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Current developments and examples of sustainable energy technologies

Wind2Hydrogen- pilot plant at the OMV site in Auersthal, Lower Austria
Photo: OMV

Hydrogen and fuel cell technology
in the energy and transport systems of the future

As our energy and transport systems are being transformed, making increasing use of renewable sources of energy, hydrogen becomes much more important as a chemical storage medium for energy. Using renewable sources of energy to isolate hydrogen and putting it to work in fuel cells which convert its chemical energy into electricity ultra-efficiently may well contribute to achieving the ambitious goals of climate protection in the future. Current Austrian developments in hydrogen and fuel cell technology are opening up new opportunities for domestic firms in international markets, in the fields of sustainable energy supply, energy storage and non-polluting transport.

POWER TO GAS

Hydrogen and fuel cell – key technologies in an integrated energy system

Photo: Ringhofer, Climate and Energy Fund

Photo: AVL

Photo: RAG

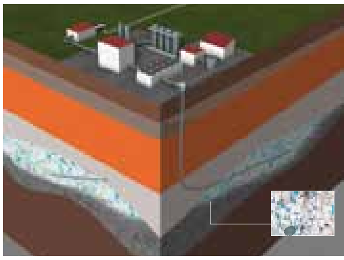


Photo: RAG

Hydrogen as a climate-neutral secondary energy storage medium and fuel cells as ultra-efficient energy converters are potentially important components in a sustainable, competitive and environmentally friendly energy supply system. There are numerous applications for hydrogen and fuel cell technologies: in transport, in stationary energy supply facilities, and in many other areas ranging from industry through trade to residential buildings.

Hydrogen – energy storage medium of the future

As hydrogen does not occur pure in nature, it must be extracted from its chemical compounds. For instance, it can be obtained by electrolysis with electricity produced from renewable sources of energy, or by reforming biofuels and fossil fuels. Energy conversion by means of hydrogen technology is sustainable and non-polluting, thus opening up a wide range of options for future energy systems. Hydrogen is the only energy storage medium with the capacity to store large amounts of energy chemically even for long periods of time. It can be used to generate electricity in stationary fuel cell systems or in gas engines; as fuel in fuel cells it provides the link to non-polluting transport.

Efficient energy conversion

The fuel cell is the ideal technology for putting the energy stored in the form of hydrogen to work. Here chemical energy is converted directly into electricity and heat in an electrochemical process. As intermediate steps such as producing steam, turbine and generator are avoided, and as the thermodynamic limits applying to thermal engines are irrelevant here, fuel cells are very efficient: Combined heat and power (CHP) facilities using fuel cells can achieve efficiency factors of more than 80 %. Fuel cells emit no pollutants, operate silently and run at much lower temperatures than combustion systems (between 100 °C and 900 °C).

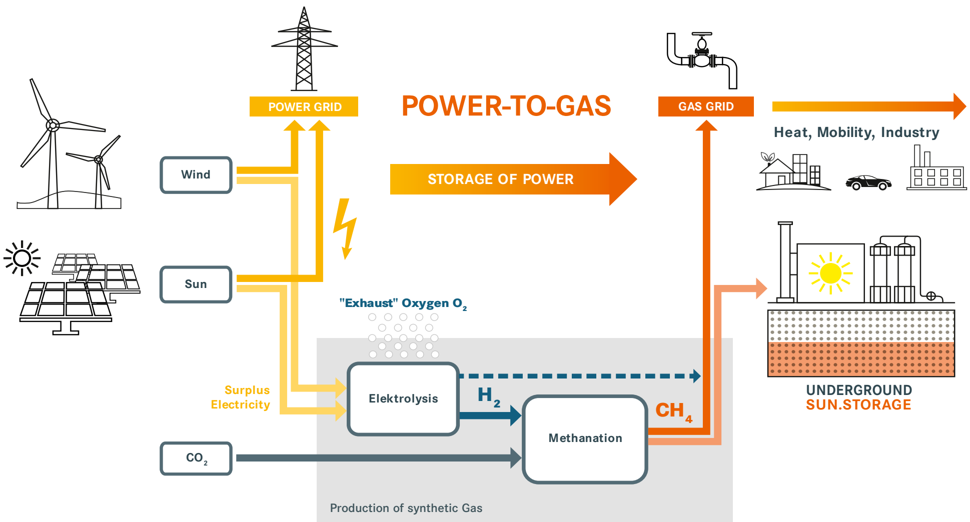
Storing energy from renewables

New storage technologies will play a central part in our future energy system. Wind power and solar energy are depending on the vagaries of the weather. This creates serious challenges for the energy system, since reliable supply and stable grid operation must be ensured even if the rate at which electricity is provided to the grid fluctuates. Chemical energy storage media such as hydrogen acquire a new significance in this context. With the aid of **power-to-gas technology** surplus electricity from wind farms and solar facilities can be used to produce hydrogen and/or methane, which can be piped and stored in the existing infrastructure for natural gas.

