Fuel cells and hydrogen
Joint undertaking

IDEALHY

Integrated design for efficient liquefaction of hydrogen

Grant Agreement 278177

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New Energy World JU
fuel cells & hydrogen for sustainability

Review Days, Brussels, 28-29 November 2012

http://www.fch-ju.eu/

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- Project dimensions
- Alignment with MAIP
- Achievements
- Cross cutting issues
- Next steps

IDEALHY

Project dimensions

- Scope
  - to develop a generic process design and plan for demonstration of efficient hydrogen liquefaction in the range of up to 200 tonnes per day
- Objective
  - to reduce liquefaction energy consumption by 50% and simultaneously reduce investment cost
- Timeline: November 2011 to October 2013
- Total budget 2.5 M€, EU contribution 1.3 M€
- Nine consortium members:

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Decarbonisation of transport by 2050

Alignment with MAIP

Longer term MAIP target: production and distribution

- Reach in 2020 the level of technology readiness required for massive expansion of the hydrogen production and distribution infrastructure as needed for decarbonisation of transport by 2050 with CO2-lean or CO2-free hydrogen

IDEALHY contribution

- Liquefaction enables transport of CO2 free energy from resource to demand areas,
  - Hydrogen produced from sunlight in southern Europe or desert regions
  - Hydrogen from wind energy in Northern Europe or other high wind areas like Patagonia
  - Hydrogen produced from fossil sources with carbon sequestration at the production location
- thus reducing cost and securing supply of hydrogen and energy in Europe

LH2 ship impression
by Kawasaki Heavy Industries

Refuelling stations volume and cost

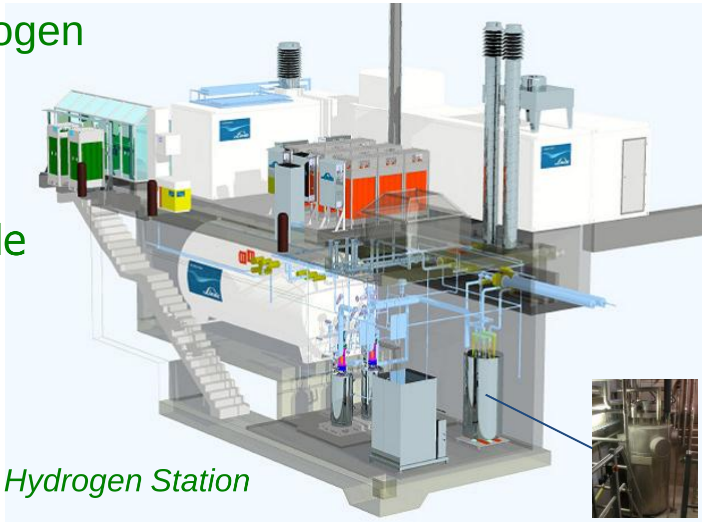
Alignment with MAIP

Long term MAIP target on hydrogen fuelling stations

- Over 2000 stations with cost between 0.6 to 1.6M€, depending on station size

IDEALHY contribution

- Hydrogen liquefaction enables cost reduction of large stations (> 400 kg/d throughput)
  - Lower storage cost of liquid vs. compressed hydrogen
  - Lower cost compression equipment at the station
  - No cooling equipment required
- Liquefaction increases the number of retail sites suitable for implementing hydrogen stations
  - Less space needed to store liquid hydrogen



Shell Berlin Liquid Hydrogen Station

Cost of hydrogen delivered

Alignment with MAIP

MAIP target on cost of hydrogen delivered

- Cost of production and delivery below 5 €/kg

IDEALHY contribution

- Hydrogen liquefaction enables distribution cost reductions
  - A single truck with driver can transport 4x more liquid hydrogen than gaseous hydrogen
  - Reduced loading and off-loading times further reduce cost of delivery
  - Less obstruction at the filling station reduces income loss

