Kick-off meeting Hydrogen Technology Roadmap

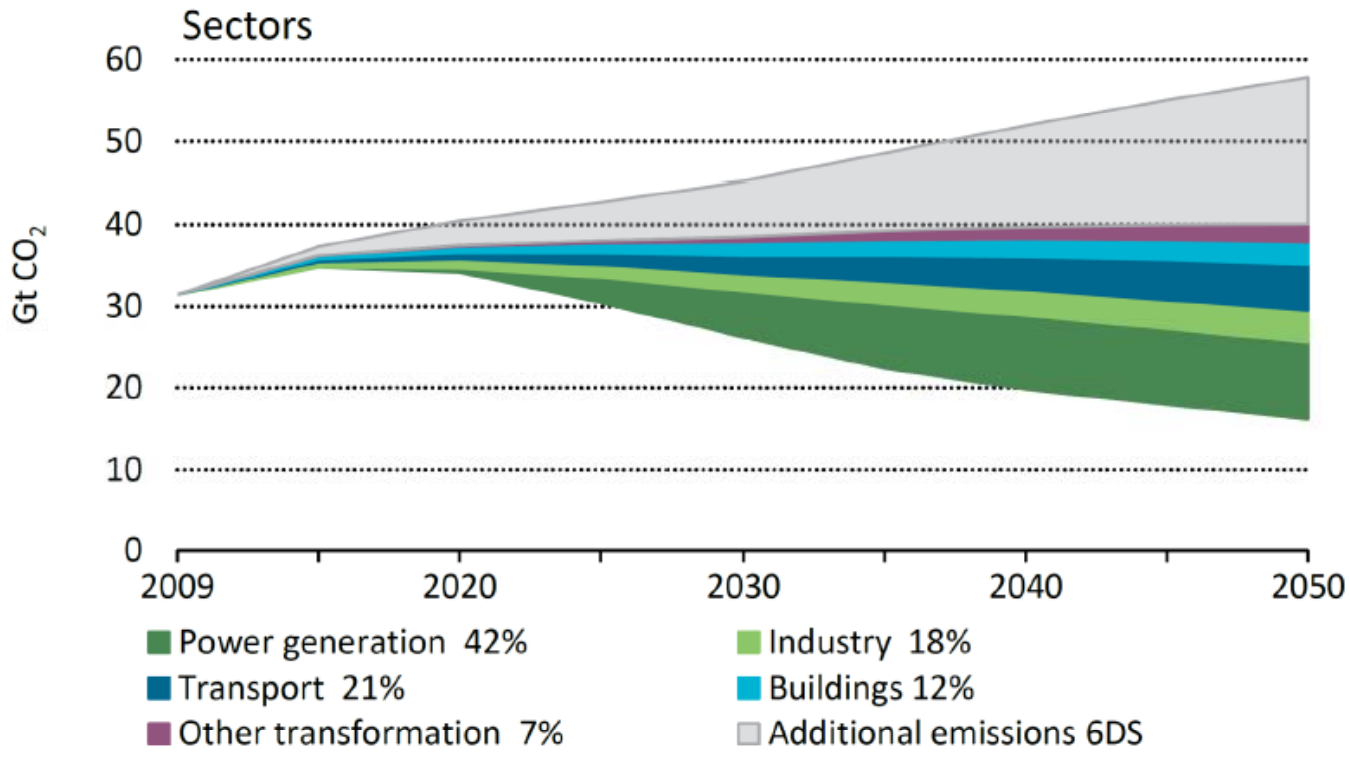
Alex Körner

alexander.koerner@iea .org

Agenda

- Global context and ETP 2DS High H_2
- Making the case for hydrogen
  - Transport
  - Energy storage
  - Synergies with other demand sectors
- Hydrogen roadmap
  - Analytical approach
- Focus on technology
  - Transport
  - Energy storage

