IEA HIA Task 28:

Large-scale Hydrogen Delivery Infrastructure

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Background to and Objectives of the Task

- Today fuel cell vehicles are commercial or close to market introduction
- Internationally, various hydrogen infrastructure initiatives are on the way, but further efforts are required to facilitate full-scale FCEV-rollout
- Initiatives and smaller-scale demonstration and R&D projects would benefit from further alignment and harmonization
- **It is necessary to investigate and compare international activities and knowledge on large-scale H_2 delivery infrastructures** (HRS and H_2 supply)
- Moreover, In many countries with large and growing shares of fluctuating renewable energy sources (RES), H_2 offers solutions for integrating RES
- **Task 28 analyses the comprehensive knowledge on infrastructure for transport, and pays some attention to H_2 as energy storage for RES, so to better understand synergies** of the combined potential of both options
- Outcome will be a state- of-the-art overview comparing and evaluating pathways towards large-scale H_2 delivery infrastructures for mobility, showing opportunities for synergies with RES storage applications
- **Report is to inform industry, policy and research stakeholders about chances and challenges of H_2 infrastructure, and help decision-making**

Timing and Outcome

- **Timing**
  - Task scheduled from June 2010 – December 2013 (extension under discussion)

- **Structure (subtasks):**
  A. Scenarios (map major H_2 transport infrastructure initiatives world-wide and develop future outlooks)
  B. Evaluation of hydrogen refueling station concepts (technology mapping of main pathways)
  C. Analysis of hydrogen delivery pathways (economic evaluation of main pathways indentified)
  D. Hydrogen for integration of RES (PtG, energy storage, etc.)

Task Participation

- **Current team:**
  - Netherlands: ECN(Operating Agent), Shell
  - USA: ANL and Proton OnSite
  - Japan: Tokyo Gas and Nissan
  - Denmark: Danish Gas Technology Centre and H_2Logic
  - Australia: Talent with Energy / AAHE
  - France: GdF-SUEZ, TOTAL and Air Liquide
  - Germany: NOW
  - Norway: HYOP
- **Links with all European H_2 Mobility initiatives, the Scandinavian initiatives and the Japanese initiative HySUT**

Subtask A: Major H_2 Infrastructure Initiatives

	Japan	S.Korea	USA California	Germany	UK	Denmark
2015-2020	100	43	68	100	65	15
2020-2025	1000	168	100	400	330	185
2025-2030		500		900	1150	>>185

– Overview of HRS projections in major initiatives on market development

- **Comprehensive overview of countries in conjunction with projections on FCEVs**
- **Analysis based on projections on station sizes *and ramp-up FCEV fleet/sales* szenarios, etc.**

Subtask B: Technical Evaluation of HRS Concepts

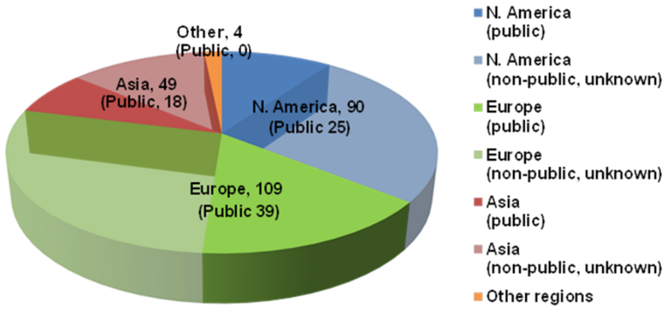
- **Description HRS standardization requirements based on public H_2 Mobility Germany technical specification document**

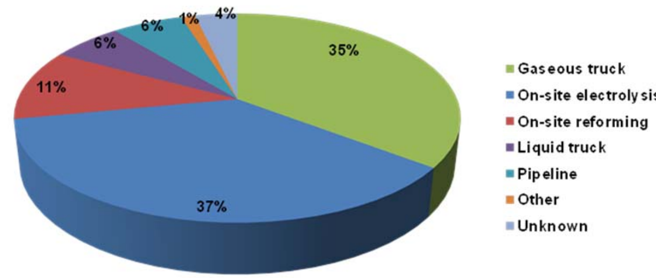
HRS size / Distribution option	Very small ≤ 80 kg/day	Small ~ 200 kg/day	Medium ~ 400 kg day	Large ~1000 kg/day	Very large ≥ 1000 kg/day
On-site electrolysis		On-site power requirement may become an issue: 400 kg/day ≈ 1 MW			
On-site reforming	Costly to capture CO_2		Required footprint is an issue		
CGH2 truck	Delivery of 300 kg up to about 1000 kg per truck				
LH2 truck	Relatively large boil-off for demand levels in early markets				
CGH2 pipeline	Due to high investments pipelines are not likely in early markets unless already available				

