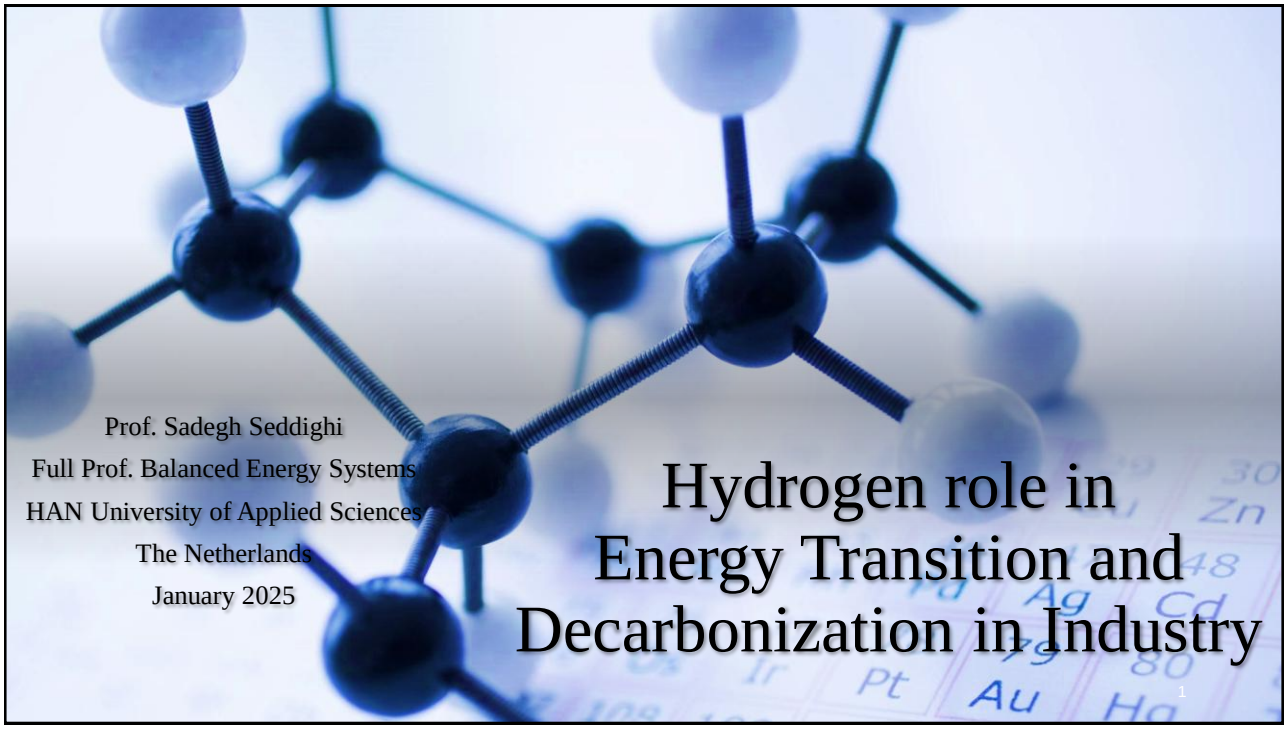


1

Outline

- Background
- Energy Transition
- Hydrogen utilization in various sectors
- Hydrogen as a fuel
- Introduction of BES at HAN

2

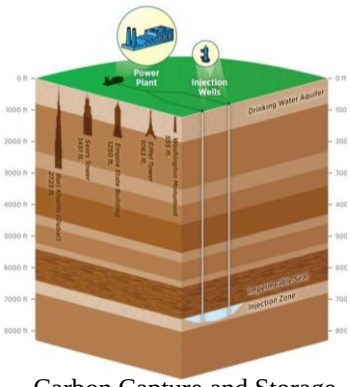
Background

"No stimulus to man's advancement ever approached that given by the acquisition of:

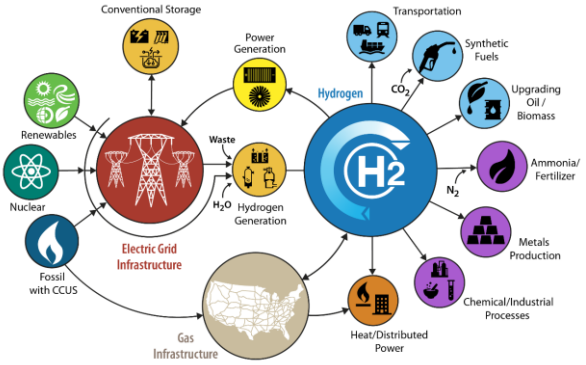
Fire"

Ref: Walter Hough, The Distribution of Man in Relation to the Invention of Fire- Making Methods, American Anthropologist, Vol.18, No. 2 ,1916, pp. 257-263

In 2022, process heat was responsible for about two-thirds of industrial greenhouse gas emissions



Carbon Capture and Storage (CCS)



Clean Hydrogen cycle of DOE

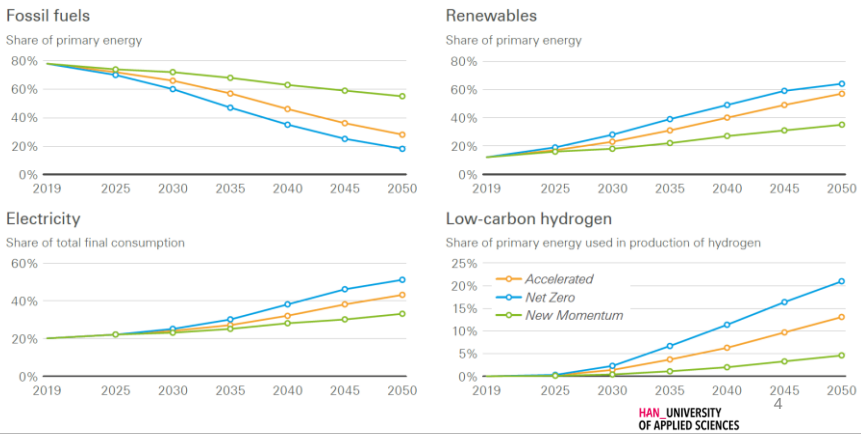
3

Future of global energy

The future of global energy is dominated by four trends:

- Declining role for hydrocarbons,
- Rapid expansion in renewables,
- Increasing electrification,
- growing use of low-carbon hydrogen

Source: BP Energy Outlook 2023



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Energy transition from 2019 to 2050: Key points

- Share of **fossil fuels** in primary energy reduces from 80% to between 55-20% by 2050.
  → Combustion and fossil fuels will still play important role.
- Share of **renewables** in global primary energy increases from around 10% to between 35-65% by 2050
  → wind, solar, bioenergy and geothermal are major renewables but require energy storage means.
- Share of **electricity** in total final energy consumption increases from 20% to between a 33-50% by 2050.
  → Global electricity generation will be dominated by wind and solar.
- Share of primary energy used in **hydrogen** increases to 13-21% by 2050.
  → According to BP, Hydrogen plays the role of an energy carrier for hard-to-electrify sectors.