H2 Mobility impression

Centralized production of hydrogen

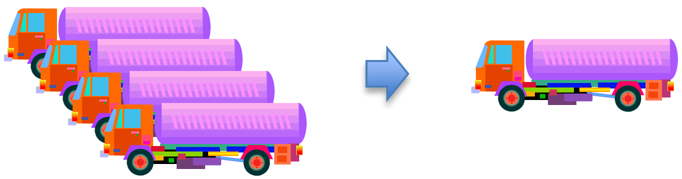
Alignment with MAIP

MAIP target on centralized production of hydrogen by water electrolysis

- 50 t/d capacity

IDEALHY contribution

- Hydrogen liquefaction enables transport of hydrogen away from the production facility
  - Gaseous truck distribution would mean 100 to 200 trucks daily at a 50 t/d facility
  - With liquid truck distribution 4x fewer trucks are needed
  - Liquid hydrogen can be transported by train and barge in ISO Containers



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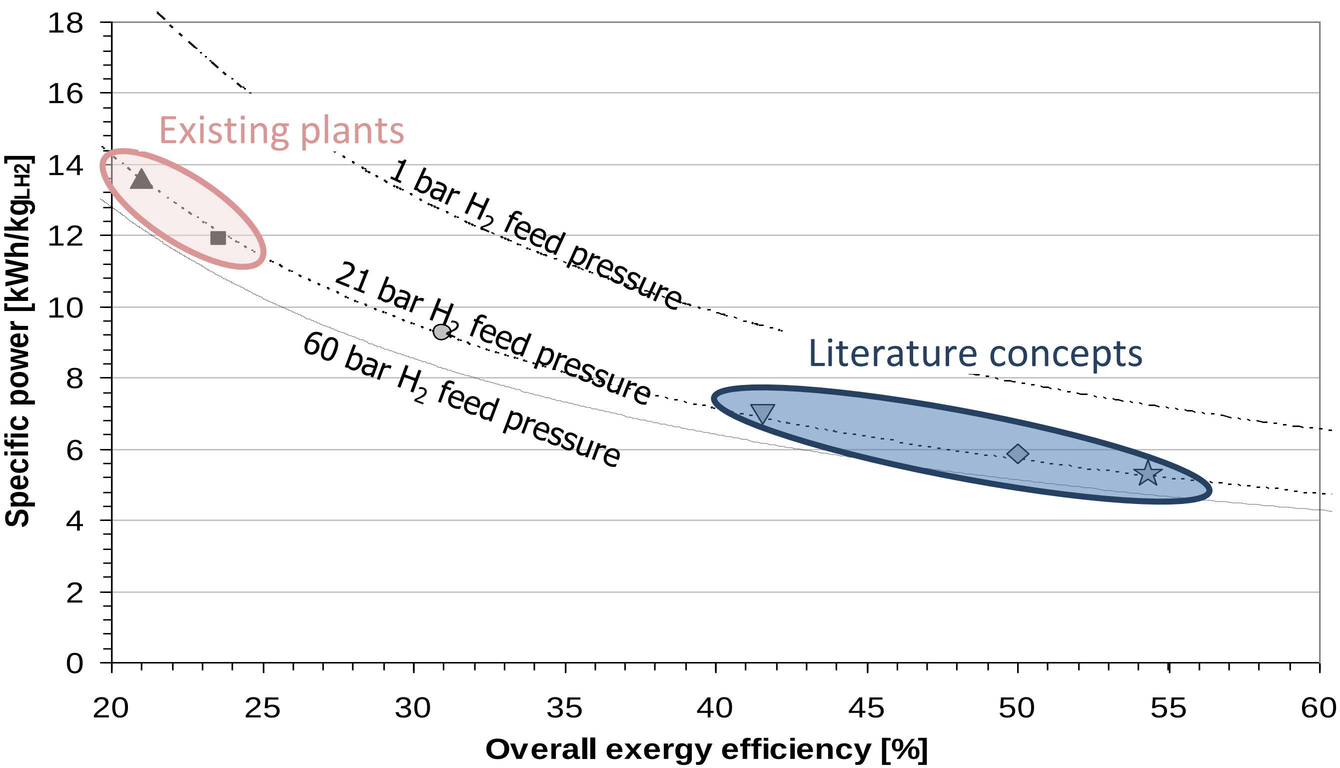
Potential for reduction in energy use

