Benchmarking of European and U.S. Hydrogen Roadmapping Efforts (HyWays-IPHE): Socio-Economic Modelling and Stakeholder Involvement

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on behalf of the HyWays-IPHE consortium

World Hydrogen Energy Conference, June 16, 2008

HyWays-IPHE Project Objectives

HyWays - IPHE
Benchmarking of Hydrogen Energy Roadmaps

- 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)
- Comparison Activities
  - Pathways that are relevant in both regions
  - Basic technical and economic assumptions
  - Hydrogen pathway analysis results

  Presented earlier
  - Modeling approaches (economic impacts, technology learning, infrastructure and transition analysis, model interaction)
  - Stakeholder involvement in the roadmapping process
- Communication and Community-Building Activities
  - Involved institutional and personal exchanges to improve understanding
  - Involved continuous consultation of industry monitoring group

What is a Roadmap?

The HyWays-IPHE consortium's understanding of a hydrogen energy roadmap is:

A **joint endeavor** of industry, government, academia and the public, providing a structured process for a coordinated, long-term public and private effort in preparing, introducing and implementing hydrogen in the energy and transport system.

An **instrument for identifying the key technologies**, **products and markets, and foreseeable obstacles** to their development, introduction, and use, and the possible measures to overcome them.

An **assessment of expected impacts** on the market, society, and environment.

A **navigation tool** for strategic planning and implementation of research development, structural change and infrastructural investment.

An opportunity for communication between all involved stakeholders of different backgrounds, viewpoints, and interests in developing hydrogen (from its production, delivery, storage, dispensing to its application in final end-use).

Based on a combination of visions, pathway scenarios and systems modeling, it typically provides **a technical, economic and strategic analysis that may lead to a master plan** with a derived list of actions.

Roadmapping Activities That We Compared

- Program structure and stakeholder involvement
- Vehicle modeling
- Energy system models
- Economic impacts
- Resulting documents

Program Structure

Nations and government entities choose different emphases of top-down and bottom-up program designs, some combination of approaches proves to be helpful

United States

Primarily government driven

DOE responsible for setting technological targets and supporting research

Industry groups, states & cities, HTAC, and NRC provide input

Project input from stakeholders including an annual project review meeting

Obvious connection between program goals and projects

Large national plan that has not been broken into regional plans

Europe

Primarily industrial stakeholder driven

A Joint Technology Initiative (JTI) calls for proposals and selects projects. It involves partners' cost-share (primary funding source), EC funding, and member states funding.

Initiative and supporting role of the European Hydrogen and Fuel Cell Technology Platform (HFP)

JTI will further define connections between goals and projects

Key role of Member-States and Regions with their own plans and selections

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Vehicle Cost & Performance Projection Comparison

- Different continents require different vehicle assumptions
  - HyWays – VW-Golf class
  - US – Mid-size passenger car
- Different portfolio and configurations of hydrogen fuel cell powered vehicles require to devise a common assessment framework (component level approach)
  - Hybrid hydrogen FC vehicle the only common vehicle assessed in both sides
  - Non hybrid FC in the EU, while PHEV 10-40 investigated in the US
- Different learning methodologies emphasize the need for a harmonized methodology for accurate comparison:
  - EU: learning by doing, exponential curve
  - US: learning by searching, economies of scale, learning by doing, asymptotic curve
- Cost is highly dependent upon market size
  - Learning function dependent upon technology, market size, market history (growth rate)
  - Estimating global markets is better than national market because learning is made by multi-national OEMs.

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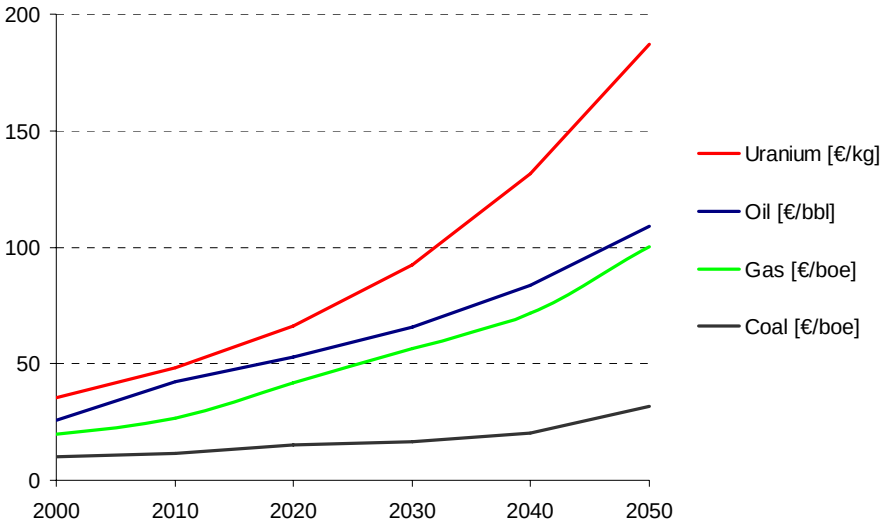
Comparison of energy prices

