

Benchmarking of European and U.S.

Hydrogen Roadmapping Efforts:

HyWays-IPHE Liaison

Rei Fernandes & Zdena Zsigraiová
IDMEC/IST Portugal

on behalf of the HyWays-IPHE consortium

IPHE Members



- HYDROGEN represents a promising way to a more sustainable energy system. However, R&D is still needed to cut costs, improve performance and evaluate advantages and obstacles to the introduction of hydrogen into transport and power generation markets.
- Many regions of the world have developed, or are making efforts to prepare a hydrogen roadmap.

IPHE Roadmapping Activities

Questionnaire

- Results are findings of a questionnaire
 - Roadmap Overview
 - Models Used
 - Results
- More qualitative than quantitative
- Broad overview to indicate state of affairs
- Answers provided by an individual

*HyWays-IPHE
Questionnaire
Comparison of modelling efforts*


Benchmarking of Hydrogen Energy Roadmaps

Introduction

The HyWays IPHE project aims to assess and compare the development efforts for the European Hydrogen Energy Roadmap prepared by HyWays with international roadmapping or comparative activities of IPHE partner countries. In the first step, an in-depth assessment and comparison of the individual elements of the national/ regional strategies, modelling approaches and experiences in the EU and the U.S. was conducted. In the second step, the project aims at broadening its scope within IPHE by including and involving other IPHE partner countries. This questionnaire aims to enable this second step.

List of questions

| | |
|---------------------------------------|---------------|
| <i>Section 1. General information</i> | <i>Page 2</i> |
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| <i>Section 3. Models</i> | <i>Page 6</i> |
| <i>Section 4. Results</i> | <i>Page 7</i> |

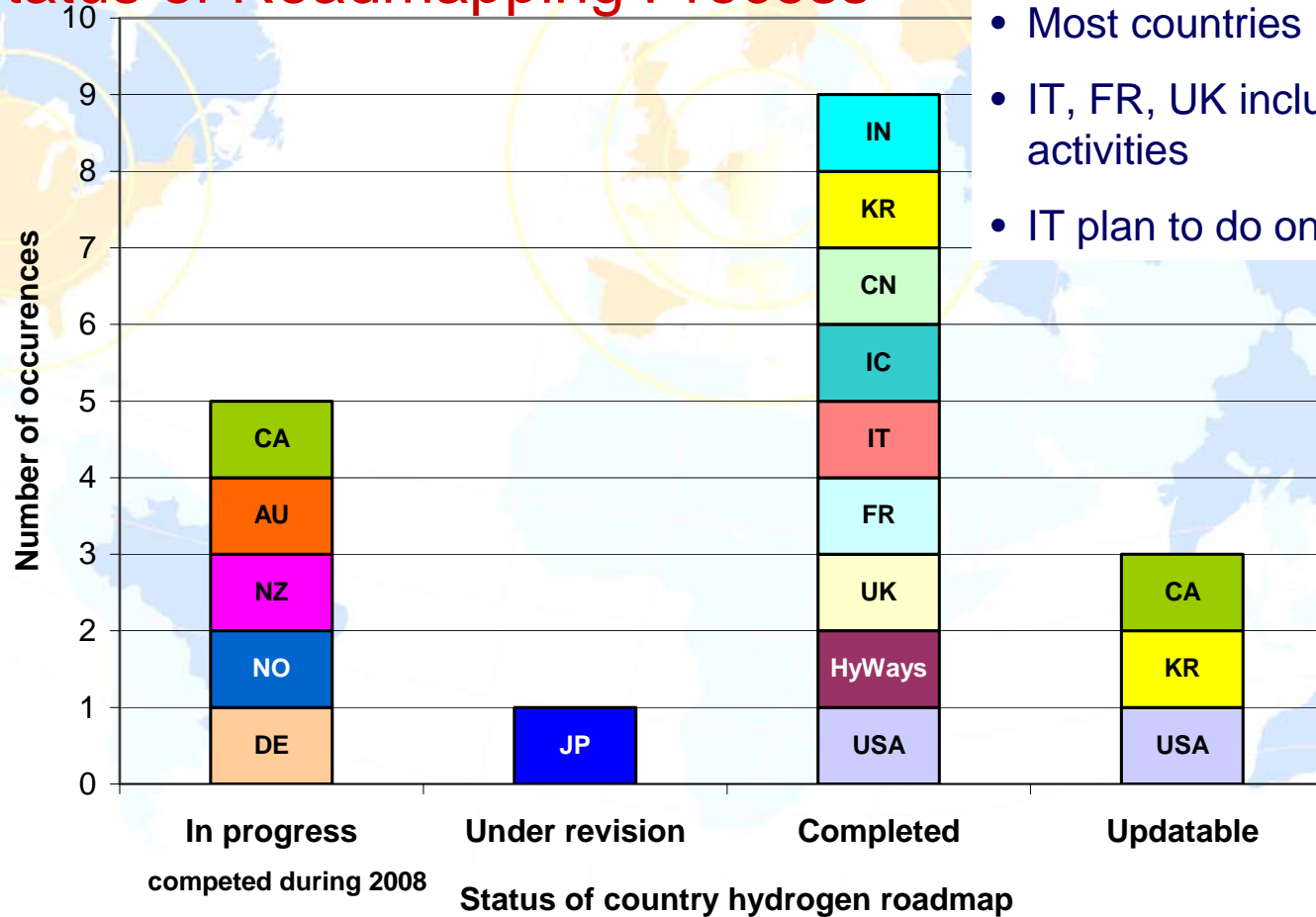
Note: the meaning of words or phrases in blue are clarified when the cursor is placed over these words.

