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Die Bedeutung von Ammoniak für die CO_2-freie Schweiz

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Hydrogen

Is it key for the path towards a CO_2-free future?...

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„I believe that **water** will one day be employed as fuel, that **hydrogen** and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable ...

... water will be the coal of the future.“

Jules Verne (1874)

Hydrogen
...or is it part of the CO_2 problem?

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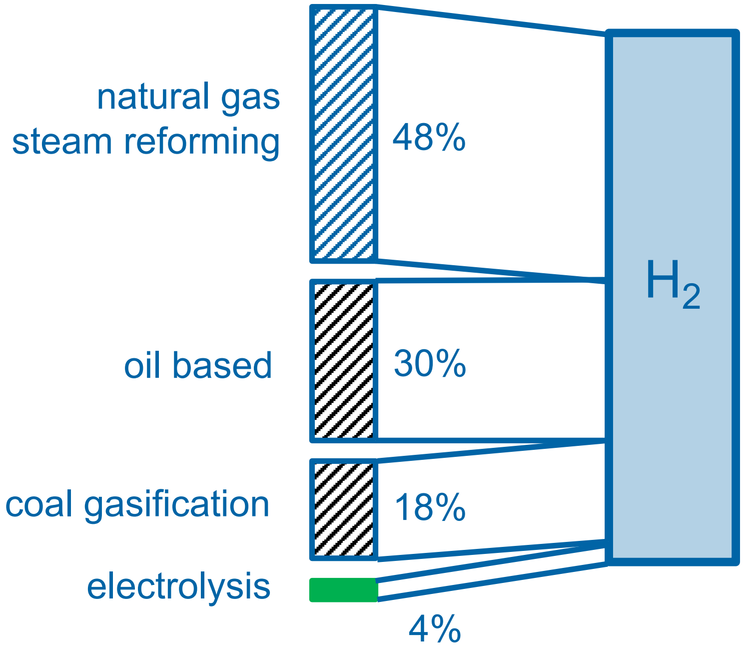


annual production of **hydrogen**

100 Mto/yr H_2

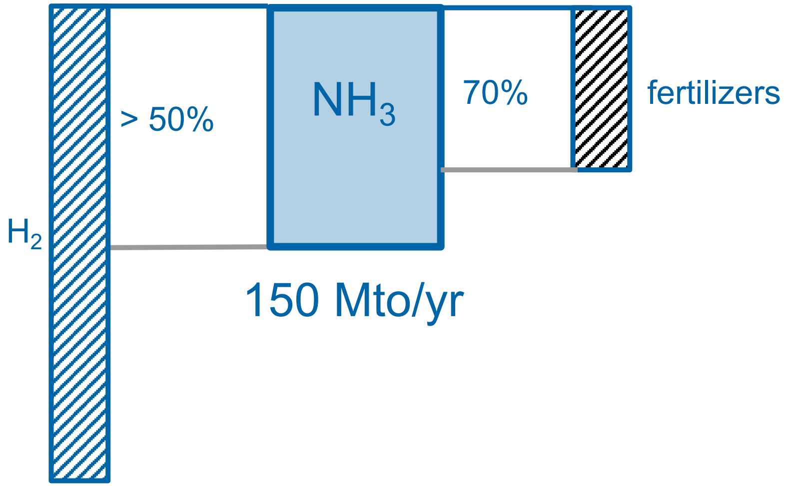
~ 550 Mto/yr of CO_2*

* Number based on natural gas reforming, for coal gasification: $100\ \mathrm{Mto}\ H_2 \approx 2'000\ \mathrm{Mto}\ CO_2$!

... hydrogen is the coal of today!