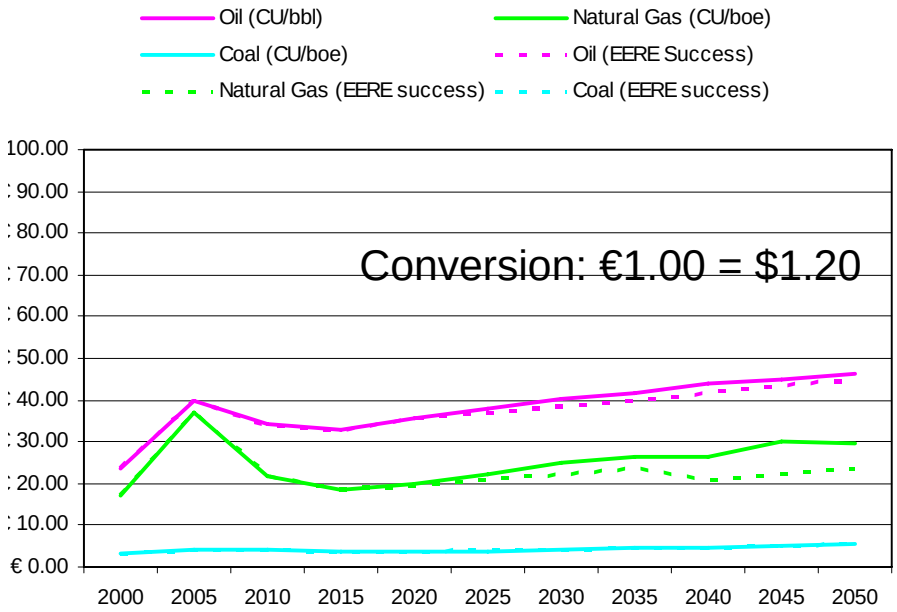
Prices of Energy Supplies

HyWays



Exogenous source

US Markal



Endogenous Calculation

⇒ Consistent energy supply costs are important for project selection. Changing them too often will cause too much disruption of projects that should be selected.

⇒ External drivers (i.e., world markets) are important but difficult to consider in a regional model.

Comparison of hydrogen production-technology mixes

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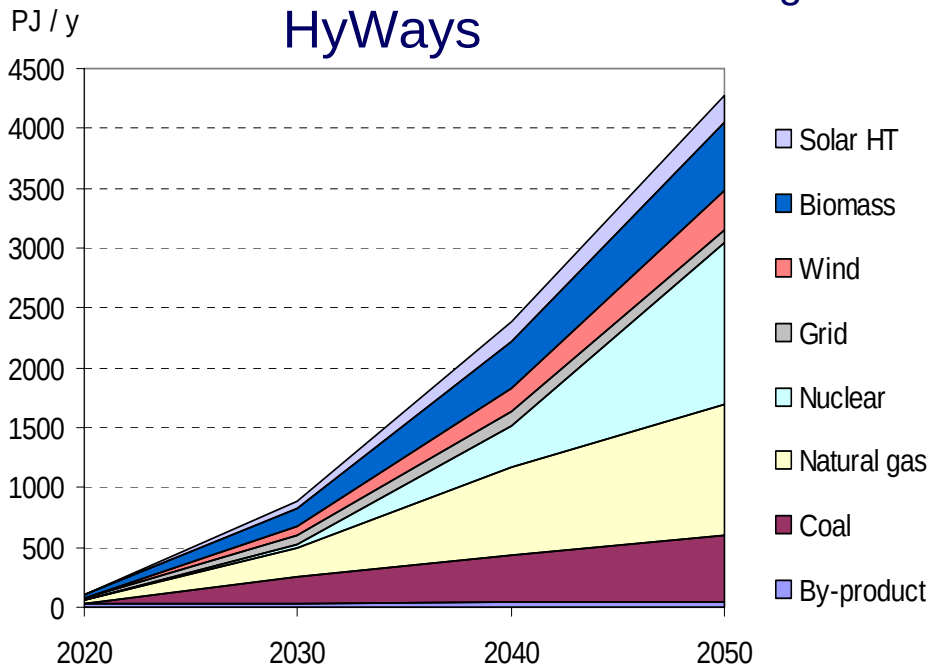
Hydrogen Production Mixture
Assuming Technology Success