*Please respond by typing into the white spaces.
For a new line press "ALT+ENTER"
To jump forward / backward press "TAB" / "SHIFT+TAB"*

Contact:
Rui Fernandes
Instituto Superior Técnico (DEM/ISTE) **e-mail** diszem@hyways-iphe.org
Pav. Mecânica 1, 2º **Tel** +351 21 841 8082
Av. Rovisco Pais **Fax** +351 21 847 5545
1049-001 LISBON, Portugal

Roadmap Overview

Status of Roadmapping Process



- Most countries have roadmap
- IT, FR, UK included in other activities
- IT plan to do one

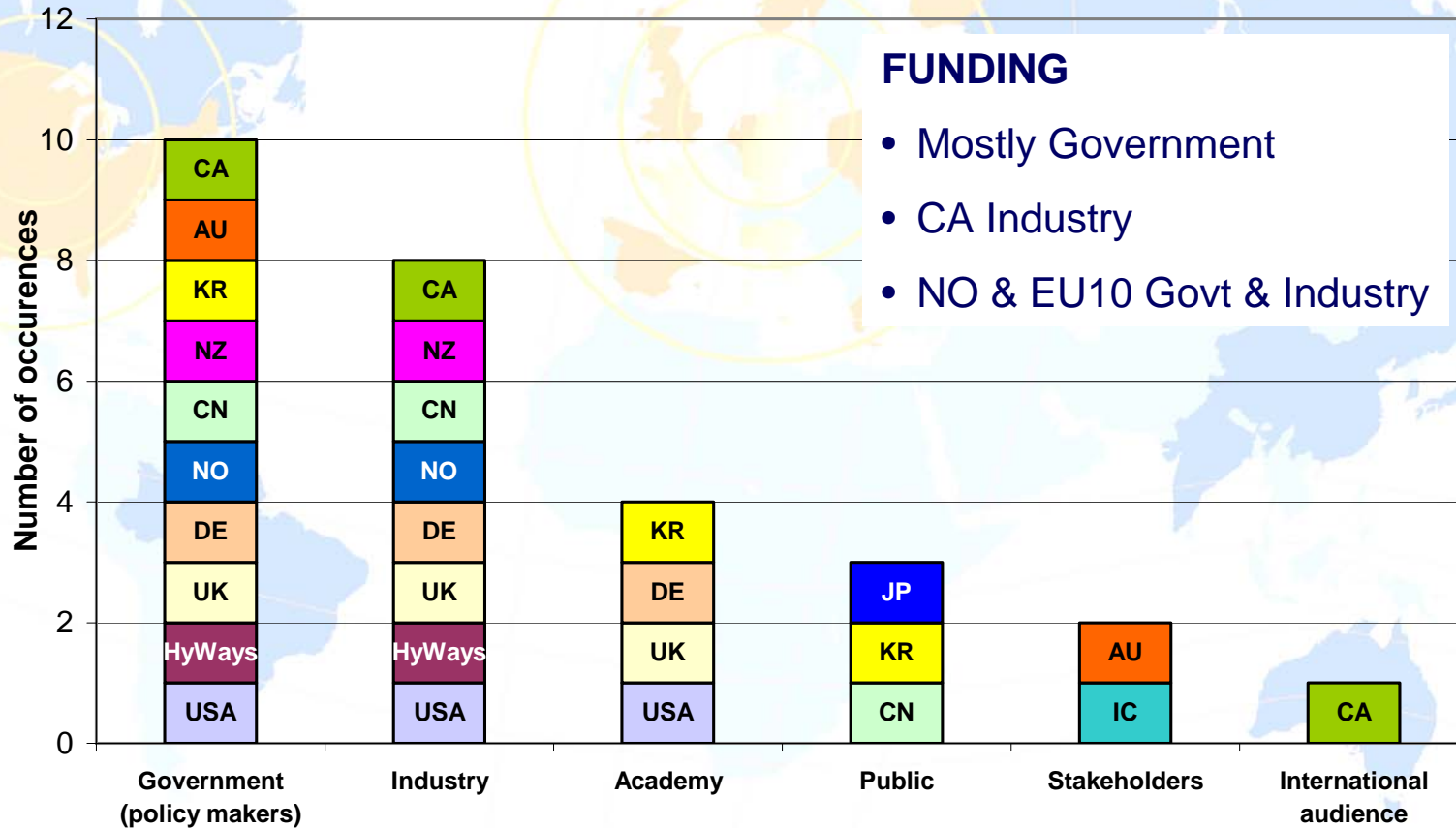
Roadmap Overview

Roadmap Objectives

- Common features
 - Introduction of H₂ to energy systems
 - Identification of viable H₂ energy pathways
 - Cost-competitive / Low cost technologies
- Country specific
 - Best utilisation of country resources
 - Identification of suitable regions in country
 - Niche markets
 - Identification of barriers, gaps and actions to be taken
 - Decision support tool
 - Suitable models development
 - Recognise that policies required and technical issues to be solved
 - Links between near-term commercial applications and long-term mass markets

