," notes Jakob Munkgaard Andersen. A PhD project is investigating the beneficial effects of LED lighting in health care. It seems that some groups of patients can benefit from certain lighting conditions. LED is an affordable and flexible way to achieve this.

Partners: Municipality of Albertslund, Gate21, HeSa Light, Philips, and about 20 other businesses.

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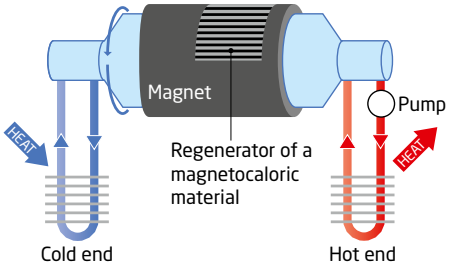
The focus of DOLL is energy-efficient LED applications in street lighting. ***Photo:*** Torben Nielsen.



Principle of magnetic refrigeration.

DTU news search: Energy efficiency

Efficient magnetic refrigeration and heating

Magnetic refrigeration holds great potential for low energy consumption and environmentally friendly cooling. It uses magnetic materials as the active components and water with additives as the medium for heat transport, relying on the so-called magnetocaloric effect which causes a temperature change if the material is subject to a magnetic field. The technology is still expensive, but there are good opportunities for application in various niches, for example supermarkets, refrigerated containers, cooling of servers in data centres and small silent installations for hotel rooms. Like other cooling technologies, magnetic refrigeration can be used "in reverse" as a heat pump. This is also a promising use of the technology.

Project: With a grant from Innovation Fund Denmark, DTU is cooperating with other Danish and international research institutions and businesses to develop the technology for using in heat pumps.

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DTU news search: Energy efficiency Energy storage Energy systems

Realistic scenarios for sustainable transport

Electric and biofueled vehicles can be an active part of a total traffic solution as well as part of the energy system's storage capacity. ***Photo:*** Colourbox.

If the Danish goal of a fossil-free society is to be achieved, cars and other transportation must be transformed. To do so, it is necessary to clarify the choices which Denmark must make as regards the technology, as there are several possible routes. It is necessary to develop tools which can show the relative costs of the various initiatives and their feasibility.

This is the aim of the project COMETS. "The project gives us, for example, the opportunity to see electric and biofueled vehicles as an active part of a total traffic solution as well as part of the energy system's storage capacity. At the same time, decisions on the use of wind power, biomass, etc. are analysed in relation to the needs of the transport sector," says Kenneth Karlsson, Group Leader at DTU Management Engineering.

COMETS integrates two large, existing decision-making and analysis tools within the transport and energy area, namely the energy model TIMES-DK from the Danish Energy Agency and the National Transport Model (LTM), and thus bridges the gap between the effective utilization of infrastructure, the means of transport and the energy system.

To ensure realistic scenarios, the researchers will involve politicians, experts and the public. This will ensure that the proposed strategy takes into account how it fits into people's everyday lives, or whether it is too expensive to receive political support. "This aspect is missing in the traditional models available today; therefore we need to replace them with an up-to-date model that can combine everything," explains Kenneth Karlsson.

Partners: Roskilde University, University College Cork, Concito, DBT Foundation, the Danish Energy Association, the DEA and E4SMA (Italy).

Sponsor: Innovation Fund Denmark (DKK 14m).

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DTU news search: Energy efficiency Energy storage Energy systems Electricity supply

Electric cars stabilize the power system

Electric cars with vehicle-to-grid technology (V2G) can be charged or discharged in the night and thus balance electricity supply and demand in a power system with fluctuating renewable production. For example, frequency regulation of the grid. If the supply of electricity does not meet demand, the frequency may fluctuate, which must be remediated immediately. This is achieved by short changes in power station output, which leads to CO_2 emissions. Charging and discharging electric cars may balance supply with demand in a sustainable way. Researchers at DTU are now testing frequency regulation of the grid using V2G cars provided by Nissan combined with the first commercial infrastructure for charging and discharging provided by Endesa.

Project: The Nikola Research Project—Intelligent Electrical Vehicle Integration.

Partners: NUVVE, SEAS-NVE, EURISCO, Nissan, Endesa.

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Electric cars from Nissan are used in the Nikola Research Project. ***Photo:*** Torben Nielsen.

