Benchmarking of European and U.S. Hydrogen Roadmapping Efforts (HyWays-IPHE): Hydrogen Pathway Analysis

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on behalf of the HyWays-IPHE consortium

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Outline

- Project objectives and organization
- Results of hydrogen pathway comparison
- Conclusions

Project Scope and Objectives

- Compare roadmapping and system analysis activities in Europe and USA (+other IPHE partners)
- Improve understanding about the ongoing activities (common language, mutual understanding, alignment of int'l approaches)
- Institutional and personal exchange under IPHE patronage

⇒ **Goal:** Develop recommendations for the preparation of an International Hydrogen Roadmap

- 24 month project (Oct 2006 – Sep 2008)
- Total budget: 537 k€ (56% EC contribution; 30% US DOE, 14% industry)

HyWays-IPHE Partners

EU Institutes

Ludwig-Bölkow-Systemtechnik

ECN

Fraunhofer Institute Systems and Innovation Research

Institute for Energy

EUROPEAN COMMISSION DIRECTORATE-GENERAL Joint Research Centre

INSTITUTO SUPERIOR TÉCNICO Universidade Técnica de Lisboa

U.S. Institutes

NREL

Argonne NATIONAL LABORATORY

OAK RIDGE National Laboratory

DOE Hydrogen Program

Industry monitoring group

acciona Biocombustibles

DAIMLER

GE Oil & Gas

TOTAL

HyWays / IPHE Project Activities

- Comparison Activities
  - Hydrogen pathways relevant in EU and U.S.
  - Basic technical and economic assumptions
  - Hydrogen pathway analysis results
  - Modeling approaches (economic impacts, technology learning, infrastructure and transition analysis, model interaction)
  - Stakeholder involvement in the roadmapping process

Presented

Mon 16:30

- Communication and Community-Building Activities
  - Involved institutional and personal exchanges to improve understanding
  - Involved continuous consultation of industry monitoring group

Hydrogen energy pathways - comparison

- Models: E3database (EU-HyWays) vs. H2A Production/HDSAM/GREET (US)
- 9 representative Well-To-Tank pathways compared (electrolysis, SMR, CTH; onsite/central, pipeline, trucked-in LH2)
- 1 pathway considering stationary use of H2 from coal (GT)
- Costs, energy use and GHG emissions compared (deterministic values and partially Monte Carlo analysis)
- Original vs. financially harmonized pathways

- **Report available online**

  http://www.hyways-iphe.org/WP2

General findings

- **Different viewpoints for economic calculations**: investor's point of view (U.S.) vs macro-economic point of view (EU)
- **Pipeline configuration**: high-pressure pipeline with upstream compression, geologic storage, and a ring architecture (US) vs. medium-pressure pipeline (plant outlet pressure), no geologic storage, and a star-like architecture (EU).
- **Model layout**: U.S.: Split into production and delivery, costs (H2A) and energy/emissions (GREET), using predefined *pathways.* EU: E3database is a stand-alone relational database with a graphic user interface and is a general and fully flexible tool for the modeling of energy chains.

