US Hydrogen roadmap study

HTAC Meeting update

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December 2018

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Objectives today

- Alignment on **context**, **objectives** and **end products** of US Hydrogen Roadmap
- Alignment on **study approach** and **existing perspectives** on energy futures and hydrogen in the US as foundation for the roadmap
- Definition of **study setup**, **timeline** and **key milestones**
- Defining **next steps** including data request procedure, contract and logistics

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Contents

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Our understanding: The objective of the project is to develop a comprehensive hydrogen roadmap for the United States

Context

- **Hydrogen and fuel cell technologies** have **reached technical maturity** in many application areas, but are facing introduction barriers, e.g., lack of infrastructure, transparency on specific needs and available technical solutions
- **The US is a leading player** in hydrogen technology through its large RD&D program led by the FCTO at the DoE, the leading role of California as a market for hydrogen mobility and the strength of US industry in hydrogen and fuel cells
- The next frontier for hydrogen is to demonstrate the **potential of hydrogen** for the US consumer, energy system and industry as a basis for building a deployment roadmap

Objectives

1. **Set the ambition level:** Quantify the role played by the Hydrogen in the US energy system of 2050 in each sector and sub-sector
2. **Develop a roadmap:** Develop an adequate ramp-up including milestones for 2020, 2025 and 2030, taking into account inter-sectoral synergies
3. **Estimate the impact:** Quantify the environmental/climate, macro-economic and social benefits resulting from this roadmap

SOURCE: McKinsey

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We propose to structure our support around 3 work packages

Work package	Description
1 Ambition level for 2050	▪ Analyze US energy, economic and climate objectives at federal and state level, including a projection of the energy system in 2050 ▪ Analyze existing work on hydrogen and energy futures in the US, and select areas for roadmap to build upon ▪ Jointly develop the aspiration for the Hydrogen roadmap, incl. areas to focus on in particular ▪ Jointly define the ambition level for hydrogen deployment in the US context (existing plans, energy prices etc.)
2 Roadmap	▪ Describe the status of the US hydrogen industry today ▪ Develop ramp-up curves for each sector until 2050, taking into account industrial constraints, cost trajectories and global spillover effects ▪ Estimate milestones for 2025 and 2030 for each sector
3 Impact	▪ Estimate the impact of the hydrogen roadmap on the US consumer and economy: – Macro-economic benefits, e.g., growth, trade balance, energy independence – Social benefits, e.g. jobs, competencies – Environmental benefits, e.g. pollution emissions decrease

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We base our approach for the US on lessons learned in other national roadmap

Lessons learned in the European, French and Korean hydrogen roadmaps

Differences in drivers and approaches	▪ **Drivers of hydrogen adoption and approaches to scaling up** the hydrogen economy differ strongly by country and have major implications on results – E.g., hydrogen imports and power generation in Korea due to constraints on renewables – E.g., fuel cell buses and vans in Europe due to pollution limits and driving bans in cities
Differences in industry developments	▪ The **development of national industry across the value chain** differs strongly by country, impacting national capabilities and priorities – E.g., current focus on BEVs by French OEMs – E.g., existing national roadmap in Korea
Industry coalition	▪ Members of the **industry coalition** differ strongly in their pre-existing knowledge and in their focus areas – E.g., companies investing in SMR vs. electrolysis
External stakeholders	▪ Alignment and persuasion of **external stakeholders** are most successful when involved early in the process – E.g., city/state governments – E.g., SMEs

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Success factors for the US

Lessons learned in the European, French and Korean hydrogen roadmaps

Differences in drivers and approaches	▪ Jointly decide on **focus areas** and **aspired impact** for the roadmap ▪ Focus on **stringent arguments for hydrogen**, rather than a quantitative modelling of all segments in detail ▪ Consider **US specifics** from day 0 (e.g., lower importance of CO_2 abatment)
Differences in industry developments	▪ Invest time upfront to **jointly build "foundation" for the study** before launching detailed analysis work; review existing US studies ▪ Consider **US-specifics** in approach
Industry coalition	▪ Create **common understanding** of H_2 (supply, applications, technology…) ▪ Align objectives, scope and approach in **joint aspiration workshop in January**
External stakeholders	▪ Identify and involve **outside stakeholders** in the process (e.g., invitations to government representatives, survey among SMEs)

