Where innovation starts

Eindhoven University of Technology (TU/e) is an internationally renowned research university specialized in engineering science and technology. The challenges of our present day society inspire our scientists and students to pursue exciting educational programs and breakthrough innovations that are beneficial for all. Our activities are embedded in strong partnerships with industry, governments and knowledge institutions worldwide. TU/e is situated in the Brainport region, the technological heart of the Netherlands.

Our society faces tremendous challenges in the fields of energy, climate, safety, sustainability, healthcare, mobility and communication. We believe technology is crucial for finding solutions, and it is our aim to contribute significantly to doing just that with our research and innovation activities. We’ve therefore combined our research into three strategic areas to help us maximize strengths. These areas are: Energy, Health and Smart Mobility, themes that also play an important role in the areas of education and knowledge valorization.

TU/e is helping to build a sustainable world. Efforts to that end include people-oriented technology, science for society, less pollution and fewer unexpected traffic jams, chemotherapy with fewer side effects, and solar power that charges your phone and lights your offices.
‘Now that my first grandchild is born, my time horizon has expanded way beyond 2020 and even 2050. Technical developments create new options for our energy supply and put more power in the hands of households in the way computing and communication technologies have expanded our personal reach to global dimensions. While use of fossil energy is still affecting the climate and our quality of life, ordinary people, authorities and companies are compelled by the need to do something about it and now we actually can.

In the seventeenth century we still burned wood and gradually switched to coal and oil and eventually natural gas. Now cleaner energy sources have emerged, albeit with new challenges especially in demand supply management. Smaller-scale solutions to generate energy mean a more individual kind of energy supply that makes people independent of their environment and offer a chance in developing countries to wrestle free of the chains of poverty. Engineering solutions will more often be found and introduced in these countries too. This will offer opportunities to address the lopsided division of prosperity in the world and improve stability for the development of mankind on its single source of life, the Earth.

I see future cities whose populations, twice what they are today, live in a highly technological yet more natural environment. Nice places to live and work, with greener and cleaner surroundings than those of today. Renewable energy solutions will allow us to have a nicer and natural environment and also reconnect the surrounding fields with city centers as most clean energy technologies today are influenced by surface area. Energy and engineering do not have to be in conflict with the environment, quite the opposite.’
Other activities: chairman supervisory boards of TIASNimbas Business School, Prodrive BV, advisory board COMMIT.
Previous positions: CTO at Royal Philips, CEO at Philips Corporate Technologies and Philips Research.

Rick Harwig
Director Strategic Area Energy, TU/e
The world is on the brink of a fundamental energy transformation. We will have to gradually say goodbye to fossil fuels. Our natural reserves are running out and climate change will force us to make alternative choices. Furthermore, energy consumption on Earth will double over the next forty years as the population rises by two billion people and prosperity in developing countries increases. Energy is part of a sustainable society.

How will we do it? Many areas of research offer room for technological advances but it will take more to realize a different type of energy society.

The approaching energy transformation is all-encompassing and will take place on a global scale. This is endorsed by the business world. By enabling sustainable lifestyles through the provision of goods and services we can meet people’s needs, without bankrupting the planet. We need to gain more insight into the whole chain: the extraction of energy from sources, the way it is transported and the way it is used. As we get better at saving energy and creating cycles, the efficiency in this chain will be increased.

The strong cohesion and rapid changes make it necessary for us to study energy systems as a whole, in all their complexity and with all their mutual links. Rethinking power. Our integral vision on energy systems is the starting point of our multidisciplinary research and education. Collaboration with the business world and other knowledge institutes ensure it will become embedded in our society. Technology allows this transformation to take place. The development of clean and sustainable technology allows us to secure the reliable and environmentally friendly provision of energy for all.

“The Sun offers us more than enough energy to power our entire civilization. The Earth’s surface receives ten thousand times the amount of energy we consume and hence solar power has enormous potential.”

Energy Conversion, René Janssen

“Sustainable energy sources constitute only a fifth of our total energy production today. All the rest is from the combustion of fossil fuels. We therefore focus on ultra-clean and highly efficient conversion of fuels from biomass waste and ultimately fuels produced from solar energy.”

Future Fuels, Philip de Goey
‘About forty percent of the global fossil fuel consumption is for operating buildings. Our ultimate goal is a sustainable energy-positive built environment with indoor environmental quality optimized for health, comfort and productivity.’

Built Environment, Jan Hensen

‘Clean, safe, zero carbon dioxide, for all and forever: that’s the great promise of fusion power. The entire world is collaborating in the development of fusion, an effort culminating in the ITER project: a 500 MW fusion reactor presently under construction in France.’

Fusion Energy, Niek Lopes Cardozo
**Future Fuels**

We need to master technologies for zero-impact use of fuels.

