The Norwegian HYDROGEN GUIDE 2016
One of several ix35 FCEVs in Bergen on the kickoff of Hyundai’s European tour to Bolzano, June 2016, which was an important contribution to fleet and HRS development in Bergen from 2017. Over 20 cars has been ordered from different entities in Bergen and Hordaland.
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Norway is pioneering green transportation and electric mobility, and has the highest share of battery electric vehicles (BEVs) per capita in the world. In 2015, almost 1 out of 5 new cars was a BEV. It is expected that total accumulated sales of BEVs will pass the 100,000 vehicles mark by autumn 2016, due to long-term policies with strong and predictable tax incentives and owner benefits for zero emission passenger cars. Norway has also over the last 5 years pioneered early testing and demonstration of FCEVs, with hydrogen refuelling stations for cars in operation since 2006 and one for buses since 2012.

With 96% of renewable electricity production and an increasing exploitation of small-scale run-off hydro and wind power due to the ambitious Nordic green certificate market, this creates the need for grid balancing and energy buffering. The growing hydrogen infrastructure could play a crucial role in meeting this challenge. Regional authorities and public financial support entities have for many years supported the development of hydrogen technologies, also backed in the early phase by large industrial players, such as Norsk Hydro and Statoil.
Norwegian companies, research institutes, and universities have over the last decades developed strong competence and long experience in hydrogen technologies. The Norwegian Hydrogen Forum (NHF) is facilitating further development of these skills and capabilities so that Norwegian stakeholders can take an active role and share in the growing global market for hydrogen technologies. NHF aims to be a visible actor in the hydrogen community in Norway and abroad, and has an important coordinator role in fostering this growing industry.

Toyota Norge started selling the Toyota Mirai in Norway from summer 2016. A first car was tested through winter tests with great success from the same year. Read more at www.toyota.no/mirai
Hydrogen is an energy carrier that can be produced from all energy sources, including natural gas and renewable energy, both of which Norway has in abundance. However, a continuous growth in power production and levelling off with respect to power demand, has resulted in a surplus of around 10 TWh/a and steadily falling electricity prices. This has lately created a substantial interest of including production of hydrogen to enhance the flexibility in the energy system.

To coordinate a rapid growth in interest and activities, the Ministries of Petroleum & Energy and Transport & Communications launched in 2005 the first National Hydrogen Strategy and established the Norwegian Hydrogen Council as an advisory body to the Ministries. The Hydrogen Council published in 2006 and 2012 two Action Plans for the periods 2007-2010 and 2012-2015 respectively, each with a set of concrete actions, activities and measures to address the challenges and exploit the opportunities in the hydrogen field. These Action Plans were met with substantial support from national industrial and academic stakeholders, and have also received considerable attention abroad. But the Council’s recommendations were not similarly embraced by the Government.
The establishment of the governmental body Transnova in 2009 for supporting low and zero emission transport was the most important outcome of the recommendations provided by the Hydrogen Council in their first Action Plan. Demonstration of the world’s first marine supply vessel with fuel cells for auxiliary power from 2009 is another noticeable achievement. Introduction of incentives to secure continued operation and extension of the hydrogen refuelling infrastructure was one of the key recommendations in the 2nd Action Plan, and this has eventually been supported by the Parliament during fall 2015.

Until 2014, Transnova contributed to the realisation of a broad range of projects with focus on alternative energy carriers for transport purposes. The new Government decided in 2013 to merge Transnova into the much larger governmental body for stationary applications Enova from 2015. They launched new transport oriented financial support schemes in the autumn 2015, although without a specific hydrogen infrastructure programme. The Parliament also last year voted for creating a new National Hydrogen Strategy, updated to reflect renewed environmental concerns, the maturation and commercialisation of hydrogen technology during the last decade, and the renewed prospects it can serve as an important vector in the Norwegian renewable energy system.
NHF and the hydrogen community has therefore for the last year worked actively to promote the opportunities in the sector, and when the Government launched a broad energy policy White Paper in April 2016, an own section with a proposition for a hydrogen strategy was included. It is now quintessential for the industry to involve in a broad political discussion to ensure high quality for a cross-political adaptation and operationalization of the strategy. One key point in this context will be the upcoming revision of Enova’s mandate for their next periodic agreement (2017-2020) by its owner, the Ministry of Petroleum and Energy.