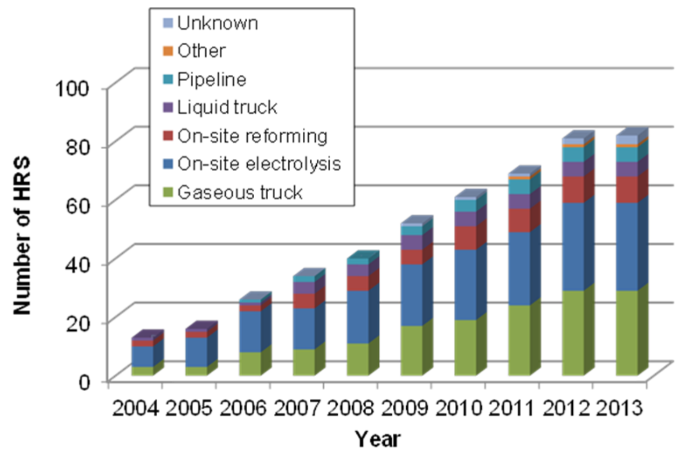
  Color coding: Suitable (green) · Possible (yellow) · Less likely (red)

- **Detailed discussion of concepts based on list of important technology requirements**

Subtask B: Mapping of Existing HRS World-Wide

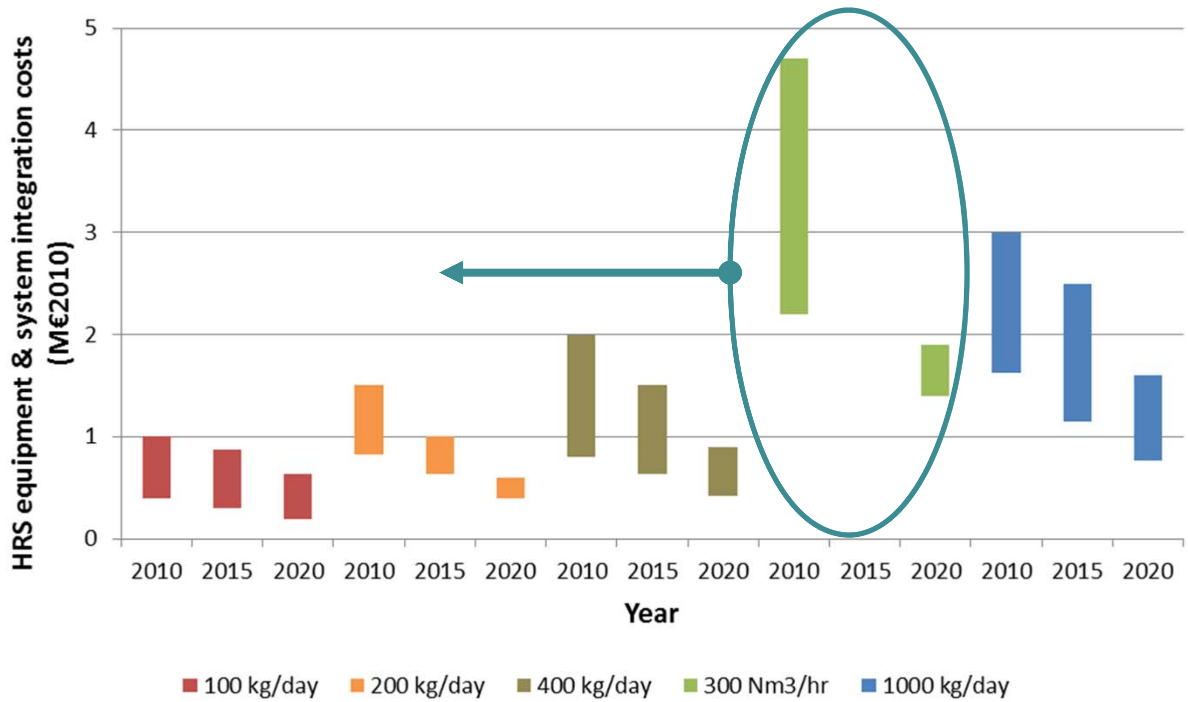






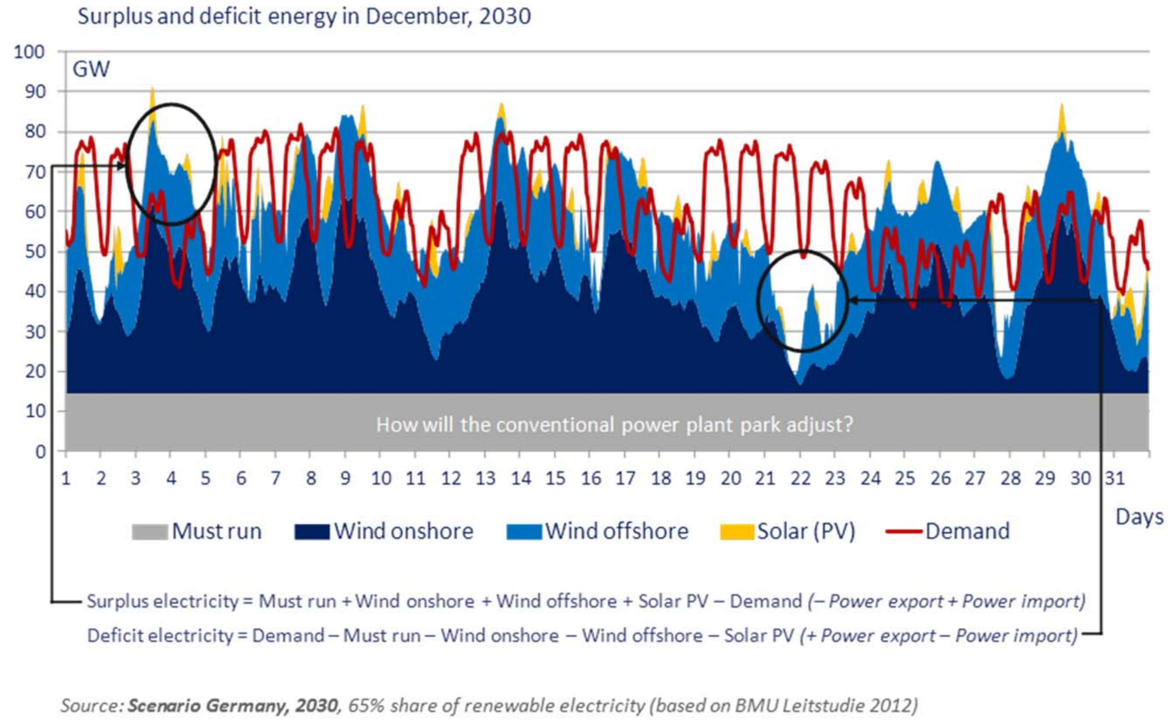
- **Currently, total 285 HRS of which 82 publicly accessible**
  - Significant differences in breakdown of delivery options: on-site reforming almost absent in Europe but important in Asia, and CGH_2 relatively unimportant in North-America

Subtask C: Analysis of HRS Component and System Costs



