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The hydrogen economy no longer belongs to a distant future. The clearest signs are the announcements from some of the world’s largest car manufacturers that they will bring hydrogen cars to the market by 2015. Right now Hyundai seems to be a front runner, with the first commercial series of their ix35 launched early this year, with an initial production of 1 000 vehicles.

With our pioneering hydrogen-infrastructure, Norway is an important pilot market for hydrogen cars and buses. In addition to the greenhouse gas issue, we see a growing concern for local air pollution. Hydrogen is not only potentially a greenhouse gas abatement measure, but represents also a way to reduce local emissions of NOx and particles.

The dramatic increase of renewable energy in our electricity production creates the need for effect balancing and energy buffering. The growing hydrogen infrastructure could play a crucial role in meeting this challenge. The Research Council of Norway has for many years supported the development of hydrogen and fuel cell technologies, and we firmly believe that hydrogen will play a key role in the energy systems of the future.
The Research Council launched the new Energy R&D program ENERGIX at the beginning of 2013. Hydrogen is one central part of this program, which also covers renewable energy production, energy efficiency, energy system, other environmental friendly fuels for transport etc.

Norwegian companies, research institutes, and universities have developed strong capabilities in hydrogen and fuel cell technologies. It is important to further develop this capability so that they can take a role in the growing global market for hydrogen and fuel cell technologies. The Norwegian Hydrogen Forum has shown itself as a visible actor in the hydrogen community in Norway and abroad, and will undoubtedly play an important role in this growing industry. I hope the Hydrogen Guide will be a useful tool to facilitate fruitful cooperation in this emerging industry.

TRYGVE U. RIIS

Special Adviser, ENERGIX | The Research Council of Norway
Hydrogen is an energy carrier that can be produced from all types of energy sources, including natural gas and renewable energy, both of which Norway has in abundance.

Norwegian research communities and industrial stakeholders are at the forefront of the development of hydrogen technologies, and many are involved in EU-projects through the public-private partnership Fuel Cells and Hydrogen Joint Undertaking (FCH JU).

In 2005 the Ministries of Petroleum and Energy and Transport and Communications established the Norwegian Hydrogen Council as an advisory body to the Ministries. The Hydrogen Council published in December 2006 an Action Plan for the period 2007-2010, with a set of concrete actions, activities and measures to address the challenges and exploit the opportunities in the field of hydrogen. The Action Plan was met with substantial support from national stakeholders, and has also received considerable attention abroad.
The establishment of the governmental body Transnova was the most important outcome of the recommendations provided in the first Action Plan. Demonstration of the world’s first marine supply vessel with fuel cells in 2009 is another noticeable achievement. The Hydrogen Council recently released a new Action Plan with updated and relevant actions, activities and measures for 2012 – 2015. Introduction of incentives to secure continued operation of the hydrogen refueling infrastructure is one of the key recommendations for this time frame.

Norwegian engagement in international efforts is of highest strategic importance, in particular through the FCH JU. This includes participation in R&D and demonstration projects as well as engagement in leading strategic positions for further development of the European program. Cooperation with Asian countries and North America is well established and will be further strengthened in the years to come.

**Steffen Møller-Holst**

*Chairman of the Hydrogen Council*
In Norway, industrial actors have produced and utilized hydrogen since 1927. Companies like Hydro developed their own electrolyser technology, which today continues to be developed by NEL Hydrogen. As can be seen from the actors represented in this guide, new companies within electrolyser manufacturing and integration are being established, building on competence from the Norwegian industry.

Hydro and Statoil, together with Raufoss Fuel Systems (Now Hexagon Composites) and Norwegian research institutes, brought hydrogen from the industrial and research arenas to the public refueling arena in the beginning of 2000 through the HyNor-project, which was established to demonstrate the readiness of hydrogen as an alternative fuel for cars. Complete station solutions were developed through large public and private investments. Since the opening of the stations in 2006 – 2009, valuable competence from the operation and maintenance of the hydrogen station network has been accumulated, and the stations are continued to being operated by the world’s first dedicated hydrogen station operation company, HYOP AS. With the car industry now ready to supply the vehicles, Norwegian industrial actors have the technology and the know-how to supply products and services in the entire value chain.
NEL Hydrogen develops and delivers electrolyzers and system solutions to industrial actors all over the world.
Unlike battery electric vehicles, where small investments are made for every car to facilitate the charging spots\(^1\), hydrogen infrastructure demands large investments, but has the capacity of serving numerous vehicles. With high costs and limited availability of the vehicles in the early phase this in turn limits the number hydrogen stations that are built, and thus also the radius of operation for the early vehicles. A conscious, well-founded and broadly industrially supported plan for the introduction of hydrogen is thus crucial to succeed. In parallel, incentives and regulations from governments is just as important in creating the appropriate framework for the strategic processes.

Norwegian industrial actors have participated in research, development and deployment of hydrogen refueling stations since early 2000. As new stations are built, the issue of operating and maintaining the stations in the pre-commercial market has become an obvious challenge. Energy companies, car dealers and national and local politicians have become involved, and processes are ongoing to establish mechanisms that ensure safe and stable operation of the infrastructure until the commercial phase.

National plans for hydrogen infrastructure buildup have been made, and Akershus County has together with the city of Oslo developed a joint strategy for hydrogen toward 2025, including both infrastructure roll-out plans and an analysis of the potential local value creation which can follow from taking a leading role within hydrogen.

\(^1\) Public charging spots have been erected per 3 BEVs sold in Norway
Norway has through years of policy- and incentive development, created an environment that greatly stimulates the introduction of zero-emission vehicles. Battery- and Fuel Cell Electric Vehicles (BEVs and FCEVs) enjoy equal benefits, which include:

- Zero purchase tax (can be as high as 100%)
- Zero VAT (25%)
- Low annual road-tax (10% of normal)
- Free public parking (1 000 EV-only spots in Oslo city center)
- Access to bus/taxi-lanes
- Free passing through toll-roads
- Free transport on public ferries

The abovementioned incentives have resulted in Norway becoming an important early market for BEVs, and the number of cars on the road, especially in the cities, is rapidly increasing. The total sales share of BEVs in 2013 will be close to 6%².

Norway is thus well positioned to become an equally important market for the FCEVs, in the early phase of market introduction. There are already prototype FCEVs from Daimler and Hyundai being tested in Norway, and the first FCEV was sold to a customer in the summer of 2013.

² Up from 3.0% in 2012 and 1.6% in 2011
Corporate and private customers in Norway can rent and enjoy the benefits of driving fuel cell electric vehicles from Mercedes-Benz Norway, who administrate 10 Mercedes-Benz B-Class F-CELL vehicles through the H₂-Moves project.
Norwegian Hydrogen Forum (NHF) was founded in 1996 as a non-profit organization which promotes the advantages of hydrogen as an energy carrier. Our members span Norwegian industry, universities, research institutes and other organizations interested in hydrogen.

NHF works as an active contributor to distribute information about hydrogen in Norway through organizing seminars and workshops, publishing newsletters regularly, and keeping the website www.hydrogen.no updated with the latest relevant national and international news on hydrogen. NHF has arranged national conferences on hydrogen, and also arranges joint conferences with our Nordic sister organizations.

