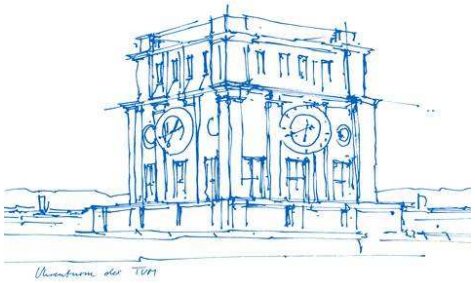
May 17, 2024
EPRG Workshop, Cambridge

From H2 Demand to Consumption: The Insights from Refinery Industry Analysis

by
Svetlana Ikonnikova

Center for Energy Markets, TU Munich, School of Management

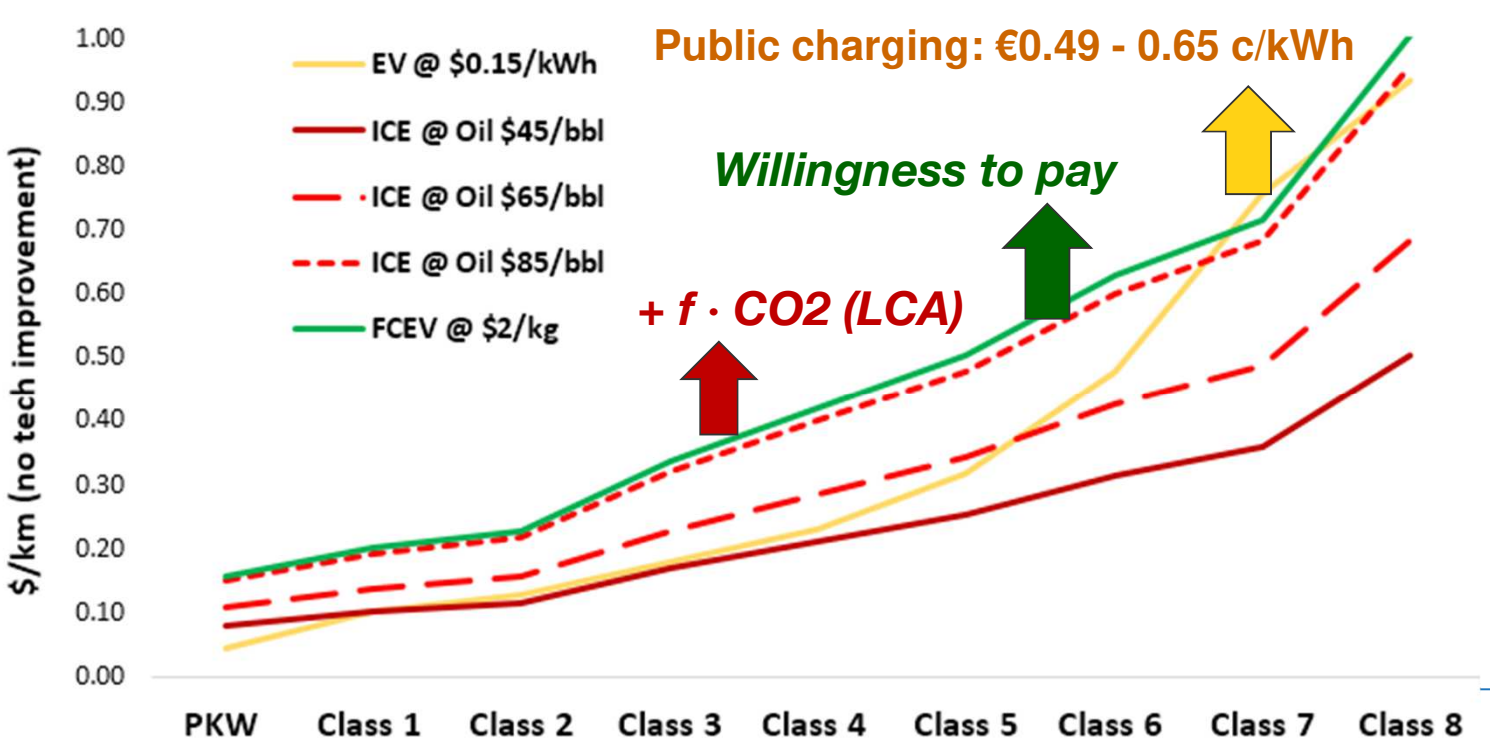


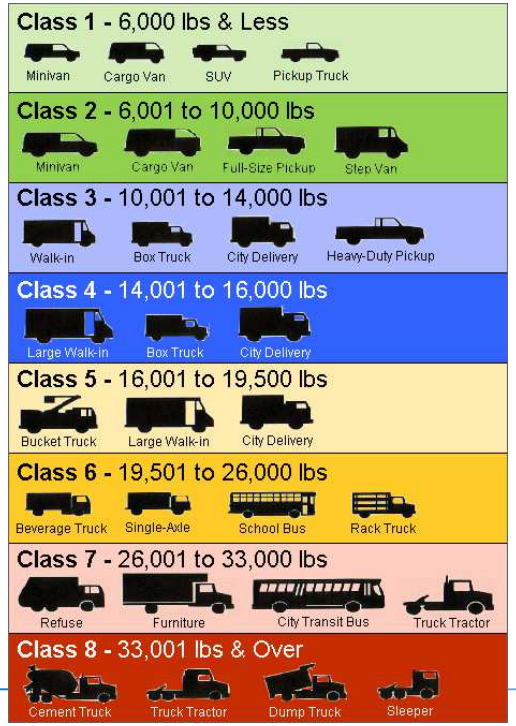
Targets for Net Zero Transportation

- Published and proposed national H2 strategies mark the value of H2 as clean and versatile energy carrier that shall play a significant role in GHG emission reduction.
- The size of H2 demand and the willingness-to-pay for “green” product, however, has remained the topic of fierce debates until recently.
- Yet, details provided by amendments to ‘Fit for 55’ legislature determine the future scenarios:
  - More ambitious standards have been set for new cars and vans in comparison to the 2021 CO2 targets: New cars registered in the EU should have 55 % lower emissions (for vans 50 % lower) and by 2035 ***all new vehicles*** should have zero emissions;
  - *Automotive manufacturers in the EU will pay €95/gr of CO2/km/car for emissions above the target.*
  - *An average EU car drives 12,540km/y emitting 134 gr of CO2/km => non-compliance will bankrupt automotives*

The Role of Hydrogen

- While EV adoption is impeded by the grid developments and cots, H2 emerges as a solution for trucks but also enabler to reduce ICE emissions via cleaner refinery products ;
- Manufacturers may report vehicles' lifecycle CO2 voluntary till 2028 and mandatory from January 2028.





Scope 1 emissions are **direct emissions** from owned or controlled sources.

Scope 2 emissions are **indirect emissions** from the generation of purchased energy.

Scope 3 emissions are **all indirect emissions** (not included in scope 2) that occur in the **value chain** of the reporting company, including both **upstream** and **downstream** emissions.

3 Other operations
- Franchises
- Paper consumption
- End-of-life disposal of unsold products
- Scrap from equipment or waste generated in the production facilities

3 Employee Commuting
- Daily commute to the office
- Employee air and rail travel, car rentals (business travel)
- Offshore site visits

2 Purchase of electricity and heat in every company owned facility
- Plants, mining sites
- Data centre operations

3 Embedded emissions
- In buildings & equipment
- In leased buildings, vehicles, assets

1 Processing
- Combustion of natural gas and other fuels in refineries, plants or other facilities
- Chemical emissions from plants

1 Exploring & Producing
- Emissions from drilling & well testing
- Operational spills
- Methane leaks and gas flaring at the wellhead