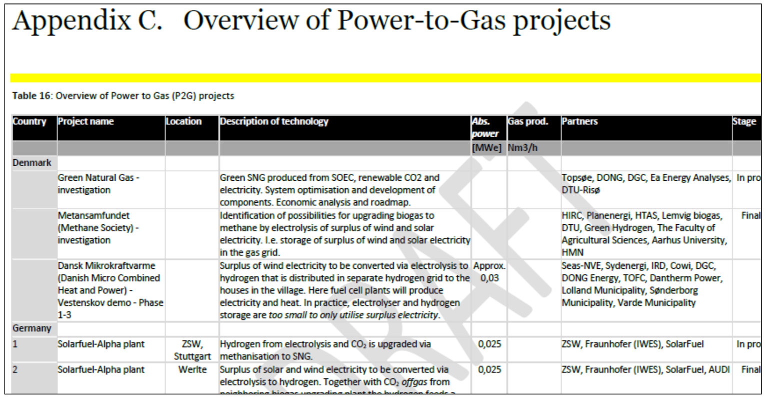
- **Clear definitions regarding cost factors and HRS cost breakdowns are important**
- ***Work in progress:***
  - *Cost of distribution*
  - *Indicative cash flow analyses*

Subtask D: Integration of Fluctuating RES by H_2



- ***High level view on role of hydrogen (work in progress):***
  - *Integration of wind and solar power into wider energy system is problem already today, but major challenge in future*
  - Power to Gas (e.g. injection of H_2 in natural gas grid) and large-scale H_2 (underground) storage are promising energy storage solutions

