idealhy

Making Hydrogen Liquefaction more competitive:

Overview of the Project and of the Supply Pathways considered

Petter Nekså, SINTEF Energy Research
Klaus Stolzenburg, PLANET

New Energy World JU
fuel cells & hydrogen for sustainability

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Overview of the Presentation

- Introduction to IDEALHY
- Hydrogen Supply Pathways Selected
- Life Cycle Assessment Method and Baseline Cases
- Aspects related to liquefaction

Further Co-Authors:

- Anna Evans, Charlotte Hatto, Nigel Mortimer, Onesmus Mwabonje, Jeremy Rix (North Energy)
- Ritah Mubbala (PLANET), Alice Elliot, Jurgen Louis (Shell)
- David Berstad (SINTEF)

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Background

- Hydrogen expected to become an important clean transport fuel
- Liquid hydrogen (LH_2) most effective way to supply larger refuelling stations in the medium term (in absence of pipeline network) and for transport from remote production sites
- Today hydrogen liquefaction is considered:
  - expensive
  - energy-intensive
  - relatively small-scale (typically 5-10 tonnes/day)
- Without competitive liquefaction capacity, serious risk to hydrogen infrastructure expansion

Picture: Linde

IDEALHY Project Outline

- Investigate the different steps of the liquefaction process in detail
- Use innovations and greater integration to
  - Reduce specific energy consumption by 50 % compared to state of the art
  - Reduce investment cost
- Conceptual process design and components development
- Plan for a large-scale demonstration in the range of up to 200 tonnes per day

Picture: Linde

IDEALHY Consortium

Duration: November 2011 – October 2013

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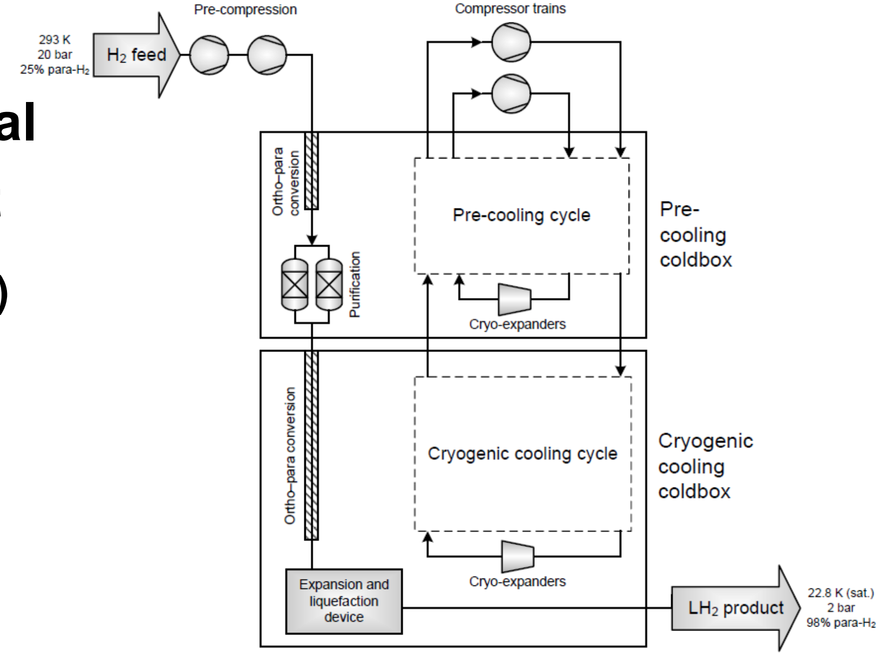
Project Steps and Results



1) **Technology analysis & conceptual liquefaction process assessment**

(see poster presentations Tue 69,105,108)

- **Technology overview**
- **Boundary conditions and duty specifications**
- **Screening and pre-selection of large-scale liquefaction concepts and alternatives for central sub-systems**

→ **Functional schemes of promising highly efficient large-scale hydrogen liquefaction processes**

→ **Targets, criteria and boundary conditions**

Project Steps and Results

2a) Process optimisation

→ Optimised process scheme and technical design of selected processes

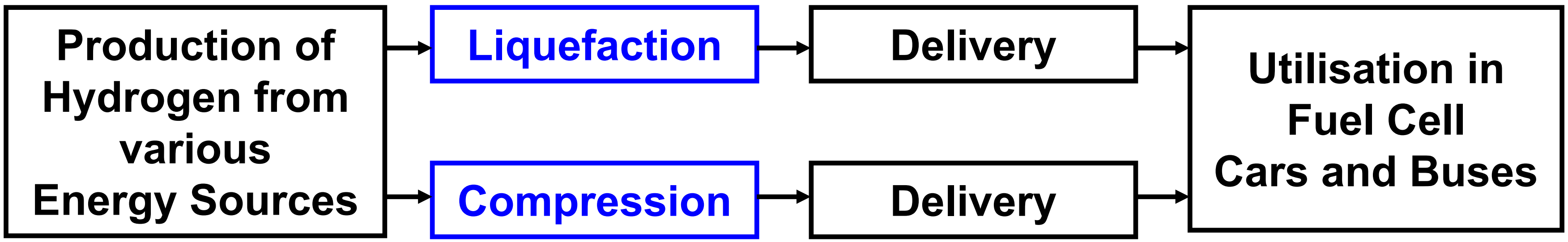
2b) Whole chain assessment

- Scenario development → Supply Pathways
- Hazard and risk assessment and mitigation measures
- Life cycle and economic assessment