Sectoral contribution to 2DS



- **The core of a clean energy system is low-carbon electricity that diffuses into all end-use sectors.**

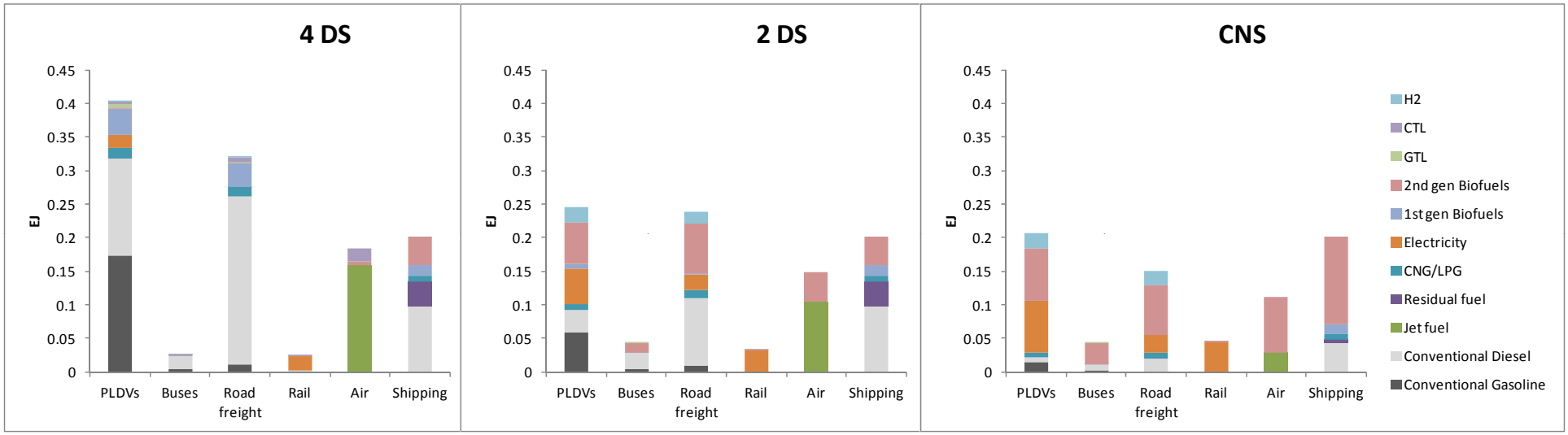
The case of hydrogen

- Hydrogen is a flexible energy carrier with potential applications across all end-use sectors
- It is one of only a few potential near-zero emission energy carriers along with electricity and biofuels
- Hydrogen can be generated from virtually all primary energy carriers
- Hydrogen can create new links between energy supply and demand
  - Power to gas
  - Power to transport fuel
  - Power to industry feedstock