Ammonia

The main use of hydrogen are fertilizers



annual production of **ammonia**

- 150 Mto/yr NH_3
- mostly used for fertilizers
- 2% of global energy consumption
- CO_2 emissions of Ammonia industry are equivalent to Australia‘s total annual emissions

Ammonia
Established production process

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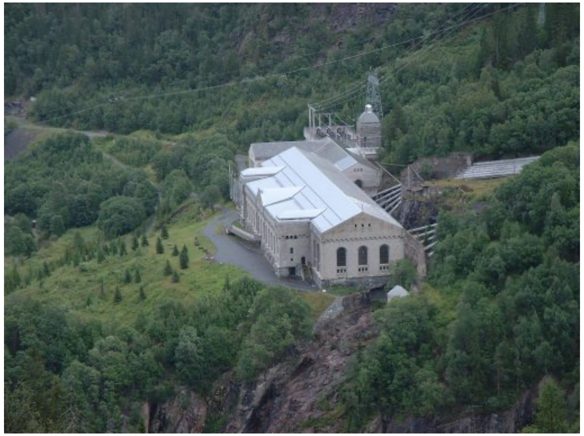
Catalytic production (Haber-Bosch)

$$N_2 + 3H_2 \rightleftarrows 2NH_3$$

→ pressure, temperature

- Nobel prize 1918
- Mainly used for fertilizers (also pharmaceuticals, plastics, textiles, explosives)



Vemork power station, Norway (largest power plant world-wide, when it opened in 1911)

Vermork was for a long time the largest facility of **green ammonia**

Hydrogen & Ammonia
Basic properties and facts

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	Hydrogen	Methane	Ammonia	Diesel
density (kg/m^3)	0.09 / 70 *	0.657	0.86 / 682 **	840
heating value (MJ/kg)	120	50	22.5	45
energy content (kWh/kg)	33	13.9	6.4	11.9

* liquid at -253°C

** liquid at -33°C

- properties
  - **hydrogen**: light, highly flammable, difficult to store and transport
  - **ammonia**: poisenous, established storage and transport infrastructure
- use
  - **hydrogen**: ammonia, refinery gas, methanol
  - **ammonia**: fertilizers, precursor of all nitrogen compounds
- main producers and consumers
  - China (30%)
  - USA, Europe, Russia, Canada, …

Hydrogen & Ammonia
Outlook globally

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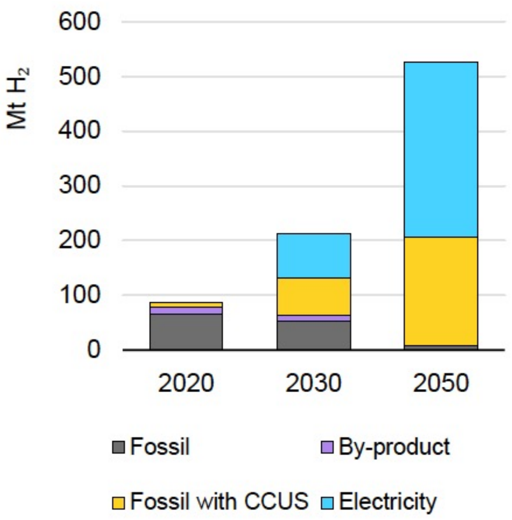
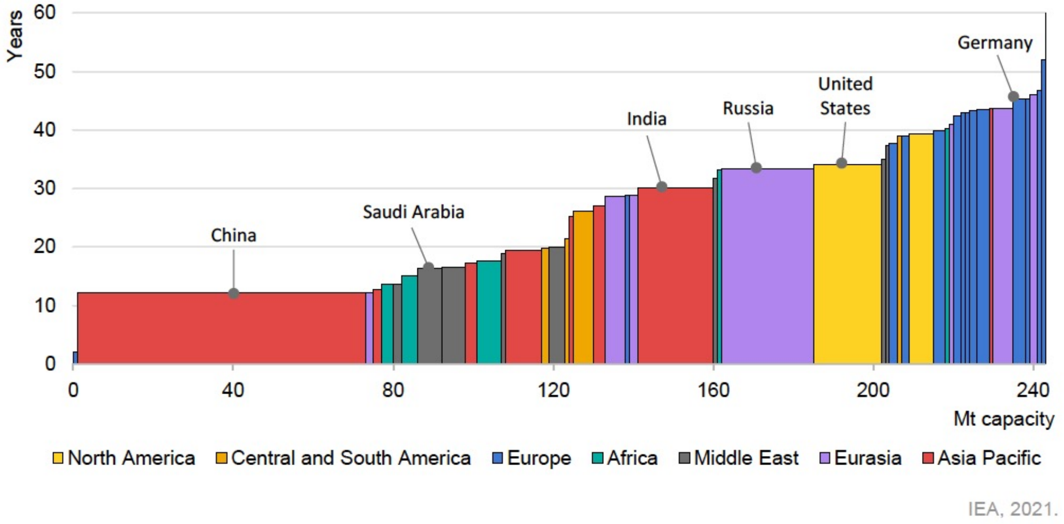
Forecast of Hydrogen growth