Roadmap Overview

Target Groups

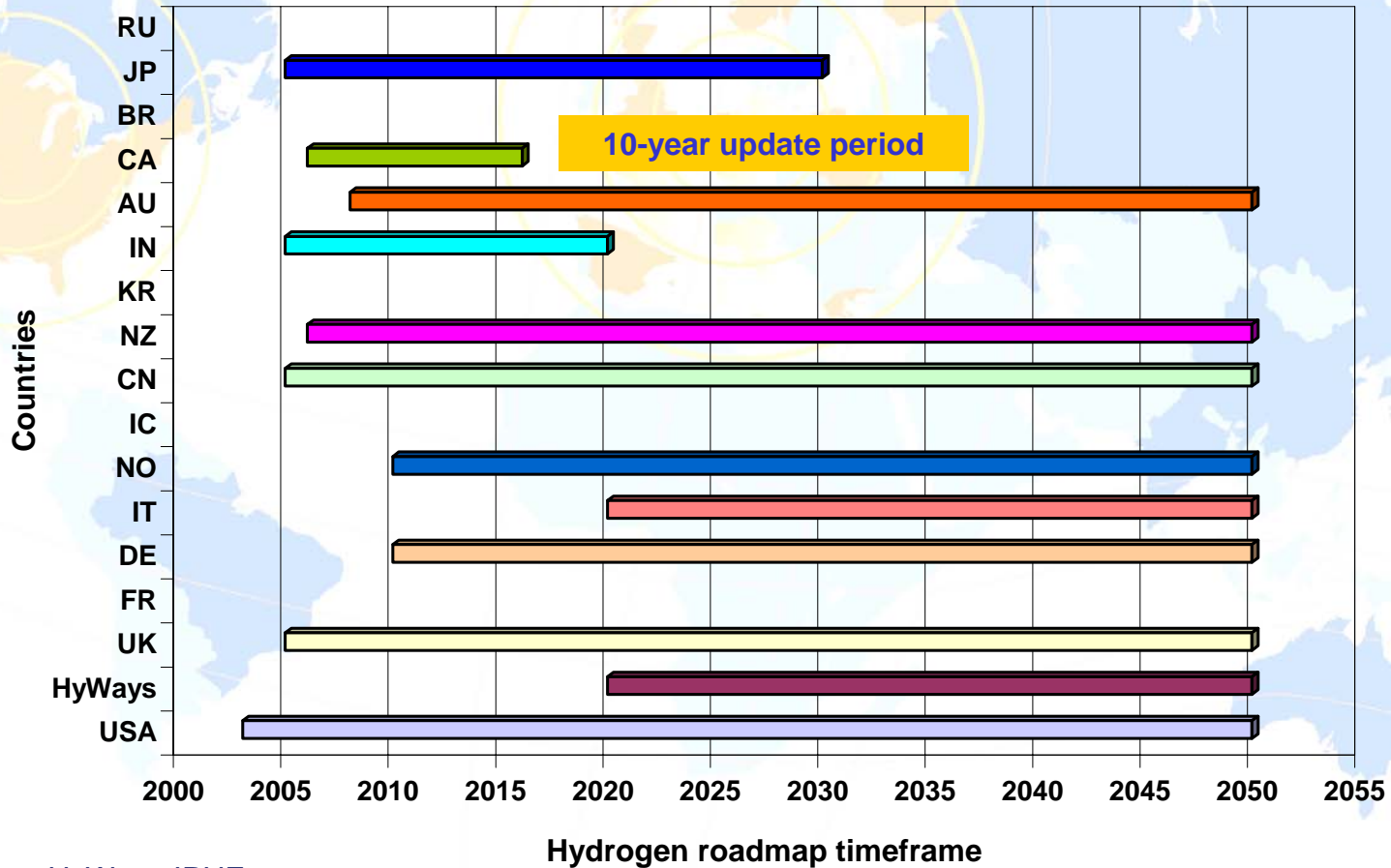


FUNDING

- Mostly Government
- CA Industry
- NO & EU10 Govt & Industry

Roadmap Overview

Roadmap Timeframe



Roadmap Overview

Roadmap Drivers

- GHGs abatement
- Energy security
- Other
 - Sustainable use of Fossil Fuels
 - Use of environmentally friendly energy
 - Energy efficiency
 - Distributed energy resources
 - H₂ technology status in country
 - Energy policy
 - Economic benefits
 - New industry
 - Competitiveness

Roadmap Overview

Stakeholders Involvement recognised as important Wide spectrum of stakeholders

- Government
- Industry
- Academic & Research