INTERNATIONAL ENGAGEMENT AND COOPERATIONS IS CRUCIAL FOR NORWAY
Norwegian engagement in international efforts is of highest strategic importance, in particular through the European FCH JU program. This includes participation in R&D and demonstration projects as well as engagement in leading strategic positions for further development of the FCH JU program. Cooperation with Asian countries and North America is also well established and will be further strengthened in the years to come.
Nel Hydrogen is now delivering the worldís most energy efficient and robust electrolyser in new low cost, high-pressure containerised solutions. See [www.nelhydrogen.com](http://www.nelhydrogen.com) for more information.
HYOP has been operating a small network of demo-stations, but has now started to convert it to a pre-commercial network with higher capacity.
In Norway, industrial actors have produced and utilized hydrogen in large scale since 1927. Companies like Norsk Hydro developed their own electrolyser technology, which today continues to be developed by NEL Hydrogen. New companies within hydrogen production, electrolyser manufacturing and integration are being established, building on competence from the Norwegian industry. Norsk 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 refuelling 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 hydrogen refuelling station (HRS) solutions were developed through large public and private investments.

Since the opening of the first prototype hydrogen stations in the period 2006 – 2012, valuable competence from the operation and maintenance of the station network has been accumulated, and the stations are continued to being operated and further developed by the world’s first dedicated hydrogen station operation company, HYOP AS (www.hyop.no). These five first operating stations have been heavily supported financially by regional authorities like Akershus County Council, which has together with the City of Oslo developed a joint strategy for hydrogen toward 2025, including both infrastructure rollout plans and an analysis of the potential local value creation, which can follow from taking a leading role within hydrogen.
With the early mover experience and the long-term know-how on hydrogen technology in Norway, the last years have led to a massive ramp-up of industrial and investor interest and engagement. NEL Hydrogen has grown significantly the last years guided by strategic investments, and an important momentum was gained with stock exchange listing, the acquisition of Danish HRS supplier H2Logic and the alliance created with the retail fuel operator Uno-X in 2015. NEL and Uno-X announced in December 2015 a letter of intent for the rollout of 20 new HRSs in major cities in Norway within 2020 conducted by the joint venture Uno-X Hydrogen AS ([www.unox.no/hydrogen](http://www.unox.no/hydrogen)). The first will be built in summer 2016 in Bærum Municipality in the western Oslo metropolitan area including an innovative integration of surplus solar energy converted to hydrogen, and an additional eight other stations are planned installed in the major cities within 2017. The next cities on the list are Bergen and Trondheim.

Since the launch of the transport programme in Enova, NEL and Uno-X as well as HYOP, aims to secure public co-funding from Enova for the further roll-out of hydrogen infrastructure. There is now an emerging national political will to support such a support, but as of April 2016 there are still a number of formal agreements on public-private organisation and clarification of the role of public players to be finalized, including the new 4-year Enova-Ministry agreement.
Uno-X Hydrogen is planning to build 20 hydrogen stations in Norway within 2020. The first will open in Bærum outside Oslo in autumn 2016, followed by two stations in Bergen by spring 2017.
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) have equally enjoyed tax exemption and significant user benefits. Government and regional politicians have, however, already started to reduce the benefits for BEVs, and warned that these will be gradually phased out. As of national policy and budget process of autumn 2016, it seems that the proposals recommended from NHF and its members will be taken into account to maintain all benefits for FCEVs until 2025 or until the car fleet reaches at least 50,000 vehicles:

- Zero purchase tax (can be as high as 100 % for petrol cars)
- Zero VAT (25 %)
- Low annual road-tax (10 % of normal)
- Free public parking (1,000 BEV/FCEV spots in Oslo city centre)
- Access to bus / taxi-lanes (saving commuters significant travelling time daily)
- Free passing through toll-roads (Recently approved extended for FCEVs in the new Oslo Road Act (Oslopakke) 3)
- Free transport on public ferries (although some ferry companies now also charge BEVs)
Furthermore, as a part of the new energy policy White Paper, it is now political consensus to tighten taxation of fossil fuel fuelled cars heavily to stimulate a zero emission car sales market by 2025. The policy scheme to assure this is to be developed in the coming years. Norway is, thus, very well positioned to become an equally important market for the FCEVs, in the early phase of market introduction. Prototypes from Daimler and Hyundai have been tested since 2011 until Hyundai started ordinary sales in 2013. Toyota is now joining and plans to deliver the first Mirais to customers in Norway in summer 2016. Also the French company SymbioFCell has started marketing their light commercial vans this year with FC as range extender to BEVs manufactured by Renault, and the Oslo-Akershus’ commitment is retained and plan to major ramp-up for fuel cell buses by 2018.
Norway has some of the strongest maritime technology industries in the world, and has been a front-runner in development of low emissions propulsion technologies such as LNG ferries and LNG offshore specialized vessels. Energy efficient diesel-electric hybrid systems have also been developed and built in ships over the last decades. A major breakthrough came in 2014 with the world’s first 100% zero emission battery electric ferry, B/F Ampere, which was put into regular operation crossing the Sognefjord in February 2015. This has led to a disruptive shift for which a vast potential for electric zero emission solutions has been identified, both nationally and abroad. The Norwegian Public Roads Administration has developed an ambitious ultra-low emission policy for car ferries in Norway for 120 different crossings, which heavily promotes 0-emissions solutions.