Fossil fuels still cover 80% of our energy demand and we will continue to depend on them. Heavy transport ships or trucks require energy densities that can only be achieved with hydrocarbons. That is why we need to design new fuels and new engine techniques.

**Biofuels**

Our fuel research focuses on second-generation biofuels from agricultural waste. Gasification, followed by Fischer-Tropsch processing, is one way to produce fuels, but we are also researching more direct chemical processing. A more distant research goal is to leapfrog biological photosynthesis altogether, making fuels directly from sunlight. Catalysis is the core technology for most of the fuels that we develop.

**Optimizing engines and turbines**

We have developed a new diesel additive which reduces the emissions of NOx, soot and particles. It can be made from biological materials. We are also testing new concepts like flameless oxidation (FLOX) for furnaces and homogeneous charge compression ignition (HCCI) in engines. We can also blend hydrogen and other synthetic gases with natural gas in turbines. The combination of computer calculations with laboratory experiments ensures the rapid optimization of combustion techniques.

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**Energy Conversion**

We are moving towards a society that runs on materials, not on fossil fuels.

The Sun provides the Earth’s surface with ten thousand times more power than the global consumption, but we still only tap a marginal fraction of it.

**Solar energy converters**

The challenge is to make photovoltaic systems more efficient, cheaper and easier to produce. Several research groups at TU/e are working closely together towards developing technologies that meet all of these requirements.

**Different roads**

Presently we study a range of different photovoltaic technologies with the emphasis on thin-film solar cells based on inorganic or organic semiconductor materials. We develop new photoactive and electrode materials and device architectures that capture and convert the solar spectrum more effectively. Detailed physical studies are performed to identify loss processes and ways to circumvent these. Fast deposition techniques are studied for high-volume production. Because sunlight is intermittent, storage of energy is crucial. That is why we want to capture solar energy in chemical bonds of molecular fuels.

**Solliance**

As member of Solliance, the research and development of thin film photovoltaic solar energy is aligned with the major research institutes in the Brainport region and the solar business community.
About forty percent of all the world’s fossil fuels is used for operating buildings. There is so much to gain!

The built environment has many different stakeholders and presents several specific challenges. Buildings are extremely important for our quality of life and for economic well-being. Existing buildings represent around 99% of the building stock at any one time. Buildings have an average lifespan of well over half a century. The vast majority of buildings are individually designed and constructed. Improving buildings is therefore not just about inventing novel materials and new technical systems. We need to optimize the quality of the indoor environment for health, comfort and/or productivity while at the same time reducing fossil fuel use in new and existing buildings.

Storage and transport of energy
One line of research within the built environment theme is the storage and transport of energy. Research projects relate to batteries, heat and cold storage, smart grids and much more.

Buildings that produce energy
A future efficient and sustainable built environment will be based on the development of net energy-producing buildings or sites. This requires computational prediction models and analysis tools capable of assimilating interoperating domains, and energy management systems that interact with the energy network operators, energy service providers and traders.

Fusion is an endgame solution. We work on it for the sake of our children and grandchildren.

Fusion is an endgame solution. It holds the promise of inexhaustible energy – clean, safe and available to all. With one drawback: it is an exceedingly complex scientific and technical challenge. Yet recent decades have seen rapid progress. Today, 34 countries are building the first power-generating fusion reactor, ITER, in a worldwide collaboration. In ITER, a ‘burning’ plasma is kept at a temperature of hundreds of millions of degrees, suspended in a magnetic field.

Fusion: big science, big technology
Spurred by the launch of the ITER project, TU/e has stepped up its ambitions in fusion research and education. With fusion being an interdisciplinary field, the departments of Applied Physics, Electrical Engineering and Mechanical Engineering have joined forces. Working side-by-side, physicists and technologists develop highly sophisticated control technology for the hot plasma and its interaction with the reactor wall. And we have established the world’s first fully interdisciplinary, two-year Master in fusion technology. This unique study attracts international students and aims to prepare a significant proportion of the future ITER workforce. All this is taking place in close cooperation with the FOM Institute DIFFER, the national center for fusion research due to join our campus in 2015, and international fusion labs. Our students do projects around the globe and are involved in research that has a direct impact on ITER.
You can spot a power plant from a mile away by the high-voltage lines that fan out in every direction, distributing the plant's output to consumers. Existing power grids are geared toward a centralized approach to the generation and delivery of electricity. However, many sustainable technologies for electricity generation require exactly the opposite. Households are increasingly able to supply energy back to the network. That means the electricity grid needs to be designed in a different, less centralized way. The power system will also need to handle greater fluctuations because of low predictability and lack of control of supply from renewable, intermittent sources such as wind, sun or home-heating systems.

The group of Wil Kling (TU/e) studies smart grids, the intelligent electricity infrastructure of the future. It is especially necessary to improve the management of the lower hierarchical branches of the electricity grid. These medium- and low-voltage distribution networks in the capillaries of the network, which are located close to customers, are where the most important developments are taking place.

