GLOBAL HIDROGEN SYSTEM ANALYSIS. IEA HIA Annex 30.

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The Hydrogen Program (HIA) of the International Energy Agency (IEA) was established in 1977 to pursue collaborative hydrogen research and development and information exchange among its member countries. Through the annexes or tasks, the HIA has facilitated and managed a comprehensive range of hydrogen R& D and analysis activities. The Annex 30 goal is to perform comprehensive technical and market analysis of hydrogen technologies and resources and "supply and demand" related to the projected use of hydrogen around the world.

IEA TASK 30 MEMBERS & GOALS

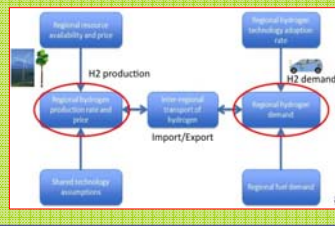
Dates: 2011 – 2013 (Final results on May 2014)
Members: 10 member countries
Co-operating agent: S. Schoenung, J. Linssen, K. Espegren
Objectives:
- ➢to prepare reliable analysis to answer questions about HYDROGEN SOURCES AND UTILIZATION
- ➢To develop an harmonized HYDROGEN TECHNOLOGY DATABASE with detailed technical and economic assumptions.
- ➢to collaborate with other IEA analyst regarding the potential future role for H2 in a clean energy future.

SUBTASK A: GLOBAL HYDROGEN RESOURCE STUDY

It focuses on a regionally-differentiated resource analysis, covering supply and demand; getting a Potential Future Hydrogen Interregional Trading scheme.
It has required:
- ❖to analyze potential hydrogen PRODUCTION and DISTRIBUTION pathways of country members;
- ❖to provide reliable data about national feedstock availability and prices;
- ❖the development of a user-friendly Global Pathways Analysis Tool (GPAT);
- ❖to define shared technology and economic assumptions to run the GPAT for several scenarios according to the demand;
- ❖to explore key sensitivities.

Tool structure based on matching country level DEMANDS for H2 with lowest cost SUPPLY options for each country.

GPAT = Global Pathway Analysis Tool developed in POWERSIM



ASSUMPTIONS

1. The delivered H2 prices include:
   - •Feedstock cost
   - •Production or conversion cost
   - •Distribution costs within regions
   - •Refilling station costs
   - •Log-distance transmission s costs between countries
   - •Carbon costs
2. Feedstock is calculated from country supplied information (cost and resource availability from 2010 to 2050) including conversion efficiency assumptions.
3. Interactive approach to gather data and assumptions was crucial.
4. Imported resources, as natural, has been included.
5. Linear interpolation has been used to estimate in-between periods without data.

Resource Cost Data

	2010	2020	2030	2040	2050
Natural Gas					
Germany	7.78	7.78	11.15	14.52	17.89
Norway	14.44	14.44	16.30	18.15	20.00
Spain	11.39	12.00	14.00	18.00	21.00
France	11.82	11.812	16.25	16.25	22.16
Japan	10.22	12.74	13.72	14.70	15.68
United States	5.60	5.21	6.67	7.67	7.67
Coal					
Germany	2.72	2.72	3.24	3.76	4.28
Norway	0.00	0.00	0.00	0.00	0
Spain	5.07	5.60	6.00	6.00	
Japan	3.78	4.2	4.62	5.04	5.46
United States	2.33	2.92	3.9	4.57	4.57
Biomass					
Germany	6.22	6.22	7.52	8.81	10.11
Norway	30.00	30.00	30.00	30.00	30.00
Spain	42.97	15.83	17.22	18.61	24.50
Sweden	30.00	30.00	30.00	30.00	30.00
France	4.67	3.89	3.89	3.89	3.89

	2010	2020	2030	2040	2050
Onshore Wind					
Germany	21.78	21.78	21.39	21.00	20.61
Spain	12.68	11.94	11.20	10.46	9.72
Sweden	0.00	0.00	11.67	11.67	11.67
Denmark	17.67	17.67	17.67	17.67	17.67
France	23.33	36.94	36.94	35.78	34.22
Japan	50.82	37.24	29.59	21.93	14.28
Offshore Wind					
Germany	20.61	20.61	20.09	19.57	19.06
Spain	25.86	23.14	20.42	17.69	14.97
Sweden	0.00	0.00	26.11	26.11	26.11
Denmark	0.00	0.00	0.00	0.00	0.00
France	23.33	36.94	36.94	35.78	34.22

Every country has supplied feedstock cost assumptions in US $

Production Cost

The production costs include all conversion costs other than feedstock cost. Data are based on H2 production technology and cost database developed in Subtask B and estimations from US Department of Energy's H2A Analysis.

Distribution Cost

Delivery costs include all costs associated with getting the hydrogen form the production plant to the vehicle. Estimated costs include compression, storage and dispensing costs. H2A Analysis has been used to get current results, HIA Task 28 developed data will may be integrated in the future.