3 Usage of products from end consumers

1 Operating
- IT emissions on premise data centre

3 Transportation and distribution
- In the entire value chain from maritime shipping to the retail dealers (if utilising vendors rather than company owned vehicles)

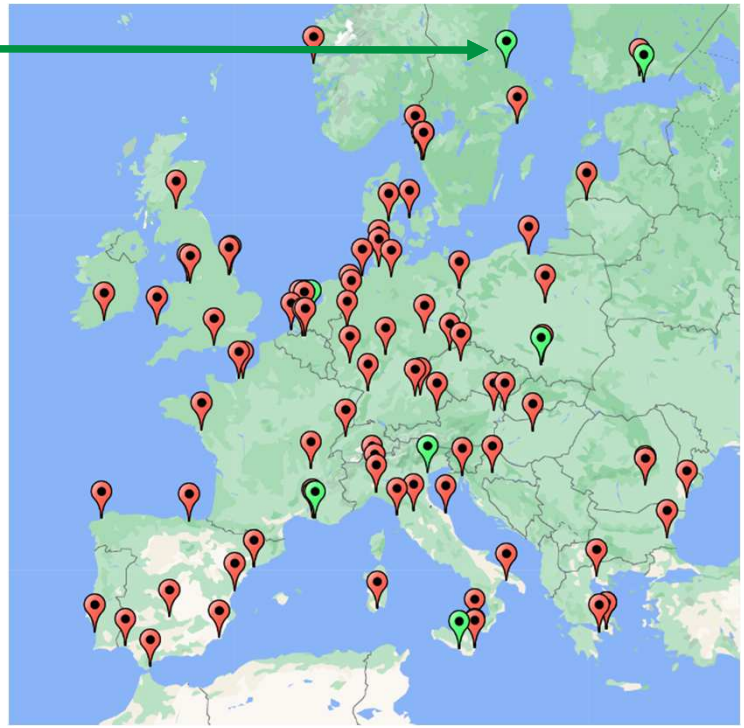
1 Transporting
- Emissions from fuel consumed by company owned vehicles such as trucks, ships, helicopters

Source: Accenture analysis, For educational purposes only

Estimating Demand for H2

- Analyzing Input-Output Tables (IOT), we may track the volumes of individual energy inputs, power, heat, etc. used by an individual industry, including refinery;
- >90% of H2 is coal and natural gas derived;
- NG & H2 are used for heat, hydrocracking
- EU refineries have great potential to reduce ICE & FCEV emissions

biorefinery vs. green H2



Interindustry IOT scheme

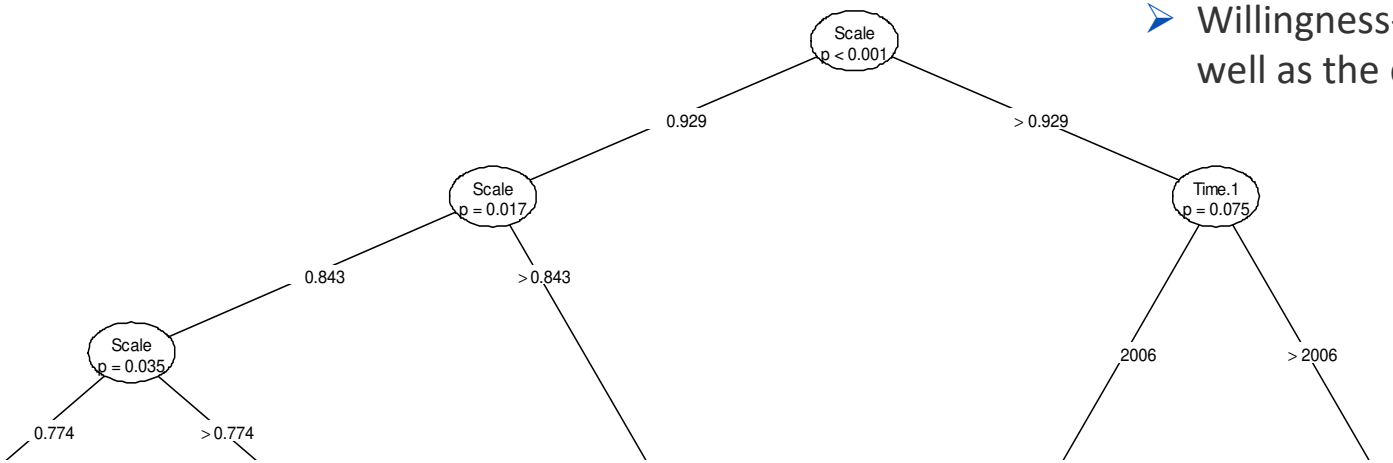
Input \ Output			Intermediate Use						
			Economy 1			...	Economy r		
			Ind. 1	...	Ind. i		Ind. 1	...	Ind. i
Intermediate input	Economy 1	Ind. 1	A						
		...							
		Ind i							
	...								
	Economy r	Ind. 1							
		...							
		Ind. i							