A new breakthrough is approaching as ferries with hydrogen powered fuel cell range extenders are being promoted, given the limitation of range for pure battery electric solutions. NPRA is now preparing the first hydrogen ferry development contract to be launched, demonstrated, and put into regular operation within 2021. Several local initiatives throughout the Norwegian coastline are looking into establishment of large scale low-cost hydrogen production to be matched with the fuel demand from hydrogen ships, also involving the assessment of export opportunities with large industrial international actors such as Kawasaki Heavy Industries.
MF Ampere, the world’s first large battery electric ferry operated by Norled, the first of many tendered electric ferry contracts. The Norwegian Public Roads Administration and the Maritime Authority is now preparing the process for the first hydrogen ferry development contract based on the successful innovation and introduction of electric ferries.
In the road based heavy duty transport, new initiatives have been established for hydrogen-based logistics and distribution operation. A major breakthrough came in April 2016 when the Norwegian foods distributor ASKO was granted funding from the public body Enova of 19,6 Mill. NOK for demonstration between 2017-2019 of four large hydrogen-powered trucks, which will be built by Scania in Sweden. 10 forklifts and a separate hydrogen production plant run by solar cells at their Mid-Norway logistics hub in Trondheim will be part of the project.

ASKO has committed to an ambitious plan of renewable fuels throughout their entire fleet of 600 trucks across the country. Electric and hydrogen powered trucks have the highest priority, and it is expected that a large share of their fleet will be hydrogen fuelled in the coming years, in a ramp-up plan following after the first demo phase.

In a wider geopolitical perspective, hydrogen may compensate for Norway’s declining export of oil & gas and provide for alternative value creation based on carbon free energy. Starting now, Norway could be a leading nation in a world with a growing demand for sustainable energy carriers.
Wholesaler ASKO is committing to electric and hydrogen vehicles and has ordered the first hydrogen trucks from Swedish Scania Trucks, and will have these delivered by early 2018, to their logistics hub in Trondheim.
Hydrogen 2020 is a new R&D and commercialization network that aims to increase the participation of Norwegian actors, especially from Norwegian industry, to the relevant R&D & Commercialization programs in EU for HFC technology. The network is financially co-supported by Research Council Norway’s (RCN) investment in Horizon 2020 and is particularly focused on the EU Joint Technology Initiative (JTI) Fuel Cells and Hydrogen Joint Undertaking (FCH JU). But other measures in Horizon2020 and EU co-funding is also within the network scope.

Hydrogen 2020 will contribute to:

- Expanding and establishing a European contact base for R&D funded by the RCN, Innovation Norway and Enova.
- Recruitment and mobilization of private sector, public institutions and research in hydrogen and fuel cells for transportation and stationary use.
- Strengthen contacts between business and Norwegian R&D to ensure the best possible transfer and strategic cooperation nationally.
- Information Sharing announcements in topical applications, a platform for the creation of alliances and partnerships and the sharing of knowledge and experience on how to establish good consortia and applications.
• Participation in the shaping of strategic documents and calls to the appropriate EU research programs to safeguard Norwegian interests.

The Hydrogen 2020 network is inviting international potential partners who are considering collaboration with the innovative R&D and business sector in Norway, which is now preparing for building a high momentum on HFC technology rollout both domestically and internationally.

The partners in Hydrogen 2020 are the Norwegian Hydrogen Forum, SINTEF, IFE, CMR Prototech, University of Oslo, NTNU and NEL Hydrogen (all of these are presented in this guide). The network will be fully operative from early 2017.

Stay tuned - scheduled events, contact details and further information will be updated and posted on www.hydrogen.no/2020
Norwegian Hydrogen Forum (NHF) was founded in 1996 as a non-profit members’ association for conveying and promoting the advantages of hydrogen as an energy carrier. As of 2016, our 53 members span Norwegian industry, universities, research institutes and other organizations engaged or otherwise interested in hydrogen. NHF works actively to disseminate key achievements from hydrogen research and technology commercialisation, market trends and international policy-making by (co-) organizing conferences, seminars and workshops. Regular updates are provided by publishing newsletters, and posting news on [www.hydrogen.no](http://www.hydrogen.no). Moreover, NHF works closely with Nordic sister organizations as well as relevant European associations and international entities.

NHF is convinced that the best way to serve our members is to contribute to the establishment of a substantial market for hydrogen technologies both in Norway and internationally. To fulfil this ambition, NHF is actively promoting our members’ interests towards public authorities and decision makers. Recently, NHF has succeeded in getting substantial political attention and support for introduction of hydrogen technologies at regional as well as national level, ensuring strong financial support schemes in the years to come.
NHF supports the vision proposed by the Norwegian Hydrogen Council, reading:

“Norway - pioneering sustainable hydrogen”
as it indicates the important role hydrogen will have in the transformation to a greener future as well as Norway’s key role in this energy future.