The case of hydrogen

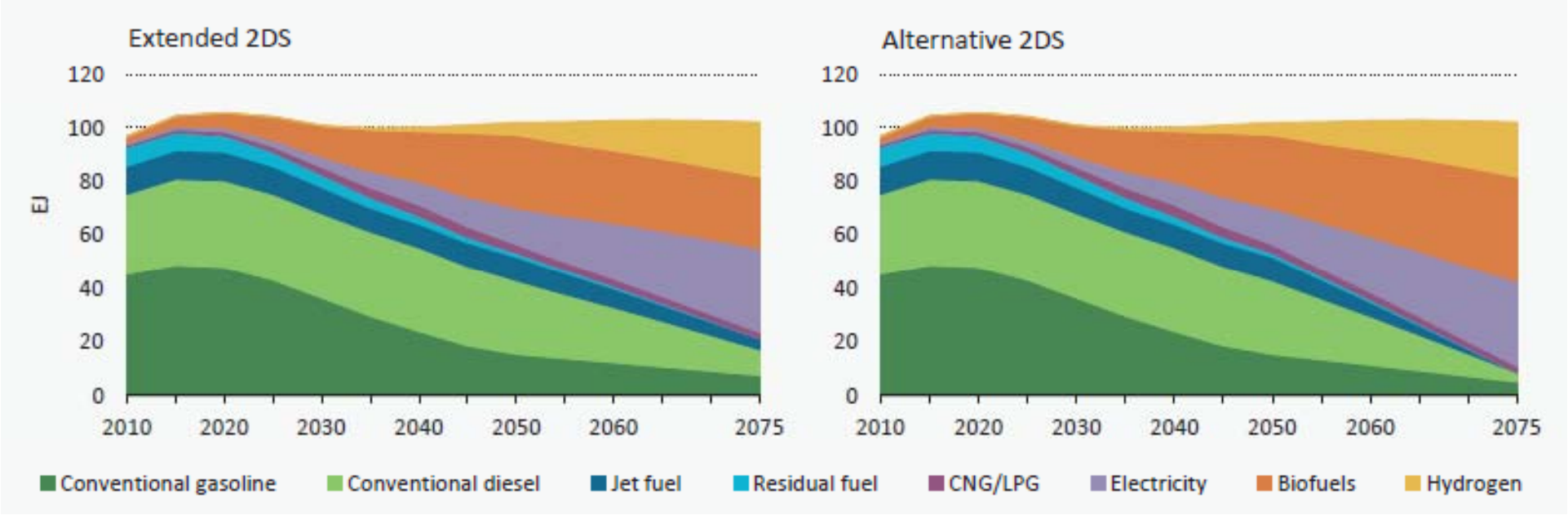
- However apart from internal industry use, hydrogen generation, transmission, distribution and retail infrastructure is virtually non-existent and will need significant investment if it should play a larger role within energy demand sectors
- Many of the hydrogen conversion technologies still face high costs with great potential to be reduced due to scaling processes
- End-use energy carriers using hydrogen as an intermediate energy carrier always face competition with other, often more economic transformation chains