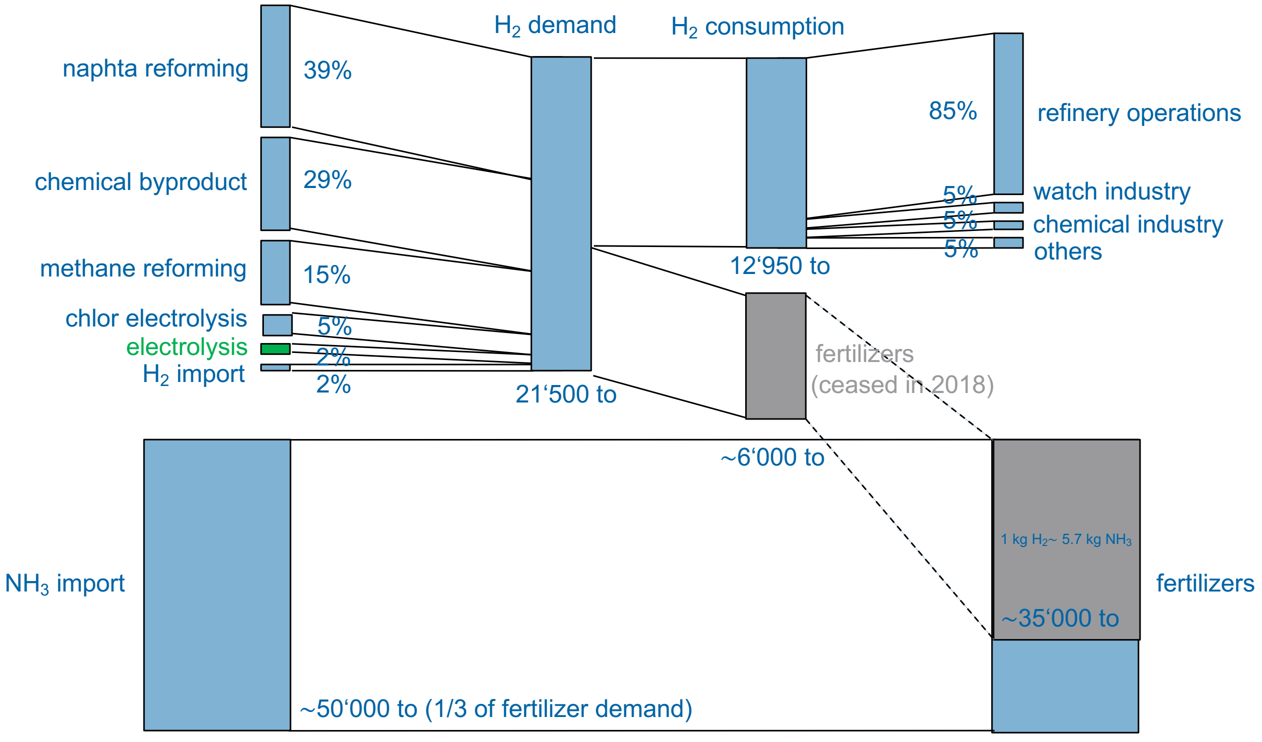
Today's age of Ammonia plants



Growth of hydrogen may not necessarily lead to CO_2 reduction!

Sources: IEA 2019 The Future of Hydrogen; IEA 2021, Ammonia Technology Roadmap

Hydrogen & Ammonia
Situation in Switzerland



(~300‘000to corresponds to 1/10 of NH3 consumption in Germany)

Significant potential to decarbonize H_2 & NH_3 production in Switzerland

Source: Swiss Federal Office of Energy 2018, Swiss Hydrogen Production and Demand. Own estimates of fertilizer/NH_3 consumption

The energy transition challenge
manage seasonal fluctuations of electricity production

