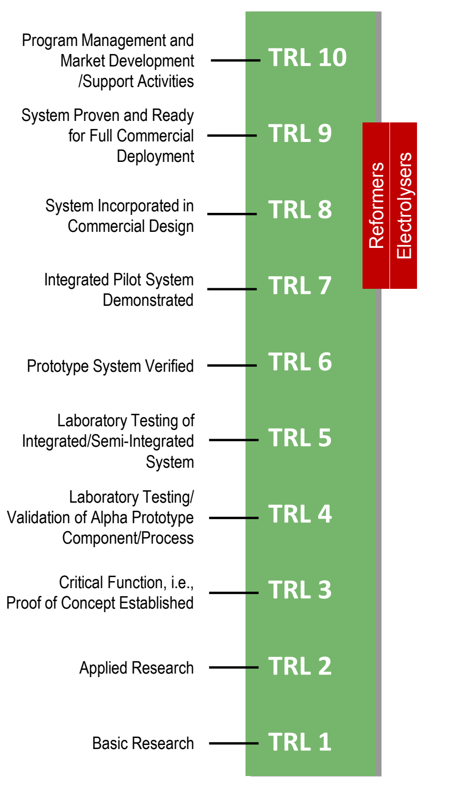
# OVERVIEW OF TECHNOLOGY

## STATUS OF THE TECHNOLOGY

Local hydrogen supply systems based on water electrolysis or reforming can be used in various energy applications, including hydrogen refueling stations for fuel cell vehicles (FCVs), production of other alternative fuels, and storage of renewable energy. The markets for local hydrogen supply system are relatively new, and there is a need for standardized system solutions and development of more key technologies with higher efficiency in order to make them commercially viable in existing and future energy markets.

## TECHNOLOGY READINESS LEVEL (TRL)

On-site small scale reformers and water electrolyser systems are modular, and can be developed for many different sizes and capacities. Several international companies supply on-site hydrogen production systems, and the technology readiness level is high (TRL 7-9).




The key technologies are commercially available, but significant improvements for energy applications can be made on efficiency and costs, especially on a system level. In order to achieve this it will be necessary to further reduce the amount of materials used in the key components (e.g., water electrolyser stacks) and to develop a more efficient balance of plants (e.g., gas clean-up and purification, compression, electrical systems, and controls). Standard and more compact designs for containerized local hydrogen production systems must be developed to enable mass production of components. This can only be achieved via a close collaboration between suppliers and end-users.

# FRAMEWORK SUMMARY

The main purpose with Task 33 is to contribute to the development, evaluation, and harmonization of on-site hydrogen production technologies and systems in order to facilitate optimal use of local feedstock and removal of barriers for introduction into energy markets. This will be achieved by continuing and strengthening an existing IEA network of reformer and electrolyser technology providers and hydrogen end-users, including gas and car companies (Figure 1). Task 33 on *Local hydrogen production for energy applications* (2013-2015) is a continuation of Task 23 on *Small scale reformers for on-site hydrogen supply* (2006-2011) and Annex 16 Subtask C on *Small stationary reformers for distributed hydrogen production* (2002-2005).

# TASK 33

## LOCAL HYDROGEN SUPPLY FOR ENERGY APPLICATIONS

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## VITAL STATISTICS

**Term**
Dates
2013-2015

**Members (level 5)**
Belgium, Denmark, France, Germany, Japan, Norway, Sweden, The Netherlands, USA

**Expert Participants**
14

**2013 Meetings**
Paris, 25-25 February

Wallingford, USA, 25-26 September

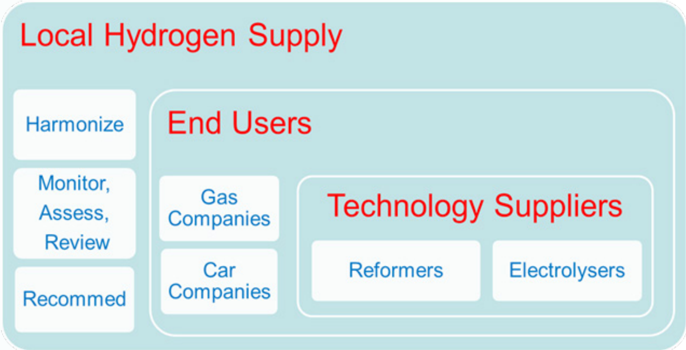


Figure 1 – An Overview of Task 33 on local hydrogen production

The main objective with Task 33 is to provide an unbiased evaluation of various pathways for local hydrogen supply for energy applications. The sub-goals are:

To assess local hydrogen supply systems and on-site hydrogen production technologies.