Specific hydrogen production costs
Comparison U.S. and EU models

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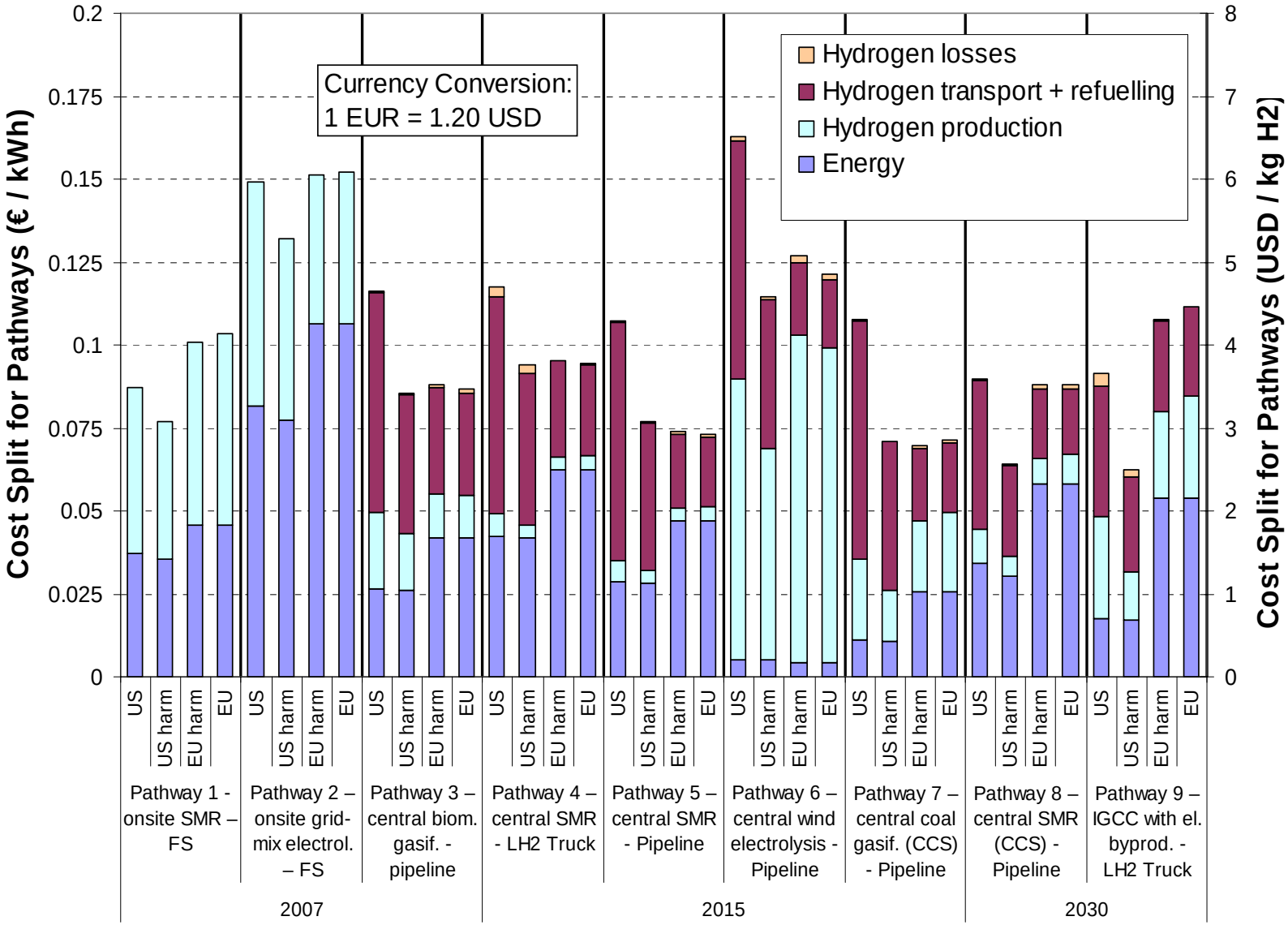
Benchmarking of Hydrogen Energy Roadmaps



Financial and cost differences

- **Financial assumptions**: U.S.: High taxes (total tax rate of 39%) and high internal rate of return (10%) (U.S.); EU: no taxes, 8% interest rate.
  ⇒ higher costs of capital for the U.S. in the original cases (not in the financially harmonized cases).
- **Energy price assumptions**: the future NG, biomass and coal price assumptions are substantially lower on the U.S. side.
  ⇒ Higher energy cost contributions in the EU.
- **Pipeline cost degression**: U.S.: Cost reductions through technological progress for gas pipelines assumed; EU: pipelines are mature technology.
  ⇒ Significant decrease of pipeline delivery cost estimation over time for the U.S. case.
- **Delivery O&M costs**: higher O&M costs in U.S. models for all hydrogen delivery cases, due to different approaches to determine the costs.