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The hydrogen refueling station for buses in Oslo by night.
AGA AS is a company in the Linde Gas Division. As the world’s largest hydrogen plant manufacturer and one of the leading gas companies 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 development and creation of new innovative applications. Linde also develops innovative refuelling and 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 as transport fuel and investigate the best, most costefficient ways of establishing a hydrogen infrastructure.

Linde hydrogen filling stations are refuelling 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 and are continuously looking for opportunities to develop the Hydrogen vehicle market. Hydrogen is included in Linde’s “Clean Energy” efforts together with naturalgas and biogas systems.

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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 55 hydrogen stations worldwide - and more are underway. In 2012 Air Liquide produced 9 000 billion Nm³ of hydrogen which is the equivalent of fuelling 6 million cars.

Air Liquide Norway A/S was founded in 1997 and is one of 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 delivered the large Hydrogen refueling station (HRS) to HyNor Oslo Bus (Ruter) and the CHIC project, which came into operation in 2012. This HRS is based on 2 electrolysers, 2 compressors and a 12 000 liter buffer. The HRS delivers hydrogen to 5 fuel cell electric buses in Oslo and Akershus.
Akershus County covers major urban areas surrounding 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. As the first region in Scandinavia, ACC started development of a regional strategy for hydrogen back in 2012, and prepares a 2nd upcoming Action Plan covering 2017-2018. For this phase, the main priorities are:

- Establishment of a robust regional infrastructure of refuelling stations
- Stimulation of fleet development of FCEVs on a regional level, for the private & public sector.

ACC has so far funded five hydrogen stations, one of them situated by Oslo Airport Gardermoen. Moreover, a funding instrument has been introduced for the purchase of vehicles as taxis and as service cars in the local municipal sector. Five FC buses deployed through the CHIC project has operated since 2012 by the publicly owned transport company Ruter. The county council has also initiated a study on the use of hydrogen as a fuel in maritime transport in the Oslo Fjord. In addition, ACC supports a number of development projects for enterprises and institutions in the regional hydrogen business sector.

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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.

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Since 1994, Daimler/Mercedes-Benz has actively been working on the development of hydrogen fuel-cell vehicles (FCEVs). Several test projects have been held, among these an extensive program which started in 2010 in Norway, Germany and USA. As the Norwegian official importer of Mercedes-Benz to Norway we are proud to participate in this test, where 10 Mercedes-Benz B-Class F-Cell have been leased to different users in the Oslo area.

The experience from the test shows that the fuel cell technology is on a high level of quality and reliability, and Daimler/Mercedes-Benz foresees to begin series production of fuel cell vehicles within the next few years.

The company Bertel O. Steen AS was established in 1901. It is Norway’s oldest and second largest car importer, and is among the biggest service- and trading companies in the country. The turnover in 2015 was NOK 11,8 billion, with 2 157 employees.

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Bilimportørenes Landsforening (BIL) is the Norwegian Association of Car Importers representing the international car industry in Norway. BIL has recently become a member of NHF (The Norwegian Hydrogen Forum) as we recognize their important role in this growing industry. The process of commercializing the hydrogen technology for vehicles is in progress, and BIL has already established its own project group together with the manufacturers developing hydrogen technology, as we see huge possibilities in joining forces working for a cleaner global environment.

There are already several vehicles containing this technology on Norwegian roads, and we expect the number to grow dramatically for the years to come. BIL is continuously working towards the authorities to improve conditions concerning vehicle taxes to stimulate development and imports of hydrogen and fuel cell technologies for the benefit of the environment.

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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.

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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.

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Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. Operating in more than 100 countries, our professionals are dedicated to helping our customers in the maritime, oil & gas, energy and other industries to make the world safer, smarter and greener.

DNV GL has invested heavily in hydrogen R&D through active participation in national and international project and networks (e.g. EU and IEA activities).

DNV GL became a pioneer in developing fuel cell technology for ships through the FellowSHIP project, successfully testing the world’s first industrial size marine fuel cell in the offshore support vessel Viking Lady. DNV GL is also leading the Norwegian Green Coastal Shipping Program, which is currently exploring environmentally shipping, including the use of fuel cells.

DNV GL has also undertaken several studies related to hydrogen market and commercial aspects, as well as hydrogen safety and process risk studies.

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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”.

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Enova SF is a public enterprise owned by the Norwegian Ministry of Petroleum and Energy. Enova SF’s goal is to contribute to reduced greenhouse gas emissions and strengthened security of supply for energy in addition to the development of energy and climate technologies. Enova supports projects mainly through the granting of investment aid with an aim to reducing barriers and stimulating lasting market development.

Since 2015, transport has been included in Enovas mandate. One of Enovas main aims is the reduction of greenhouse gas emissions from transport. This includes hydrogen projects.