5

Estimating Demand for H2

- Using the input and output data + associated CO2 values, we may estimate the production function to see how much H2 we need to keep the refinery at a given production level

$$logQ = log\beta_0 + \sum_{k=1} \beta_k logX_k + \frac{1}{2}\sum_{i=1}\sum_{j=1} \beta_{ij} logX_i logX_j$$



Using a cluster-regression approach, we find that:

- Refineries' use of energy inputs is scale-dependent
- Willingness-to-pay depends on NG & power prices as well as the costs of the associated CO2 (or certificates)

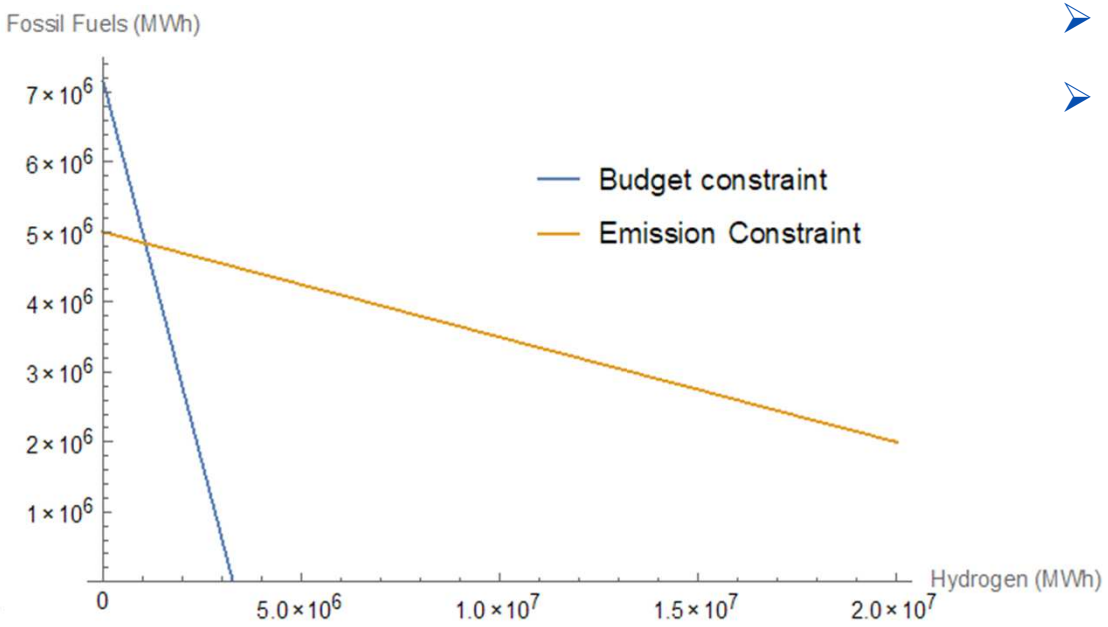
But considerably reducing gasoline's CO2:

- Automotive can buy time for transformation without going bankrupt, e.g., Porsche