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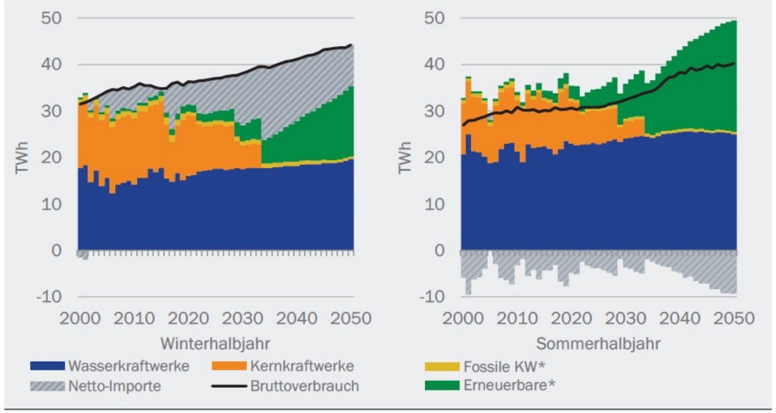
Main challenges from today to 2050

	Europe	Switzerland
Decarbonize average production (electricity only)	71% based on carbon fuels	replacement strategy for nuclear
Manage seasonal fluctuations (electricity only)	only possible with negative CO_2 emissions	BfE 2050 strategy contains energy deficit

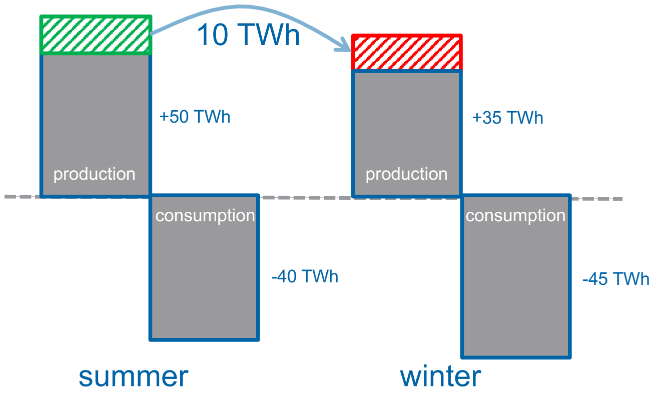


* gekoppelt und ungekoppelt

gap closure of **10 TWh/yr**:
- store excess energy in H_2 during summer
- import excess wind energy in winter (to avoid efficiency losses of factor 2.5)

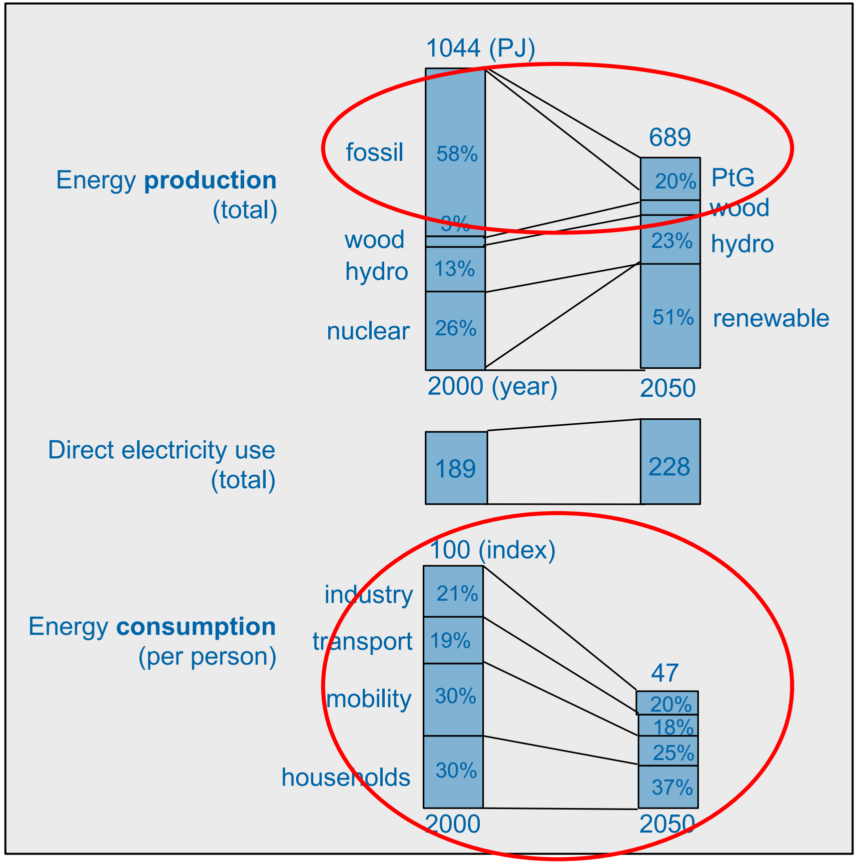
Source: Swiss Federal Office of Energy 2020, Energieperspektiven 2050+