Achievements

In existing liquefaction a lot of energy is used to liquefy the hydrogen, however process optimization was never a main driver. Improvements are needed in

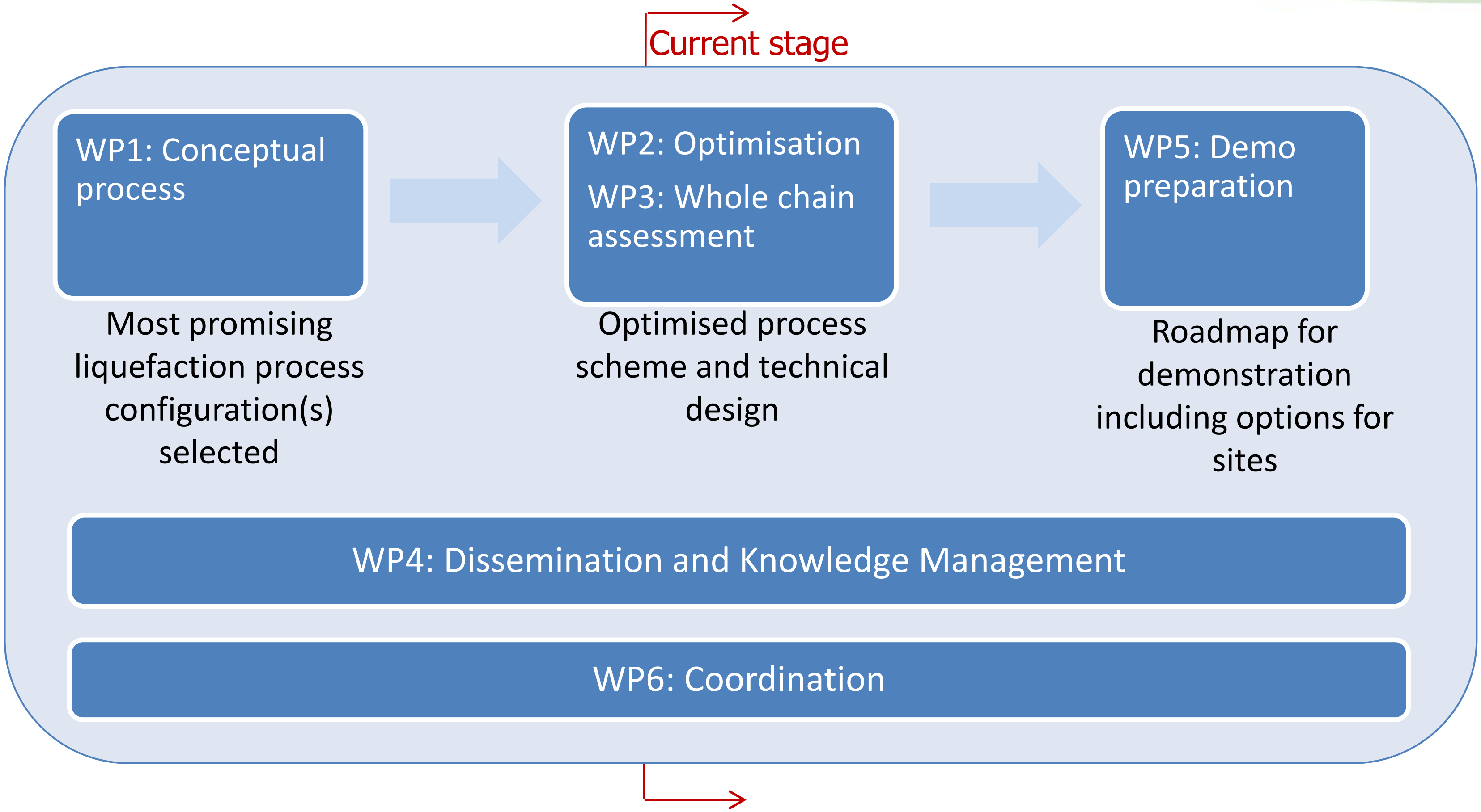
- process schemes
- equipment
- integration