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We propose a 15-page visualization of the roadmap and a 40-page report outlining the key results of the study as end products

Roadmap presentation

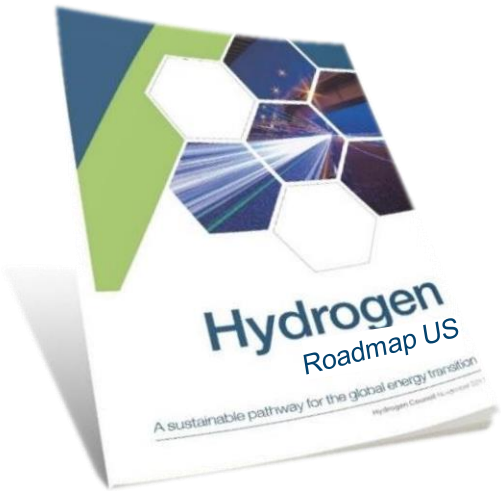
~15 slides visualization of the most important results of the roadmap:

- 2050 ambition
- Roadmap
- Impact

Targeted to be used for communication to key decision makers and to the public

In format similar to Hydrogen Council Roadmap

Roadmap memo



~40 pages written report

Includes key results of study and selected visualizations

Targeted to be used for communication to policymakers and public

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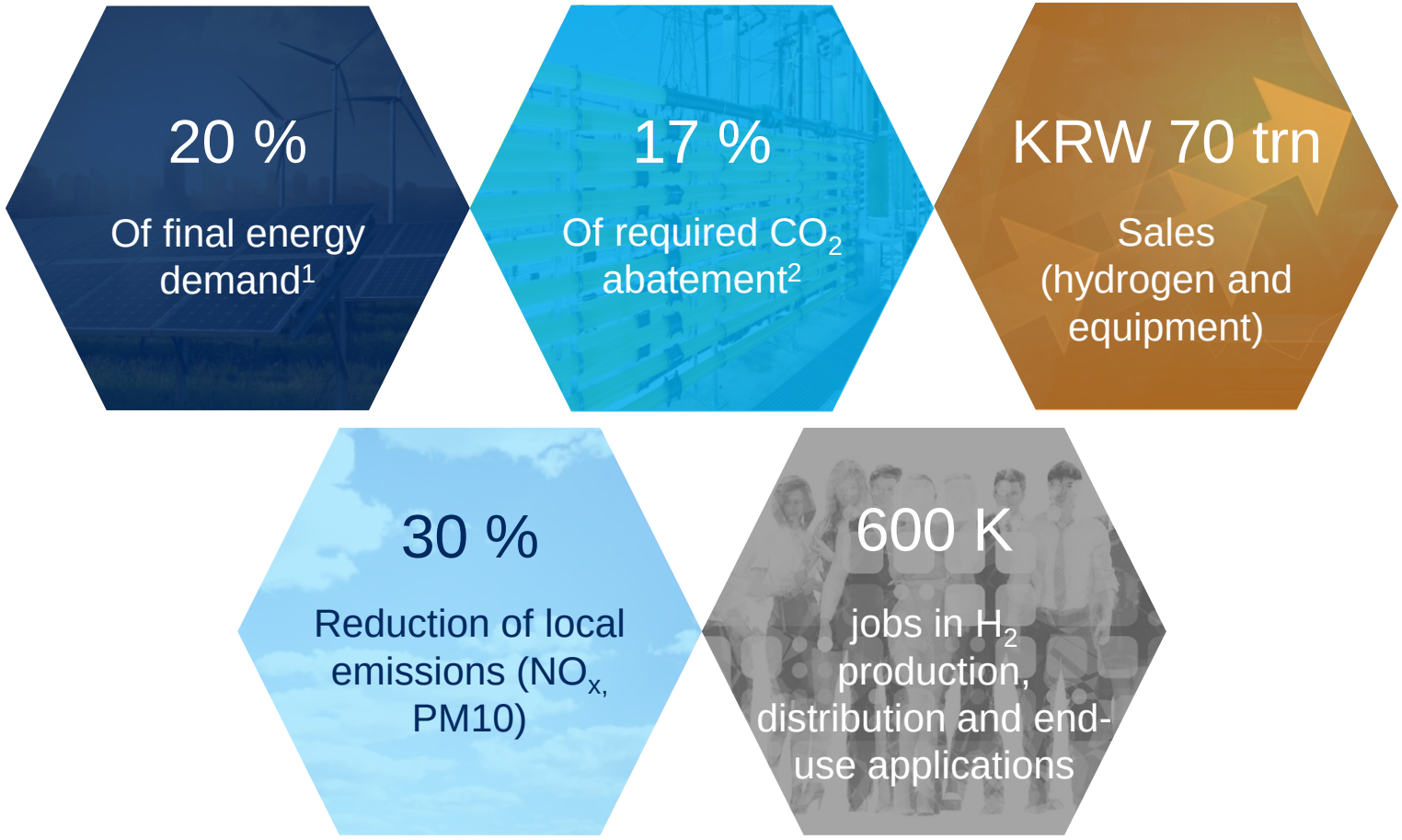
Example output: Macro-economic impact and social benefits of the hydrogen vision for Korea