NHF believes that the best way to serve our members is to contribute to establish a substantial market for hydrogen in Norway. To do this NHF is an active and constructive partner to public authorities and other organizations.
We support the vision proposed by the Norwegian Hydrogen Council: **Norway – pioneering sustainable hydrogen.** It indicates the important role hydrogen will have in the transformation to a greener future. Hydrogen could be an alternative to oil & gas and if we start now Norway could be a leading hydrogen nation in a world with a growing demand for sustainable energy carriers.

NHF is an active member of the board of the European Hydrogen Association, and meets with the other European associations regularly.

The Hydrogen Guide has been made by NHF with the support of Innovation Norway, the Research Council of Norway and Transnova.

**Vegard Laukhammer**
*Chairman, Norwegian Hydrogen Forum*
The hydrogen refueling station for buses in Oslo by night.
AGA AS is 100% owned by Linde AG, and is one company in the Linde Gas Division. As the world's largest hydrogen plant manufacturer and leading gas company in Europe, Linde has delivered hydrogen for a number of applications since 1910. Linde traditionally maintains a close cooperation with science, research and industry, enabling continuous advancement creation of new innovative applications. Linde also develop innovative tank systems and collaborates with leading car manufactures.

Linde is involved in nearly all major hydrogen initiatives worldwide. Currently working closely with the European Commission to define a viable roadmap for hydrogen and investigate the best, most cost-effective ways of establishing a hydrogen infrastructure.

Linde hydrogen filling stations are built to be able to fill corresponding hydrogen vehicle tanks at 350 and 700 bar, according to SAE J2601 standard. AGA AS in cooperation with Linde delivered and installed the first hydrogen filling station for the HyNor project in Stavanger in 2006. Hydrogen is included in Linde’s “Clean Energy” efforts together with natural gas and bio gas distribution and refueling systems.

CONTACT: John Melby | john.melby@no.aga.com | www.aga.no
Air Liquide develops technologies and knowhow for the hydrogen market in areas such as production, distribution, storage and fuel cells. During the past 10 years the Air Liquide group has established more than 40 hydrogen stations worldwide - and more are underway. In 2012 Air Liquide produced 9 000 billion Nm³ of hydrogen which is the equivalent of fueling 6 million cars.

Air Liquide Norway A/S was founded in 1997 and is on the leading companies in the field of industry gas in Norway, and is a part of the Air Liquide group which is active in 80 countries. Air Liquide Norway has put a lot of effort in the HyNor Oslo bus project. This is to show to the coming Norwegian hydrogen market that Air Liquide, is able to and wish to participate in this important environmental marked. Air Liquide have establishes and run the biggest Hydrogen refueling station (HRS) in Scandinavia for at least 5 years. This HRS is based on 2 electrolysers, 2 compressors and a 12 000 liter buffer. The HRS delivers hydrogen to 5 buses in Oslo.

CONTACT: Niels Kragh | niels.kragh@airliquide.com | www.airliquide.no
Akershus County covers the area east and north of Oslo, and accounts for about 10% of the population of Norway. Akershus County Council (ACC) has for many years been involved in hydrogen projects, supporting demonstration of hydrogen stations and vehicles.

The most important projects are the HyNor Oslo Bus project, which will lead to 5 hydrogen buses operating in the county, and the HyNor Lillestrøm project, which will work as a hydrogen technology test center. Local research institutes are involved in the planning and design of the center which will have an adjoining station for car refueling. Amongst others ACC also supports a project at the Oslo international airport at Gardermoen.

It is the goal of ACC to reduce local emissions in the county, while promoting business development. Supporting hydrogen technology achieves both those goals. ACC is working to establish a regional strategy on hydrogen and other non-fossil energy sources in transport.
Akershus Energi is a medium sized energy producer. In Lillestrøm we run a district heating plant, which combines several local renewable energy sources. Our main energy source is wood-chips. We have also built a 5 kilometer long pipeline, which transports landfill gas, used in heat production.

A portion of this gas is to be used by Hynor Lillestrøm AS to upgrade and convert to hydrogen. Akershus Energi has constructed a R & D building at the site, which houses hydrogen production equipment and other hydrogen and biogas-related demonstration projects, and will facilitate the hydrogen refueling on the premises of the energy park.

CONTACT: Bjørn Dag Gundersen | bdg@aeas.no | www.akershusenergi.no
Bellona endeavors to identify and implement sustainable solutions to the world’s most pressing environmental problems. Among these is the development of clean energy chains. Our activities within hydrogen range from policy development to campaigning for hydrogen as an energy carrier. Bellona imported the first two hydrogen vehicles to Norway, Mercedes Sprinter vans with converted IC-engines, as early as 2002. Bellona strives to be a bridge builder between industry and policy makers, working closely with the former to help them respond to environmental challenges in their fields, and proposing policy measures that promote new technologies with the least impact on the environment.

The Bellona Foundation is an international environmental NGO based in Norway. Founded in 1986 as a direct action protest group, Bellona has become a recognized technology and solution-oriented organization with offices in Oslo, Brussels, Washington D.C., St. Petersburg and Murmansk. Altogether, some 75 engineers, ecologists, nuclear physicists, economists, lawyers, political scientists and journalists work at Bellona.

**Contact:** Martin Hviid Nielsen | martin@bellona.no | www.bellona.no
Since 1994, Mercedes-Benz has actively been working on the development of hydrogen fuel cell vehicles, and has had an extensive test project with Mercedes-Benz B-Class F-CELL vehicles in Germany, USA and Norway since 2010. As the Norwegian official importer of Mercedes-Benz, we are proud to participate in this test project. 10 F-CELL vehicles are leased to different users, mostly large public and private companies and institutions. The test-project was part of the project “H2moves Scandinavia”, which was funded by the EU hydrogen program Fuel Cells and Hydrogen Joint Undertaking, and by the Norwegian state institution Transnova. The test program continues, and will be evaluated annually.

The experience so far shows that the fuel cell technology is on a high level of quality and reliability, and Daimler/Mercedes-Benz foresee to start series production of fuel cell vehicles for mass market distribution by 2017.

Bertel O. Steen AS was established in 1901. The company is Norway’s oldest car importer, and among the biggest service- and trading companies in the country. The turnover in 2011 was NOK 11,8 billion, with 2 702 employees.

CONTACT: Henning Larsen | henning.larsen@bos.no | www.bos.no
BBU is a consultancy with a business concept of innovation through cooperation and partnership. The company’s charter is to identify environmental and Corporate Social Responsibility (CSR) issues and facilitate innovative sustainable solutions.

BBU operates through “CSR Norway”, a network with representatives from some of Norway’s largest business enterprises. CSR has over the last decade developed into a well respected participant within the disciplines of environmental solutions and is engaged in projects both nationally and internationally. BBU is also heavily involved in the project “Cities of the Future”. Through close collaboration between the 13 largest cities in Norway, the business sector and the Government the goal is to implement solutions necessary for a substantial cut in greenhouse gas emissions.

The composition of members in the network fosters both commercially viable and environmentally sustainable solutions and represents thus an enabling platform to introduce hydrogen into the society. In this respect BBU has the ambition of being a catalyst, promoting adequate actions from members of the network.

**Contact:** Dag Sanne | sanne@bbu.no
Carbontech aims to become a producer of high quality carbon and hydrogen rich gas from natural gas. The carbon material produced, so far in small quantities, is nanoparticles of uniform size, diameter 20 nm. The hydrogen rich gas obtained is mainly hydrogen with some CO, CO$_2$ and H$_2$O present.

Carbontech has no fuel cell related activities, other than possible use of the hydrogen rich gas as fuel for fuel cells.