Source: Berstad D., Stang J. and Nekså P. Comparison criteria for large-scale hydrogen liquefaction processes. Int J Hydrogen Energy 34(3):1560–8, 2009

Project is on schedule

Achievements



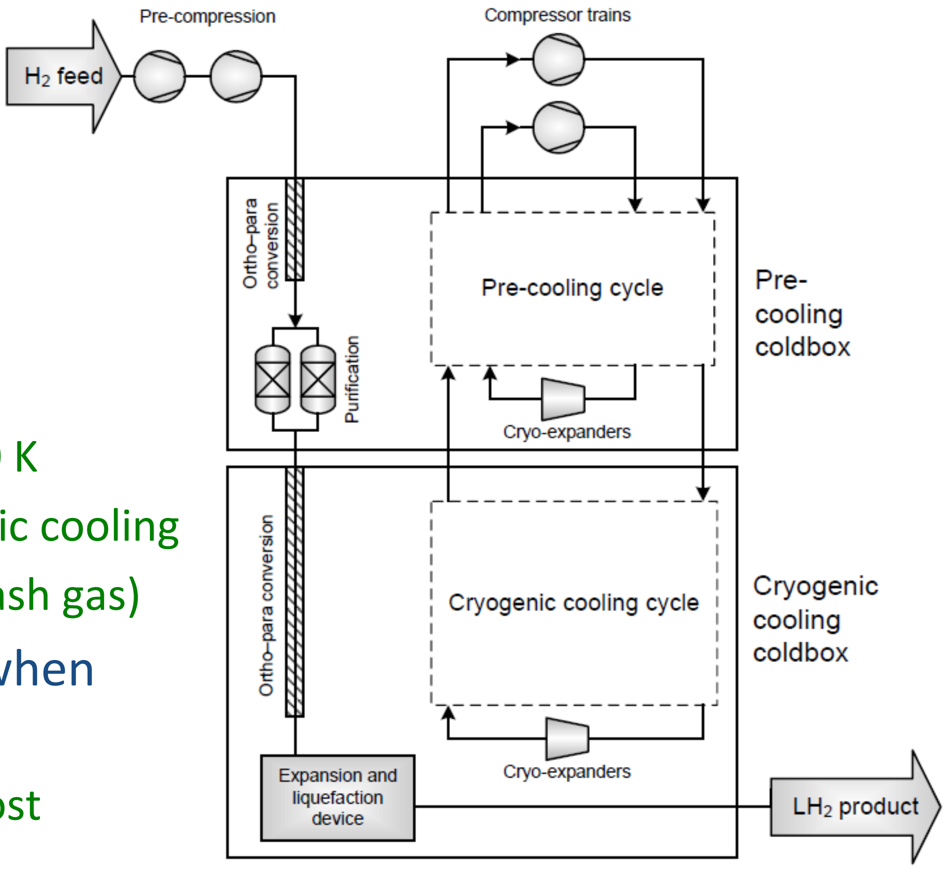
Single optimum process defined

Achievements

- Technology analysis and conceptual process assessment completed
- Functional schemes of efficient large-scale hydrogen liquefaction processes examined
  - boundary conditions and duty specifications established
  - modelling tools of 4 partners compared and validated
  - existing schemes compared using rigorous modelling process
  - alternatives for central sub-systems analysed
- All partners aligned on the optimum process combining high efficiency with realism regarding construction