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Gexcon is a wholly owned subsidiary of Christian Michelsen Research (CMR). Gexcon continues the research activities on explosion safety 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 100 employees worldwide. About 50 work in the main office in Bergen, Norway, and the rest in subsidiaries in the US, UK, Indonesia, China, India and the Middle East. Gexcon provides services in the following areas of hydrogen safety:

- Sale, lease and consulting services of FLACS CFD-software for H2 & LNG consequence assessments: dispersion, fire, explosion scenario & ventilation and studies thereof, incl. Quantitative Risk Assessments.
- 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, including participation in the IEA HIA Task 37 Expert Group on Hydrogen Safety, active participation in HySafe, and coordinator of the EU-funded project HySEA in Horizon 2020 (www.hysea.eu).

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Greenstat is a private company based in Bergen, Norway. The company’s two main business areas are Hydrogen and Local Energy, and Greenstat’s Hydrogen vision is to be a large-scale industrial hydrogen producer, delivering green hydrogen to the industry, road and maritime transport and for export. Greenstat is owned by both larger financial investors and a larger number of people investing smaller amounts of capital.

Greenstat have projects both within large-scale and small-scale hydrogen production. Some of the potential projects are large-scale hydrogen production at Statoil Mongstad and in Tyssedal, where Greenstat signed a letter of intent with the titanium producer TiZir in the fall of 2015. The company is also looking into potential small scale hydrogen production projects in Høyanger, Glomfjord and Bodø, to name a few.

**Greenstat – Making green happen**
Hexagon Composites ASA is the global leader in composite pressure cylinders for gas applications. Headquartered in Aalesund, Norway, the Group operates some of the world’s most advanced facilities for designing, testing and manufacturing of all-composite cylinders for gas applications.

In 2016 Agility Fuel Systems and Hexagon Composites’ CNG Automotive Products Division merged to create Agility Fuel Solutions. Furthermore, the Hexagon Composites acquired xperion Energy & Environment. Both will enable Hexagon Composites to strengthen its global market presence and further broaden its product and technology portfolio.

Hexagon Composites is well positioned across the hydrogen value chain with vehicle tanks for cars and buses, cylinders for ground storage (refuelling stations), transportation, backup power solutions, marine and train applications. Development and production take place at modern facilities in USA, Germany and Norway.

Type 4 tanks are the best combination of safety, efficiency and durability available. Their lightweight construction improves vehicle range, payload and handling.

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www.hexagon.no
Hordaland County is made up of 33 municipalities including Norway’s second largest city, Bergen. Hordaland County Council (HCC) aims to reduce GHG emissions by 40% from 1991 to 2030 based on the region’s rich natural and human resources. Therefore, we promote clean hydrogen production, distribution and usage. HCC has supported an interregional study on the economic potential of new H\textsubscript{2} value chains in Western Norway. Our region will draw upon existing research knowledge platforms, i.e. CMR Prototech, and our hydro-powered renewable energy production (18.6 TWh/a). We rely on innovative businesses, e.g. TiZir Lmt. who are installing a new smelting furnace which will enable them to replace coal with hydrogen in the future.

To stimulate demand, HCC focuses on maritime and road transport:
- We support R&D projects exploring security, acceptance and legislation aspects in the maritime sector.
- We are co-financing two H\textsubscript{2} filling stations for fuel cell electric vehicles (FCEVs).
- Hordaland is already a hub for zero emission vehicles (31% of all new registered cars 2015 were fully electric). Together with private companies and the municipality of Bergen we have ordered more than 20 FCEVs.

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Hynor Lillestrøm AS owns and operates a hydrogen refueling station (HRS) and a hydrogen and fuel cell test center in collaboration with key partners at Kjeller. The Hynor Lillestrøm HRS (700 bar hydrogen for fuel cell vehicles) and test facilities has been designed for testing and validation of small-scale prototype systems.

The existing infrastructure includes capabilities to test new system concepts for biogas-to-hydrogen reforming, alkaline and PEM water electrolysis, hydrogen compression and storage in metal hydrides, hydrogen purification using Pd-membranes, low temperature fuel cells (PEMFC), and high temperature fuel cells (SOFC).

Hynor Lillestrøm is currently the host for fuel cell and hydrogen (FCH) systems operated by research institutes and companies, such as Institute for Energy Technology (IFE), ZEG Power, Hystorsys, and HYOP. The Hynor Lillestrøm test center now being developed by IFE to become the Systems Laboratory for the Norwegian FCH Centre, a collaboration between SINTEF, IFE, and NTNU.
HYOP is a company dedicated to operate hydrogen refuelling 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 operates four hydrogen stations – Porsgrunn, Gardermoen (Oslo Airport), Gaustad and Lillestrøm. As part of the FCH JU funded European Hydrogen Mobility Europe project (H2ME), HYOP is co-funded to build a new station at Høvik in the autumn 2016, which will be replacing the old Økern station. HYOP has two additional H2ME-funded stations in planning for 2017. These are important elements of alltogether 49 H2ME stations to be built in Northern Europe, where 10 stations will be deployed in collaboration in the Scandinavian Hydrogen Highway Partnership (SHHP).