Carbontech has developed and patented its technology in EU, Norway and US. A pilot plant has been successfully built and operated, and a larger prototype plant is being tested.

We currently work to enhance the efficiency and quality of the process equipment and products. For this purpose we seek cooperation with other parties, and contact with investors with interest for our activity.

CONTACT: Arne Godal | arne.godal@carbontech.no | www.carbontech.no
CerPoTech (Ceramic Powder Technology AS) is a spin-off company from the Norwegian University of Science and Technology (NTNU), developing and producing high quality ceramic powder for energy technologies and electroceramics. SOFC (solid oxide fuel cells) is one of the main market segments for the powders, where CerPoTech deliver materials for anodes, cathodes as well as electrolyte.

CerPoTech specializes in the fabrication of multicomponent oxide powders according to the customers’ specifications regarding composition and powder morphology. In addition to commercial sales to industry and R&D-purposes, CerPoTech is partner in national and EU funded R&D projects treating SOFC and membrane technology.

The company operates its own industrial production facility close to Trondheim and is still benefiting from its close proximity to its founding organization, NTNU, through close cooperation with several research groups.

CONTACT: Arve Solheim | arve.solheim@cerpotech.com | www.cerpotech.com
Christian Michelsen Research AS (CMR) is a technology research company that focuses on commercial research and development. The company is based in Bergen and has 150 employees.

CMR Computing focuses on IT-R&D, with emphasis on advanced visualization and analysis of data. The goal is to develop new program modules and program systems that contribute to increased value creation for clients in four solution areas: visual communication, data analysis, simulation and decision-making support.

CMR Instrumentation's activities are directed towards instrumentation R&D. We offer expertise on a wide range of sensor technologies including in particular acoustic, electromagnetic, optic and nuclear technologies as well as application knowledge within our three main market areas: Oil and gas, Fisheries and aquaculture and Environment and geophysics. Metering solutions for hydrogen quality and flow is one of the application areas where CMR Instrumentation is involved.

Fuel cell and hydrogen activities in the subsidiary companies Gexcon AS and Prototech AS are described in their respective entries in this guide.

Contact: Arvid Nøttvedt | arvid@cmr.no | www.cmr.no
DNV is an independent foundation with the purpose to safeguard life, property and the environment. Our core competence is to identify, assess, and advice on how to manage risks. DNV operates through 300 offices in 100 countries.

DNV has invested heavily in hydrogen R&D through active participation in national and international project and networks (e.g. EU and IEA activities). DNV has undertaken several hydrogen risk and safety studies for processes and projects involving the production of or utilization of hydrogen. Based on this, our competence, cross discipline technical expertise and wide industry knowledge are available to help you realizing the potential for safe and cost efficient introduction and use of hydrogen. Our services include hydrogen risk and safety assessments (e.g. HAZID, HAZOP, RRR and QRA studies) and certification of hydrogen equipment and components.

DNV became a pioneer in developing fuel cell technology for ships through leading the FellowSHIP project. FellowSHIP developed the world’s first marine, industrial size fuel cell (320 kW). The fuel cell was successfully tested and integrated in the offshore support vessel Viking Lady. The technology provides ultra clean, fuel efficient operation, and zero emissions of NOx, SOx and particles. DNV is also engaged in R&D initiatives for development of fuel cells in new build cruise vessels.

**CONTACT:** Gerd Petra Haugom | gerd.petra.haugom@dnv.no | www.dnv.no
Eidesvik Offshore ASA is a Norwegian shipping company operating a fleet of various offshore vessels. Eidesvik participates in the FellowSHIP development programme where our vessel the PSV Viking Lady had a 330 kW MCFC fuel cell installed for qualification testing. The vessel has now class notation “Fuel Cell Safety”.

The FellowSHIP programme is ongoing to 2013 with the Viking Lady as laboratory. A battery system will be installed and control system will be developed for hybrid configuration of all machinery. More information about the FellowSHIP project at: www.vikinglady.no

CONTACT: Kjell Sandaker | kjell.sandaker@eidesvik.no | www.eidesvik.no
Energy Norway is the trade organization for around 260 generators, suppliers, distributors and a few water regulation associations. The main purpose of Energy Norway is to deal with industry-related economic, political and R&D issues on behalf of its members, to provide as good framework conditions for the industry as possible with respect to financial, legal and technical issues. Internationally Energy Norway represents Norway in EURELECTRIC – The Union of the Electric Industry.

The main activities related to hydrogen are theoretical R&D projects.

Part of Energy Norway’s strategy is to increase competence and knowledge related to new energy and strategic sources for the future environmental-friendly energy system.

When it comes to hydrogen, Energy Norway evaluates hydrogen as an important source for a future environmental-friendly energy system.

Energy Norway coordinates and manages research and development projects funded by power- and network companies in Norway and “The research council of Norway”.

**CONTACT:** Solgunn Furnes | sf@energinorge.no | www.energynorway.com
Enova SF is a public enterprise owned by the Royal Norwegian Ministry of Petroleum and Energy. Enova SF’s main mission is to contribute to environmentally sound and rational use and production of energy, relying on financial instruments and incentives to stimulate market actors and mechanisms to achieve national energy policy goals.

Enova SF’s objectives, as stipulated by the Norwegian Parliament, apply to stationary land-based use and production of energy. Part of the activities is funding of hydrogen and fuel cells market introduction.

CONTACT: Kjell Olav Skjølsvik | kjell.olav.skjolsvik@enova.no | www.enova.no
GasPlas AS has developed a groundbreaking non-equilibrium (or “cold”) plasma technology for production of hydrogen from biogas or natural gas. The technology enables clean hydrogen transport system with close to zero CO₂ emissions from well to wheel. Effective distribution of H₂ can be achieved using existing natural gas networks and generating hydrogen on demand at the point of use. Carbon can be collected as powder and used as a high valued product (Carbon Capture and Use — CCU), eliminating the need for expensive CO₂ capture technology (Carbon Capture and Storage — CCS).

GasPlas AS owns patents and related IP for cracking hydrocarbon feedstock through a novel, scalable microwave plasma reactor at atmospheric pressure or above. The non-equilibrium plasma breaks the molecular bonds resulting in free C and H atoms. Free C and H atoms combine to form desired products, i.e., hydrogen gas and elemental carbon, either in amorphous powder or nano structured form.

GasPlas AS invites partnership for commercialization of the H₂ and carbon production technology.

CONTACT: Per Espen Stoknes | post@gasplas.com | www.gasplas.com
Gassnova SF is the Norwegian state enterprise for carbon capture and storage. Gassnova supports research, development and demonstration of CCS technologies by providing state financial support. Gassnova is managing the states interests in the realisation of industrial demonstration and full scale CCS projects decided by the Parliament. Gassnova also act as advisor to the Ministry of Petroleum and Energy. Our work lies at the intersection of the climate debate, ambitious political objectives, research on CCS, as well as the establishment of a new type of industry. It is important to find efficient models for cooperation between industry and research environments to ensure effective implementation of CCS.

Relevant focus for hydrogen:
- Stationary full-scale production of hydrogen for power generation (pre-combustion technology)
- Technology development within pre-combustion technology:
  - Reforming of natural gas
  - Membranes and absorbents for hydrogen and CO$_2$
  - Process- and energy optimization
  - Hydrogen enriched combustion
- Stationary full-scale power generation by natural gas or hydrogen driven fuel cells

CONTACT: Eirik Gjernes | eg@gassnova.no | www.gassnova.no
GexCon is a wholly owned subsidiary of Christian Michelsen Research (CMR). GexCon continues the explosion research activities initiated at Chr. Michelsen Institute (CMI) in 1970, including the development and validation of the computational fluid dynamics (CFD) code FLACS that started in 1980. GexCon has about 90 employees worldwide. About 50 work in the main office in Norway, and the rest in subsidiaries in the US, UK, Italy, Australia and Indonesia.