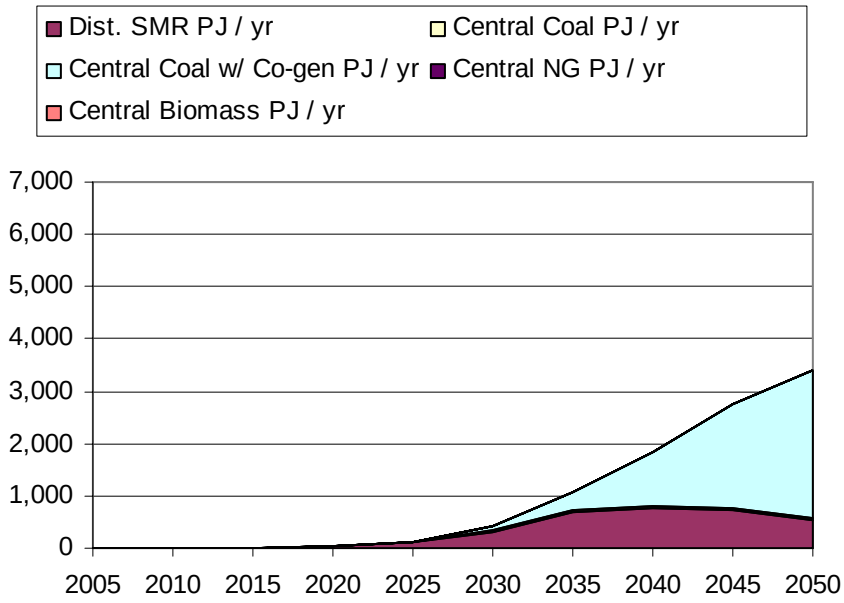
HyWays



Vehicle penetration set exogenously

Mix constrained by workshop results

US Markal



Endogenous least-cost calculation using single- region model with nested logit function

⇒ Endogenous vehicle penetration identifies the impact of assumptions and conditions, but the results may neglect the views of the stakeholders.

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Macro-Economic Estimates – Employment Studies

- Both the EU & the US used an input output approach (EU to 2030; US to 2050)
- EU also used a CGE model to analyse GDP effects
- The US model is more detailed in its disaggregation of employment by sector and type
- The EU model is integrated in the harmonized HyWays framework
- Both sides calculate disaggregated results, the EU for the 10 HyWays countries, the US for 5 regions of interest
- Both sides looked at international competitiveness