Very low emission transport - Lessons learned from Nordic ETP



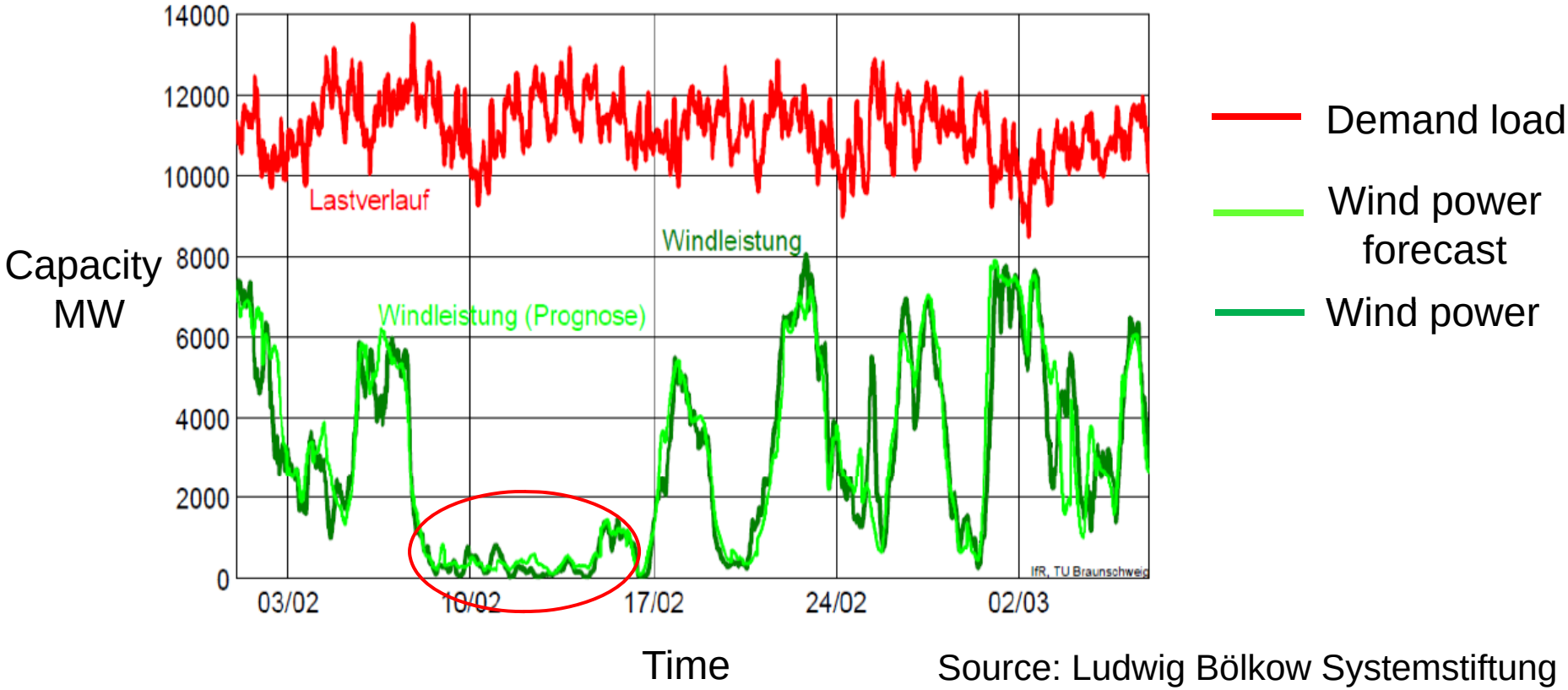
- Electrification has clear constraints: Heavy road freight, air, shipping
- High energy density, low carbon fuels are needed in several transport sectors – road freight, air and shipping
- Hydrogen can substantially diversify the transport energy mix depending on primary energy use for hydrogen generation

Transport: Biofuels under pressure in the very long term



- By 2050 around 60 EJ of raw biomass are needed in transport
- Together with demand from heat&power generation raw biomass demand increases to a total of 150 EJ
- IPCC: tripling raw biomass demand by 2050 is ambitious but feasible, with high uncertainties concerning sustainability issues and land use change