**GexCon provides services in the following areas of hydrogen safety:**

- Sale/lease of the CFD-software FLACS for hydrogen and natural gas consequence assessments: dispersion, fire and explosion scenarios.
- Consulting services using FLACS: dispersion, ventilation, fire and explosion studies, including quantitative risk assessments (QRAs).
- State-of-the-art test facilities for dispersion and explosion experiments with hydrogen, other gaseous fuels, dust and sprays/mists.
- Equipment testing, hazardous area classification, and explosion protection documents within the framework of the ATEX directives.
- Safety training courses, including live demonstrations.

GexCon has extensive experience from various aspects of hydrogen safety, participates in the IEA HIA Task 31 Expert Group, and is a member of HySafe.

**Contact:** Trygve Skjold | trygve@gexcon.com | www.gexcon.com
Hexagon Composites is a listed Group, with head office in Ålesund, Norway. The Group had 511 employees and achieved a turnover of MNOK 1033 in 2012. The Group develops and commercializes competitive products based on advanced materials and technologies. The Group aim to be a leader in global market for composite cylinders.

In our companies, 70MPa hydrogen storage cylinders has been in production for more than 15 years, and since 2007 also 50 and 105MPa cylinders dedicated for storage of hydrogen at Hydrogen Refueling Stations.

Hexagon Composites focuses on products with potential to be produced in highly automated production lines, customized products for major stakeholders and composite cylinder products for dedicated application.

Today, Hexagon Composites is a global supplier of composite cylinders to major stakeholders in automotive, bulk hauling and for stationary storage of compressed gases. Product sizes in serial production are ranging from 11L and up to 8400L and for some of the products with pressure rating up to 105MPa.

**Contact:** Per-Sigurd Heggem | per.heggem@hexagonraufoss.com | www.hexagon.no
Hynor Lillestrøm AS is responsible for the overall design, construction, and operation of a hydrogen refueling station with on-site hydrogen production based on renewable energy sources. The station is located in Akershus Energy Park in Lillestrøm, 30 kilometers north of Oslo.

The plant consists of a hydrogen refueling station (HRS) and an Innovation Zone for R&D. The HRS features small-scale hydrogen production, compression, and dispenser system, supplying hydrogen to fuel cell vehicles in the Oslo area.

The Innovation Zone includes a sorption enhanced steam methane reformer, developed by Institute for Energy Technology (IFE), which converts upgraded landfill gas to hydrogen. A thermally-driven metal hydride hydrogen compressor developed by Hystorsys AS is used for hydrogen compression. In our Innovation Zone we welcome test and demonstration of relevant technology from national and international companies. Several companies have already signed up to use the infrastructure to demonstrate their innovative solutions. Institute for Energy Technology (IFE) is responsible for the overall system integration.

Hynor Lillestrøm welcomes visitors to the plant, which also includes a hydrogen laboratory used by teachers, students and others to increase the competence about hydrogen and fuel cells.

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HydrogenPartner AS is a technology company focusing on delivery of alkaline electrolysers. Our electrolysers can produce from 5 to 600 Nm³/h with a pressure up to 50 bars from one cell block, so you can avoid compressors for most applications. All our electrolysers are well proven and they are very reliable and cost effective. We are a complete supplier and can deliver turnkey solutions including compressors for bottles filling, storage systems and other belonging units. Our partner factory is certified according to ISO 9001, and has delivered more than 300 complete hydrogen plants worldwide.

We can be your partner in large scale electrolyser plants for grid balancing, hydrogen refueling stations, and new energy solutions. We can supply onsite hydrogen plants to the traditional industry as well.

HydrogenPartner has been granted a patent for the combination of renewable energy sources (PV panels or Wind mills) in combination with Fuel Cells. More details are given on our WEB page.

HydrogenPartner AS is based in Skien, Norway.

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HYOP is a company dedicated to operate hydrogen refueling stations and hydrogen production facilities. HYOP will plan for, and establish a wider hydrogen infrastructure, bringing hydrogen fuel towards commercialisation.

HYOP was established late 2011 and has four hydrogen stations in operation; Porsgrunn, Drammen and two in Oslo – Økern and Gaustad. Even though HYOP has a very short history, it is one of the most experienced companies in the world on planning, building and operating hydrogen infrastructure. Several decades of knowledge from Norsk Hydro and Statoil is carried on into HYOP, and the company has almost a decade of operational experience with building and operating hydrogen stations. HYOP is owned by Kjeller Innovation AS, the CEO and CTO, and will as it develops attract other owners to the company.

CONTACT: Ulf Hafseld | uh@hyop.no | www.hyop.no
Hyundai Motor Company of Korea is the world’s fifth largest auto manufacturer, with approx. 78,000 employees. In Norway, the company has around 67 dealers, and has sold more than 82,000 vehicles since its launch here in 1992.

Hyundai Motor Norway AS (HMN) imports and markets cars and accessories from Hyundai. HMN’s head office in Ensjø in Oslo has more than 35 staff. Hyundai’s main advantage is state-of-the-art and reliable vehicle models with and Norway’s best warranty of 7 years - 200,000 km.

One of Hyundai’s objectives is to produce zero-emission vehicles. Hydrogen vehicles are a major step in this direction, and Hyundai is therefore focused on commercialising this technology for vehicles used for longer distances, while we believe that battery-electric vehicles are best suited for urban use and shorter distances. HMN has together with HyNor and ZERO field-tested two prototype ix35 FCEV hydrogen vehicles as part of the H2-Moves Scandinavia project, and the latest generation FCEVs are now available for purchase by private customers and companies.

**Contact:** Morten Brusletto | morten.brusletto@hyundai.no | www.hyundai.no
Hystorsys AS develops and manufactures hydrogen storage and compression systems based on metal hydrides (MH).

The company is based on the long-term research expertise of Institute for Energy technology (IFE), and thus possesses experience on the complete hydrogen chain from fundamental understanding of hydrogen-metal interactions to their use in hydride-based energy systems.

**MH-compression:**
MH-compressors enable compression of ultra-clean hydrogen without the need of a high-quality energy carrier such as electricity, exploiting heat (e.g. industrial waste-heat) for compression. Furthermore, thermal MH-compressors have a minimum of moving parts giving long maintenance intervals.

**MH-storage:**
One of the main advantages of MH-storage is high hydrogen density at low pressures. Some metal hydrides have volumetric storage densities higher than liquid hydrogen, without the need of maintaining a low (20 K) temperature. In the MH-system hydrogen is chemically bound - thus, not volatile or mortgaged with boil-off. The MH-system eliminates the need for expensive high-pressure compression, and has the property of an intrinsic safe system.

**Contact:** Jon Eriksen | post@hystorsys.no | www.hystorsys.no
The objective of Innovation Norway is to promote private- and socio-economic profitable business development throughout Norway, and to release the commercial opportunities of the districts and regions by encouraging innovation, internationalization and image-building. Core clients are Norwegian companies, predominantly SMEs. Innovation Norway is owned by the state, and has offices in all the Norwegian counties and in more than 30 countries worldwide.