HyWays Employment Study Results

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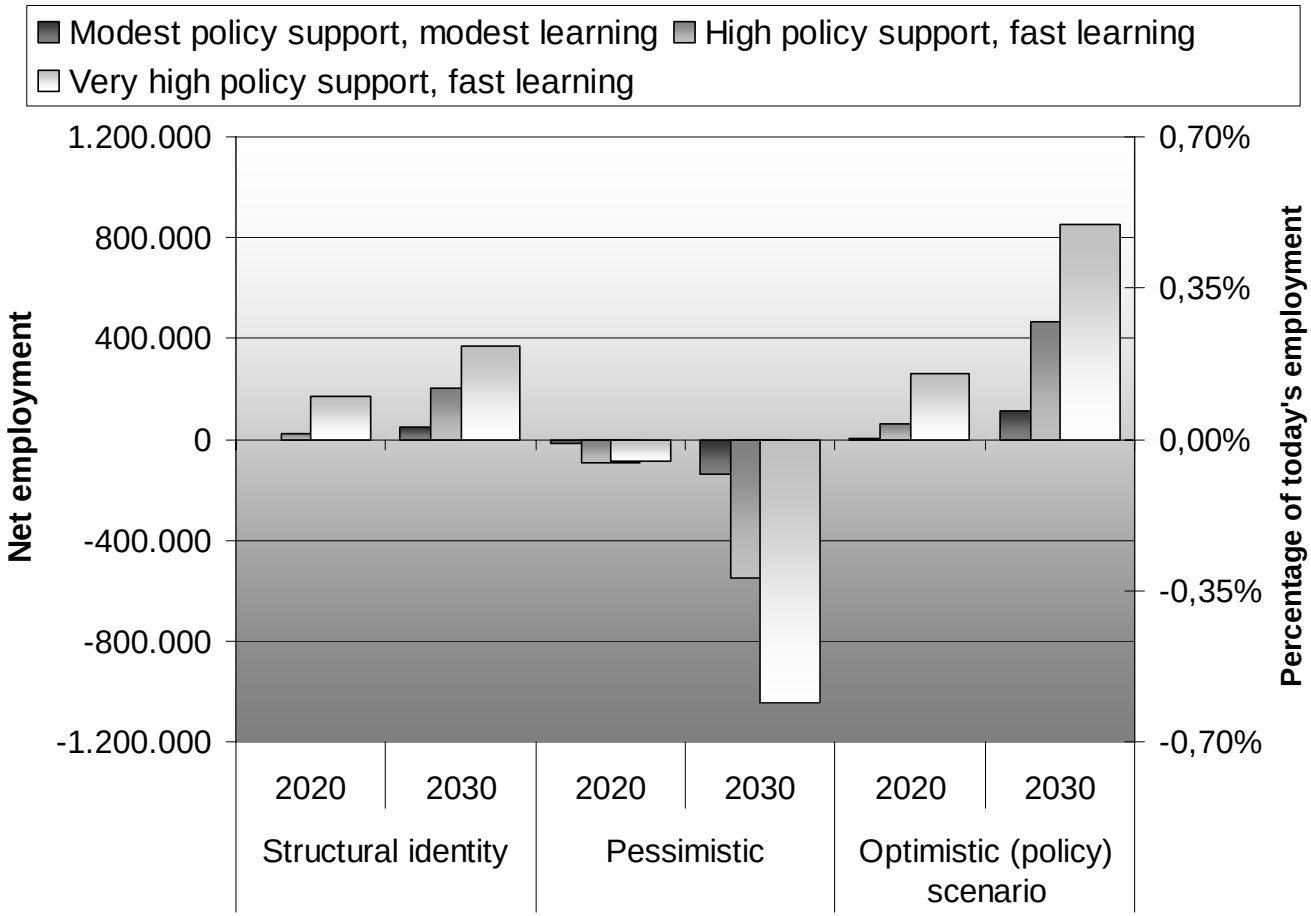

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Resulting Documents

- US
  - Roadmap identifies key issues and challenges and potential for penetration
  - Posture Plan identifies DOE roles, activities, targets – Execution Plan
  - Available at http://www.hydrogen.energy.gov/library.html
- HyWays
  - Roadmap
  - Action plan
  - 2-page summary, executive summary, background documents, etc.
  - Available at http://www.hyways.de/

Conclusions

- On both sides, all stakeholders were involved in the roadmapping process; however, the format was highly dependent upon the region's culture.
- The set of models was largely consistent although the assumptions and approaches varied.
  - Vehicle size and technology
  - Energy prices and how they were modeled
  - Role of government in constraining markets (energy mix)

- **Detailed report available online**

  http://www.hyways-iphe.org/WP3

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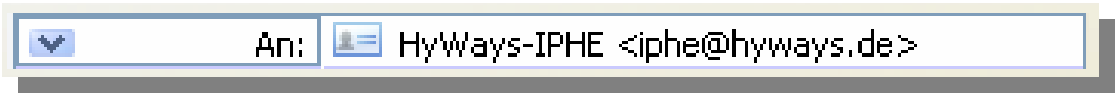
Visit our roadmap workshop!

- 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 Partners

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EU Institutes

Ludwig-Bölkow-Systemtechnik

ECN

Fraunhofer ISI Institute Systems and Innovation Research

ie Institute for Energy

EUROPEAN COMMISSION DIRECTORATE-GENERAL Joint Research Centre

INSTITUTO SUPERIOR TÉCNICO Universidade Técnica de Lisboa

U.S. Institutes

DOE Hydrogen Program

NREL

OAK RIDGE National Laboratory

Argonne NATIONAL LABORATORY

Industry monitoring group

acciona Biocombustibles

DAIMLER

GE Oil & Gas

TOTAL

Vehicle Cost & Performance Projection Comparison

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EU-Timelines		2015		2025	
Learning rate (High Policy Support)		Medium	High	Medium	High
Volume scenarios EU+US	Mio units	0,03	0,06	9	18
Comp. Hydrogen @ 70 Mpa	€/kWh	21	18	6	5
Electric motor + controller FCs	€/kW	71	64	34	27
Battery					
Li-ion Battery	€/kWh	683	618	327	262
FC system	€/kWnet	112	112	31	24

In both regions, costs are built up from drivetrain components, based on posited vehicle design and market introduction rates.