2010 US $ = 0.71 €

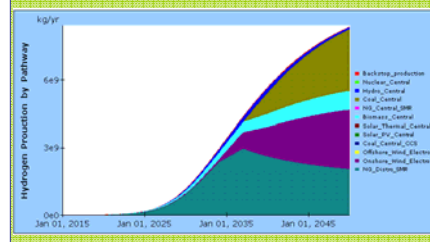
Pathway	Production cost (excluding feedstock) $/GJ ($/kg)	Local Distribution cost $/GJ ($/kg)	Feedstock conversion efficiency (MJ H2/MJ Feedstock)	Well-to-Tank GHG emissions (kg CO_2e/kg H_2)
Natural Gas: Distributed SMR	6.67 (0.80)	13.75 (1.65)	71.9%	14.3
Natural Gas: Centralized SMR	3.25 (0.39)	21.50 (2.58)	53.6%	14.7
Coal: Centralized gasification	10.75 (1.29)	21.50 (2.58)	53.6%	44.7
Coal: Centralized gasification with CCS	14.67 (1.76)	21.50 (2.58)	53.6%	7.5
Biomass: Centralized gasification	8.92 (1.07)	21.50 (2.58)	49.6%	3.1
Electrolyzer options (wind, solar, nuclear	5.25	21.50 (2.58)	72.5%	2.9

Hydrogen Demand

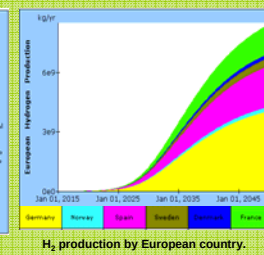
It is assumed that 40% of passenger vehicle market will be shared by Fuel cell vehicle by 2050. It means a Spanish FCEV fleet of more than 20 millions vehicles and 2.000 tons/year of H2 demand.

RESULTS

In the early years, hydrogen is produced using onsite natural gas reformation. The share produced from natural gas levels declines after 2035 as onshore wind, biomass, coal, and hydro capture market share as their costs drop relative to natural gas.



H2 Production pathways for Europe (Scenario 1_No carbon tax)



H_2 production by European country.

The inclusion of carbon tax drives out the use of coal gasification in favor of biomass gasification

Delivered H2 Cost	Germany	Norway	Spain	Sweden	Denmark	France
Germany	50.80	63.13	79.00	68.27	67.61	76.30
Norway	71.91	42.02	87.94	56.69	66.08	91.67
Spain	89.44	89.80	40.16	94.18	79.96	76.54
Sweden	76.23	56.95	91.50	42.84	66.77	94.72
Denmark	67.30	56.99	69.00	58.50	51.12	85.72
France	70.52	77.13	60.12	80.96	80.25	56.59

Columns are Supply and Rows are Consumption (Vertically it is the price supplied to the horizontal country)

Delivered H2 cost in between European regions

INT Trading doesn't make sense: Due to delivery cost and despite to lower H2 Spanish production cost, the price of domestic H2 is always below.

Source: Global Resource Analysis. Thomas E. Drennen. SANDIA REPORT: SAND2014-0300

SUBTASK B: HYDROGEN TECHNOLOGY DATABASE

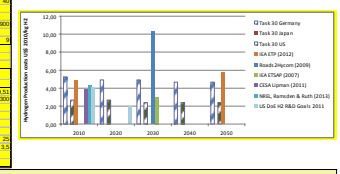
The efforts of Task 30 to perform system analysis result in the development of a consistent and comprehensive database. This database includes not only technical and economic information on hydrogen technologies but also information on regionally differentiated resources (and reserves), energy requirements and costs.

Technology description: Centralised gasification of lignite

Technical Data	Unit	Spain				
		2010	2020	2030	2040	2050
Nominal Capacity	GJ/a	187,008	187,008	187,008	187,008	187,008
or Nominal Capacity	kg/h	178	178	178	178	178
Full load hours	h/a	6000	6000	6000	6000	6000
Partial load	h/a	570	570	570	570	570
Minimum Partial load	% of nominal capacity	50	50	50	50	50
Dynamics	% per minute	3				
Ramp-up Time Cold Starting	min	720				
Efficiency (nominal load, all energy fluxes, HHV)	%	46.5	46.5	46.5	46.5	46.5
Efficiency (partial load, all energy fluxes, HHV)	%					
Electricity for auxiliaries	kWh/GJH2	120.0				
CHP Factor	-	0				
Construction Time	a	4	4	4	4	4
Operational Lifetime	a	40	40	40	40	40
Time for Dismantling	a	1	1	1	1	1
Operating Temperature	°C	40				
H2-purity at Outlet	%	99.9900	99.9900	99.9900	99.9900	99.9900
H2-pressure at Outlet	bar	15				
Technology Readiness Level	-	9	9	9	9	9

Economic Data	Unit	Spain				
		2010	2020	2030	2040	2050
Investment (overnight cost) per hydrogen output	US$ / (GJ/a)	9.51	9.51	9.51	9.51	9.51
Investment (overnight cost) per hydrogen output	US$ / kW	300	300	300	300	300
Fixed annual operating costs (maintenance, salary etc.)	% of invest p.a.	3				
Variable Operating Costs (without feedstock)	US$ / GJ					
Variable Operating Costs (without feedstock)	US$ / kgH2					
Costs for Removal (Disposal)	US$ / GJ/a					
Amortisation time	a	25	25	25	25	25
Interest Rate	%	3.5	3.5	3.5	3.5	3.5
Scaling Factor	-					
Learing Rate	-					

Bibliography provides very different values of technology and economic parameters. This database try to find consensus and reliable parameters



A HANDBOOK is going to be edited in May 2014. It contents not only the methodological approach made to harmonize the technology and economic data collected but also it provides an updated technology description to document these database. This Handbook also includes links to the resource analysis performed in subtask A. But due to the fast changes on these new technologies, thanks to the market economy; a continuous update process has to be established to assure a consistent database availability: And not to throw away the effort made in this task.

SUBTASK C: COLABORATION WITH IEA ANALYSIS GROUP

The consensus between the WEO and ETP reports and HIA task experts is very important and this is the goal of this subtask: To check that the outlook and prospect IEA analysis are according to the real hydrogen technology facts, reviewing and making comments to the drafts.