2050 hydrogen vision, in approximate annual figures



1 Excluding feedstock hydrogen use 2 Compared to the business-as-usual scenario

SOURCE: Hydrogen Coalition Members' Study; Hydrogen Korea Study team

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Example output: Milestones in hydrogen scale-up in the hydrogen roadmap for Europe

2030 and 2040 hydrogen milestones, in approximate annual figures

	2030	2040	
One in...	12	5	…**light commercial vehicles sold** are **FCEVs**…
...and **one in**...	22	7	…**passenger vehicles sold** are **FCEVs**.
There are...	45 '000	450 '000	…**trucks and buses on the road**...
...and…	570	2,000	...**of diesel trains** replaced with hydrogen.
There are…	7 %	32 %	…**of natural gas** (by volume) **replaced by hydrogen**
...equivalent to...	30 TWh	120 TWh	
...meaning...	2 m	11 m	…**households** are heated.
The deployment of...	250 '000	2,560 '000	…**fuel cell CHPs** increases energy efficiency.
There is...	33 %	63 %	**…carbon-free hydrogen production** in all applications.

SOURCE: Hydrogen Coalition Members' Study; Hydrogen Europe Study team

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Contents

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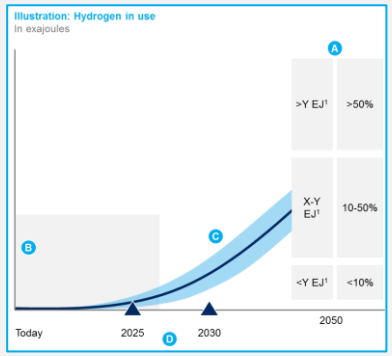
Overview of approach to building the Hydrogen Roadmap US

Inputs per scenario

- **External/published data**
  - **Energy system baseline and forecasts** (energy demand, production mix, power prices)
  - US Hydrogen **industry landscape**
  - Environmental performance data and economic multipliers
- **Hydrogen Council data,** validated by coalition members
  - **Hydrogen adoption rates**
  - **Cost data** (capex and opex)

Roadmap modelling



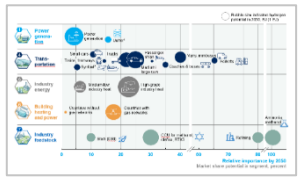
A Quantify the **vision for 2050**

B Define **starting point**

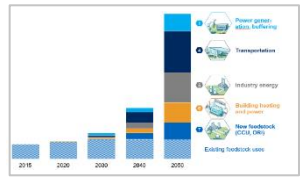
C Build **roadmap**

D Estimate **milestones**

Outputs/key analysis per scenario



Potential of hydrogen per application



Annual hydrogen demand

2030 and 2050 milestones of US hydrogen roadmap

Impact of hydrogen roadmap for the US

For discussion: What are the best existing studies and perspective on energy futures which we should use as foundation?