A component-by-component comparison of assumptions necessary, but challenging.

US-Timelines		2015			2030	
		Low	High	FC Goal	Low	High
Comp. Hydrogen	$/kWh	15	4	2	15	2
Electric Motor&Controller	$/kW	14	12	12	11	7
Battery						
HEV	$/kWh	1010	500	500	750	400
PHEV10	$/kWh	418	367	367	367	220
BEV	$/kWh	285	250	250	250	150
Fuel Cell	$/kW	67	45	45	52	30

Vehicle Cost & Performance Projection Comparison

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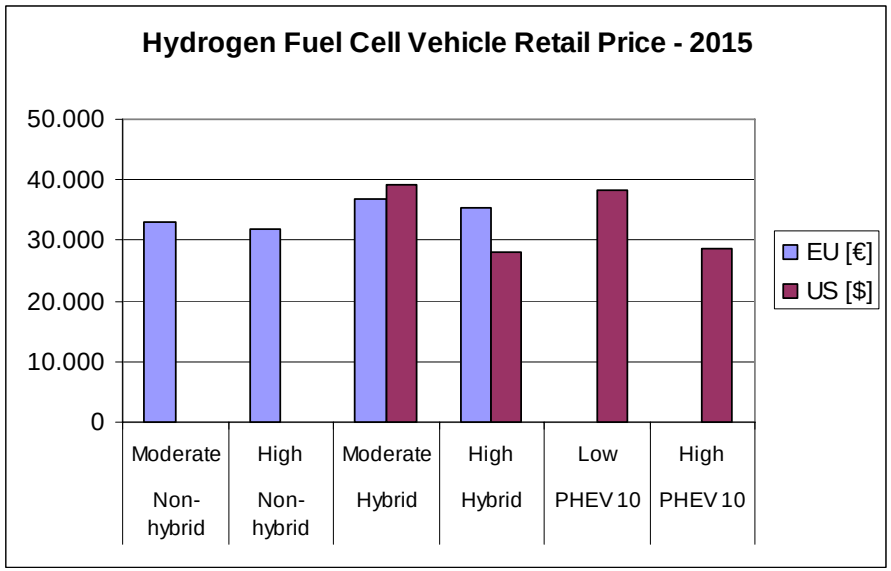

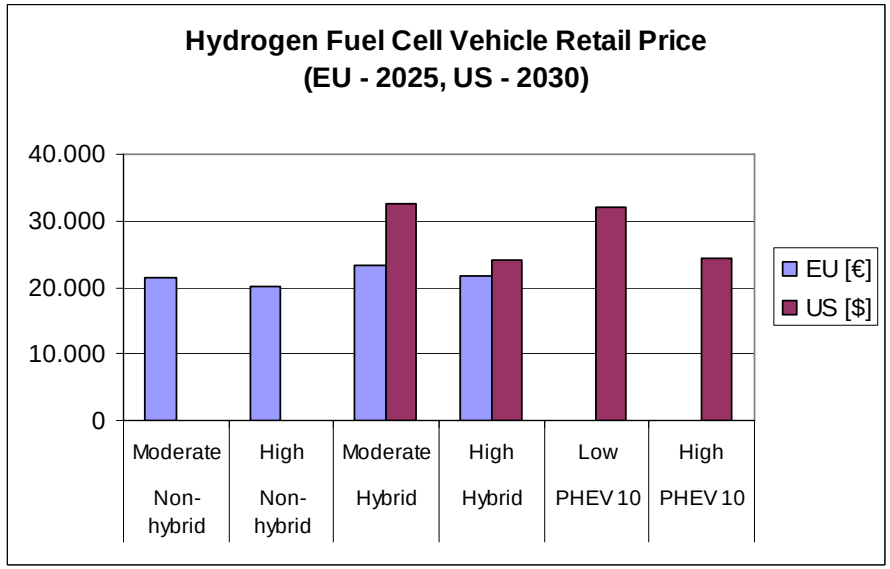

Costs declining for all H2-FCV vehicle types, somewhat faster under these cases for EU.