→ Liquid hydrogen implementation scenario and whole chain assessment benchmarks

3) Planning and preparation of a large-scale demonstration

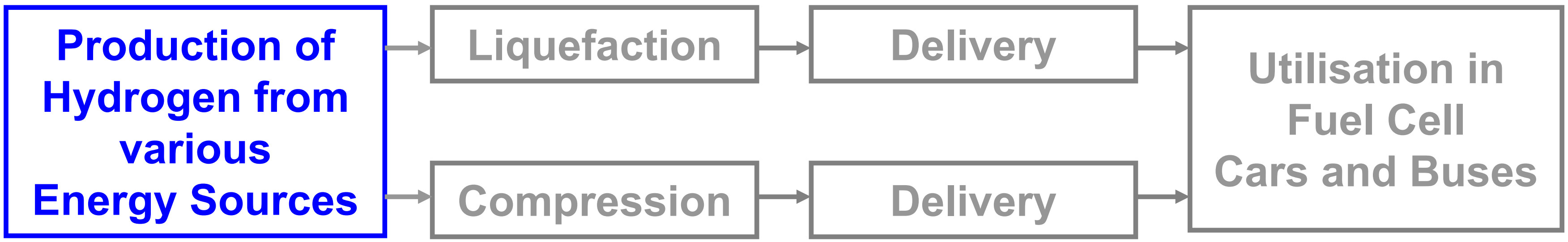
Supply Pathways of Hydrogen as a Fuel for Road Vehicles



Core element: Liquefaction

- **Expected max. capacity per "cold box": 50 tonnes/day (tpd)**
  - **Assume 1 cold box per plant**
    if hydrogen produced in demand country / region
  - **Assume 10 cold boxes in parallel (500 tpd)**
    if production region and demand region far from each other
- **Compression only considered for "production = demand region" (50 tpd)**

Hydrogen Production Routes



- Case "resource = demand region" (50 tpd)
  - Surplus wind electricity → electrolysis → H_2 cavern storage
  - CNG / LNG → reformation with and without CCS
    (200 tpd of which 50 tpd for liquefaction)
- Case "resource ≠ demand region" (500 tpd)
  - Coal and CNG → gasification / reformation with CCS
  - Solar power → electrolysis

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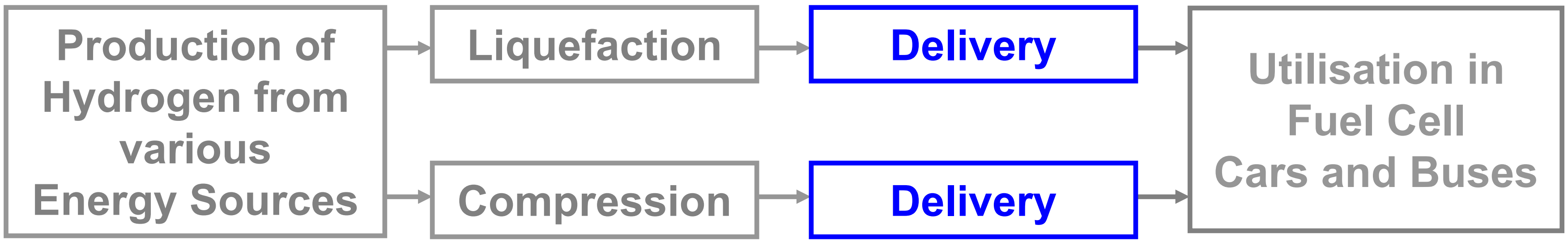
Hydrogen Delivery



- **Liquid delivery**
  - **Resource region to demand region by ship**
  - **Up to 4.000 kg per road trailer**
- **Gaseous delivery**
  - **200 bar today (< 600 kg per trailer)**
  - **500 bar in the future (expected about 1.000 kg per trailer)**
- **Pipeline delivery expected beyond time horizon (2018 – 2030)**