SOURCE: McKinsey

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Contents

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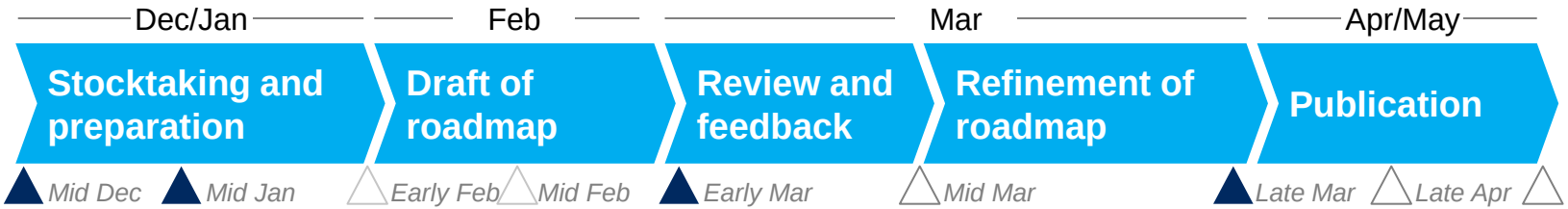
△ Call/Mail

We propose an approach of 4 months to develop the roadmap in a coalition with industry and public stakeholders



Mile-stones	Intro / Kick off	Aspiration workshop	Dataset for review	Feedback on dataset	Draft roadmap workshop	Feedback on roadmap	Revised roadmap workshop	**Sign-off**	Final comm. package
Key activities	▪ Stocktaking of current activities, programs and US hydrogen industry landscape ▪ Assemble industry and public stakeholder coalition ▪ Develop and discuss “day 1 hypothesis” on all work packages ▪ Align on detailed scope and approach; as well as structure of data request	▪ Develop energy baseline and projections towards 2050 ▪ Provide feedback on dataset ▪ Analyze feedback, derive adoption scenarios and build first draft of roadmap ▪ Identify areas for further detailing of roadmap	▪ Review first draft of roadmap and provide feedback ▪ Clarify questions, incorporate feedback and align members towards joint perspective	▪ Incorporate feedback and refine roadmap (WP1, WP2) ▪ Estimate impact (WP3) ▪ Synthesis of all results into communication package	▪ Review of and alignment on roadmap presentation ▪ Write, edit, review and fine-tune report ▪ Finalize communication package			

Preliminary proposal – to be refined based on objectives, focus areas and team setup

1 Prices quoted in EUR, free of all duties, taxes and other charges, including VAT. Prices quoted are fixed amounts including all charges (including travel and subsistence).

Roles and responsibilities of Steering group and Study group

Groups	Members	Roles	Meeting schedule	Contribution
Steering Group	▪ Small set of companies	▪ Actively **steering the project with high level of commitment** across the project	▪ Weekly calls	▪ Very **active involvement** in the project and **weekly project calls**; **providing input** data; **reviewing workshop material** and taking prepared **leading rolls in workshops**; reviewing interim project results; **providing feedback and guidance**
Study Group	▪ All coalition members	▪ **Guiding the project with expertise**, focusing on core areas of each partner	▪ Workshops	▪ **Providing input** data; **providing feedback** on the outputs, **active participation in workshops** and participate in discussions

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Contents

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Open questions and next steps

Questions	**Coalition members**	▪ Participating companies? ▪ Who will represent the companies? *We would recommend each member to nominate 1-2 project contacts for participation in meetings and as experts during data alignment phase*
	Logistics	▪ Where should meetings take place? ▪ Who will participate in key meetings and who will send out invitations?
	Kickoff meeting	▪ When should the aspiration workshop with the full group take place? ▪ What is the preferred location?
	Contract	▪ Contract closure and signing between FCHEA and McKinsey ▪ Signing of NDA with coalition members and FCHEA
Next steps	**Before kickoff**	▪ Assemble participating companies and their contacts ▪ Send out invitations for all workshops ▪ Gather/share existing perspectives on energy and hydrogen in the US ▪ Prepare kickoff meeting
	After kickoff	▪ Circulate assumption data set / survey for validation and input from US companies