Roadmap for power-to-gas

In 2014, at the instigation of the Federal Ministry for Transport, Innovation and Technology (bmvit), and in collaboration with numerous specialists in research, industry and public administration, the Energy Institute at the Johannes Kepler University Linz drew up an RTI (Research, Technology and Innovation) roadmap for Austria‘s route to power-to-gas technology. For research and development in this field both the technological and the systemic perspectives are important. As part of the roadmap a vision for 2030, the extent to which action is required, and the necessary RTI instruments for developing and demonstrating the power-to-gas technology were worked out. If Austria succeeds in implementing power-to-gas facilities, its standing as a key player in the field of energy storage can be further enhanced. That will serve Austrian firms as a reference in the international marketplace, which could result in a significant competitive advantage.

In Austria intensive research into hydrogen and fuel cell technology has been going on for years; pioneering approaches are being developed and implemented in the fields of energy and transport. Here we present some current projects funded and carried out within the framework of the Climate and Energy Fund‘s and bmvit‘s programs. ◘



Source: RAG

TECHNOLOGY

In the **power-to-gas process** surplus electricity from PV and wind farms is used to dissociate water into oxygen and hydrogen by electrolysis. If desired, hydrogen obtained in this way can be then made to react with carbon dioxide to form methane or other hydrocarbons, liquid or gaseous. The only "waste product" from the process is oxygen (released when water is dissociated). The energy storage media hydrogen and methane can be used to generate heat and power, as fuel for vehicles or as raw materials for industrial processes.

Flagship project
Underground SUN.STORAGE

Compared with the storage technologies currently available for electricity, gas grids have enormous storage capacity. If electricity is converted into hydrogen, the existing infrastructure for natural gas, consisting of pipelines and gas storage facilities, can be used to buffer surplus energy from renewables.

Underground gas storage facilities have long since proved their worth in bulk energy storage. To date no investigations of how these facilities could store hydrogen – particularly where pore storage is involved – are available. In the flagship project on energy research "Underground SUN.STORAGE" an Austrian consortium headed by RAG (Rohöl-Aufsuchungs-Aktiengesellschaft) is for the first time investigating how to use underground gas storage space for long-term storage of energy from wind and sun by chemical means. The consortium includes Montanuniversität (University of Mining and Metallurgy) Leoben, the Interuniversity Department for Agrarbiotechnology (IFA-Tulln) within the University of Natural Resources and Life Sciences, Vienna (BOKU), the Energy Institute at the Johannes Kepler University (JKU) Linz, the electricity supplier Verbund and Axiom Angewandte Prozesstechnik GmbH.

The project is mainly concerned with how suitable underground gas storage facilities are for hydrogen. The aim is to demonstrate that hydrogen contents of up to 10 % are feasible. If this succeeds, the natural-gas storage facilities with their huge capacity (7 billion m^3 in Austria, equivalent to 77,000 GWh) could play an important part in buffering energy from renewables in energy systems of the future. It must be shown that this type of storage is hydrogen-compatible even if the methanation route is chosen for the power-to-gas system, because a few percent of hydrogen residue remain in this case, too.

The project involves a large number of laboratory experiments, simulations and model investigations, in order to predict how storage formations will behave when exposed to hydrogen or to typify microbial processes when hydrogen is fed into an underground gas storage facility. In addition, a full-scale field trial is being carried out in what was once a natural-gas field with characteristics similar to the major reservoirs tapped in Austria (Commune of Pilsach in Upper Austria). An assessment of risks, a life-cycle assessment and the analysis of the legal and economic setting are being carried out alongside the research work. The findings from the laboratory, simulations and the field test can be used to calibrate the simulation tools developed as part of the project – thus providing a basis for investigating many other types of storage structure all over the world. ◘

Photo: RAG

„Europe is focussed on expanding the role of renewables. However, the production of solar and wind tends to be volatile. None the less, a reliable supply of electricity is needed around the clock – and gas as a storage medium makes this possible. With the "power-to-gas" technology of the future it may be feasible to transport wind and solar power and store it in existing gas storage facilities on a large scale at reasonable cost, so that it is available at any time."