**Innovation Norway has a number of different services related to:**
- Skills-based financing
- Consultancy
- Network building

In the context of hydrogen and fuel cells, a relevant financial support service is our Industrial Research and Development (IFU) Contracts. These require an agreement between two or more companies to cooperate in developing a new “state-of-the-art” product, an innovative process or service which one or more of the participants need. Through our international offices, we have access to relevant network and competence which can assist Norwegian companies in their involvement and cooperation related to hydrogen and fuel cells market developments internationally.

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IFE has been involved in hydrogen research for more than 50 years. At present 3 departments are working within the field and their activities are presented separately. Institute for Energy Technology is an independent research foundation performing research on the following subjects related to hydrogen and fuel cells:

- Hydrogen production
- Hydrogen storage
- Fuel cells
- Hydrogen energy systems

Department of Physics is performing fundamental studies on new hydrogen storage materials. Example: complex hydrides (alanates), Magnesium-based hydrides.

Department of Environmental Technology focus on co-production of $H_2$ and electricity with integrated $CO_2$-capture through sorption enhanced reforming.

Department of Energy Systems is involved in both modelling and experimental research on hydrogen storage in metal hydrides, PEM fuel cells and electrolyser, and hydrogen energy systems.

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Kongsberg Automotive supplies premium products to the global vehicle industry. The company’s products enhance the driving experience by making it safer, more comfortable and sustainable. With revenues of about EUR 1 billion and approximately 10 000 employees in 20 countries, Kongsberg Automotive is a global supplier. The company is headquartered in Kongsberg, Norway, with 32 factories worldwide.

ePower - a development company owned by Kongsberg Automotive and QRTECH, focuses on systems for electric and hybrid vehicles. The company designs and develops electronic and electromechanical components and systems for vehicles with electric or hybrid powertrain. In the product portfolio you will find converters, inverters, chargers and other power electronics components in the boundary layer between the battery and the electric motor in a vehicle.

The main activities of ePower will be to provide R&D and design services for power electronics connected between the battery and the electric motor in pure electric-, hybrid- and fuel cell electric vehicles.

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www.kongsbergautomotive.com
Lillestrøm Centre of Expertise (LCE) connects cutting edge research from local research institutions, visionary energy companies and progressive local environmental policies, and facilitates large public-private projects – which are locally beneficial, but are an integral part of both national and international hydrogen projects.

LCE holds the secretariat for the Norwegian Hydrogen Forum and the Hydrogen Council, plays a central part in the HyNor project and is also managing the Norwegian part of the Interreg IV project “NextMove”, which includes partners from Denmark and Sweden. Recently, LCE took the initiative and led a feasibility study for the use of hydrogen at Oslo airport Gardermoen.

LCE is also part-owner of Hynor Lillestrøm AS.

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Lindum’s vision is “leading innovating and value-creating waste treatment – for the environment”. We are established as a significant actor in Norway within waste handling, having developed special competence within biological waste treatment and biogas treatment and utilization. Our strategy is to be involved in the development of future energy systems.

We are involved in two hydrogen-related projects:
THE HYNOR PROJECT. The Hydrogen Road between Oslo and Stavanger was opened in 2009, and the hydrogen station in Drammen will be provided with “green” hydrogen gas produced from biological waste from 2014.

THE HYDROGEN PROJECT IN COOPERATION WITH INSTITUTE OF ENERGY TECHNOLOGY (IFE). IFE has developed a new hydrogen production process (Sorption Enhanced Steam Methane Reforming – SE-SMR) they are modifying this process use Lindum’s CO₂ neutral biogas as feed gas. Lindum’s contribution is to produce and upgrade the biogas to fit the SE-SMR process. Lindum has built the first full-scale hydrogen sulfide removal unit in Northern Europe designed for landfill gas.

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Lloyd’s Register Consulting provides independent risk management and engineering dynamics services to a wide range of international clients. Our service portfolio represents the rich union between Scandpower and Lloyd’s Register ODS. Together, we work to advance safety and technical excellence.

Lloyd’s Register Consulting’s main market areas are the following: Oil and gas | Nuclear | Transportation | Energy and industry

Lloyd’s Register Consulting’s risk management services fall within the following areas:
Risk based management | Risk analysis | Technical safety and consequence modeling | Human factors and work environment | Reliability and asset performance | Risk management software

Lloyd’s Register Consulting is a member of the Lloyd’s Register Group. Lloyd’s Register Consulting has performed several safety studies for different uses of hydrogen. This includes risk analysis, emergency preparedness analysis and audits for different stations within the HyNor project, but also within the area of industrial use of hydrogen.

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Lyse Neo is a company in the Lyse industrial group, which is based in Stavanger in the Southwestern part of Norway. Lyse Neo is working with the development of new energy solutions within natural gas, biogas, heating, cooling, and new fuels such as natural gas, biogas and electricity for transport. The aim of the company is to contribute to an efficient and economical use of the region’s energy resources, and to provide strong competence in the areas of analysis, planning and development.

Lyse Neo is open for collaboration with actors who want to integrate hydrogen refueling possibilities at the already existing refueling stations that provide gas and fast charge electricity.

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NAF is the largest member and consumer organisation in the Nordic countries with about 500 000 members. The members are e.g. offered road assistance, technical and legal consultancy, and insurance. More than 180 000 assistances are handled by road patrols and 200 000 vehicles tested at NAFs 49 test centres nationwide each year. NAF keeps a high profile in media and the magazine “Motor” has almost 1 million readers.

Safer and more environmentally friendly mobility is a major goal for NAF. This means among other things that NAF is searching solutions politically, as well as giving consumer advise on new technology and mobility options. Making alternative fuels and technology available and attractive for our members is important.

NAF is represented in the Norwegian Hydrogen Forum, and currently member of the board.

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NEL Hydrogen is a world-leading supplier of hydrogen generation plants based on alkaline water electrolyser technology. Our range of large scale NEL A electrolysers that produce hydrogen under atmospheric pressure are considered world class. With decades of experience in the field of electrolysers together with sustained efforts in research and development we have managed to reach today’s unique technology. The NEL A electrolysers are today well recognised for its robustness, reliability and energy efficiency. With these features our technology sets a benchmark for others to follow.

NEL Hydrogen is today a privately owned company based in Notodden, Norway. Our roots lie more than 85 years back when Norsk Hydro started up large scale electrolyser plants providing hydrogen for ammonia production. We have successfully delivered electrolyser solutions since the 1920’s within a wide number of worldwide references across numerous industrial segments.

We have heart for hydrogen – we have strong traditions – and we have the vision to provide superior hydrogen solutions today and in the future.

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Nordic Power Systems is preparing for commercial market introduction of a diesel fuel cell auxiliary power unit (APU). The APU is virtually emission free, has a higher efficiency than a conventional generator, and may be used for both electricity & heat production.

The diesel fuel cell APU runs on conventional fuels like diesel and bio fuels. The technology has especially attracted the defense industry due to its silent operation. The latest prototype is a fully integrated APU running on auto diesel and automatically adjusts power from idle to full power depending on demand. Development is currently done to mature the Solid Acid fuel cell technology, this includes development of stamped metallic bipolar plates to increase fuel cell stack robustness and reduce weight, volume and cost.

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NorECs was founded 2001 by prof. Truls Norby at Department of Chemistry, University of Oslo, and develops and produces products based on Norwegian university research, with sales worldwide.