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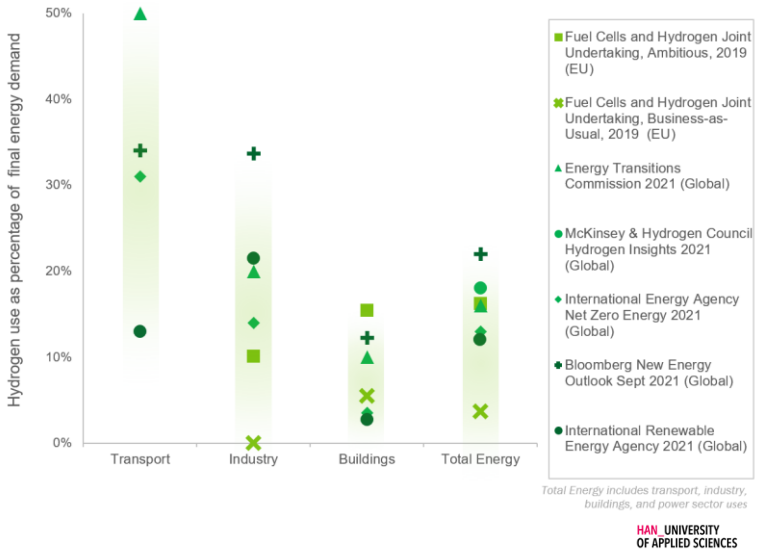
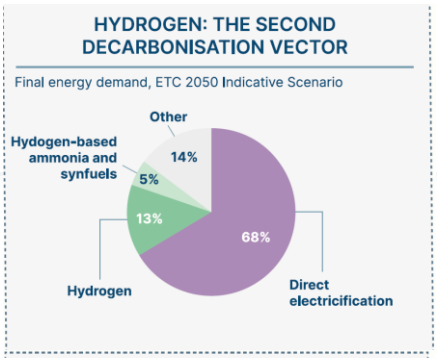
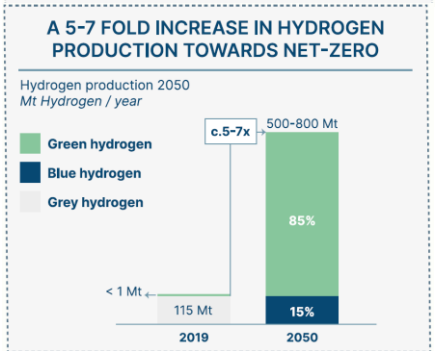
Hydrogen utilization in various sectors

From US DOE and Eu







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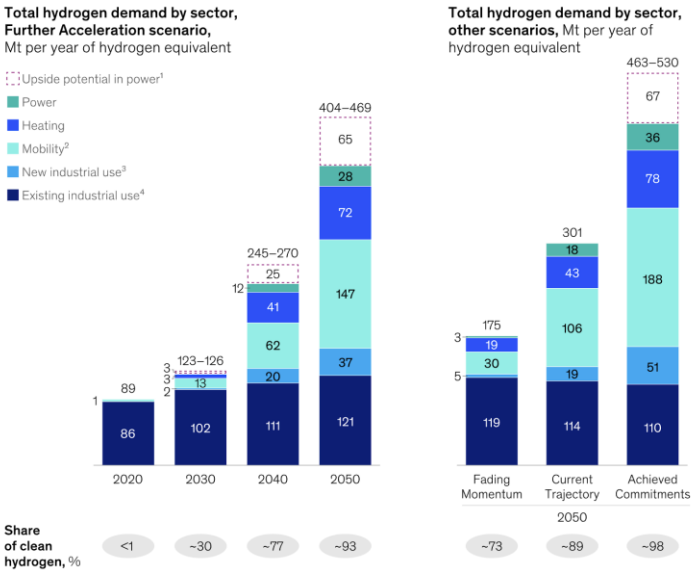
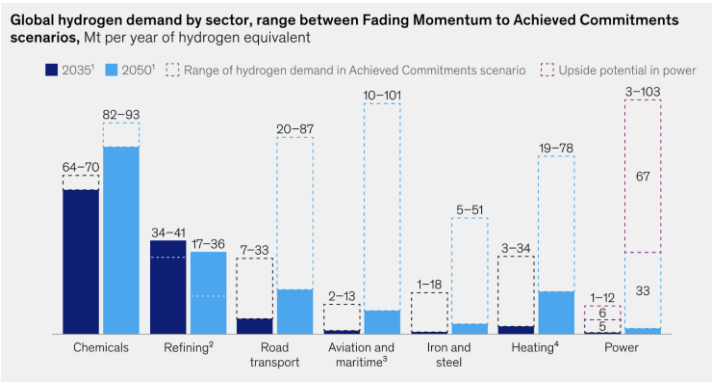
H_2 Demand by sector

According to McKinsey



By 2050, in the Further Acceleration scenario, mobility applications are projected to remain the largest drivers for clean hydrogen uptake, with road transport accounting for around 80 Mtpa and aviation around 50 Mtpa, with the remaining 15 Mtpa coming from maritime.