Another approach to smart grids is more market oriented and requires the active involvement of consumers. Variable pricing or real-time pricing, which reflects the current capacity of the power grid, could motivate consumers and industries to change their behavior. This would mean, for example, that users would turn on their dishwasher as soon as the wind builds up and the electricity price drops.

A third approach integrates the two. For example, consider remote switching of refrigerators and washing machines, taking into account the actual price of electricity, the local electricity production and grid capacity. Clearly, these concepts involve not only technology. An integral part of the research is the assessment of societal issues that would accompany the transition toward a smarter electricity infrastructure. Eventually, we could end up with a self-organizing grid that automatically adapts when new generators or heavy loads are plugged in. Self-healing, rerouting, adaptive protection and decentralized controls are all aspects that are being pursued to make our electricity grid smarter.
Dynamic Glass for Solar Shading and Lighting Comfort

Glass is a very versatile construction material, excellent in visually connecting the inside of the building with the outdoors. The challenge with respect to glass facades is to make optimal use of the outdoor conditions for the people working or living within the building. Currently too much glass heats up a building and generates glare. While this can be tackled by air-conditioning, such an option uses large amounts of energy to cool and shading devices can block the view.

We at Peer+ think a better and more elegant solution is Smart Energy Glass. Both overheating and glare can be reduced while views to the outside are undisturbed and the aesthetics of the building are not compromised. Peer+, a TU/e spin-off company, develops Smart Energy Glass. We closely work together with the Functional Devices (FD) unit of the Department of Chemical Engineering & Chemistry and with the Building Physics and Services (BPS) unit of the Department of Built Environment. Ideas that still need long-term research are first developed and tested within the FD group. Once the ideas are proven and promising, Peer+ performs the last part of the R&D to translate this knowledge into product improvements.

The architecture collaboration focuses on the effect of Smart Energy Glass, which is essential input for the priorities in the R&D roadmap and for communication to architects and building physics experts.
Storing Solar Energy in Chemical Bonds

TU/e recently entered into a strategic alliance with Utrecht University and University Medical Centre Utrecht to strengthen ties in research, education and knowledge valorization. The focus in the cooperation lies on renewable energy, medical imaging and regenerative medicine. One prominent initiative is to address the challenges of a sustainable supply of energy and fuels from renewable resources. A critical challenge is to use chemical bonds to store surplus solar energy in chemical bonds. Two new assistant professors have been appointed in the catalysis groups of Emiel Hensen (TU/e) and Bert Weckhuysen (UU, Spinoza Laureates 2013). Together with several PhD students, this team will be developing novel inorganic materials for solar light harvesting and catalytic conversion of abundant molecules such as carbon dioxide and water into chemical fuels. The ultimate goal is to construct a solar fuels device. The researchers will cooperate with the Dutch Institute for Fundamental Energy Research (DIFFER), which will join our campus in 2015.
The coming decade is likely to see a strong shift in the feedstock of chemical industry from fossil hydrocarbons to secondary and bio-based materials. This development will ensure that Europe will remain a world leader in terms of the chemical industry and sustainability. Eindhoven researchers are working at the forefront of valorization of biomass. In the group of Emiel Hensen, the research of assistant professor Evgeny Pidko has shown how novel catalysts can be designed by understanding, at the molecular level, how sugars are converted to platform molecules. Together with the combustion technology group of Philip de Goey and Michael Boot, who is also heading the TU/e spin-off Progression Industry, these researchers have developed a novel solvothermal process to convert waste lignin to high-value biobased fuels. These new fuels can be combusted in conventional diesel engines with much reduced soot and NOx emissions. This research has attracted widespread interest from industry; part of the funding comes from KIC InnoEnergy, which is part of the European Institute of Technology. All these processes are relevant to the development of sustainable processes that will find their place in the chemical industry.
Solar Team Eindhoven has won the Cruiser category of the World Solar Challenge with the world’s first solar-powered family car, Stella. The team got the best score for speed, kilometers driven on a per-person basis, energy consumption, comfort and user-friendliness during the 3,000 kilometer-long contest through the Australian Outback.

A multidisciplinary team (with 22 students from six different TU/e departments) has spent a year on this project that involves challenges from the fields of energy and mobility. The knowledge and experience of energy at TU/e has been a significant contributor to this success: the integration of solar technology into innovative design and energy management systems.
Society’s need for highly educated, multidisciplinary engineers in the field of energy is increasing rapidly. That is why TU/e invests in educational programs to prepare students and young researchers for a career in energy. Our students learn how to work in highly motivated teams to solve today's technological challenges for tomorrow's sustainable future.