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 already a decade of operational experience with building and operating hydrogen stations. HYOP is owned by Kjeller Innovation and the CEO.

**Contact:** Ulf Hafseld | uh@hyop.no | www.hyop.no
Hyundai Motor Company of Korea is the world’s fourth largest auto manufacturer, with approx. 100,000 employees. In Norway, the company has around 40 dealers, and has sold more than 90,000 vehicles since its start-up in Norway in 1992. Hyundai Motor Norway (HMN) imports and advertises cars and accessories from the Hyundai Motor Company. HMN’s head office at Alna in Oslo has a staff consisting of 25 people. Hyundai’s main advantage is state-of-the-art and reliable vehicle models with and Norway’s best warranty of 5 years – unlimited mileage. Hyundai is the world’s first auto company offering all powertrains, including fuel cell, electric, hybrids and plug-in hybrids. The world of the consumer is not one-dimensional, and Hyundai is striving to provide alternatives that work for everyone on our way towards a zero emission society.

Hyundai was the first manufacturer to mass produce our ix35 Fuel Cell, starting in 2013, a natural progression of the ground-breaking R&D done over the last 15 years. Hydrogen vehicles are a major step in a green direction, and Hyundai is focused on commercialising the technology to be used for longer distances, while battery-electric vehicles are so far somewhat better suited for inner city driving and day to day commute. However, Hyundai will still adapt and adjust for the future, creating ever more environmentally friendly vehicles.

**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.

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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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Institute for Energy Technology (IFE) is an independent research foundation that has been involved in research on hydrogen for more than 50 years. Three departments at IFE are working within the fields of hydrogen production, hydrogen storage, fuel cells, and hydrogen energy systems: (1) Physics performs fundamental studies on new solid state hydrogen storage materials, (2) Environmental Technology focus on hydrogen production and CO$_2$-capture using sorption enhanced reforming processes, while (3) Energy Systems performs research on metal hydrides, PEM fuel cells, alkaline and PEM electrolysers, and hydrogen energy systems.

IFE is the host for MoZEES, a national FME centre on environment-friendly research with focus on zero emission energy systems for transport, with specific focus on battery- and hydrogen technology and heavy duty and maritime applications.

Read more about MoZEES at [www.ife.no/mozees](http://www.ife.no/mozees)

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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 is a regional member organization established to serve knowledge intensive R&D & businesses – and for renewable energy activities we host the network “Oslo Renewable Energy & Environment Cluster – OREEC”, with several ongoing Interreg and EU projects ongoing for renewable transport (www.oreec.no).

LCE and OREEC holds the secretariat for the Norwegian Hydrogen Forum, and we're the Norwegian lead partner of the Scandinavian Interreg IV project “Blue Move”, see www.bluemove.no. LCE conducted a study that led to establishment of a HRS Oslo airport Gardermoen, and we are responsible for dissemination activities in the FCH JU-funded large scale fuel cell bus infrastructure study “NewBusFuel” – see www.newbusfuel.eu.

LCE is also part-owner of Hynor Lillestrøm AS.

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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 47 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.

CONTACT: Geir Malmedal | geir.malmedal@naf.no | www.naf.no
Nel is a publicly listed hydrogen company which builds on more than 90 years of combined experience within hydrogen technology, providing solutions for efficient hydrogen production and fuelling, as well as hydrogen energy solutions. With more than 850 electrolysers delivered around the globe, Nel is the world leading company for alkaline water electrolysis. Since the initial electrolysers were put in operation in the 1920’s, sustained R&D efforts have contributed to continual improvement, setting the benchmark in the market. Our electrolysers are recognised worldwide for their high efficiency, reliability, and robustness.

The fueling stations from Nel have the highest reported availability in the world, and were the first to comply with the newest standards for fueling. Our latest H2Station product has a footprint of only 10 m2 and capacity to accommodate for peak hour traffic. It has been designed for mass production, easy transport, and for easy integration in conventional refueling stations, with the dispenser taking up only a third of the footprint of regular gasoline dispensers. Empowering generations with clean energy forever, is the vision of Nel. Our technology allows people and businesses to make everyday use of hydrogen, the most abundant element in the universe.

**Contact:** Jacob Krogsgaard | jakro@nel-hydrogen.com
www.nel-hydrogen.com
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 of M.Sc. Renewable Energy gives 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 NMBU have completed a hydrogen related Master thesis at Institute Energy Technology (IFE).