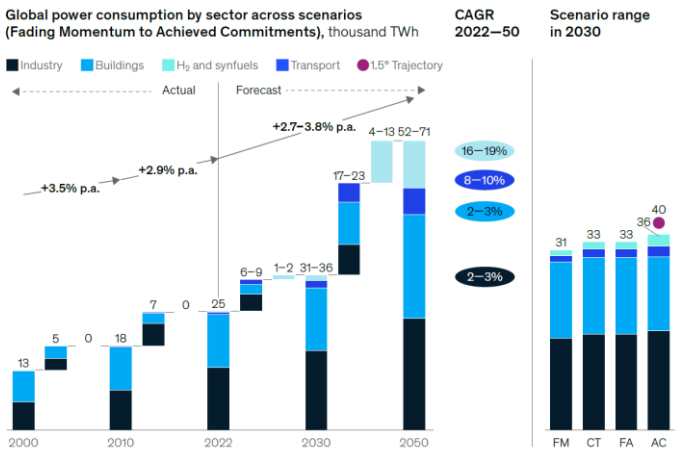
Uncertainty in H_2 demand by sector



Uncertainty inn hydrogen demand in emerging applications stems from a combination of factors:

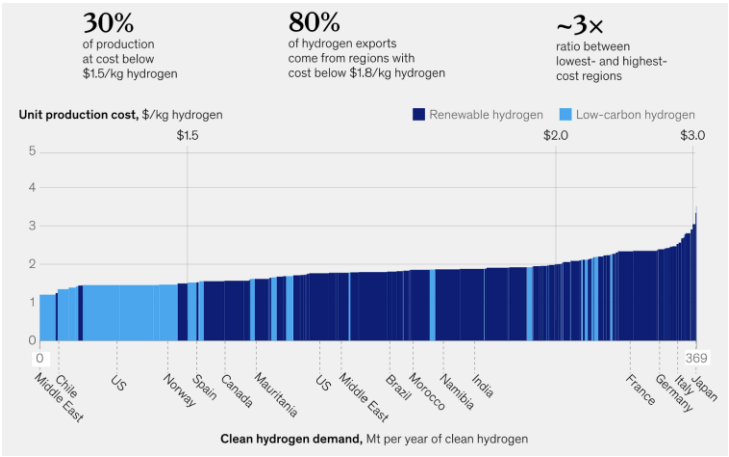
- Lack of clarity in government support
- Development of enabling infrastructure
- Evolving competitive dynamics with other decarbonization technologies

Power demand increase for electrification and H_2 production



Power demand is projected to keep increasing by 3–4% p.a. across scenarios due to electrification and a rising green H_2 demand

Hydrogen cost competitiveness by region



Clean hydrogen production costs are expected to drop significantly by 2030–50, with large differences across regions

Hydrogen Basics

- Hydrogen production is 48% from natural gas, 30% from petroleum, 18% from coal, and 4% from electrolysis
- Natural gas reforming (blue hydrogen) and water electrolysis (green hydrogen) are developing rapidly.
- Major hydrogen uses are listed below:

Table 1:
United States and World Hydrogen Consumptions by End-Use Category

	United States		World Total		U.S. Share of
Captive Users	Billion m^3	Share (%)	Billion m^3	Share (%)	World Total (%)
Ammonia producers	33.7	38	273.7	61	12
Oil refiners	32.9	37	105.4	23	31
Methanol producers	8.5	10	40.5	9	21
Other	3.4	4	13.6	3	25
Merchant users	10.8	12	16.1	4	67
Total	89.3	100	449.3	100	20

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BES: Hydrogen lab

- Ventilated enclosure test cells of 4m^2, according to NEN-EN-IEC 60079-13
- 2 x 15 kW Bi-directional loads (for electrolysis and fuel cells)
- 1 kW 10 bar PEM electrolysis test setup
- H_2O and 02 concentration in H2 analyzer
- Potentiostat and impedance spectroscope with 30 A current booster
- Thermal camera
- Hydrogen 5.0 supply, 35 kg storage.
- 10 kW fuel cell test setup
- Various open-cathode fuel cell systems ranging from 12W to 1000W

