Hydrogen Roadmap

Analytical approach of the supply side modelling

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Low-carbon energy technology roadmaps
Supply-side modelling
ETP-TIMES
ETP modelling framework

ETP-TIMES model

Energy demand

Energy costs

Conversion sectors

Primary energy

Fossil

Renewables

Nuclear

End-use service demands

Material demands

Heating

Cooling

Passenger travel

Freight

etc.

End-use sectors

Industry

Buildings

Transport

End-use service demands

Model horizon: 2009-2050 (2075) in 5 year periods

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Regional structure of ETP-TIMES

- 28 model regions representing individual countries or aggregations of countries
- Only one geographic point per model region; differentiation within a single region, e.g. through different resource categories
Structure of supply side model (ETP-TIMES)

- Least-cost optimisation approach
- Methodology developed by ETSAP (Energy Technology Systems Analysis Programme) implementing agreement of the IEA

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Hydrogen supply options

Centralised hydrogen production
- Pyrolysis/Gasifier/Reformer with and without CCS
- Sulfur/Iodine cycle
- Electrolysis

Decentralised hydrogen production
- Electrolysis at fuel station
- Reformer at fuel station
- Reform/Gasifier at refinery

H₂ pipeline
- Natural gas pipeline
- H₂ distribution
- H₂ gas storage
- LH₂ storage

H₂ use in transport
- H₂ use in refining
- H₂ use in transport, industry, buildings, electricity generation, refining

Natural gas
- Heavy fuel oil
- Coal
- Biomass

Nuclear
- Solar
- Electricity

Electricity

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Hydrogen supply costs in comparison to other fuels

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Global hydrogen supply in the 2DS

Hydrogen may become an attractive storage option for surplus electricity from variable renewables by 2050

Note: Captive generation at refineries and chemical plants not included.
Energy storage

First hydrogen balloon flight by Jacques Charles and Nicolas Robert in Paris on 1 December, 1783.
The way electricity is produced changes in a 2DS

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...but also electricity consumption changes

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Systems thinking is needed

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Storage technologies are different

Hydrogen/gas storage

CAES

High-temperature batteries

Pumped storage

Lead-acid battery

Lithium-ion battery

Double-layer capacitor

Flywheel storage

Superconductive energy storage

Source: Schegner, Vor- und Nachteile verschiedener Prinzipien der Speicherung elektrischer Energie, 2012

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Comparison of storage cycle costs: Daily operation

1 GW for 8h (8 GWh), 1 cycle per day

Hydrogen

CAES (adiabatic)

Pumped storage

Costs (Euro Cent/kWh)

Source: VDE-Study: Energy storage in power supply systems with a high share of renewable energy sources

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Comparison of storage cycle costs: Weekly operation

500 MW for 200h (100 GWh), 2 cycles per month

Hydrogen

CAES (adiabatic)

Pumped storage

Costs (Euro Cent/kWh)

Source: VDE-Study: Energy storage in power supply systems with a high share of renewable energy sources

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Energy storage analysis

• **Enhanced ETP-TIMES model (long-term; horizon up to 2050):**
  - 4h-load segments for a typical day (6 per day, four typical days per year)
  - Large-scale storage: electricity, thermal, hydrogen
  - Considering other flexibility options for the electricity system:
    • Flexible generation technologies
    • Inclusion of demand response, e.g. V2G
  
  Investment decisions in generation technologies and first estimate on storage needs; better capturing impact of operational aspects on capacity needs

• **Dedicated TIMES model for operational analysis (short-term; one year):**
  - 1h-timeslice resolution
  - Analysing operation of electricity system within a year for specific region with investment decisions for generation technologies from long-term model
  - Additional operational constraints (ramp-up/-down, min load, min up/down times)
  - Improved analysis on storage needs and role of competing flexibility options

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Modelling of the electricity sector

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Challenges of the H₂ analysis on the supply side

- **Lack of complete information on captive (on-site) generation** at refineries and chemical plants today
- **Development of H₂-related technologies** in terms of their technical and economic characteristics as well as scale
- **H₂ infrastructure: spatial and scale aspects** only covered to some degree in global ETP-TIMES model, possible approaches:
  - Expanding transport infrastructure model
  - Relying on existing national studies
- **H₂ as flexibility option for the electricity sector**:
  - Assessing synergies with storage needs for end-use consumption
  - Role of natural gas infrastructure (power-to-gas)
  - Competing options for flexibility (flexible generation, other storage technologies, demand response, larger balancing area)
Thank you!

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Example: Variability of wind

Wind generation in Germany in 2011

- Transforming variable wind generation of 2011 in constant base load generation would require a storage capacity of 3 TWh (largely based on long-term H₂ storage)
- For comparison: around 0.040 TWh of pumped storage capacity today
- Theoretical example, as other flexibility options, notably flexible generation, are not considered

Data source: EEX Transparency