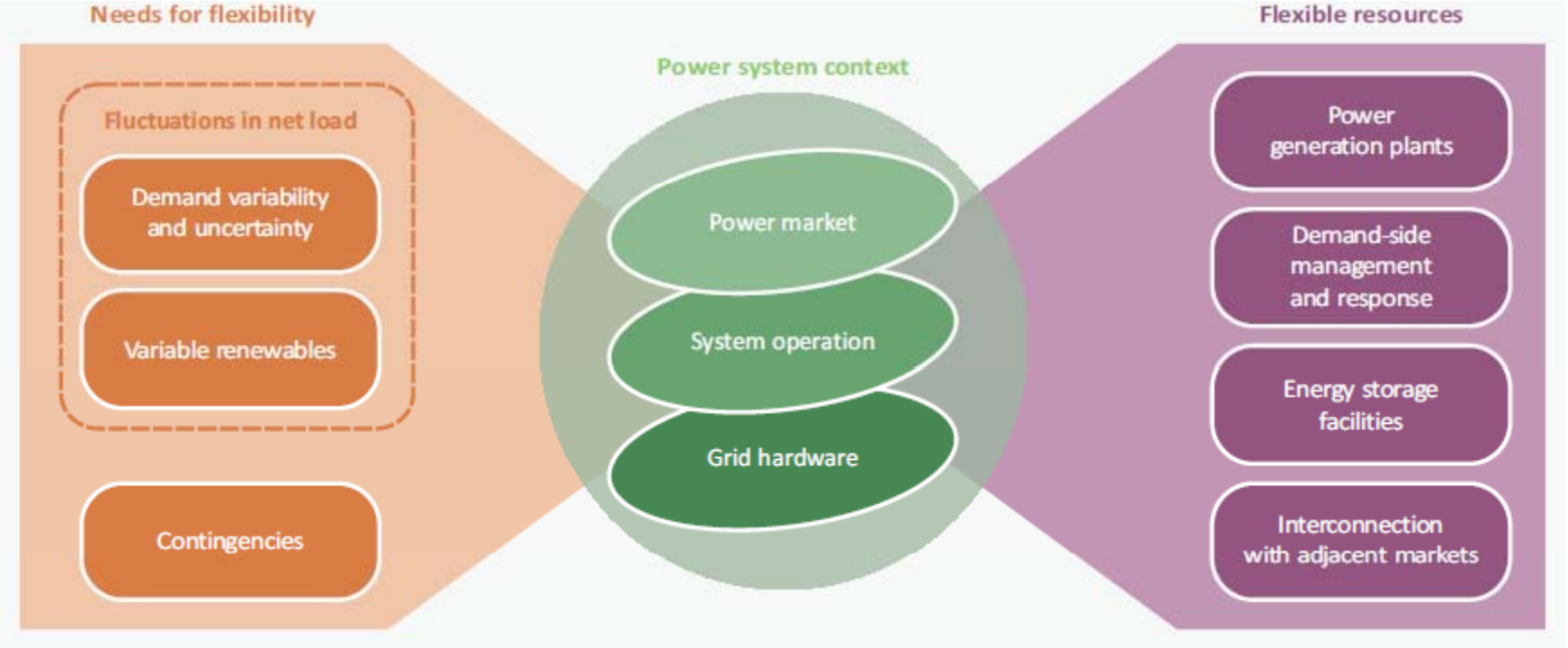
Integration of variable renewables in the energy system



Source: Ludwig Bölkow Systemstiftung

- **Integration of variable renewable energies results in an increased demand for flexibility in the energy system**

Need for flexibility



- Need for flexibility can be addressed on the power market, system operation and system hardware level
- Energy storage can be attractive when other variability measures are exploited

Energy storage options*

Generation	Transmission & Distribution	End-Use
Pumped hydro (e)	Supercapacitors (e)	Vehicle-to-grid - batteries (e)
CAES (e)	Flywheels (e)	Batteries (e)
Batteries (e)	Etc…	Refrigerators (t)
Hydrogen storage		Water storage (ice, hot water heaters) (t)
Storage for CSP (t)		Residential heaters with storage (t)
Storage in CHP (e,t)		Phase change materials (t)
Storage in DHC (t)		Thermal-chemical storage (t)
Waste heat applications (t)		Heat pumps with storage (t)
Etc….		Underground thermal energy storage (t)
		Etc…

- **Hydrogen offers the possibility to store large quantities of energy for long time periods**

***electricity (e), thermal (t)**

Industry and other Transformation

- Large quantities of hydrogen already used in the chemical and refining sectors mainly as feedstock
  - Pathways to green this hydrogen?
  - Are there synergies during the roll-out of hydrogen infrastructure for transport and can this create viable business models?
- Hydrogen could play a larger role in future low carbon steel making processes

Residential

- Fuel cell micro CHP can play a role in a more diversified, low carbon residential energy market
- Modest availability of competitively priced micro-CHP units
- Japan and Korea seem the only markets to push for the technology

