Fuel for **thought**

Alice Elliott of Shell explains how the IDEALHY project is breaking new ground in the move towards new sustainable fuel and its transportation

Why is it important that we develop our capacities for hydrogen liquefaction?

Hydrogen for vehicle refuelling is generally supplied in gaseous form by trucks with much smaller capacity than a liquid hydrogen truck. Moving to liquid hydrogen means fewer trucks on the road, lower distribution cost and the possibility to build larger hydrogen retail stations.

In the past, there has been little incentive to increase scale or improve efficiency for hydrogen liquefaction. Plants in Europe and the US supply the small existing market with ease, and liquid hydrogen plays virtually no part in the energy infrastructure.

All this needs to change when hydrogen starts to play a more significant role as a fuel for mobility. Large, efficient liquefaction plants will support the liquid hydrogen distribution chain that will be required if hydrogen for mobility is to grow in the medium to long term.

Can you summarise the overall aims of the IDEALHY project?

We aim to design a hydrogen liquefaction plant which will be at a larger scale and with higher efficiency than any plant until now. This is not a small challenge; it means a plant at an order of magnitude larger than the biggest yet built, consuming only half the energy of the most efficient existing plant per kilogramme of liquefied hydrogen and built with components larger than any yet made. What is more, we are not simply developing process schemes and optimising models for lowest energy consumption on paper; we are including component design and preparations for a demonstration plant.

The main deliverable is a roadmap for the construction of a liquefaction plant of up to 200 tonnes of liquid hydrogen per day, including proposals for its location. It includes life cycle assessment of the options considered and a full analysis of the safety issues involved.

Carrying out a life cycle assessment (LCA) of existing liquefaction processes is no mean feat. Have you encountered any significant hurdles to date? What do you anticipate will be the main technological, scientific or administrative challenges to overcome in the remainder of the project?

One of the main challenges of performing greenhouse gas (GHG) LCAs of existing

hydrogen production, liquefaction and distribution pathways is the collection of data. Hydrogen liquefaction is not a common process, and where relevant GHG emissions figures are available, they often lack 'transparency' as to the methodologies used for their calculation and the system boundaries of the processes they describe. Additionally, where data is available for similar processes at different locations, there can be significant variation between the figures with little or no information to identify causes.

Fortunately we have Europe's main experts in the field participating in the IDEALHY consortium and analysing existing liquefaction plants and schemes from literature, so a comprehensive assessment can be made.

In preparation for the potential rollout of hydrogen vehicles, plans are underway to implement a hydrogen refuelling infrastructure in Europe. Can you elaborate on these plans? Where does IDEALHY fit in?

All the project's partners are watching developments in Europe with interest, and most are actively involved in other hydrogen-related projects, both EU-funded and independent. While IDEALHY is not formally linked with these, there are obvious synergies – H2Mobility in Germany, for example, aims to establish a network of hydrogen refuelling stations in Germany within the next decade, and we anticipate that a number of the larger stations may be supplied with liquid hydrogen.

Liquid hydrogen can easily be converted to the high pressure hydrogen needed for the vehicles. Shell already operates a liquid hydrogen-supplied station in Berlin, which, with minor modifications, could refuel 400 fuel cell cars per day.

For a significant increase in liquid hydrogen supplied stations, liquefaction capacity must be expanded. This is exactly what the IDEALHY project prepares us for.

Fuel of the future

The development of new technologies for cleaner fuels must be matched by investments in infrastructure. **IDEALHY** is working on upscaling hydrogen liquefaction in the EU, to enable a low-carbon energy supply chain

IT IS WIDELY anticipated that hydrogen will play an important role as a clean fuel in the future. To enable this, massive expansion of the hydrogen production, storage and distribution infrastructure will be needed and without a pipeline network, liquid hydrogen is the most effective way to supply the larger refuelling stations needed from 2020 onwards. Furthermore, liquid hydrogen can be transported over large distances by truck, train or ship, evening out local supply imbalances and thus ensuring that hydrogen is available at the station at all times.

To realise the full potential of liquid hydrogen, the liquefaction process has to be scaled-up and its energy consumption reduced significantly, bringing the chain efficiency to the same level as gaseous hydrogen distribution.

IDEALHY is an EU-funded project coordinated by Shell and involving experts from all over Europe and Japan. It aims to prepare for a liquid hydrogen infrastructure in Europe, with the main goal of planning a hydrogen liquefaction plant at a scale of 50-200 tonnes per day, much larger than any currently in operation. Not only that, but the energy consumption will be halved compared to existing plants. The project also analyses the journey ('life cycle') of hydrogen, from the source to the customer, to trace both its efficiency and its carbon footprint. Health and safety (HSSE) considerations are fully integrated into the project to ensure safe operation – not only of liquefaction, but along the whole journey.

The project will support the commercialisation of fuel cell vehicles and the rollout of a hydrogen refuelling infrastructure in Europe beyond the initial phases, but could also supply hydrogen as a clean burning fuel for other uses.

THE BENEFITS OF HYDROGEN LIQUEFACTION

For Dr Alice Elliott, who works on IDEALHY on behalf of Shell, the advantages afforded by liquid hydrogen cannot be overstated: "Liquid hydrogen is by far the most effective way to supply hydrogen refuelling stations in the absence of a pipeline network, because gaseous hydrogen, even under very high pressure, has quite low density". Indeed, the standard trucks that transport gaseous hydrogen currently carry the gas at 200 bar pressure and, with 400 kg capacity, contain only enough to refuel about 100 cars. Although suppliers are in the process of testing 500 bar trucks, even these can only transport up to a tonne of fuel. Liquid hydrogen, on the other hand, can be transported at quadruple the mass and at a pressure just over atmospheric, enabling 1,000 cars to be refuelled from a single truck load.