The energy transition challenge
seasonal fluctuations & total energy consumption



10 TWh / CH ~ 1‘000 kWh / person =
=10 days of total energy consumption / person

fuel	quantity / person	what does it mean?
hydrogen	300 m^3 / 30 kg	(plus a 600 kg steel tank)
ammonia	150 l	10 x fertilizer use
diesel	80 l	1 car tank filling



Source: Swiss Federal Office of Energy 2020, Energieperspektiven 2050+

Hydrogen and ammonia production

main cost drivers

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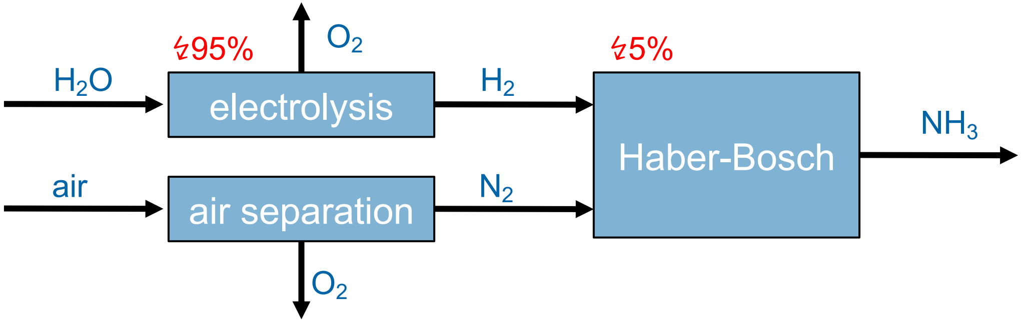
hydrogen production methods

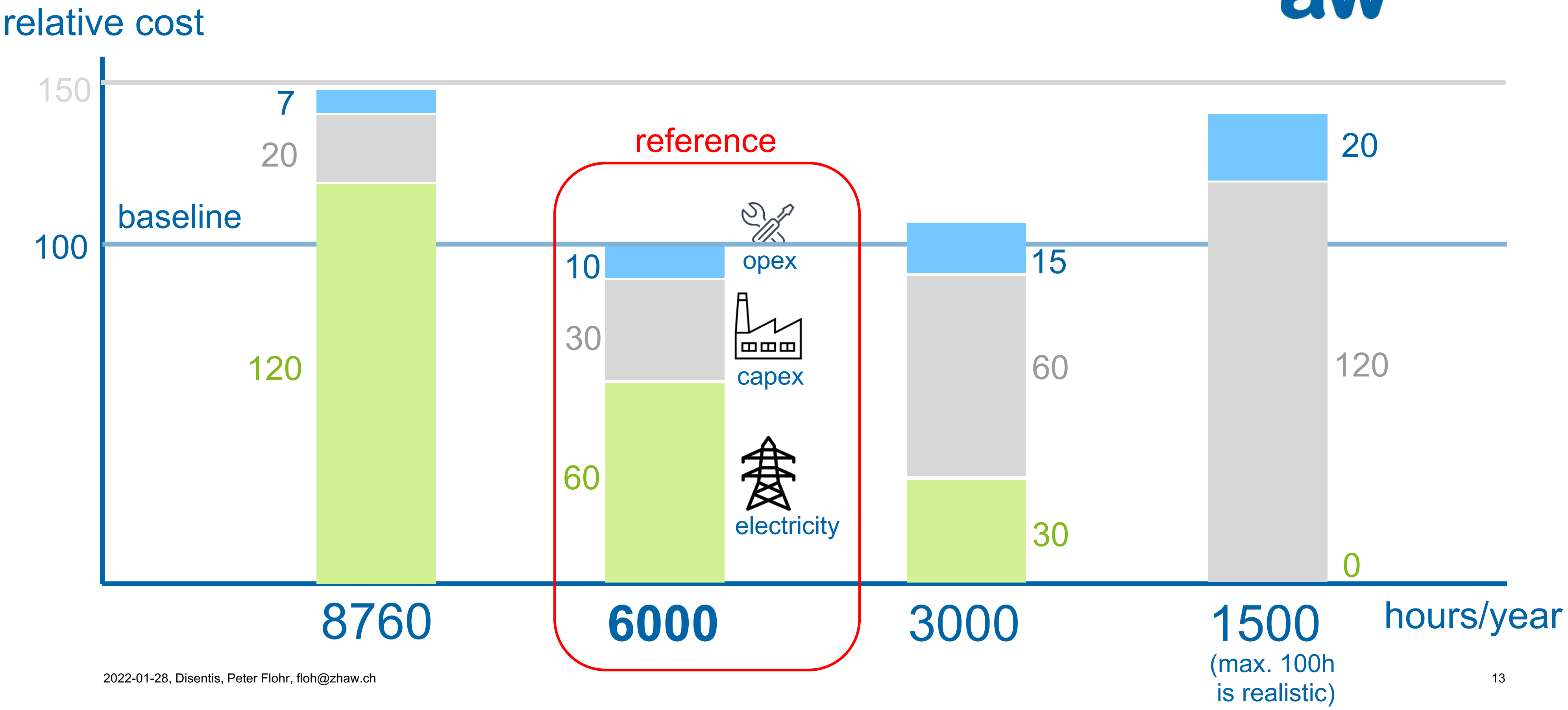
share		method	cost ($/kg)	fuel cost	capex/opex cost
60%	80%	steam reforming	~2	75% (CH_4)	25%
	18%	gasification	~2.5	50% (coal)	50%
	2%	electrolysis	~5 (2 ... 10)	60-80% (electricity)	20-40%
40%		(byproduct)	0	negligible	