Main products comprise the ProboStat™ sample holder system for high temperature electrical materials properties measurements and periphericals (furnaces, gas mixers, flowmeters, software, test samples). The system is in widespread use also for research and laboratory tests of ceramic button and tubular fuel cells, steam electrolysers, and gas separation membranes.

For tests of small fuel cell systems (e.g. button cells) NorECs delivers a suitable gas mixer (FCMix) with simple and safe humidification bubblers.

NorECs is also Norwegian representative for Swiss-made Vögtlin high quality gas control equipment such as mass flow controllers, precision valves and rotameters.

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Norgestaxi is a taxi company, operating in Oslo, Bergen, Trondheim, Stavanger, Kongsberg, Drammen and Hønefoss. The company is owned by the Swedish company, Taxi Kurir which is based in Stockholm, and is thus part of a total taxi fleet of 5 000 cars operating in Norway, Sweden and Denmark.

In Norway the fleet consists of approximately 800 cars, operated by separate limited daughter companies in the seven cities. The biggest operation is in Oslo, where Norgestaxi Oslo AS operates 350 cars.

Norgestaxi is currently exploring the possibilities of phasing in hydrogen vehicles in the fleet, as a part of Norgestaxi’s environmental efforts toward lowering emissions from the operation.

**Contact:** Erlend Eidsvoll | ee@norgestaxi.no | www.norgestaxi.no
FFI is the prime institution responsible for defence-related research in Norway, and is the chief adviser on defence-related science and technology to the Ministry of Defence and the Norwegian Armed Forces.

Primary focus on hydrogen and fuel cells has been on implementation of sealed systems for underwater application. Both stationary and mobile power source systems have been developed at FFI, such as the Sea Water Battery and HUGIN (autonomous underwater vehicle (AUV) with an aluminium/hydrogen peroxide semi-fuel cell). Currently, work is being done on implementing a PEM fuel cell into an AUV.

FFI also has fuel cell activity on soldier systems, which typically includes engineering and testing of fuel cell systems based on commercially available products.

Due to the military community’s interest in power generation from military fuel (kerosene/JP-8), FFI has plans of implementing a fuel cell based auxiliary power unit (APU) in a military vehicle, fueled with kerosene.

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The study program gives the students a combination of qualifications in both the natural sciences and technology, qualifications which are required by society for operation and innovation within businesses, management and research. The study program emphasizes topics which are central to the maintenance and development of a sustainable society.

The students acquire the qualifications necessary to become key employees, specialists, within businesses where the combination of natural science and technology plays an important part. The students have upon completion of the program a basic knowledge of mathematics, physics and computer science and are also able to plan and perform data acquisition, treatment, analysis and interpretation of data. The acquired knowledge is applicable in experimental situations within environmental physics or energy use. The graduates also have a scientific platform within the central environmental political questions.

The program encompasses courses chosen according to preferred knowledge and the topic for the Master thesis. Several students at UMB have completed a hydrogen related Master thesis at Institute Energy Technology (IFE).

**Contact:** Espen Olsen | espen.olsen@umb.no | www.umb.no
HYCONES - Hydrogen storage in carbon cones.
n-Tec and its consortium partners finished an EU funded research project called HYCONES at the end of 2009. HYCONES proved that the use of a new, leading-edge nanomaterial called carbon cones (CCs) could be used as a practical, inexpensive, lightweight, and high capacity H₂ storage medium, capable of storing and releasing over 4 weight % of H₂ at room temperature.

Carbon cones are a new allotrope of carbon, fundamentally different from other known carbon structures and are composed of carbon microstructures in the form of flat discs and cones. The CCs consist of curved graphite sheets. Patented experiments clearly demonstrate unprecedented uptake-release of hydrogen compared to other carbon materials, as well as a new form of interaction between carbon and hydrogen, capable of releasing hydrogen at room temperature.

HYCONES main target is to develop a radically new hydrogen storage material with the potential to meet vehicle on-board storage requirements.

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Research activities are mainly related to hydrogen production, membrane separation and CO₂ sorbent technologies, and some activities within fuel cells. Catalysis is important in the production of hydrogen from hydrocarbons. The conversion of transportable hydrogen carriers such as natural gas, biomass, propane and (bio)alcohols are studied. Micro structured reactors are being developed, tested and structured supports (monoliths, foams) are being studied for short contact time reaction systems, such as partial oxidation. Carbon molecular sieve membranes and mixed matrix materials are being investigated for the recovery of hydrogen from mixed gas streams.

Separation technology also includes membranes for selective CO₂ capture. CO₂ and/or H₂ separation technologies in hydrogen production processes are targeted through CO2 sorption enhanced reaction concepts, chemical looping and membrane reactors based on novel Pd thin film technology as well as high temperature oxygen membranes. The department is also developing improved fuel cell catalysts based on carbon nanofibers.

Dynamic modelling and development of control strategies for fuel cell systems are also being carried out.

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The facilities at the department of chemistry relevant for hydrogen and fuel cells include:

- Several test stations to test PEM fuel cell performance
- Equipment to measure the thermal conductivity of materials
- Apparatus to measure transport numbers of ions and water
- A calorimeter to measure electrochemical heat effects

The group produces around 10 journal articles and the same number of conference papers per year in the field of non-equilibrium thermodynamics for systems from the nano-meter to the meter scale. Of particular relevance is:

- Issues related to energy efficiencies of systems
- Renewable energy sources (osmotic power, thermoelectricity)
- Computer simulations of hydrogen adsorption on graphite

The group of non-equilibrium thermodynamics has studied transport properties in membranes over a 20 year period, and have developed theories of transport relevant for fuel cells. We are now studying surface phenomena in order to learn more about the optimal microporous catalyst layer performance. The group does experiments as well as theoretical modeling of electrolysis systems, and collaborates with around 20 international groups.

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www.chem.ntnu.no/nonequilibrium-thermodynamics
The electrochemical energy group at the Department of Material Science and Engineering is headed by Professor Svein Sunde and Associate professor Frode Seland, and includes typically some ten PhD students, Post docs, and in addition a varying number of MSc students. The laboratory facilities include standard electrochemical equipment, and an Electrochemical Scanning Probe Microscope (AFM / STM), equipment for differential electrochemical mass spectroscopy (DEMS), and various photoelectrochemical equipment. The group also has at its disposal access to other major equipment units at the Department as well as the NTNU Nanolab.

The main areas of research are electrocatalysis for PEM fuel cells and water electrolysis (PEM and alkaline), and embrace both theoretical and experimental work. The group collaborates with a number of organizations in Norway and abroad. The academic staff associated with the group teaches several courses at MSc and PhD levels related to hydrogen technology at NTNU.

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Founded in 2008 as a spin-out from the University of Oslo and the Norwegian university of science and technology (NTNU), Protia AS is a venture-backed, development-stage company focused on use of ceramic proton conductors to make energy cheaper and cleaner.

Today, Protia is developing proprietary proton conducting membrane materials and manufacturing processes to build highly efficient reactors that convert natural gas to synthetic petroleum liquids. These next generation gas-to-liquid (GTL) reactors will be scalable, have lower carbon emissions than alternative GTL technologies, and they will generate pure hydrogen as a valuable by-product.

Protia’s ceramic proton conducting membrane technology will also be applied for pre-combustion carbon capture processes and next-generation high-efficiency hydrogen fuel cells.