Markus Mitteregger
CEO, RAG

left and middle Wind2Hydrogen pilot plant, right OMV hydrogen filling station, Photos: OMV

Wind2Hydrogen (W2H)
Pilot plant to generate hydrogen from renewables

The aim of the power-to-gas development thrust is to couple the electricity and natural-gas grids together. A key element in the forthcoming system are flexible, efficient, cost-effective electrolysers. An Austrian consortium made up of OMV, EVN, FRONIUS International GmbH, HyCentA Research GmbH and the Energy Institute at the Johannes Kepler University (JKU) Linz is currently researching how to generate "green hydrogen" by means of a novel type of high-pressure electrolyser, how to feed the hydrogen generated into the natural-gas grid, and how to fill and employ it in motor vehicles.

To this end a pilot plant with a 100 kW rating has been set up at the OMV site in Auersthal (Lower Austria), where future business cases (from the perspective of electricity and of the natural-gas grid operator) can be simulated experimentally. In addition, the physical effects of feeding hydrogen into an OMV gas pipeline are investigated. This is the first pilot plant of this type and size anywhere in the world. The project is intended to gather experience ranging from the planning phase to day-to-day operation. Meanwhile legal, economic and ecological assessments will be carried out and various business models laid out in preparation for the actual rollout.

Pioneering electrolytic process

The high-pressure PEM Proton Exchange Membrane electrolyser specially developed by FRONIUS International GmbH is an industry first, delivering as it does at a pressure for which expensive compression downstream is normally necessary. The PEM electrolyser generates high-purity hydrogen at 163 bar; its modular design makes it suited to ultra-dynamic operation, with no risk of shutdowns in connection with fluctuating levels of wind or PV-generated power. This high pressure is mainly needed for feeding into the high-pressure grid, or where such units are installed at a filling station.

Linking up to gas infrastructure

The electrolyser is being tested with various different load profiles (from renewable sources of energy). Investigation covers base load operation, operation as a function of the price of electricity, accommodating surplus power, supplying grid services and providing operating reserve. A simulation model based on EVN real-life data from wind farms and local natural-gas grids regulates power supply and hydrogen generation in line with the various operating models and frameworks under investigation. As a test, the hydrogen generated is fed straight into the OMV high-pressure grid via the Auersthal compressor station. The flowrates involved are such that the detection threshold would not be reached; so a special mixing line has been installed, making it possible to set ratios between 1 % and 10 %. This line is also used to supply the gas mixture to the HylyPure facility (see page 5).

With hydrogen being fed into a natural-gas pipeline, control systems and quality control can be improved. The aim is to identify how well the gas infrastructure (transit and distribution grid) copes with hydrogen, and how much "green hydrogen" can be stored in the Austrian natural-gas grid.

Hydrogen to fuel vehicles

Part of the hydrogen generated in the pilot facility is compressed to 200 bar and filled in cylinders. This high-purity hydrogen is supplied to an OMV hydrogen filling station; in future it should be available for other research projects, too. Supplying hydrogen in cylinders to industry or to filling stations is a real possibility. There are plans for going all the way to 350 bar. Then the filling process will not need a compressor. ◘

Photo: FRONIUS International GmbH

„Switching to energy supply based on renewables matters a great deal to us at Fronius. Storing energy generated locally makes us independent of fossil fuels imported from politically unstable regions and helps to create value and provide jobs on the spot."

Elisabeth Strauss-Engelbrechtsmüller
CEO, FRONIUS International GmbH

Photo: OMV

„For OMV hydrogen is the number one choice among the energy technologies of the future. In researching these new technologies we are facing up to the challenge of climate change – and see them as our contribution to make the transition from the present to the long-term climate targets. Essential are solutions suitable for market conditions, from generation via storage and transport to the final application, e.g. in on-board fuel cells."

Walter Böhme
Head of Science & Innovation, OMV AG

HylyPure test facility at the Vienna University of Technology, Photos: IVT TU Vienna

HylyPure
Recovering green hydrogen without wasting energy

The Wind2Hydrogen strategy involves storing hydrogen in the natural-gas grid and delivering it (mixed with natural gas) to individual consumers at low cost. For the hydrogen to be available as a feedstock in the chemical industry, or for transport applications in fuel cell quality, it is essential to recover it in pure form from the mixture.