To monitor, review, and evaluate the new on-site hydrogen production technologies and system concepts.

To study on the barriers and opportunities for local hydrogen energy supply in existing and future energy markets.

**Subtask 1 – Technology Assessment**

*Subtask 1 Leader: Everett Anderson, Proton Onsite, USA*

The goal of Subtask 1 is to assess the technological and economic level of available on-site hydrogen supply. The sub-goal of Subtask 1 is to evaluate system design (containerization, modularization, etc.), operation (compressor challenges etc.), costs (CAPEX and OPEX), and propose how to reduce costs (standardization, mass manufacturing of systems and units, outsourcing, etc.).

**Subtask 2 – New Concepts**

*Subtask 2 Leader: Christian Hulteberg, Lund University, Sweden*

The goal of Subtask 2 is to monitor and review new system concepts and technologies for local hydrogen production. The sub-goal of Subtask 2 is to study fuel feedstock options and available hydrogen production technologies, assess future demands on hydrogen quality, and evaluate next generation reformers and electrolyser technologies and system concepts.

**Subtask 3 – Barriers and Opportunities**

*Subtask 3 Leader: Magdy Meimari, Air Liquide, France*

The goal of Subtask 3 is to develop concepts for harmonization of technologies for local hydrogen supply. The sub-goal of Subtask 3 is to study barriers and opportunities for local hydrogen supply, develop new business cases, study standards and their relevance to the technologies, and develop technological interfaces to support the social acceptance of local hydrogen production systems.

## MEMBERS

### TASK MEMBER AND EXPERT TABLE 2013

| COUNTRY | ORGANIZATION | EXPERT |
|---|---|---|
| Belgium | Hydrogenics | Roel De Maeyer |
| Denmark | Haldor Topsoe | John Bøgild Hansen |
| France | GDF Suez | Jacques Saint-Just |
| France | Air Liquide | Magdy Meimari |
| France | Nissan | Francisco J. C. Sierra |
| Germany | Mahler AGS | Ralph Stauss |
| Japan | Mitsubishi Kakoki Kaisha | Akira Obuchi |
| Norway | Institute for Energy Technology | Øystein Ulleberg |
| Netherlands | HyGear | Dick Lieftink |
| Netherlands | European Joint Research Centre | Georgios Tsotridis |
| Netherlands | Shell | Andrew Murphy |
| Sweden | Catator | Fredrik Silversand |
| Sweden | Lund University | Christian Hulteberg |
| USA | Proton Onsite | Everett Anderson |

The task 33 member table above shows the experts that attended the meetings in 2013. The number of participants (14) is about the same as in the past on Task 23. Relevant organizations and experts in the UK and South Korea will be approached in 2014.

## ACTIVITIES AND RESULTS IN 2011

### PROGRESS AND ACCOMPLISHMENTS

**Subtask 1 – Technology Assessment of Water Electrolyzers**

Water electrolysers are typically delivered in modular containerized systems with a hydrogen production capacity of 30-60 $Nm^3/h$ consisting of several small stacks (10-15 $Nm^3/h$). New and more efficient water electrolyser technologies for 1-2 MW systems are under commercial development. Stack costs are still the most dominant cost driver. New PEM water electrolysers capable of operating at high current densities for better integration with fluctuating renewable power system are under development. On a system level there is focus on reducing the amount of components and materials, and on the development of more efficient balance of plants and power conversion systems. A significant (up to 40%) cost reduction (CAPEX) is expected in the next generation systems.

**Subtask 1 – Technology Assessment of Reformers**

Cost curves (cost vs. hydrogen production capacity) for small-scale reformers (50-500 $Nm^3/h$) developed in Task 23 have been validated in Task 33, and compared to cost curves for large scale reformers (>1000 $Nm^3/h$). The results showed that compact small-scale reformers with a capacity of 500 $Nm^3/h$ can be competitive with more traditional large-scale reformers with a low hydrogen production capacity (1000 $Nm^3/h$).