- Public

Interventions

- Workshops/Meetings/Discussions
- Interviews/Feedback
- Technical data/Visions/Opinions
- Reviews/Comments on Results

Roadmap Overview

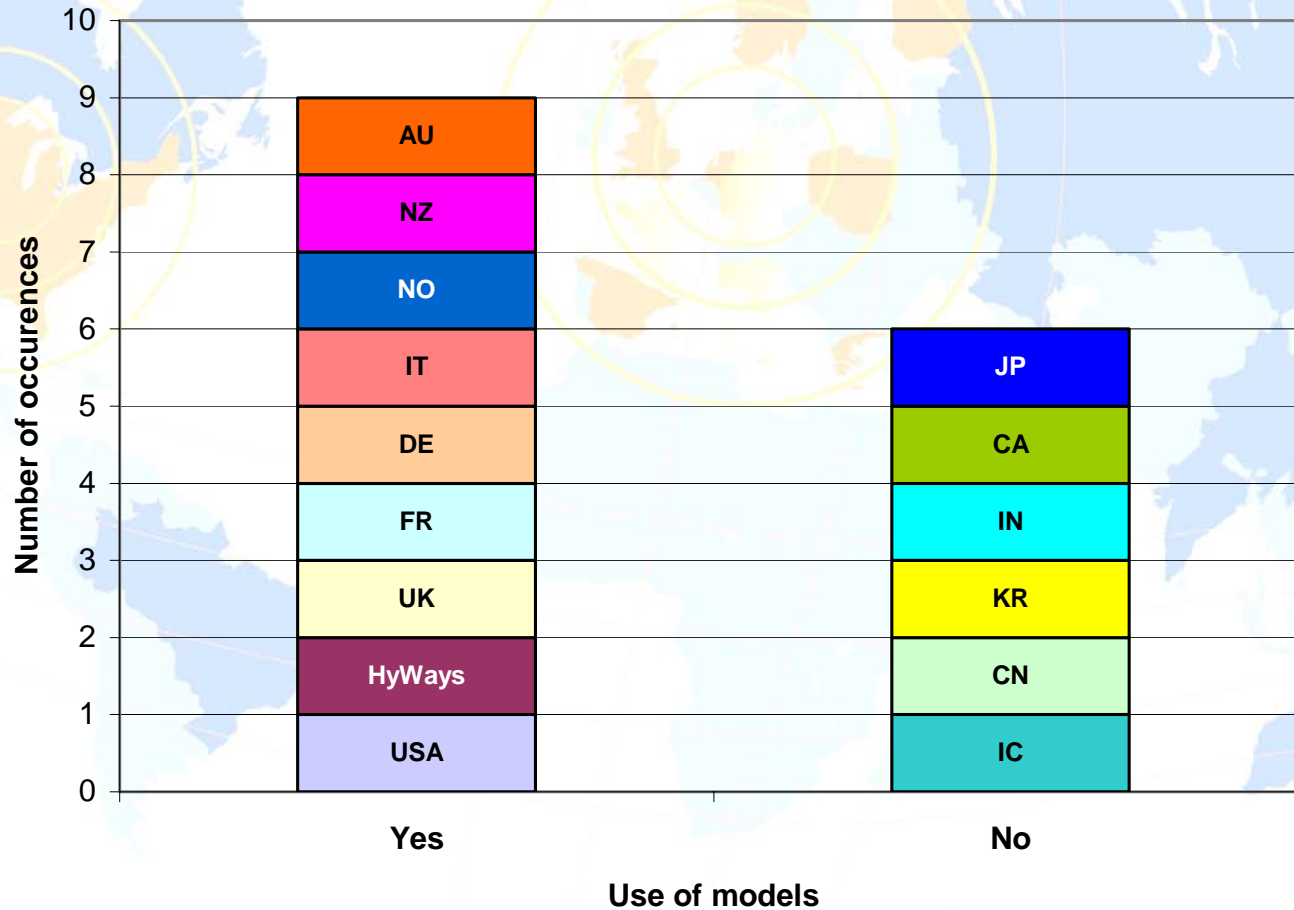
- **Challenges**
 - **Organisational**
 - Very tight timeframe for roadmap completion
 - Coordination of inputs & organisation of activities
 - **Technical**
 - Lack of, or conflicting data
 - Difficulties in acquiring data from Industry
 - **Consensus**
 - Agreement by all stakeholders
 - Diverging interests
 - **Scope**
 - All aspects of H₂ economy
 - Technological barriers
 - Performance, Lifetime & Cost of Technologies