Estimating Demand for H2

- Using the input and output data + associated CO2 values, we may estimate the production function to see how much H2 we need to keep the refinery at a given production level

$$logQ = log\beta_0 + \sum_{k=1} \beta_k logX_k + \frac{1}{2}\sum_{i=1}\sum_{j=1} \beta_{ij} logX_i logX_j$$



Using a cluster-regression approach, we find that:

- Refineries' use of energy inputs is scale-dependent
- Willingness-to-pay depends on NG & power prices as well as the costs of the associated CO2 (or certificates)

But considerably reducing gasoline's CO2:

- Automotive can buy time for transformation without going bankrupt, e.g., Porsche

Tranformation of the Supply Chains

- While planning on the upstream side seem straight forward, the details are less clear
  - Mixing up 20% H2 + NG would reduce the energy content of the flow by ~15% => you need to transport more vs. CO2 reduction per Joule of energy is ~7%
  - (Re-) using pipelines for H2 transportation is possible volumetrically, but would require 3x of energy used by compressor stations due to the energy density issues => cost triple (or more considering embrittlement problem)
  - Issues related to energy costs of H2 compression also translate into storage cost inflation.

⇒ Together that compels companies to focus on coastal refineries for conversion

⇒ Search for H2 production co-located with facilities

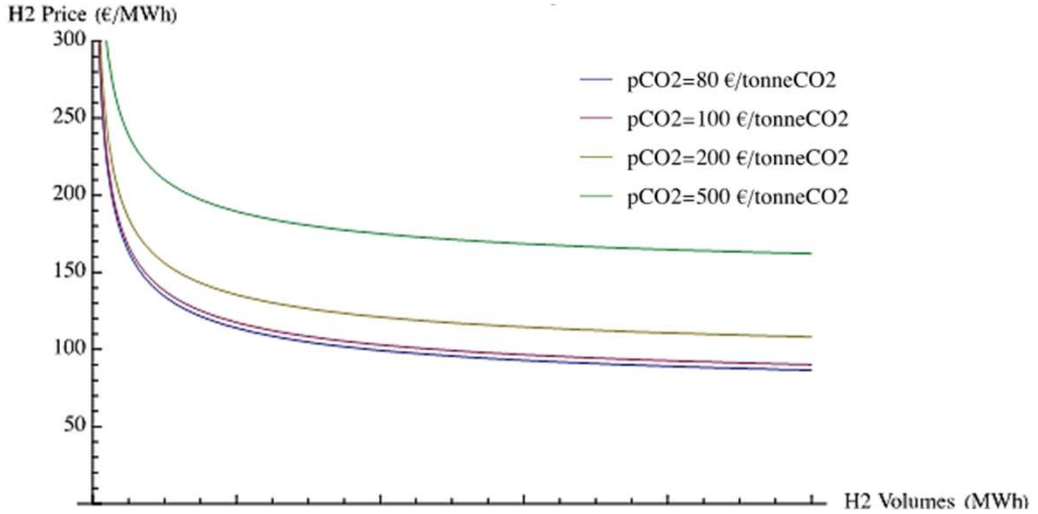
⇒ Discuss the closure of refineries over the next 10 years

Costs vs. Competitiveness

- While competition models suggest that marginal cost would drive the market, the scarcity of local H2 pushes to consider remote locations and therewith, transportation cost adjustments to competition
- Markets differ in MC arbitrage and local incentives and distances to export markets

Fuel use & CO2 costs affect the final cost at the market:

- Ship size&weight + cargo
- Engine type and efficiency
- Speed and distance
- Weather conditions