IDEALHY

INTEGRATED DESIGN FOR EFFICIENT ADVANCED LIQUEFACTION OF HYDROGEN

OBJECTIVES

IDEALHY is an enabling project to develop an economically viable hydrogen liquefaction capacity in and for Europe. This will help in accelerating rational infrastructure investment and enabling the rapid spread of hydrogen refuelling stations across the continent. The project will investigate the different steps in the liquefaction process in detail, using innovations and greater integration in an effort to reduce specific energy consumption by 50 per cent compared to the state of the art, and simultaneously to reduce investment cost.

PARTNERS

Shell Global Solutions International BV, The Netherlands • **Linde Kryotechnik AG**, Switzerland • **SINTEF Energi AS**, Norway • **Loughborough University**, UK • **Technische Universität Dresden**, Germany • **North Energy Associates Ltd**, UK • **WEKA AG**, Switzerland • **PLANET Planungsgruppe Energie und Technik GbR**, Germany • **Kawasaki Heavy Industries Ltd**, Japan

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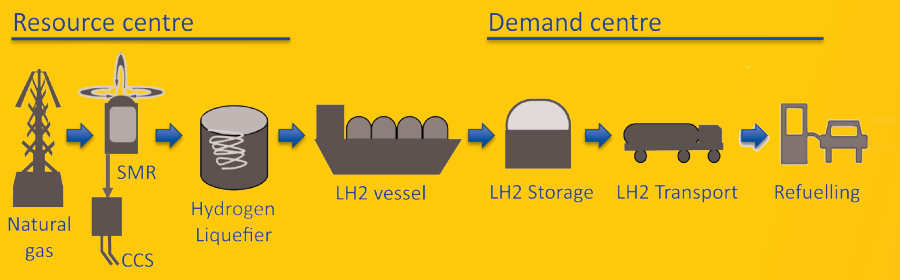
ALICE ELLIOTT is a Senior Hydrogen Engineer at Shell, working on issues around bringing hydrogen into the energy chain for mobility. She has a background in polymer membranes for flow batteries, and during her 12 years at Shell has spent time on hydrogen research, LNG energy/greenhouse gas emissions consultancy and small-scale power solutions. Most recently she has been exploring the synergies between hydrogen for mobility and other renewable and distributed energy technologies.

idealhy
Integrated Design for Efficient Advanced Liquefaction of Hydrogen



LH2 SUPPLY CHAIN

At the moment, however, liquefying hydrogen consumes too much energy, meaning the liquid supply chain performs poorly from an energetic and an economic point of view. IDEALHY intends to make this section of the energy chain more robust, through reducing the energy consumption and increasing the manufacturing scale.

Participants in IDEALHY include several key liquid hydrogen technology players in Europe, and synergy between their technical and business expertise is further strengthening the project. Alongside the development work, it is important to make others aware of the need for liquid hydrogen and progress made within the IDEALHY project. The communication of accurate information about the possibilities – and limitations – of liquid hydrogen forms an integral part of the project.

IDEALHY has come a long way in terms of designing an efficient, large-scale hydrogen liquefaction plant. "We're now half-way through the project and well on schedule, having devised a novel liquefaction process scheme which will be optimised over the next 6-10 months," Elliott observes. "The efficiency improvement will be achieved through a combination of modifications – some of which have conflicting requirements – meaning that the optimisation process is very complex."

> Liquid hydrogen is by far the most effective way to supply large hydrogen refuelling stations in the absence of a pipeline network

Concurrently, talks are also being held with equipment manufacturers to discuss the restrictions and potential of the components needed for such a plant, the biggest of its kind ever built. But again, IDEALHY exudes positivity, benefiting from the expertise of Linde Kryotechnik, as well as components manufacturer WEKA. Indeed, making good connections with other component suppliers is imperative for the project's future. Not only does IDEALHY have to produce a theoretical flow scheme, but also a design using specific and realistic components so that the technology can be demonstrated at a later stage.

As with the creation of any new process, it is a long voyage from design to implementation, taking into account development, testing, safety assessments, demonstrations and certification. Hazard analysis and risk assessments/mitigation form a significant part of this process, as there are many elements of a liquid hydrogen supply chain which differ markedly from the gaseous form. Working on this for IDEALHY are experts from Shell and Loughborough University, who have considerable experience with industrial gas installations.

CHALLENGES AND THE FUTURE

The next steps of the project are as important as those that preceded them. With just one year to go before completion, those involved in the research and development are already discussing how they might progress to a demonstration stage. As yet there are no concrete plans or commitments, but the shared vision is to develop a European hydrogen liquefaction plant capable of producing 30-50 tonnes of liquid hydrogen per day. This plant would work alongside a hydrogen manufacturing unit, producing hydrogen from renewable sources and/or natural gas while capturing and sequestering the CO_2 produced, in keeping with the low-carbon energy supply initiative. "Options for combination with an LNG re-gasification terminal are also under investigation, because of the energy and product integration synergies. Shell has a particular interest in options such as these, as part of its long term integrated gas position," Elliott notes.

As the world moves to a new model of energy supply with a shift in focus towards sustainability, IDEALHY is opening up new possibilities for low-carbon energy chains.