Analytical approach

Hypothesis: Transport drives H_2

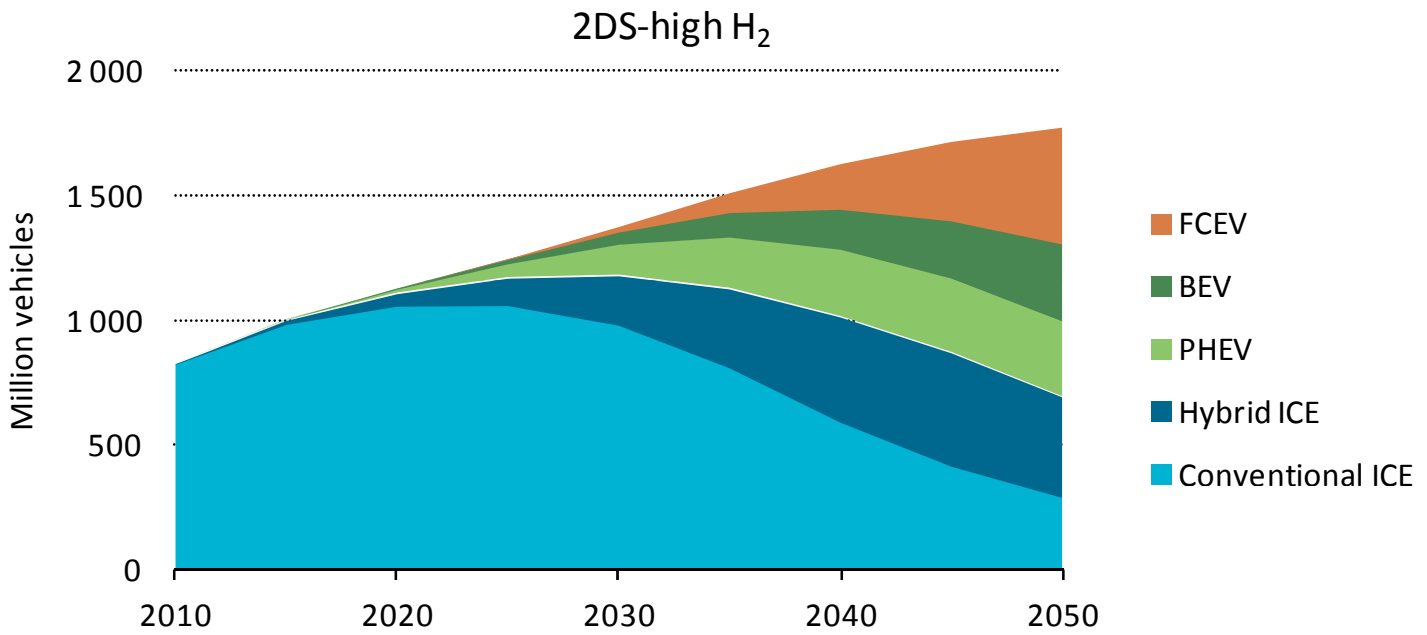
- Deeply decarbonizing the transport sector together with limited direct use of electricity and pressure on biofuel demand make hydrogen a possible candidate to diversify the transport fuel portfolio

- The transport sector might be the most likely sector to reach mass production of hydrogen technologies in order to take advantage of economies of scale

- Hydrogen demand from the transport sector might open a way to valorize otherwise curtailed renewable energy

Transport

2DS high H_2 PLDV stock



- **The Hydrogen Roadmap analysis will be based on the 2DS high H_2 scenario**
- **Globally by 2050 around 25% of the vehicle stock are FCEVs**
- **Discussion of global fuel use and emission reduction potential based on ETP 2012 analysis**

Transport

- **Analysis of a technology roll-out strategy for selected regions – EUG4, USA, Japan**
  - **Evaluation of costs and benefits based on ETP 2012 scenarios and updated techno economic assumptions for vehicle technology**
  - **Discussion of evolution of H2 T&D infrastructure as function of hydrogen demand and transport distance**
  - **Discussion of economic gap based on incremental vehicle costs, fuel costs and necessary infrastructure investment**
  - **Discussion of necessary steps to reach targeted technology costs**
    - **Fuel cell development**
    - **On-board storage**
    - **Infrastructure development, HRS investment costs**
    - **Standardization efforts**
  - **Brief discussion of hydrogen generation mix & targeted costs**
  - **Evaluation of synergies with the industry sector to provide the needed hydrogen during technology roll-out**