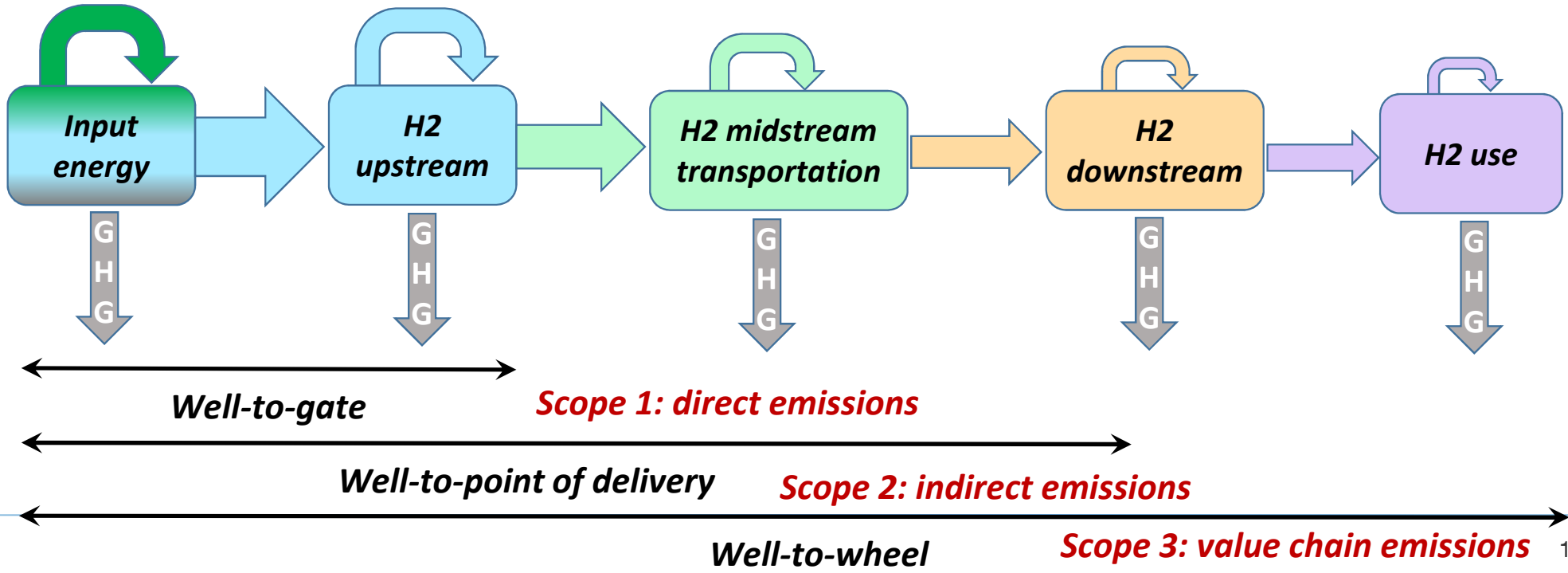


- *100% of maritime emissions is set to become taxable under the EU ETS and since 2023 IMO requires ships to report their Carbon Intensity Indicator (CII)*

Green or Not Green?

- No internationally agreed framework or standard on how to define the GHG intensity of hydrogen exist yet.
- Certifications vary in the system boundaries, scope, purpose, reporting type (use-base, origin, etc.)

System boundaries or supply chain: ***well-to-point of delivery (H2Global)*** or ***well-to-tank boundaries*** include transport, conversion and reconversion of H2 (e.g. ammonia) vs **well-to-wheel system boundary** is used for the definition of renewable hydrogen in the Renewable Energy Directive II of the European Union



Summary

- The demand for H2 and its commercial value becomes more concrete with fees and fines formulated, we get a clearer picture on the demand volumes and willingness-to-pay by individual industries.
- But while the supply and off-take are shaping up, the question about transportation remains open, calling for capacities and consistent CO2 accounting & measuring along the geographical boundaries (CBAM).
- The willingness to pay emerges as a function of available substitutes (fossil fuels, power) and their prices; CO2 budgets & prices; fines & fees faced for non-compliance.
- Infrastructure planning is complicated by the physical issues, energy accounting, and CO2 assignments
- The decisions on the domestic level has to be adjusted for the international market developments, both on the upstream side and shipping.