For small-scale reformer systems in the low range (50-100 $Nm^3/h$) the main cost reductions (CAPEX) can be obtained by increasing the sales volume, while for small-scale reformer in the high range (250-500 $Nm^3/h$) the largest cost saving can be made by using less materials in the way of making the systems more compact. New and more flexible designs for reformer units with respect to hydrogen production (1-50 $Nm^3/h$ per reformer tube) are under development, and highly compact (containerized) reformer systems (250 $Nm^3/h$) are now being tested and validated.

**Subtask 2 – New Concepts**

New concepts for local hydrogen production are being analyzed, with focus on the concepts that address the following two major future energy challenges:

1. Uptake of the increased amount of variable renewable energy
2. Large scale storage of renewable energy

Different Power-to-gas (PtG) concepts are being considered, where renewable energy based hydrogen, which is produced via water electrolysis, is used in $CO_2$ methanation to increase the yield from the same amount of substrate (e.g. biogas). The water electrolyzer companies are mainly focusing on low-temperature water electrolysis, which requires the separate handling of $H_2$ and $CO_2$ before the gases are combined in a methanator.

The two main challenges with the PtG-concept based on low-temperature water electrolysis are the low overall energy efficiency and high cost. An alternative PtG-concept is to use high-temperature solid oxide electrolysis (SOECs), but here the product gas is a syngas (SNG or upgraded biogas) and hydrogen is only used internally in the process. The high-temperature SOEC option has the best potential for a high energy conversion efficiency (up to 80% overall energy efficiency).

New sorption enhanced reforming (SER) concepts are also under development. SER has the potential for high overall conversion efficiency (up to 95% hydrogen yield) combined with $CO_2$-capture. Local hydrogen production via reforming of biogas from waste water treatment plants has been identified as a near-term application for small-scale reformers.

There are several economic and financial issues related to the PtG-concept, as today it is only possible to monetize the energy content of an RE-based gas as the climate benefit is currently not being valued. Barriers for energy storage assets must be removed or properly mitigated; markets for load-based ancillary services must be created; and, optimally, the climate value must be monetized. Today, there exist few tariffs for biogas and renewable SNG, and in the future it will be necessary to value the renewable $H_2$ or SNG for decarbonizing the gas grid, heat sector, and transportation sector.

**Subtask 4 – Opportunities and Barriers**

There are several opportunities and barriers for local hydrogen supply system. A comparison between on-site hydrogen production systems and bulk hydrogen delivered by trucks is provided in the table below. The growing market for hydrogen refuelling stations (HRS) world-wide is one of the main opportunities for local hydrogen supply. One major challenge is the strictness of the standard on hydrogen quality for fuel cell electric vehicles (FCEVs). In practice, the existing hydrogen quality standard requires the installation of gas analysers that can verify a hydrogen quality of 6.0 N. Hence, there is a consensus in Task 33 that the hydrogen quality standard for FCEVs is too strict and should be revised.

Opportunities and Barriers and Bulk & On-Site Supply

| SUPPLY MODE | BULK | ON-SITE |
|---|---|---|
| **Description** | Tube trailer swap<br>Ground tubes | Electrolyser<br>SMR<br>bulk back-up |
| **Technical / operational barriers** | Location<br>Access<br>Safety<br>Regulatory codes | Same as bulk delivery<br>Indoor/outdoor<br>Duty cycle/operating profile<br>Sizing (generator capacity vs. backup capacity)<br>Access to utilities and feedstock |
| **Financial barriers** | Capital investment<br>Profitability<br>- Market price<br>- Cost of molecules<br>- Distribution cost | Capital investment<br>Profitability<br>- Low bulk market price<br>- Contractual commitment |
| **Economic barriers** | Traffic<br>Safety<br>Carbon footprint | $CO_2$ emissions (SMR) |
| **Opportunities** | High storage pressure<br>Standard docking station design<br>Harmonized regulatory standards<br>Use up excess bulk | Cost reduction (SMR)<br>Electrical efficiency (electrolyser)<br>On-site / filling station model |

## FUTURE WORK

Task 33 will end in December 2015.

## REFERENCES

Task 33 will be presented at the WHEC 2014 conference in Gwangju, South Korea.