In the HylyPure project the Institute of Chemical Engineering at Vienna University of Technology, in collaboration with OMV, is developing a made-to-measure process based on membrane gas permeation and adsorption to recover hydrogen from a mixture with natural gas without wasting energy. The aims are to identify the most suitable membranes and separation sequences, to ensure that the facility is flexible as regards hydrogen/methane supply and capacity, and to develop control strategies.

How secondary components in the gas mixture (such as carbon dioxide, other hydrocarbons, hydrogen sulphide) affect separation performance and the quality of the hydrogen recovered will also be investigated. Depending on the exact quality specification of the hydrogen, it may be necessary to remove other components completely, which involves additional separation steps; in this case gas permeation must be combined with other ancillary processes, such as adsorption or absorption. In the course of the project various absorbents have been tested for their ability to deliver high-purity hydrogen.

Development work has resulted in a compact facility which is installed on the Institute of Chemical Engineering premises at Vienna University of Technology and supplied with gas mixtures from the mixing section at OMV's Auersthal site. Hydrogen is recovered in three stages in an ecologically and economically efficient way: in stage one, membrane gas permeation, the hydrogen concentration is increased at minimum energy cost and the quantity of gas drastically reduced. In stage two, pressure-swing adsorption (PSA), the hydrogen concentration is increased further. Depending on requirements, the hydrogen stream can then undergo further adsorptive purification in an optional stage three, to ensure the desired product quality.

The residue is brought back to the original pressure and fed back into the natural-gas line. Provided that the electricity needed comes from renewables, the separation process is carbon-neutral. ◘

Fronius Energy Cell,
Photo: FRONIUS International GmbH

E-LOG-BioFleet
Fuel cell range extender for pallet trucks

In the largest market for electric powertrains, the pallet truck segment (in 2011 the worldwide sales volume came to 950,000 units), exclusively battery-powered vehicles cause limited productivity, particularly in multi-shift operation. The critical factors here are the vehicles' restricted range and the length of time it takes to recharge their batteries.

Using fuel cells as range extenders is a pioneering approach to solving the problem. In E-LOG-BioFleet, an Austrian Electric Mobility Flagship Project, the advantages of this approach as regards operability, user benefits and freedom from pollution are being demonstrated. HyCentA Research GmbH is carrying out the project in collaboration with partners in industry and research (OMV, FRONIUS International GmbH, Linde Fördertechnik GmbH, DB Schenker and JOANNEUM RESEARCH Forschungsgesellschaft mbH).

Pioneering technology and infrastructure

For the first time in Austria, battery-powered vehicles used in materials handling have been converted to hybrid operation with a fuel cell range extender. They use a power pack developed by FRONIUS International GmbH, comprising fuel cell, pressurized hydrogen storage, lithium-ion accumulators and control electronics. The system has been certified and installed in 12 Linde T20AP pallet trucks instead of the original lead-acid accumulators. Hydrogen is supplied carbon-neutral via a local reformer unit which extracts hydrogen from biomethane. For the first time in Europe a hydrogen refuelling station has been installed inside a warehouse, certified and started up.

The project embraces the entire spectrum of value creation, from developing and fabricating components for powertrain, storage system, the vehicle as a whole and the infrastructure, all the way to maintenance and service. It contributes to augmenting Austria's technological lead in the field of range extenders for materials handling applications.

Experience with demo operation

The converted vehicles are tested since June 2013 in an industrial setting (at DB Schenker in Hörsching). Day-by-day operation in demanding multi-shift conditions has successfully demonstrated how reliable the fleet of vehicles and the infrastructure are. The combination of hybrid power strategy and regenerative braking results in high driving-cycle efficiency (up to 53 %). As refuelling takes less than 3 minutes, the trucks are always available – which means greater flexibility with unchanged performance. Two more units are in use at BMW's Leipzig plant, as part of the H2intradrive project.

In the next two years demo operation will continue, to obtain valuable findings as regards service life, user acceptance and behaviour, and maintenance and service needs, in real-life circumstances and with the system gradually aging. The aim here is to achieve the prerequisites for efficient, competitive market entry. ◘

Refuelling, Photo: HyCentA Research GmbH

Truck with hydrogen unit, Photo: HyCentA Research GmbH

ASys I & II
Fuel cell technology for mobile generators

The mobile generators used for air conditioning and to power electrical appliances in long-range goods vehicles, caravans or boats when these are stationary, feature internal-combustion engines that drive a generator. With their low ratings these small engines are very inefficient and involve rather a lot of noise and pollution.