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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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www.chemeng.ntnu.no
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.
Praxair Norge AS is a part of Praxair Inc., one of the leading industrial gas companies worldwide. Praxair is well established in Scandinavia with several ASUs, filling plants and a dry ice factory and ensures local presence through an extensive dealer network with over 170 dealers. Praxair products, services and technologies are making our planet more productive by bringing efficiency and environmental benefits to a wide variety of industries. For a decade, Praxair has been providing fuel and related technical support to fuel-cell developers and vehicle fleets.

Praxair Norge AS has been producing hydrogen at Rjukan since the beginning of the last century. Production is 100% green using hydroelectric power to split the hydrogen atoms from the oxygen in the water molecules. This produces pure hydrogen with no possibility for hydrocarbon pollution. The hydrogen is then compressed to 200 or 300 bars before transportation to the customer sites.

In 2016 Praxair entered into the joint venture Uno-X Hydrogen, alongside Uno-X and NEL. Uno X-Hydrogen will as a first step build 20 hydrogen fueling stations in Norway by 2020. Praxair’s extensive hydrogen production- and distribution experience will be an important contribution when establishing a supply network for the future hydrogen car fleet in Norway.

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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, and 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 develops low/zero-emission offshore and maritime fuel cell power systems and has established Norwegian Electric Fuel Cells AS together with Norwegian Electric Systems for commercialization of maritime fuel cell systems. Prototech has also been one of the main drivers for establishing the first hydrogen refuelling stations in Bergen.

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.

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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 commercialization, testing and demonstration of hydrogen technologies in the transport sector is mainly covered by Enova. 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).

The Council supports both Researcher Projects, Competence projects (with research institutions as contracting parties), and Innovation projects, where industry companies are contracting parties. A new instrument is called Pilot-E, where the research Council is collaborating with Enova and Innovation Norway to follow the projects from research to demonstration and market introduction. The research Council also supports Centers for Environmentally Friendly Energy Research (CEER, or FME in Norwegian). For 2017-2021, 8 new centers are established, amongst them the FME MoZEES, covering environmentally friendly transport based on hydrogen and batteries.

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The RotoBoost vision is to be the leading innovator in hydrogen production under “high G” conditions.

RotoBoost has developed a rotating alkaline water electrolyzer, the RotoLyzer®. This patented technology gives extremely compact, efficient units, which integrates a new compression method.

The RotoLyzer is licensed to NEL ASA in 2015.

Currently RotoBoost is exploring a rotating SMR (Steam Methane Reformer) for production of pure Hydrogen from Natural Gas with CO₂ capture. This RotoReformer® uses an integrated rotating Heat Pump (RotoHeatPump®) to transport heat from the produced gasses (H₂ and CO₂) back to the endothermic, catalytic shift reactor at the periphery of the rotor. This method gives a very efficient and compact reformer (SMR) with liquid CO₂, and cold, compressed Hydrogen directly from the rotor.

RotoBoost AS invites partnership for commercialization of the RotoReformer®.

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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 over 300 million travels a year.

Ruters target is to reduce local air pollution and noise and to use only renewable energy to power all public transport in the region from 2020. This transition is well under way, including the use of biofuels, electric trains, metro and trams, and hybrid diesel electric buses.

Fuel cell (FC) buses with hydrogen are also being tested. Ruter has been operating five FC buses been since 2012 as part of the EU project CHIC-project (Clean Hydrogen In European Cities). A hydrogen production and refuelling station has been constructed for the buses at the bus depot at Rosenholm.

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

**INTEF’s hydrogen related research and development projects include:**
- Production of hydrogen from fossil and renewable energy sources
- Membrane technology for hydrogen separation
- Hydrogen liquefaction and storage (incl. metal organic frameworks)
- Fuel cell and electrolyser materials, components and systems
- Hydrogen combustion (gas turbines and internal combustion engines)
- Well-to-wheel analyses, market studies and deployment
- Safety, societal and political aspects (decision support services)

**SINTEF employees hold key positions in strategic forums including:**
- Fuel Cells and Hydrogen Joint Undertaking (Chair for Transport)
- EERA Joint Programme on Fuel Cells and Hydrogen technologies
- Norwegian Hydrogen Forum (Chairman of the Board)

**SINTEF operates significant “open access”-laboratory infrastructure facilities for:**
- Materials synthesis and characterisation
- Fuel cell and electrolyser single cell and stack testing
- Determination of degradation mechanisms for extended lifetime

**Contact:** Steffen Møller-Holst | steffen.moller-holst@sintef.no | www.sintef.no
The Norwegian Small Hydropower Association is the national organization for companies who build and operate small hydropower stations. Since year 2000 there has been built 750 such plants scattered all over the country where you will also find good potential for H₂-consumption and customers. Each of these new plants have an installed effect beneath 10 MW and all together they represent a yearly production of 5 TWh.