Issues unresolved:

- Exist but to be defined at end of process
- Lack of data from Industry
- Specific cases of Isolated Communities (UK)
- Limited opportunity to discuss barriers (HyWays)

Modelling

Use of models



Modelling

Models & Tools used by country I

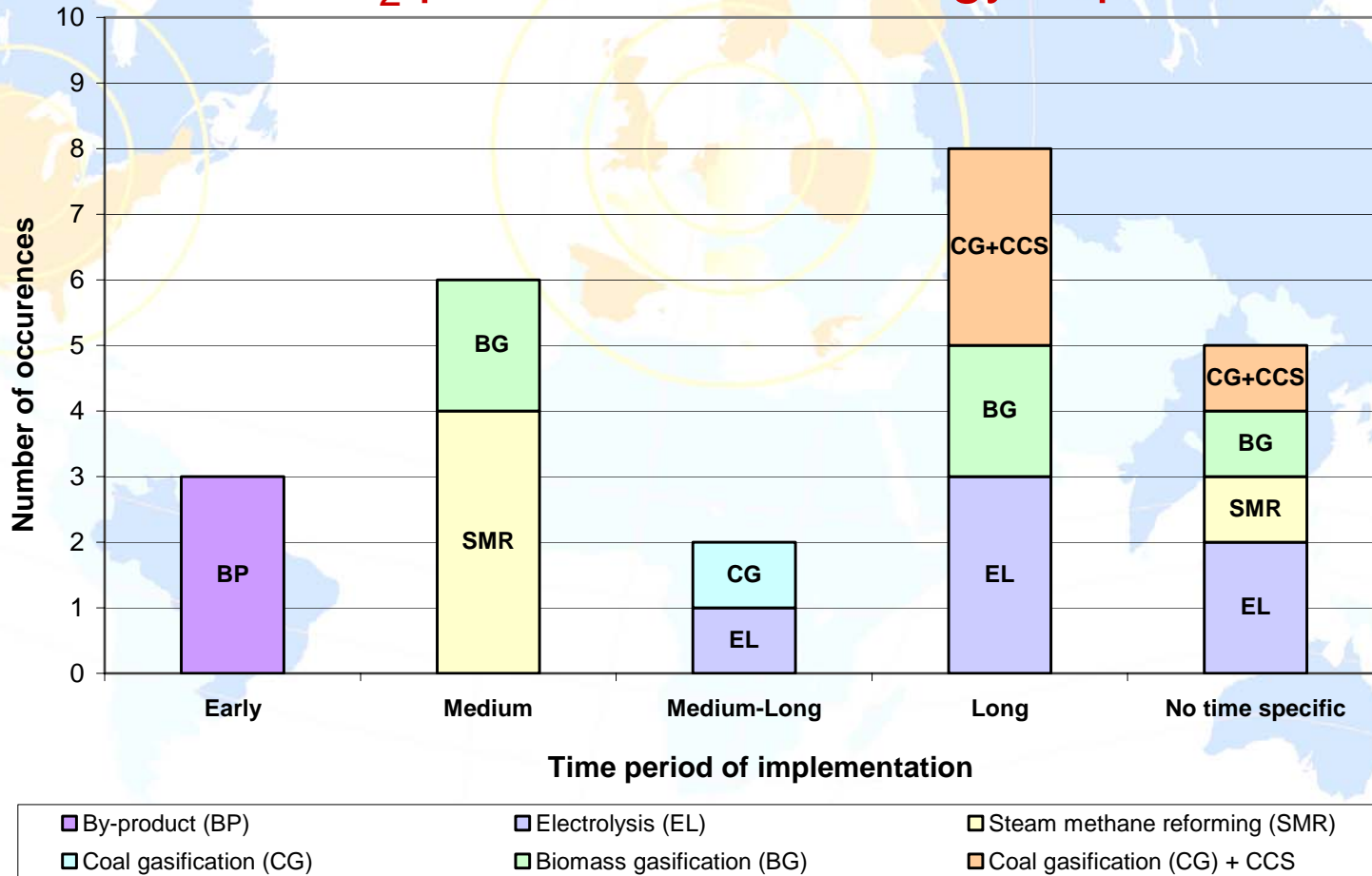
| MODELS & TOOLS | COVERAGE | USA | UK | FR | DE | IT | NO | IC | CN | NZ | KR | IN | AU | CA | BR | JP | RU | |
|----------------|-----------------------------------------------------------------------------------------|--------|------|------|------|------|------|-----------------------|-----------------------|------|-----------------------|-----------------------|----|-----------------------|----|-----------------------|----|--|
| | | HyWays | | | | | | | | | | | | | | | | |
| H2A | H2 Cost analysis | Used | | | | | | Without use of models | Without use of models | | Without use of models | Without use of models | | Without use of models | | Without use of models | | |
| GREET | GHGs and petroleum use | Used | | | | | | Without use of models | Without use of models | | Without use of models | Without use of models | | Without use of models | | Without use of models | | |
| HyTrans | Consumer choice & vehicle penetration impacts on H2 use, vehicle & infrastructure costs | Used | | | | | | Without use of models | Without use of models | | Without use of models | Without use of models | | Without use of models | | Without use of models | | |
| E3database | pathway costs; energy requirements; GHGs | | Used | | Used | | | Without use of models | Without use of models | Used | Without use of models | Without use of models | | Without use of models | | Without use of models | | |
| MARKAL | Energy system modelling: Bottom-up optimisation | Used | Used | | | Used | Used | Without use of models | Without use of models | | Without use of models | Without use of models | | Without use of models | | Without use of models | | |
| MoreHys | Energy system modelling: Regional bottom-up optimisation | | Used | | | | | Without use of models | Without use of models | | Without use of models | Without use of models | | Without use of models | | Without use of models | | |
| COPERT | non-CO2 emissions | | Used | | | | | Without use of models | Without use of models | | Without use of models | Without use of models | | Without use of models | | Without use of models | | |
| Pace-T | Production & consumption elasticities | | Used | | | | | Without use of models | Without use of models | | Without use of models | Without use of models | | Without use of models | | Without use of models | | |
| ISIS | Import/Export modelling | | Used | | | | | Without use of models | Without use of models | | Without use of models | Without use of models | | Without use of models | | Without use of models | | |
| CONCAWE | database | | | Used | | | | Without use of models | Without use of models | | Without use of models | Without use of models | | Without use of models | | Without use of models | | |