Specific CO_2 equivalent emissions Comparison U.S. and EU models

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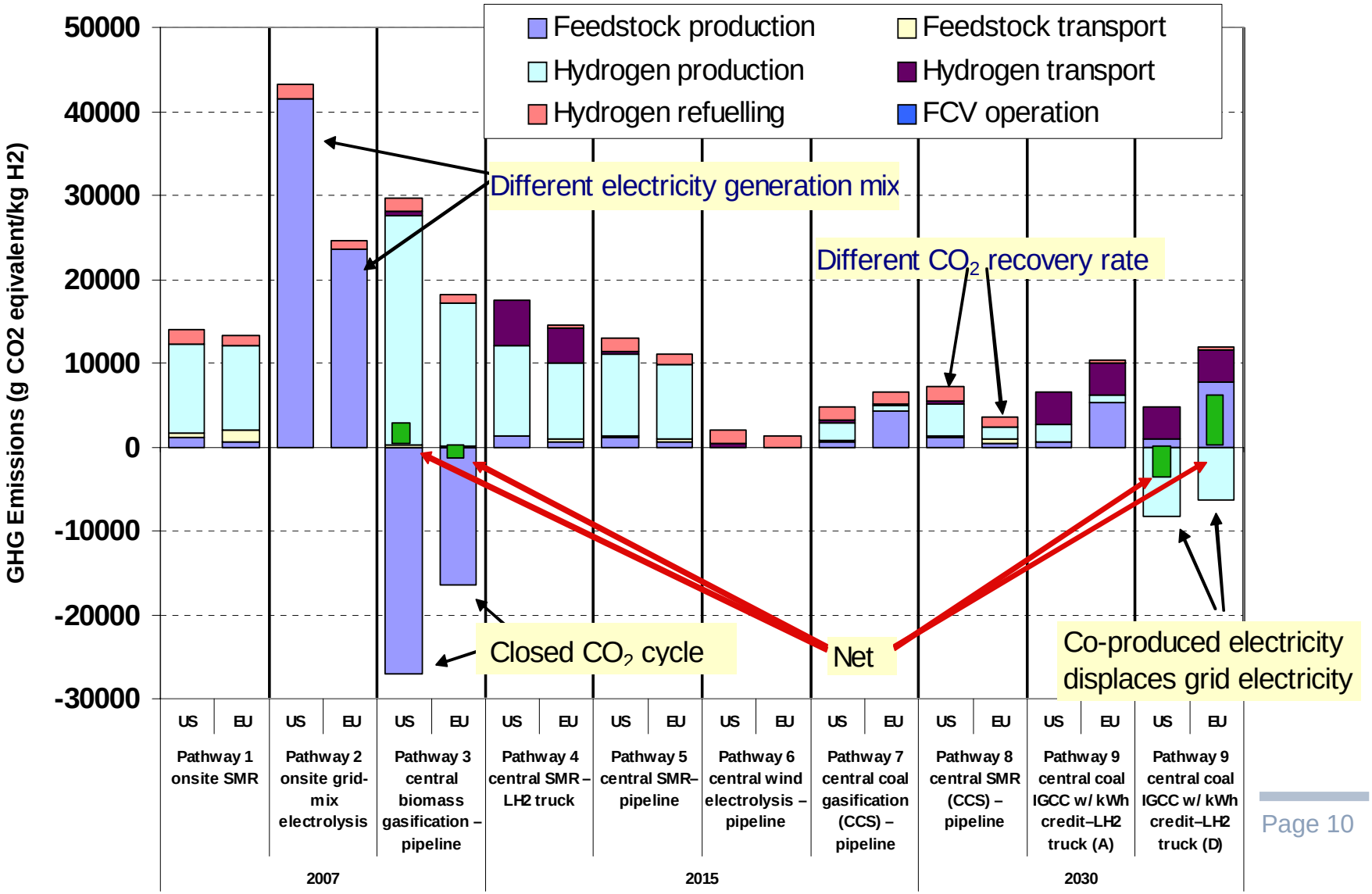

Techno-economic differences

- **Vehicle fuel economy**: U.S.: lower fuel economy for fuel cell vehicles than EU.
  - Reason: partially size of the assumed vehicles

  ⇒ Higher costs and GHG emissions per km in the U.S.
- **Biomass/coal gasification efficiency**: EU uses higher biomass gasification efficiency (due to different gasifier efficiency, PSA recovery rate, and compression). U.S. uses higher coal gasification efficiency (through lower CO2 recovery rate).

  ⇒ Affects energy use and costs of the respective pathways.
- **Dispensing pressure**: U.S.: 6250 psi (430 bar) dispensing pressure; EU 12800 psi (880 bar)

  ⇒ Slightly higher compression energy effort in the EU cases

Conclusions

- A project is underway that is comparing analysis approaches and models between the EU & U.S.
- A common understanding and language has been developed
- Results will be useful for hydrogen energy roadmaps in third countries and strategic planning in industry
  - Finding the right approaches for their specific purposes
  - Improving awareness of regional socio-economic and geographic differences
- Need for further development and alignment of models and approaches have been detected
  - Interaction between different world regions to further specify the evolution of infrastructures, energy prices, and technology costs.

Acknowledgement

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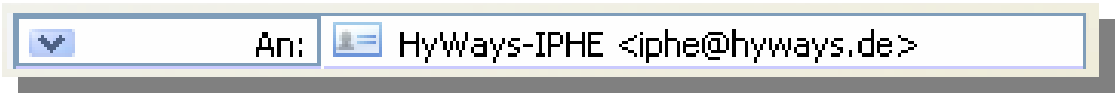
Visit our roadmap workshop!

- More details on HyWays-IPHE findings
- Presentation of the Australian and NZ roadmaps
- Facilitated discussion on Drivers, Objectives, Approaches for roadmaps, Appropriate Models

Tuesday 14:10 Plaza P1

Thanks for your attention.

For further questions: Write to



Or visit

HyWays-IPHE Website at www.hyways-iphe.org