The small hydro industry consists mainly of entrepreneurs who are searching for new business opportunities. That’s probably why our association is the first player among Norwegian organizations for electricity producers who has started to work systematically with exploring H₂ production as a new business area for its members. Among other projects we also have a R&D-project running over three years with the Norwegian Water Resources and Energy Directorate.

Our main focus is how hydrogen can play a role in improving the Norwegian power system. We are looking into how the grids problems with peaks in consumption, capacity constraints and production can be reduced and thereby also downsize the need for grid investments. From the electricity producers point of view hydrogen production can generate added values in periods with low prices and high production.

Contact: Knut Olav Tveit | knut.olav@smakraftforeninga.no
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Sogn og Fjordane County (SFC) is located on the West Coast of Norway. With an annual energy production of 15.8 TWh from renewables such as hydro- and windpower, and highly competent businesses within the maritime/marine and industry sectors, the region is a perfect hub for production, development, commercialization and use of hydrogen.

SFC supports several local H₂ value chain projects. One of them is located in Høyanger Municipality, where a small scale hydropower system can be adapted to supply the local fish farm Osland Havbruk with hydrogen, oxygen and thermal energy. SFC is also involved in a pilot project with Flora Municipality, Brødrene Aa, Maritime Association Sogn og Fjordane, DNV GL and others, to develop and test hydrogen-fuel cell technology for passenger vessels.

SFC has initiated a two year development project (2016-2018) to establish a H₂ network of businesses, municipalities and R&D institutions in the region. The project aims to build a portfolio of H₂ pilot- and R&D projects with international ambitions. National and international partners are welcome to join us in these projects.

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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.

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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 $\text{H}_2$ 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.

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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.

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.

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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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Uno-X Hydrogen AS is a Joint Venture company between Uno-X, NEL and Praxair. The three companies bring world leading technology and world class distribution and customer interface into the cooperation.

Uno-X is a leading Norwegian retail company owned by Reitangruppen. The company currently operates more than 700 refuelling stations in Norway/Denmark.

NEL was established in 1927 by Norsk Hydro, and it is today an independent company listed on the Oslo Stock Exchange. NEL is a world leading supplier of electrolyser for hydrogen production and hydrogen refuelling stations – and operation of refuelling station networks. The company has more than 500 deliveries in more than 50 countries worldwide and also owns the patents and the intellectual property of the previous development of Hydrogen refuelling stations in Norway.

Praxair produces, sells and distributes atmospheric, process and specialty gases. Praxair Norge AS is a subsidiary of Praxair, Inc., one of the largest industrial gas companies in the world. The company has more than 300 employees in Scandinavia and several ASUs, fillings stations and one dry ice factory.

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www.unox.no/hydrogen
ZEG Power; more energy and less emission! The ZEG-technology (ZEG®) is an innovative, hybrid technology for high efficient co-production of electricity and hydrogen from hydrocarbon fuels, with integrated CO₂ capture. Electricity is produced by high temperature solid oxide fuel cells (SOFC). Hydrogen is produced in a modified reforming reaction where CO₂ is removed by a high temperature CaO-based sorbent in a carbonation reaction – Sorption Enhanced Reforming (SER). Close thermal integration between the SOFC and SER reactor system provide high overall system efficiency, more than 75%. CO₂ is delivered from the plant as a pure concentrated CO₂ stream and can be pressurized for further industrial use or storage. Pressurized hydrogen can be sold directly to the customer or used in integrated industrial processes. The use of biogas for ZEG offers a unique possibility as CO₂ from biomass is considered climate neutral and also allows for carbon negative solutions if CO₂ storage is included.

Critical technology components and system integration are tested and verified in 50 kW scale. The results are used to establish system design and cost estimate for upscaling of the technology to a 400 kW scale plant, including a reformer system with a hydrogen production capacity of about 200 Nm³/hour. Further technology development is planned with a pilot fuelled with biogas.

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ZERO is a non-profit environmental organization working for zero-emissions 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 participation earlier in the HyNor project, ZERO has been active on hydrogen implementing activities. ZERO is currently participating in the Interreg Blue Move project, and has had a central role in projects like H2moves Scandinavia and in the reference group in Ruter’s hydrogen bus CHIC-project. ZERO was the coordinator of the ZeroRally, which was an important fully certified rally for zero emission vehicles in the BEV/FCEV introductory years in Norway.

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.

CONTACT: Kari Asheim | kari.asheim@zero.no | www.zero.no
Hexagon Composites has developed the next generation hydrogen cylinder for Daimler's new Mercedes-Benz GLC F-CELL vehicle. The next generation cylinders are the result of years of research, development and testing together with Daimler.
The Norwegian Hydrogen Guide 2016 has been assembled by Norwegian Hydrogen Forum with support from The Norwegian Research Council, the County Councils of Akershus, Hordaland and Sogn & Fjordane

Norwegian Hydrogen Forum
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