DTU news search: Energy production Physics Energy efficiency

Thermoelectric generators improve truck fuel efficiency

A thermoelectric generator (TEG) can supplement or replace the on-board generator which is powered by the motor, and in this way increase overall fuel efficiency. A TEG is made of two different types of semiconductors arranged in a sandwich – a thermoelectric module (TEM). In order to use the exhaust waste heat efficiently on a truck, a number of TEMs are mounted in a heat exchanger. The aim is to obtain an efficiency improvement of 2.5–4 per cent.

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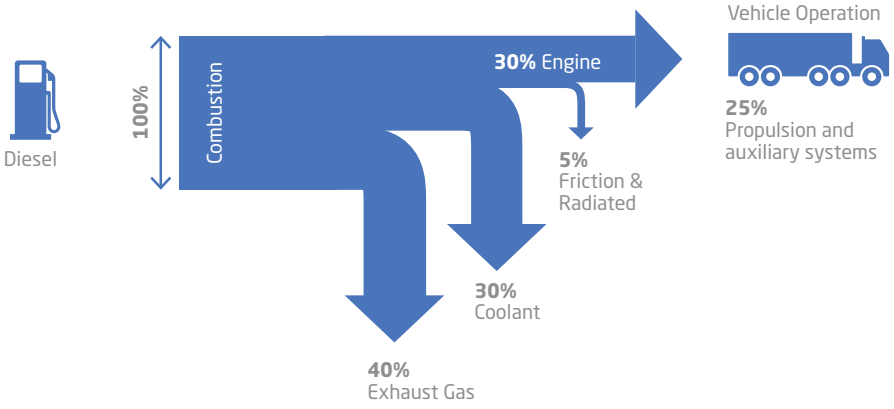

DTU news search: Energy efficiency CO2 separation and CO2 storage Construction materials Building production and management

New road surface cuts carbon emissions

The greater the resistance tyres encounter on the road surface, the more fuel the vehicle consumes. This is why new types of asphalt that reduce rolling resistance also reduce CO_2 emissions. The new asphalt surface cuts fuel consumption by 3–5 per cent. Fuel savings are likely to correspond to at least 64 million litres of fuel per year.

Project: Partnership with the Danish Road Directorate, Roskilde University and NCC Roads.

Sponsor: Innovation Fund Denmark (DKK 13.8m).

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DTU news search: Electrotechnology Chemistry Robot technology and automation Chemical engineering Ships and offshore constructions Construction and mechanics Engineering

Partnership for cleaner shipping

The Blue INNOShip partnership is working for cleaner shipping, and aims to help the partners achieve their shared goal of reducing CO_2 emissions by 30–50 per cent, and emissions of SOx and NOx by 80 per cent relative to 2008 levels.

Project: The Blue INNOShip partnership involves DTU, CBS, Aalborg University, University of Southern Denmark, the maritime industry, and public authorities.

Sponsor: Innovation Fund Denmark (DKK 50m).

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New road surface reduces resistance for tyres.
Photo: Colourbox.

DTU news search: Energy efficiency

Greener driving with lighter engines

Cars, trucks and ships can cut 20–40 per cent of their weight if various metal parts can be made thinner and lighter. This reduces fuel consumption and benefits the climate. DTU and Jydsk Aluminium Industri A/S have joined forces in the project PROALCO to make it possible to cast thinner and lighter aluminium components for the transport sector while optimizing the complete manufacturing chain of such components.

Partners: Jydsk Aluminium Industri A/S, TWT A/S Machine & Tool Works, VST Industries A/S, Zebicon A/S.

Sponsor: Innovation Fund Denmark (DKK 4m).

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DTU news search: Construction and mechanics | Transport and logistics | Operations analysis

DTU's centre for The Blue Denmark

At DTU's Maritime Centre, researchers from all parts of the university pool their input to create new interdisciplinary solutions to the challenges facing the maritime industry. The centre coordinates maritime activities at DTU in the areas of research, teaching, innovation, and scientific advice.

Also, the intention is that the centre reinforces the partnership between Danish and international universities through running shared courses and exchange programmes for undergraduates, PhD fellows and lecturers. Another important goal is to identify what is needed for education, research, and innovation in consultation with the maritime sector.

"The Blue Denmark" is a term used for all maritime businesses and professions in Denmark, such as the shipping companies, shipyards, industry suppliers, offshore companies, educational institutions, and the authorities. Denmark is one of the world's foremost shipping nations, leading in cargo transport, tanker shipping, refrigerated cargo, and offshore. Danish ships sail the entire globe and enter harbours about 50,000 times a year.

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DTU's Maritime Centre creates new interdisciplinary solutions to the challenges facing the maritime industry. ***Photo:*** Lars Bahl.