ammonia production (electrolysis & Haber-Bosch)



Ammonia production cost

Influence of electricity price & operation hours



Ammonia production cost

Influence of production method & CO_2 tax

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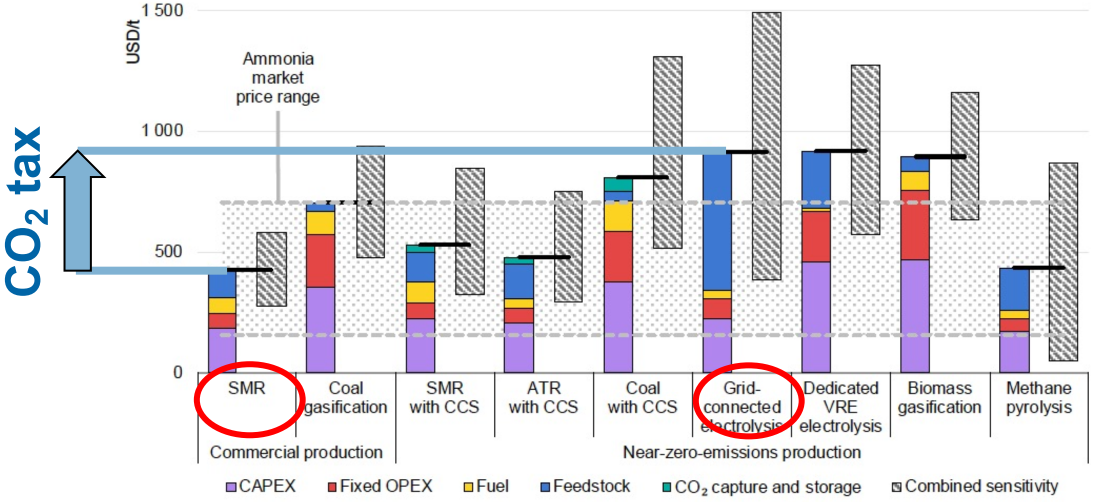
Figure 1.6 **Simplified levelised cost of ammonia production for commercial and near-zero-emission production routes in 2020**



IEA, 2021.