Subtask D: Snapshots from Discussion and Draft Report

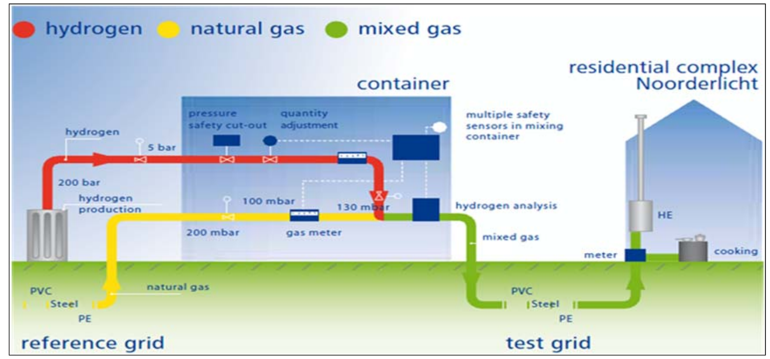


Appendix C. Overview of Power-to-Gas projects

Table 16: Overview of Power to Gas (P2G) projects

Country	Project name	Location	Description of technology	Abs. power	Gas prod.	Partners	Stage
				[MWe]	Nm3/h		
Denmark							
	Green Natural Gas - investigation		Green SNG produced from SOEC, renewable CO2 and electricity. System optimisation and development of components. Economic analysis and roadmap.			Topsøe, DONG, DGC, Ea Energy Analyses, DTU-Risø	In pro
	Metansamfundet (Methane Society) - investigation		Identification of possibilities for upgrading biogas to methane by electrolysis of surplus of wind and solar electricity. I.e. storage of surplus of wind and solar electricity in the gas grid.			HIRC, Planenergi, HTAS, Lemvig biogas, DTU, Green Hydrogen, The Faculty of Agricultural Sciences, Aarhus University, HMN	Final
	Dansk Mikrokraftvarme (Danish Micro Combined Heat and Power) - Vestenskov demo - Phase 1-3		Surplus of wind electricity to be converted via electrolysis to hydrogen that is distributed in separate hydrogen grid to the houses in the village. Here fuel cell plants will produce electricity and heat. In practice, electrolyser and hydrogen storage are *too small to only utilise surplus electricity*.	Approx. 0,03		Seas-NVE, Sydenergi, IRD, Cowi, DGC, DONG Energy, TOFC, Dantherm Power, Lolland Municipality, Sønderborg Municipality, Varde Municipality	
Germany							
1	Solarfuel-Alpha plant	ZSW, Stuttgart	Hydrogen from electrolysis and CO_2 is upgraded via methanisation to SNG.	0,025		ZSW, Fraunhofer (IWES), SolarFuel	In pro
2	Solarfuel-Alpha plant	Werlte	Surplus of solar and wind electricity to be converted via electrolysis to hydrogen. Together with CO_2 *offgas* from	0,025		ZSW, Fraunhofer (IWES), SolarFuel, AUDI	Final

Source: Task 28 Draft Report



Ameland (NL) PtG Project. Source: Draft Report

Falkenhagen (GER) PtG Plant. Source: E.ON

Case	"Less fuel"	"Standard Northeast"	Investment electrolysis 700 €/kW	Investment electrolysis 500 €/kW	Price driven electrolysis operation
Electrolysis full load hrs	3.052	3.052	3.052	3.052	5.600
Tonnes H_2 per year	32.044	32.044	32.044	32.044	59.100
Share for power plant	38%	7%	7%	7%	39%
	Specifc Revenue to break even [€/kg H_2 fuel]				
Spot market price	3,71	2,92	2,50	2,08	2,06
40 €/MWh	6,80	5,00	4,58	4,16	
80 €/MWh	9,90	7,08	6,66	6,24	

Study Integration of Wind H_2. Source: NOW

Key Overall Findings and Messages

- **All hydrogen delivery options are technically feasible – there are no technical issues that cannot be overcome**
- **There is no blueprint for the type of hydrogen delivery infrastructure that needs to be rolled out – everything is possible**
- **Best practical and economic combination depends on specific national, regional and local circumstances**
- **Most major car OEMs have FCEV commercialization plans**
- **Several hydrogen infrastructure initiatives are on the way**
- **Many demonstration projects involving electrolysis, PtG and H_2 storage are running or are planned, prove technical feasibility of and show economical perspectives for the integration of RES**
- **With both transport and energy storage applications, however, specific technical problems remain to be solved and further political support will be required**

Thank you very much for your attention!

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