Vehicle Cost & Performance Projection Comparison

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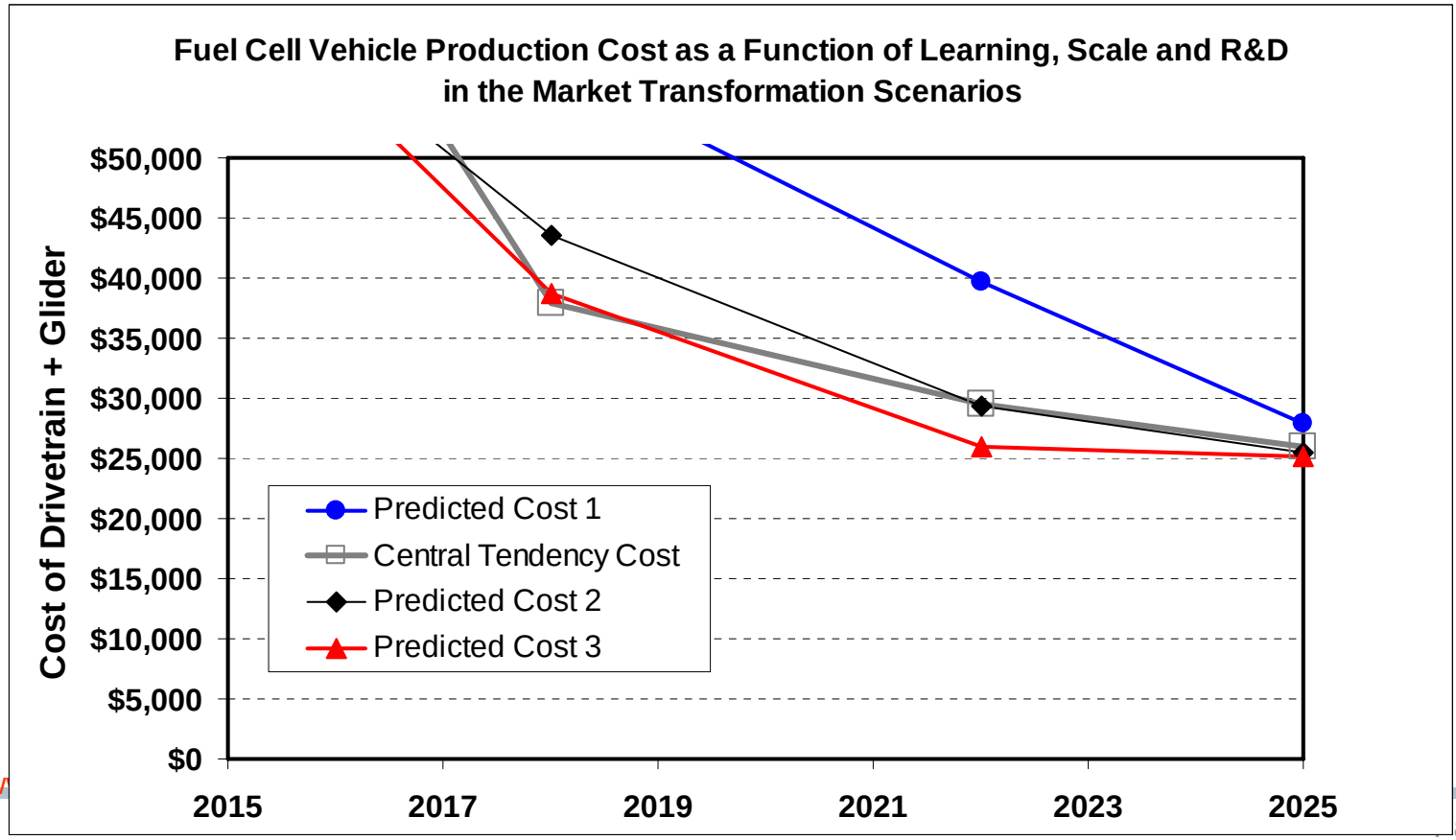
Cost Reductions Over Time Depend on Rate of Introduction in Scenario.

Effect of combined learning dimensions and sequencing for 3 U.S. deployment scenarios



Models involved in vehicle comparison

United States
PSAT

Powertrain Simulation Analysis Toolkit

Developed by Argonne National Lab

The Argonne PSAT modelers ran simulation analyses for all the advanced technologies to size components and estimate performance and fuel consumption.

Europe
ADVISOR

Advanced Vehicle Simulator

Developed by National Renewable Energy Lab

It is noted that no direct modeling has been made in this project, but vehicle performances derive from CONCAWE, EUCAR, JRC, *Well-to-wheels analysis* March 2007.