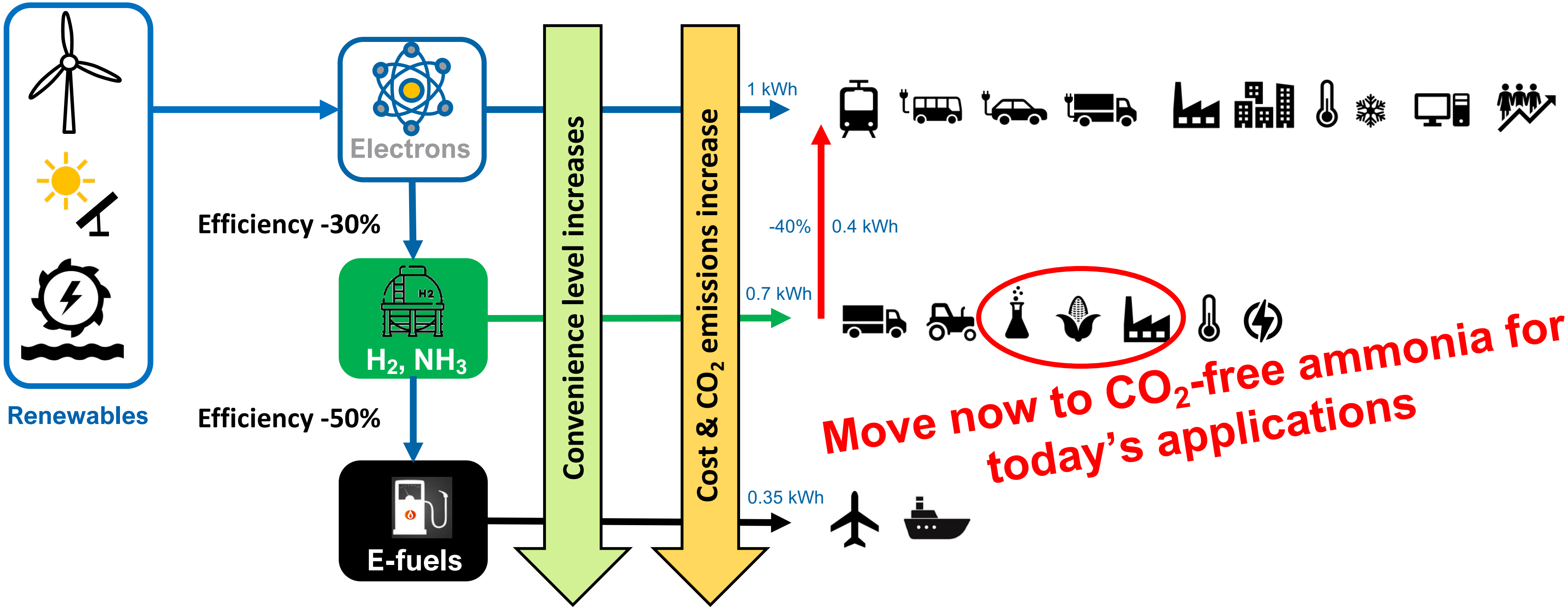
method	cost ($/to)	CO_2 tax ($/to) for parity
steam reforming	450 (200-700)	350 (0-1000)
electrolysis	900 (400-1500)	

1 to NH_3 ~ 1.3 to CO_2

- Breakeven on average only reached at 350 $/to CO_2
- ➢ This tax level is currently predicted for 2050 or later
- ➢ Due to large variability in production cost the commercial production is possible **today**

Source: International Energy Agency 2021, Ammonia Technology Roadmap

Efficiency matters in a renewable energy system
Framework for best energy use



CO_2 emissions will decrease only with a hierarchy of applications

2022-01-28, Disentis, Peter Flohr, floh@zhaw.ch

Concluding Remarks

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Situation today:

- 1to H_2 ~ 5-20to CO_2: today's use of H_2 and NH_3 needs to be decarbonized first
- the potential in Switzerland for decarbonization for hydrogen and fertilizers is large!
- the use of low-cost excess energy alone is not commercially viable

Situation in future:

- Break-even for CO_2-free NH_3 is at 350 $/to CO_2, with huge variability. So start now!
- H_2 and NH_3 are equivalent in cost and will co-exist
- NH_3 is preferred for storage & over distances
- Direct use is always better than indirect use due to efficiency losses

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