Modelling

Models & Tools used by country II

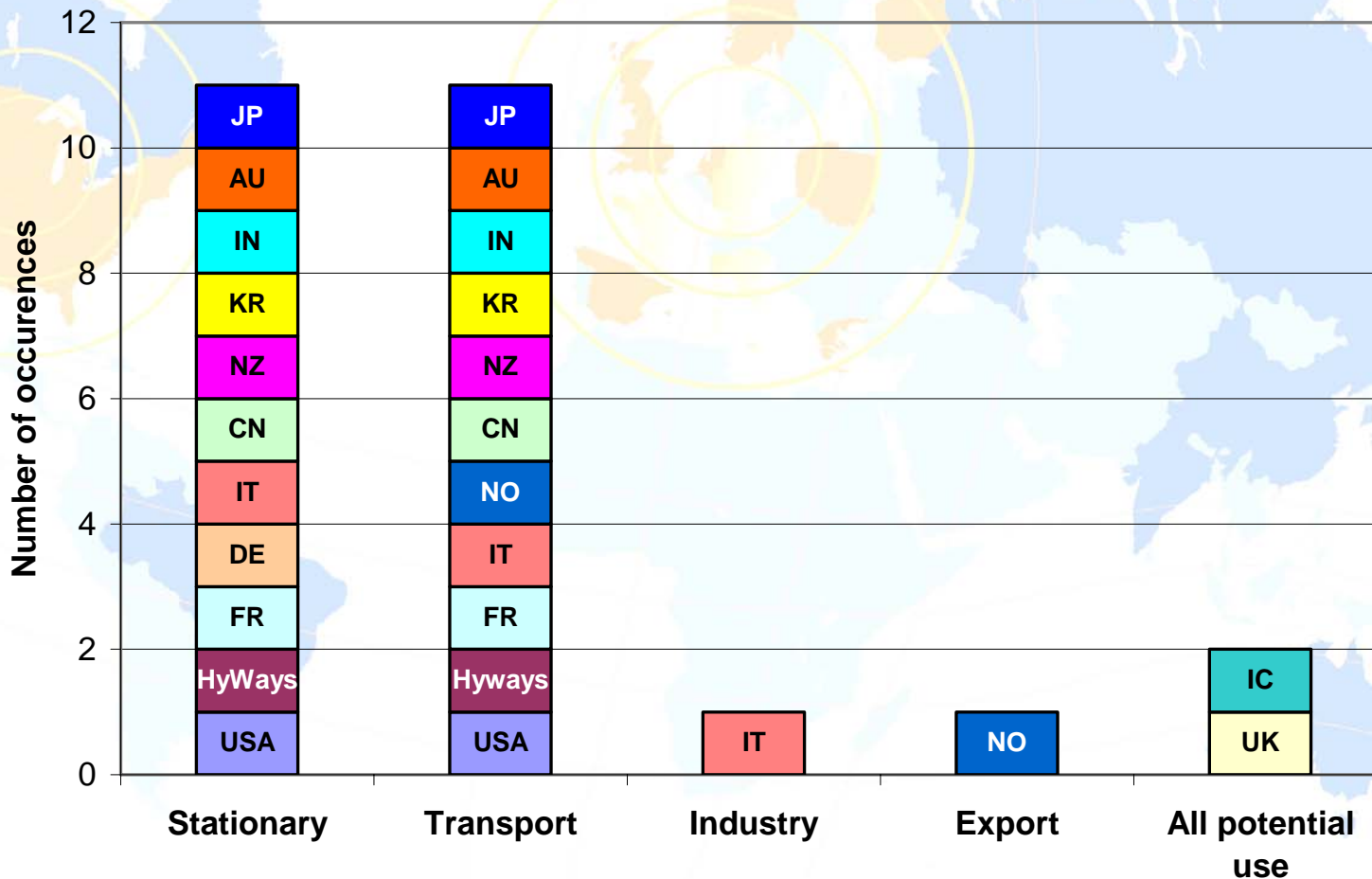
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|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------------------------------------------------------------------------------------------|----|------|----|------|----|---------|---------|---------|---------|---------|---------|---------|----|---------|----|
| | | POLES | Simulation and economic analysis of sectoral impacts of climate change mitigation strategies | | | | Used | | | | Without | Without | | Without | Without | | Without | |
| Unnamed model | Energy system model as the link and collecting vessel for all assumptions (H2 infrastructure analysis; energy demand and availability; conversion processes; cost and CO2 emissions) | | | | Used | | | | Without | Without | | Without | Without | | Without | | Without | |
| TIMES | MARKAL family optimisation model | | | | | | Used | | Without | Without | | Without | Without | | Without | | Without | |
| STELLA (SU) | System dynamics model | | | | | | | | Without | Without | Without | Without | Without | | Without | | Without | |
| Unnamed model | Long-run electricity generation costs | | | | | | | | Without | Without | | Without | Without | Used | Without | | Without | |
| Unnamed model | H2 production cost | | | | | | | | Without | Without | | Without | Without | Used | Without | | Without | |