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Prototech AS works with national and international prototype technology and product development, was established in 1988 and is a part of the Christian Michelsen Research (CMR) group. Prototech has four market areas: Energy, Space, Oil & Gas and Industrial Product Development.

Prototech has been involved in fuel cell development since 1990. Prototech develops fuel cell systems for different applications using commercially available components. Prototech has competence within design, analysis, manufacturing and testing of stack components, stacks, balance-of-plant and complete systems.

Prototech has participated in a number of national as well as EU projects related to fuel cells and fuel cell systems. Prototech has also carried out projects for the European Space Agency related to hydrogen storage and compression systems as well as regenerative fuel cell systems for satellites and spacecraft.

Prototech supplies balance-of-plant components and complete systems for test and demonstration. Testing and demonstration are carried out in our own fuel cell and hydrogen laboratories.

CONTACT: Arild Vik | arild.vik@prototech.no | www.prototech.no
The Research Council of Norway provides funding for fundamental, strategic and applied research on the hydrogen area. This is both in terms of technologies for production, storage, distribution/transport and the use of hydrogen. Support for the testing and demonstration of hydrogen technologies in the transport sector is now mainly covered by Transnova.

The Research Council of Norway is pivotal in relation to Norwegian participation in international cooperation agreements.

Support for hydrogen and fuel cells related projects will mainly be through the national programs ENERGIX (Clean energy for the future) and NANO2021 (nano materials).
RotoBoost has developed a rotating alkaline water electrolyzer, the RotoLyzer®. The RotoBoost vision is to be the leading innovator in hydrogen production under “high g” conditions with RotoLyzer® units. This patented technology gives extremely compact, efficient units and also integrates a new compression method.

Prototype tests have proven;
- Significant reduction of power consumption.
- Extremely compact stack construction.
- Clean gas separation, high gas purities.
- Very large range in current densities (A/cm²).
- Electrode gas-blocking is reduced dramatically.
- Quick start up (seconds).
- Potential for many further improvements and optimizing.

A complete hydrogen production plant based on RotoLyzer® technology will be significantly less complex, smaller, and have very low investment and gas production costs. Long-term testing of commercial scale cells is ongoing and the basic design elements of a commercial product are established.

RotoBoost AS invites partnership for commercialization of the RotoLyzer®.

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Ruter As is the public transport authority for the city of Oslo and the surrounding county of Akershus. Ruter plans, procures and markets the public transport in this area, providing nearly 300 million travels a year.

Ruters target is to reduce local air pollution and noise and to use only renewable energy by 2020. This transition is well under way, including the use of biofuel, electric trains, metro and trams, and hybrid diesel electric buses.

Fuel cell (FC) buses with hydrogen are also being tested. Ruter participates in the HyNor Oslo Buss project which has been granted EU funding, and is a member in the CHIC-project (Clean Hydrogen In European Cities). Ruter has since 2012 operated five FC buses running between the Kolbotn area and Oslo City. A local hydrogen production and fuelling station has been constructed at Rosenholm.

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SINTEF is the largest independent contract research organization in Scandinavia and the 3rd largest in Europe. SINTEF develops and implements technological solutions in society and thereby creates value through knowledge generation, research and innovation.

**SINTEF’s hydrogen related research projects include:**

- Production of hydrogen from fossil and renewable energy sources
- Membrane technology for hydrogen separation
- Hydrogen liquefaction and storage (metal organic frameworks)
- Fuel cell and electrolyzer components and systems
- Hydrogen combustion (gas turbines and internal combustion engines)
- Well-to-wheel analyses and market studies
- Safety, societal and political aspects

**SINTEF employees hold key positions in strategic forums including:**

- EU’s Joint Undertaking on Fuel Cells and Hydrogen (chairing WG “Transportation and Refueling Infrastructure”)
- EERA Joint Programme on Fuel Cells and Hydrogen technologies (co-establiser and participant)
- Advisory board for Norwegian Government (chairing the Strategic Hydrogen Council)

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Established in 1975, SVAFAS, Stavanger Valve & Fitting AS, is Swagelok’s authorized sales and service center in Norway. We deliver an expanding range of the highest quality fluid system products, solutions and training seminars. This together with knowledge, resources and innovation, brings value for our customers in Norway. Extraordinary quality is our promise and we provide services that are exceptional - that exceed our customers’ expectations.

Our supplier Swagelok Company is a $1.3 billion, privately-held company. Swagelok designs, manufactures, and delivers an expanding range of the highest quality fluid system products and solutions. Through an exclusive network of authorized Swagelok sales and service centers Swagelok Company delivers knowledge, resources, innovations, and value to customers worldwide.

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Tel-Tek is a national research institute with focus on energy efficient processes and low emission. We are a project contractor and conduct projects for and in collaboration with industry and public enterprises. Through research, development, technology transfer and advisory services we contribute to strengthening the development of a competitive industry, and encourage new business.

We combine expertise in research and business development to create new opportunities and develop results-oriented solutions.

Tel-Tek is a technological R&D institute with a skilled staff with research expertise and industry know-how. We offer flexible and customized business assistance. Together with the customer we contribute to problem solving and development within our subject areas:

- Powder Technology
- Energy
- CCS
- Industrial Innovation

In cooperation with private and public actors, nationally and internationally, Tel-Tek initiates and develops projects, both professionally and financially.

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Transnova provides financial support to projects within the transport sector that will contribute to the reduction of CO$_2$ emissions. Transnova was established against the backdrop of the Norwegian report on climate in 2008 and the following political consensus.

The most important objective is replacing fossil fuel with fuels with lower levels of – or zero – CO$_2$ emissions and the development of the distribution and use of hydrogen within the transport sector is in this respect important. Transnova mainly funds projects ready for pilot or demonstration.

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UNIK – the University Graduate Center at Kjeller, is a collaboration between UiO, NTNU and the research institutions at Kjeller on education in science and technology at Master and PhD level.

Among the different topics at UNIK, the energy and environment section provides education and training within renewable energy technologies, including hydrogen storage.

We focus on synthesis and characterization of advanced materials for hydrogen storage for vehicular or stationary applications through collaborations at national and international level.

CONTACT: Sabrina Sartori | sabrinasartori@unik.no | www.unik.no
Hydrogen research at University of Agder has been carried out by the renewable energy group at the Department of engineering sciences for many years, originally focusing on alkaline electrolyser technology. Recently the emphasis has shifted towards fuel cell technologies. Several projects focus on developing better electrocatalysts and fuel cell systems. The research activities are also integrated with the teaching program, giving students insight into the latest trends and acquire practical experience. Specific projects include several PhD degrees on the use of nickel based electrodes for hydrogen production in alkaline systems. Both a 5 kW alkaline fuel cell system for stationary applications and several PEM fuel cells are situated at the campus and used in educations and research projects. At the moment the research focus is on the electrolytes and electrodes used in solid oxide fuel cells.

Hydrogen as a fuel is also a major aspect of study and we are looking at ways to generate H₂ from sources other than electrolysis of water. These include biogas, algae and from alcohols such as bio-ethanol and bio-butanol. In addition there is activity on gas generated from biomass such as wood chips. The research group regularly published their results in scientific and engineering journals.

**Contact:** Turid Knutsen | turid.knutsen@uia.no | www.uia.no
The Department of Physics and Technology offer Bachelor and Masters’ degrees as well as research projects aimed at PhD degrees in physics, process technology and nanotechnology. Research in hydrogen-related technology is within the field of fuel cells, particularly solid oxide fuel cells:

1. **Materials research.**
   A range of oxide nanoparticles relevant for ceramic fuel cells have been produced using a new, patented concept of the sol-gel process. These particles have been sintered to produce functional materials, specifically electrolytes and anodes. Work is now in progress to produce thin layers for a new concept of planar solid oxide fuel cells.