In collaboration with research partners (Institute of Lightweight Design and Institute of Thermal Engineering at Graz University of Technology) AVL LIST GMBH has developed a Solid Oxide Fuel Cell Auxiliary Power Unit (SOFC APU): a fuel cell generator for mobile applications which converts pretty well any fuel, e.g. synthetic methane, bioethanol, biomethanol, into electricity

SOFC APU system, Photo: AVL

with remarkable efficiency, free of pollution and with little noise. The current system runs on ordinary diesel fuel, but consumes only half as much fuel as a diesel engine for a given amount of electricity.

First the fuel goes to a catalytic reformer, which converts the fuel completely into a syngas containing hydrogen. This gas is then fed into the actual fuel cell, where an electrochemical reaction between hydrogen and carbon monoxide generates electricity.

Pioneering SOFC APU system
Within ASys I an entirely stand-alone 2-3 kW SOFC APU system was set up with new components, successfully operated for 1,000 hours and subjected to intensive analysis (inter alia in a vibration test). At the same time a reliability study analysed and modelled dominant error mechanisms; accelerated test procedures were derived from this. Overall, the project team made remarkable technical progress toward competitive SOFC APU systems, achieving all the targets set: a power rating of 2 kW, an efficiency factor of 30 % and a noise level below 55 dB (A).

The complete AVL SOFC APU system is a compact integrated unit, small and light, with a volume of 80 l and weighing 70 kg. As part of the project a vehicle integration strategy was worked out, and a control unit for automated system operation developed, together with partners in the US commercial vehicle industry. The packaging concept for the first-generation SOFC APU involves installing two SOFC stacks, making ratings up to 4 kW attainable even at this early stage.

Excellent results
The fuel cell generator can reduce commercial vehicles‘ diesel consumption and carbon dioxide emissions when idling by up to

SOFC APU system, Photo: AVL

60 %. The project won the Province of Styria‘s Innovation Prize “Fast Forward Award 2012”, and was nominated for the Austrian State Prize “Innovation 2013”.

In the follow-up project ASys II the focus will be on increasing service life, with the aim of reaching a service life of more than 5,000 hours for hydrocarbon-based SOFC systems. To this end the basic processes by which damage occurs while an SOFC system is running on a hydrocarbon-based fuel are to be investigated. At the same time extensive validation tests are to be carried out, so as to learn more about environmental and detrimental influences during actual operation. ◘

International research
Fuel cell technology

The Implementing Agreement "Advanced Fuel Cells (AFC)" of the International Energy Agency (IEA) is intended to boost the development of key components and systems for fuel cells in the IEA member states. The main emphasis is on analysing the market environment and on providing support for market entry by developing the necessary political framework and instruments. The countries taking part are Australia, Austria, Denmark, Finland, France, Germany, Israel, Italy, Japan, Mexico, South Korea, Sweden, Switzerland and the USA. Austrian experts are currently participating in four research projects within this international collaborative framework and conducting R&D activities, system and market analyses, analyses of barriers to implementation and dissemination measures. ◘

IEA research projects with Austrian involvement:

> IEA AFC Annex 31: Polymer Electrolyte Fuel Cells, Institute of Chemical Engineering and Environmental Technology, Graz University of Technology
> IEA-AFC Annex 33: Stationary Applications, Austrian Energy Agency
> IEA-AFC Annex 34: Transport Applications, Austrian Association for Advanced Propulsion Systems (A3PS)
> IEA-AFC Annex 35: Fuel cells for portable applications, Institute of Chemical Engineering and Environmental Technology, Graz University of Technology

Photo: Austrian Energy Agency

„How successful stationary fuel cells are in the marketplace will depend to some extent on the way prices develop and the technological quality (robustness/stability) that systems of this kind can achieve for end users. Great progress has already been made in field tests carried out in several different countries, particularly in Asia. Then again, creating a suitable political and legal framework will have a decisive influence on the fuel cell's continuing success in penetrating markets (in Austria, too)."

Günter Simader, Austrian Energy Agency,
representing Austria in the IEA's Implementing Agreement "Advanced Fuel Cells (AFC)"

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