Timeframe of H₂ production technology implementation



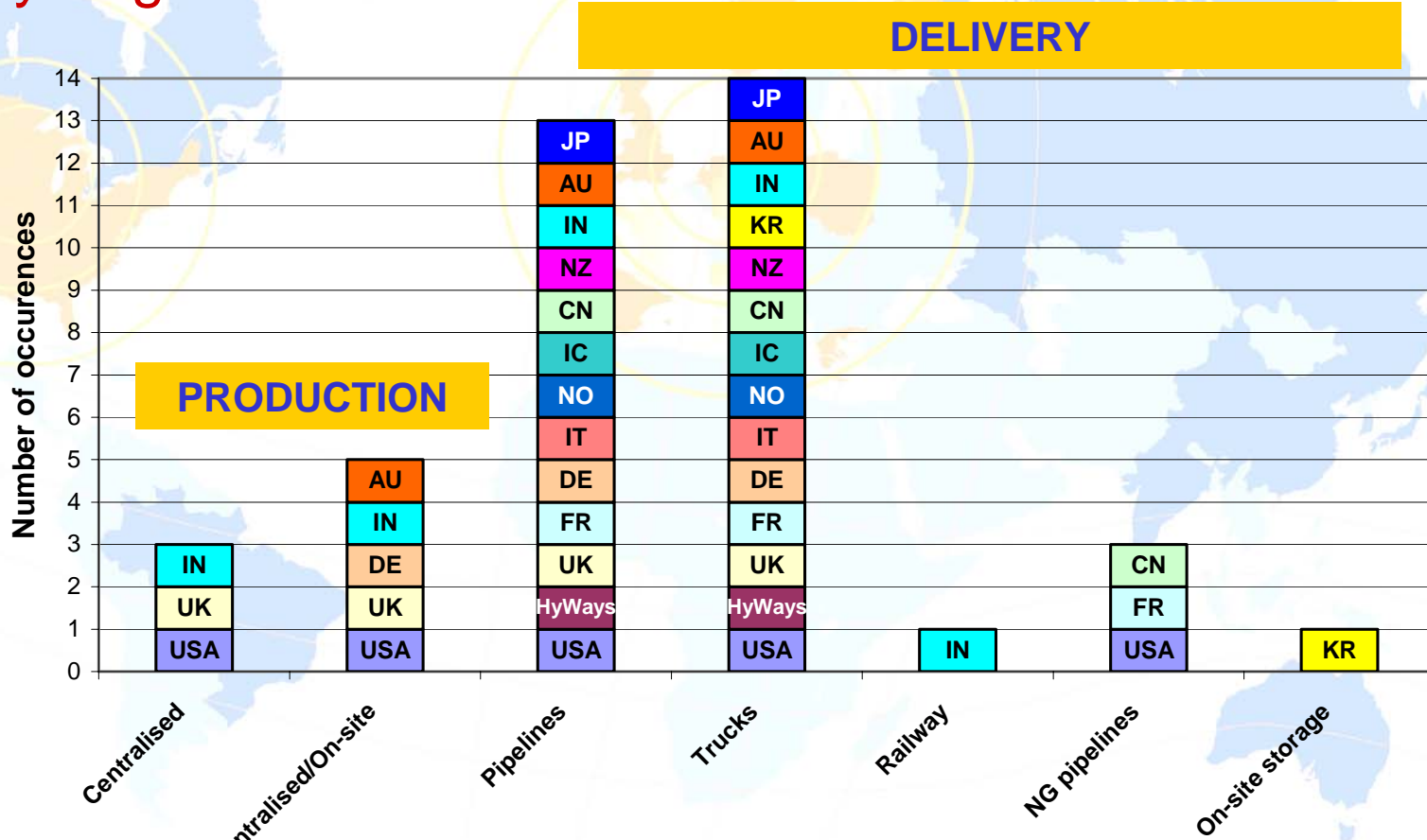
Results

Hydrogen use



Results

Hydrogen infrastructure



Infrastructure: production / distribution

Assessment of Economic & Environmental impacts

- Most countries assessed economic & environmental impacts associated H2 economy.
- Few countries made quantitative assessment
- Others considered impacts, noting a degree of uncertainty, or that the focus was on qualitative expression
- Indicators of economic impact were not specified, except for HyWays - cash flow and employment
- Environmental evaluation included GHG (+/- other air pollutants especially for transport)

CONCLUSIONS I

- Roadmaps important – all have something
 - Specific programme
 - Part of another programme
- Mostly Government sponsored
- Roadmap targets Government & Industry
- Objectives vary
 - Common features
 - Country specific
- Stakeholders Involvement recognised as important

CONCLUSIONS II

- Majority use models
 - Some Major players do not use models
- H₂ production technology:
 - Scenario dependent
 - Time frame of implementation
- End-use predominantly Transport & Stationary
- Impacts considered in roadmaps:
 - Mostly Environmental
 - Secondary Economic

Acknowledgement

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Thank you for your attention!

<http://www.hyways-iphe.org/>