### Sustainable Energy Technology – SET

The MSc Sustainable Energy Technology program trains engineers who are able to anticipate the change processes in the energy market. Social and economic demand for sustainable energy supplies is growing. The generation and use of energy are becoming more efficient and clean all the time. One factor of change is the increasing use of renewable energy sources such as biomass, photovoltaic energy and wind. The energy market is also changing as a result of internationalization and liberalization.

### Science and Technology of Nuclear Fusion

The Fusion Master program is the obvious path for those who want to specialize in fusion. The curriculum is truly interdisciplinary – combining elements from applied physics, mechanical engineering and electrical engineering – and emphasizes the goal-oriented nature of fusion research as well as the international character of fusion research, work in interdisciplinary groups and the societal aspects. Just to be sure: your diploma will say ‘Master of Science and Technology of Nuclear Fusion’.

### European Master program – SELECT

The MSc Environmental Pathways for Sustainable Energy Systems (SELECT) program offers advanced education in the field of sustainable energy systems for the future. SELECT is a European program in which seven European universities are cooperating. The program is supported by Erasmus Mundus and KIC InnoEnergy. Students learn to work in an international environment. In the first year students cooperate with fellow students from all over the world. In the second year, students move to one of the partner universities. Students graduating from the SELECT Master program will have gained experience in multidisciplinary problem analysis and problem-solving in the field of sustainable energy.

### Smart Energy Buildings & Cities - SEB&C

The SEB&C program trains MSc graduates to become a technological designer, capable of integrating relevant knowledge in a process of integral designing for a dedicated Smart Energy system for the built environment. A SEB&C designer will be able to use his specialism to contribute to the development of:

- Intelligent and energy-efficient building components
- Building concepts aimed at the intelligent use of the least possible energy
- Intelligent networks aimed to align the supply and demand of energy

TU/e offers a range of programs and courses on energy and energy-related topics at all levels, from Bachelor to postgraduate level. For further information on TU/e Energy education: www.tue.nl/en/research/energy/education
**Energy-Efficient Buildings and Cities**
The Co-Location center Benelux (CC Benelux) coordinates the theme: Energy-Efficient Buildings and Cities. Klaas Schuring, CEO: ‘It is a cross-disciplinary theme whose aim is to strengthen the sustainability of the energy system and to reduce environmental impact by developing the deployment of energy-efficient buildings and energy systems in cities’. The CC Benelux is establishing a joint innovation platform to stimulate and support innovation and high-tech entrepreneurship within the KIC InnoEnergy community.

**What we do**
As CC Benelux we deliver innovative products and services for energy-efficient buildings and cities. We help entrepreneurs to realize start-up companies. The Master, PDEng and PhD programs supported by KIC InnoEnergy will also enable students to shape the future of energy.

Full partners: TU/e, KU Leuven, TNO, VITO, Eandis

[www.kic-innoenergy.com/ccbenelux](http://www.kic-innoenergy.com/ccbenelux)
Particularly in urban areas, which are growing all over the world, there is a need to integrate the presence, production, distribution, storage and efficient use of energy. The intelligent application of high-tech innovations is central in this, not only generating business opportunities per region but also contributing to climate goals.

**A comprehensive approach**
The proposed Smart Energy Regions approach combines smart energy business propositions in an overall plan that can be used in an international market. A combination of Smart Energy applications in all kinds of business segments like mobility, homes & offices, energy grids and lighting makes the Smart Energy Regions approach suitable for integrated urban design.

**International playing field**
The comprehensive approach customized for energy use in urban areas makes Smart Energy Regions an excellent option for international implementation. This is happening within Europe through our cooperation in the European Knowledge & Innovation Community ‘InnoEnergy’, which extends the industry-research-government cluster to an international scale: an essential element in tackling the energy issue.

**Smart Energy Regions Brabant**
The local heart of the cluster is its ‘Smart Energy Regions Brabant’ program, where there is a convergence of research, testing & integration and business development. This is tangibly visible in the testing & integration facilities being constructed at the TU/e Science Park where the smart energy technologies of the partners are being realized; technologies that will find their way within the Smart Energy Regions label to international implementation.

S\E\R-B is funded by the Province of Noord-Brabant, TU/e and industrial partners.

[www.smartenergyregions.com](http://www.smartenergyregions.com)
Spin-off: Progression Industry
Progression Industry, one of TU/e’s successfully launched spin-offs, is working on green technologies for the automotive industry. The company has developed WEDACS technology for petrol engines, which reduces the amount of petrol used and increases engine torque. The PFAMEN fuel atomizer reduces the amount of soot emitted, which in time will render soot filters redundant. The most recent developments are related to the second generation of biodiesel: CycLOX. TU/e is collaborating with Progression Industry on a test project to create CycLOX from wood waste. In the near future, this biodiesel will be sold as a 10% mix at a gas station on the TU/e campus to TU/e employees and visitors.