2. **Modeling of fuel cells.**
   A comprehensive numerical model for a SOFC combining CFD with modeling of the chemical reactions and heat flows has been built. Another modeling effort concentrates on building a molecular model for solid oxide fuel cell electrolytes. The influence of the configuration of the material, particularly the arrangement of the dopant ions and the effect of realistic grain boundaries on the ion conductivity of the material, is being investigated in this way.

**Contact:** Alex C. Hoffmann | alex.hoffmann@ift.uib.no | www.uib.no
University of Oslo (UiO) offers education at the Bachelor, Master and PhD level in disciplines relevant to hydrogen technology; physics, chemistry, and materials science, and supporting areas like ICT, mathematics and statistics/risk analysis. The “Materials, Energy, and Nanotechnology” (MENA) program provide knowledge and training within renewable energy technologies, among these hydrogen.

There are several strong and relevant activities at UiO for hydrogen technologies, all organized within Centre for Materials Science and Nanotechnology (SMN) with participating groups from the Departments of Physics and Chemistry. Topics include petroleum chemistry and catalysis; solid electrolytes and materials for gas separation membranes, fuel cells and electrolyzers; hydrogen storage materials; semiconductors for solar energy conversion; high temperature sensors; and fundamental research in materials science and nanotechnology. The University partakes in a number of national and international projects within or related to hydrogen technology.

The University of Oslo commercializes its research through its technology transfer company Inven2.com

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Vardar AS is an energy company owned by Buskerud County Council. Vardar wishes to be a cairn (cairn = varde in Norwegian) within the field of renewable energy.

The greatest share of Vardar’s energy production stems from hydroelectric power. The company owns, develops, builds and runs wind power facilities in Norway, Sweden and the Baltic. The forest is another important source of renewable energy, and Vardar thus owns and runs “Hønefoss Fjernvarme AS” a central heating plant at Ringerike, which heats the majority of Hønefoss with raw wood chips as energy source.

Vardar is also engaged in the HyNor project. Earlier Vardar was a co-owner of the company Cenergie, which had as its main purpose to produce stationary fuel cells. Vardar has together with the Technical University of Tallin developed a new converter for fuel cells called UBIK, with the aim of delivering energy to businesses and households. The product is now ready for commercialization.

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The research and development of fuel cells is performed in the Bio-electronics Group at Vestfold University College under the Department of Micro- and Nanosystems Technology (IMST). Our work focus on the development of miniaturised fuel cells that is capable of converting chemical fuels into electrical potential energy.

This cross disciplinary research into novel fuel cells designs were originated through a collaboration with Buskerud University College based on traditional hydrogen fuel cells technologies as well as the Berkeley Sensor and Actuator Centre (BSAC) at the University of California, USA.

The main R&D work is focusing on the use of fuel cell technology as means of generating electricity by the aid of glucose, which is the universal energy source for all living systems. The goal is to develop glucose based micro fuel cells that is capable of powering sensory microsystems that monitor a disease condition inside the human body. Our technology may also realise energy harvesting from flora, based on their natural conversion from light energy to glucose as well as powering autonomous synthetic robots feeding on organic materials from their surroundings.

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Westcon Power & Automation (WPA) has played a major role in the production and development of Low Emission Ships starting with LNG fuel vessels, and has been involved in 9 of 10 Norwegian LNG fueled ships up until 2011.

At present we are working with concept development of a car ferry based on pure hydrogen as energy carrier with electrical power production by fuel cells. The ship does not require any other means of power production or energy storage.

The pre project study involves a ferry driven solely by 8 hydrogen PEM (polymer electrolyte membrane) fuel cells. An alternative solution involves 2 – 6 PA (Phosphoric Acid) fuel cells.

The project involves use of the Organic Rankine Cycle (ORC) in combination with a turbo generator to increase the efficiency of the fuel cells. The goal is to reach an efficiency level of 80% or more.

The project also involves design of a hydrogen production plant for fuel supply at one of the ferry terminals.

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Western Norway Research Institute (Vestlandsforsking) performs a wide range of activities connected to hydrogen and fuel cell research, through cross-disciplinary research approaches, often involving Life Cycle Assessments and Well-to-Wheel analyses. The work is a part of the assessment of environmental impacts from the implementation of various forms of alternative energy. Identification of non-technical barriers to the implementation, as well as development of strategies to overcome the barriers, are key areas of work.

Vestlandsforsking served as project leader for the initiation phase of HyNor - The Hydrogen Road Oslo-Stavanger in 2003, as well as coordinating the input from all Norwegian stakeholders in the EU Integrated Project HyWays - the European Hydrogen Energy Roadmap.

More recently, Vestlandsforsking has conducted a project for the Research Council of Norway on the implementation of alternative fuels, including hydrogen. The main goal was to synthesize the knowledge generated through the many projects in the research programme “Clean Energy of the Future - RENERGI”, connected to barriers for the implementation of alternative energy.

Much of the research carried out by Vestlandsforsking on hydrogen is disseminated internationally through the book “Unintended Consequences of Renewable Energy” published by Springer.

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The ZEG-technology (ZEG®) is a hybrid technology for co-production of electricity and hydrogen from hydrocarbon fuels, with integrated CO₂-capture.

ZEG® provides the power concept with highest energy efficiency from hydrocarbon fuels, in the range of 70 to more than 80% depending on the plant scale. ZEG® is the only concept with the potential to produce electricity and hydrogen with integrated CO₂-capture at lower cost than existing state of the art technologies. In addition there are no emissions from a ZEG Power plant, and the technology also shows great flexibility; all types of hydrocarbons can be used and the relative amount of electricity and hydrogen can be adjusted according to market demand. A 50kW scale plant based on biogas is in the commissioning phase late 2013 at the same time as the pre-engineering of a 400kW plant has started.

ZEG® is a module based platform technology for several applications. On a short to medium term the goal is flexible distributed small to medium scale ZEG® plants for integrated processes that requires power and where hydrogen are needed in further industrial processes or for sale directly to the customers.

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ZERO is a non-profit environmental organization working for zero-emission solutions. In our view, emission-free alternatives exist for all energy use, and ZERO works continuously for their realization. We are not consultants, but participate in partnerships financed by third parties.

ZERO works with a wide range of sources for greenhouse gas emissions, and have focused work on: CCS, biofuels, buildings and heating, hydrogen, electric vehicles, and renewable energy sources like solar and wind energy.

ZERO has been working with hydrogen since 2002. Through participating in the HyNor project, ZERO has been active on hydrogen implementing activities. ZERO is currently participating in the Next Move project, and has had a central role in projects like H2moves Scandinavia and HyNor Oslo Buss, which is part of the CHIC-project. ZERO annually arranges the ZeroRally, which is a fully certified rally for zero emission vehicles.

ZERO is also working actively with politicians and decision makers to secure good incentives for hydrogen vehicles and refueling stations, and through a broad cooperation network ZERO works to make more municipalities, public and private companies buy and use fuel cell vehicles in their daily transport activities.

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The newly developed module by Hexagon Composites has the capacity of carrying 500 kilograms of hydrogen at 500 bar pressure – several times the capacity of current solutions for transport of gaseous hydrogen.
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