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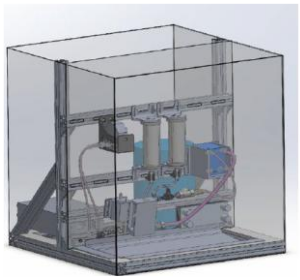
BES: Hydrogen lab

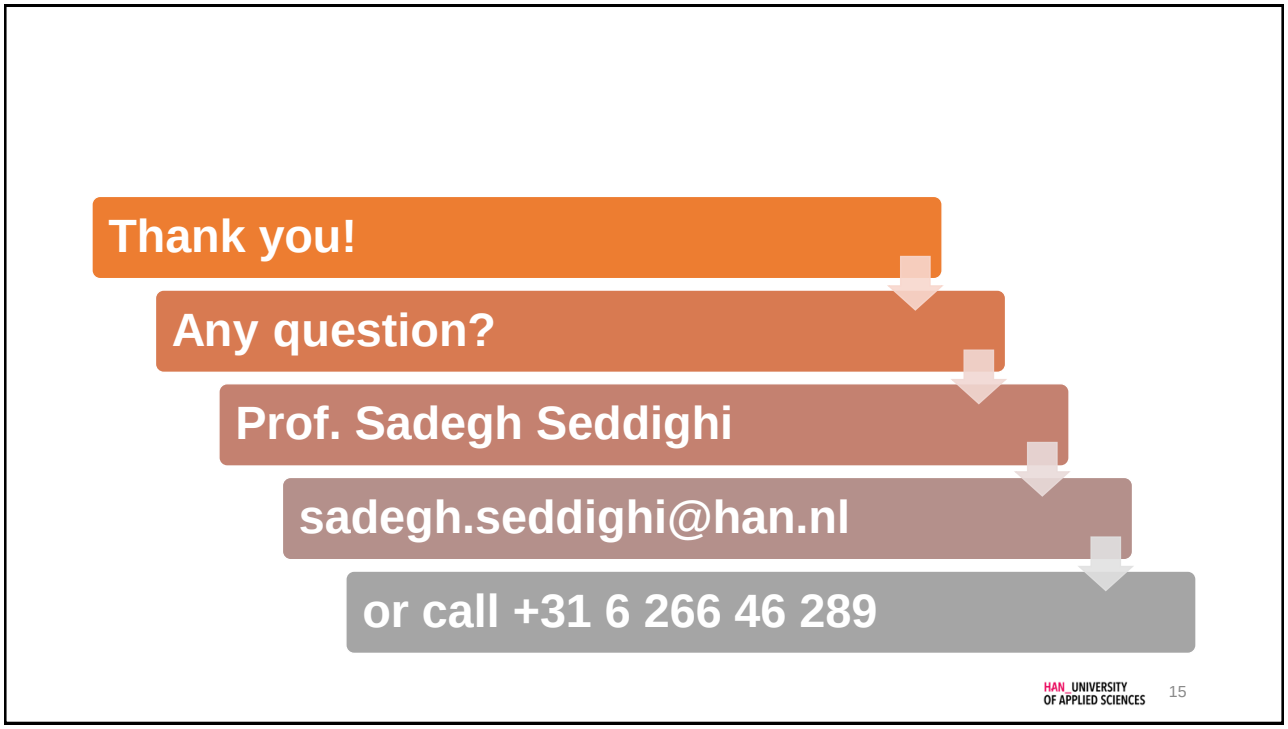
- 10 kW fuel cell system
  - Fuel cell stack from the Nedstack company
  - Aim to safely monitor the electrochemical reaction.
  - Ongoing work on Start-up and heating strategies, and secure shutdown
- 200 W Alkaline Electrolyzer test setup
  - Aims at testing low power alkaline stacks
  - Alkaline stacks have the benefit of PFAS free membrane.
- DCDC converter, max 200kW/400A
  - Zekalabs LB-1024-01 DC/DC REDPRJME
  - Aim: Electrical conversion for high power and/or high current applications



BES and Connectr

CONNECTR
energy innovation

Joint profiling


Thank you!
Any question?
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sadegh.seddighi@han.nl
or call +31 6 266 46 289
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