Liquefaction scheme selected

- Predicted energy use 6.3 kWh/kg
  - vs. 12 to 14 of existing plants
- Max. train size approx. 150-200tpd
- Three-stage cooling process:
  - pre-compression to max. 80 bar
  - mixed refrigerant cooling to 200-80 K
  - He/Ne refrigerant used for cryogenic cooling
  - saturated liquid as product (min. flash gas)
- Equipment cost included as factor when designing cycle
  - trade-off between efficiency and cost skewed towards efficiency



Optimisation of process started

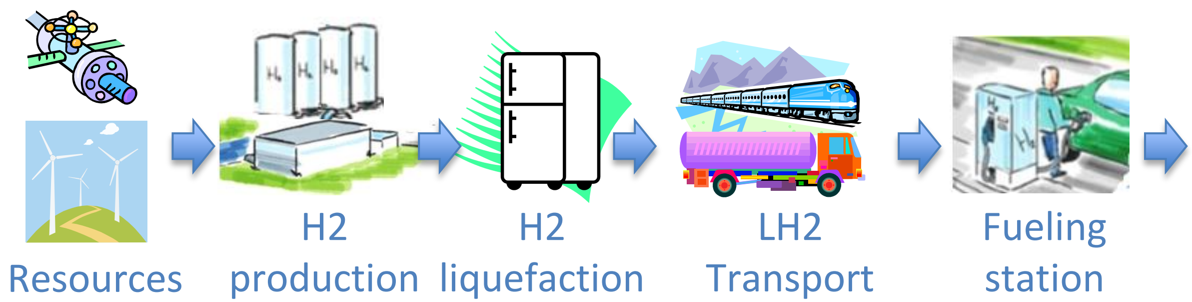
Achievements (next objectives)

1. Confirmation of predicted energy consumption of selected process
2. Process optimisation, including
   - temperature break point between sections to be optimised
   - variant included which integrates LNG regasification for pre-cooling step
   - (possible) flash gas handling to be optimised
   - compressor specifications
3. Component optimisation, including discussions with component manufacturers
   - testing of novel valves/seals etc.
   - feasibility of large compressors with proposed refrigerant mixtures
   - timescale for prototypes, testing and manufacture

Hydrogen pathways selected

Achievements

Demand country wind and (liquid) natural gas + CCS hydrogen (50-200 tpd)



Resource country solar and natural gas or coal / fossil + CCS (500+ tpd)

Compressed hydrogen for mobility

Life Cycle & HSE Assessments

Achievements (next objectives)

- Life cycle assessment of selected hydrogen pathways started
  - includes primary energy inputs, greenhouse gas emissions and total internal costs
  - Comparison against gaseous hydrogen distribution
  - Benchmark against gasoline / diesel baseline
- HSE: hazard and risk assessments for H2 liquefaction
  - Hazard identification process (HAZID) started

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Dissemination

cross cutting issues

- Dissemination with focus on
  - How liquid hydrogen helps meeting EU goals
  - Sharing results with technical and related industry community
- Main publications
  - Project flyer
  - 19th World Hydrogen Energy Conference, Toronto, June 2012
    - Presentation, three posters
  - 12th Cryogenics IIR International Conference, Dresden, Sept 2012
    - Two presentations with scientific papers
  - Presentation at the EU Sustainability Week 2012
  - Article planned in the International Innovation Energy report
- Reports and publications available on *www.idealhy.eu*

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Hydrogen liquefaction next steps

- IDEALHY: recommendations for demonstration project, including
  - Basic design: process scheme and equipment requirements
  - Environmental and safety considerations
  - Options for location

- Next stage: demonstration project
  - 30+ ton per day liquefaction plant in EU
  - Potentially linked to a low CO_2 / renewable hydrogen production demonstration
  - Potentially including a distribution demonstration by barge, train and truck

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