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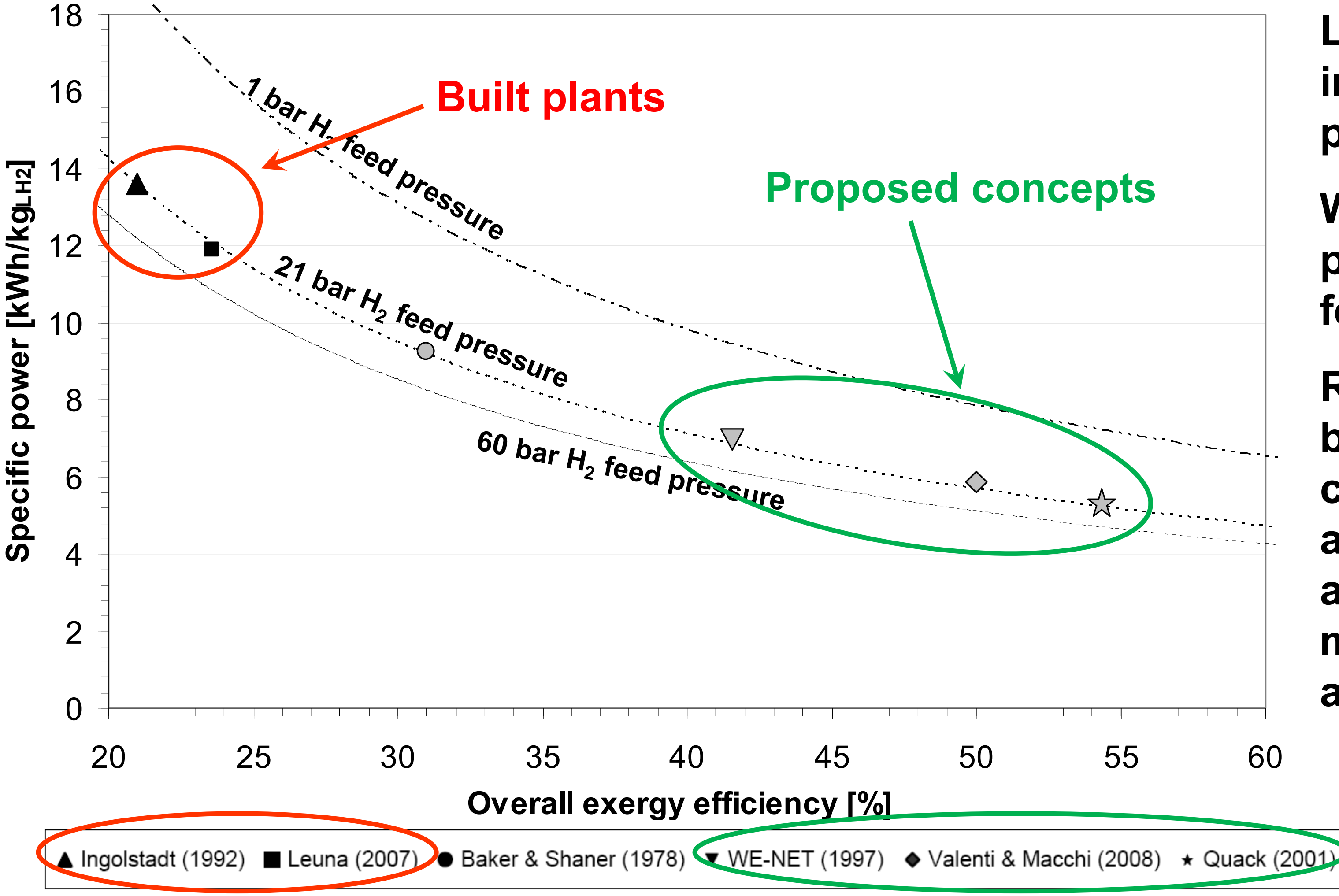
Life Cycle Assessment Method and Baseline Cases

- Use of transparent spreadsheet workbooks
- Facilitate both
  - Attributional LCA (for regulatory purposes, such as the EC Renewable Energy Directive) and
  - Consequential LCA (for policy analysis)
- Focus on primary energy inputs and greenhouse gas emissions (CO_2, CH_4 and N_2O) and, in economic terms, total internal costs
- Baseline cases are petrol and diesel
- Further detail in Baseline Results Report and Pathway Report, soon available on www.idealhy.eu

Efficiency of Built and Proposed Hydrogen Liquefiers,

recalculated to equalised feed pressure



Large improvement possibilities

What is practically feasible?

Realistic boundary conditions and assumptions must be applied

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

Conclusions

- **High efficiency hydrogen liquefiers is required to realise an efficient hydrogen supply chain utilising LH2**
- **This may be obtainable for large-scale liquefiers with energy optimisation, extensive process integration and high-efficiency compressors and expanders**
- **40–50% reduction of power consumption, down from 12 to 6–7 kWh/kg, will represent a radical improvement within large-scale hydrogen liquefaction and contribute to further enhancement of the competitiveness of LH2 as energy carrier in an hydrogen-based energy chain**
- **IDEALHY will develop a technology platform that contribute to realise this**