50,000
times a year Danish ships are docking at harbours of the entire globe.

DTU news search: Energy efficiency

Engines to make shipping greener

In the coming years, polluting emissions from marine engines and the fuels which are used will be subject to ever-stricter requirements. Together, these requirements present considerable problems as regards the operation of marine engines. DTU is engaged in a project to find solutions for more efficient and environmentally friendly marine engines. One of the major challenges in this context is to prevent the formation of corrosive sulphuric acid. In the SULCOR project, DTU and MAN Diesel & Turbo have teamed up with international universities to try and understand and describe the mechanisms underlying the formation and condensation of sulphuric acid in engines. The hope is that it will identify ways in which to avoid the problems.

Sponsor: Innovation Fund Denmark (DKK 15.6m).
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DTU news search: Micro and nanotechnology | Catalysis

Nanotechnology to provide cleaner diesel engines

When it comes to diesel engine catalysts, platinum is the only viable option, and accounts for half the price of a diesel catalyst. In a new project, researchers will find viable alternatives to platinum. The focus is on nanoparticles in order to maximize the surface area. The greater the surface area, the less material is needed. Each time the platinum surface is optimized, you save material and thus achieve greater effect at less cost. The aim is to achieve a 25 per cent reduction in the amount of platinum used, which will put the Danish company Dinex among the global leaders in catalyst production.

Partners: Aarhus University, Danish Technological Institute, Dinex A/S and DTU.
Sponsor: Innovation Fund Denmark (DKK 15m).
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DTU news search: Energy efficiency Energy systems

Promoting energy efficiency by example

A powerful driver for private companies to engage with the Global Energy Efficiency Accelerator Platform is the opportunities they see for making business. ***Photo:*** Louis Vest.

The Copenhagen Centre on Energy Efficiency (C2E2) was established in 2013 as a part of the UNEP DTU Partnership. The Centre serves as the energy efficiency hub of the UN initiative on Sustainable Energy for All (SE4ALL) to promote energy efficiency worldwide.

The SE4ALL initiative has identified public-private partnerships as a key strategy to accelerate energy efficiency to achieve its goal of doubling improvement rate of energy efficiency by 2030. Currently, eight such partnerships or "Accelerators" have been established, collectively referred as Global Energy Efficiency Accelerator Platform.

An example of the lighting accelerator is the en.lighten initiative of UNEP on energy efficient lighting, where major industry players like Philips and Osram and other key stakeholders have teamed up. The initiative is engaged in more than 60 countries.

"A powerful driver for private companies to engage with the Global Energy Efficiency Accelerator Platform is the opportunities they see for making business," says Jyoti Painuly, Head of the C2E2.

The seven other current accelerator programs include electric appliances, buildings, transportation and vehicle fuel efficiency, district energy (both district heating and district cooling), industry, and two newly established power sector, and finance accelerators. Further, the Centre aims to increase the capacity and willingness of countries to implement policies and actions to scale-up energy efficiency. Four regional studies in Latin America, Africa, Asia and the Commonwealth of Independent States have been carried out.

The Centre will partner with a number of countries in these regions. "In the past, energy efficiency has been advocated as a "no regret" option with a high rate of return. This is probably too simplistic as transition costs and other barriers need to be considered. However, we are entering a more mature phase where positive impacts of energy efficiency on environment, jobs, energy security and economic growth are understood better. This realization motivates governments and private corporations to invest in energy efficiency," Jyoti Painuly says.

Partners: SE4ALL partners, The World Bank, IRENA, Regional Development Banks, UNECE, TERI, UNEP, Regional Centres of excellence and others.

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DTU news search: Energy production Electricity supply Power stations

Preparing Europe for carbon capture and storage

The construction of the first carbon capture and storage – CCS – demonstrator at a thermal power station in the EU is underway as part of the OCTAVIUS project. The project includes research at three pilot-scale units, and researchers at DTU are simulating the entire demonstration plant, which must be capable of removing 200 tonnes of the greenhouse gas per hour. Today, CO_2 is captured at low temperatures and released by heating the solvent, which consumes a lot of energy. In the EU project INTERACT, researchers are exploring future CCS technologies with a view to reducing the cost of carbon capture by 50 per cent. At DTU, this is achieved by using enzymes to facilitate the capture and release of CO_2.

Projects: OCTAVIUS and INTERACT are projects run under the EU's Seventh Framework Programme

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Test facility for carbon capture and storage. ***Photo:*** Torben Nielsen.

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