Analytical approach: Transport

- **Challenges/limitations**
  - **Development of regional T&D and HRS infrastructure based on rough spatial disaggregation: “urban centers”**
  - **Evolution of H2 T&D and distribution pathway based on rough assumptions on average transmission distance as well as city radius**
  - **Conditioning of H_2 poorly taken into account**
  - **Exogenous evaluation of inter-sectoral synergies**

Power to power

- **Power-to-power**
  - High energy density compared to pumped hydro and CAES provides the possibility to store large quantities of energy
  - Levellized cost of large scale hydrogen electricity storage indicate dependency on long storage times.
  - Large scale hydrogen electricity storage might hence be subject to specific meteorological conditions or very high shares of variable renewables

- **Analysis/Discussion**
  - Analysis of techno economic parameters along the transformation chain
  - Benchmarking against competing technologies
  - Discussion of prerequisites for large scale power-to-power hydrogen energy storage
  - Synergies with the transport sector: if hydrogen transmission, distribution and retail infrastructure was in place:
    - Could the intrinsic storage potential be estimated???
    - Could part of this storage be used for large scale and long time energy storage???

Power to gas

- Power-to-gas
  - Provides link between power and gas grid and has potential to significantly reduce curtailment
  - Blending H2 into the gas grid offers potentially high storage capacities even at low blend share
  - Hydrogen blended in the gas grid would face low gas prices to compete with

- Analysis/Discussion
  - Analysis of techno economic parameters along the transformation chain
  - Case study on storage potential for region with large natural gas grid and possible challenges with respect point of injection
  - Benchmarking against competing technologies
  - Discussion of prerequisites for power-to-gas hydrogen energy storage
  - Attempt to evaluate maximal possible excess electricity potential from variable renewables using simplified dispatching model (after ETP fixed capacity) for one model region

* if wind variation > generator flexibility→ storage capacity

Power to transport fuel

- **Power to transport fuel**
  - Provides link between power and transport fuel and has potential to significantly reduce curtailment
  - Producing transport H2 offers potentially high storage capacities
  - Hydrogen produced as transport fuel offers the highest hydrogen value
  - Potential business models may exist in the control power market
  - Hydrogen T&D and retail infrastructure is not in place and demands for significant investment

- **Analysis/Discussion**
  - Analysis of techno economic parameters along the transformation chain
  - Benchmarking against competing technologies
  - Discussion of prerequisites for power-to-transport fuel hydrogen energy storage

H2 storage discussion

- Discussion of value chain and prerequisites for the regarded three hydrogen storage transformation chains
- Discussion of synergies with transport sector and its possible capability to achieve mass market production of H2 technologies
- Data availability will be challenging
- Estimates on maximal theoretical storage potential based on broad assumptions and limited interaction with other flexibility measures

Residential

- Case study Japan
  - Around 55,000 fuel cell micro CHP installed

- Analysis/Discussion
  - Analysis of techno economic parameters and existent barriers for further deployment
  - Benchmarking against competing technologies
  - Assumption on future market penetration and its influence on hydrogen T&D network utilization and costs
  - Evaluation of CO2 reduction potential

Industry and other Transformation

- More stringent environmental legislation will drive an increasing demand of H2 as feedstock specially on Chemicals and Refining

- Integration of H2 in industrial process technologies: H2 reduction Iron and Steel making process
  - H2 is produced by amplifying technique using BFG and COG and then used as reducing agent reducing the process coke needs.

Industry and other Transformation

- **Analysis/Discussion**
  - **Analyse impact of increasing H2 from different demand sectors on plant design practices and new flexible business models to meet cross-sectoral requirements**
  - **Discuss current research status of H2 reduction Iron and Steel making process**
  - **Analyse expected development and deployment time frame and consequent potential global impact on CO2 emissions generated by the sector.**

Thanks!