Energy Innovation Summit 2025

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Planning Hydrogen under uncertainty and complexity

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The hydrogen vision is old

… but for a long time, it was a niche topic

- Hydrogen as an energy source started out as **science fiction** (like many good ideas).

Sources: Nitsch et al. (2008): Leistudie 2008
Pfluger et al. (2017): BMWi Langfristszenarien für die Transformation des Energiesystems

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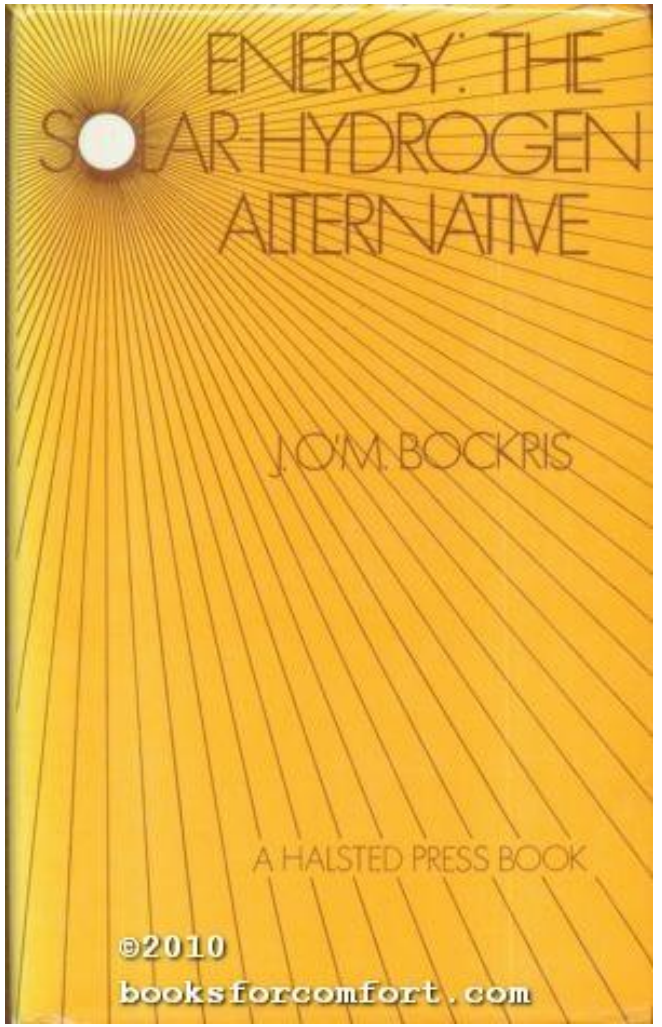

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- The oil crisis sparked the first more concrete ideas of a "**hydrogen economy**."
- After the crisis, the topic faded into obscurity.
- In energy scenarios in Germany and Europe, hydrogen has long played a role — if any — mainly in transportation.
- The reason for this is that hydrogen is neither necessary nor cost-effective for achieving an 80% reduction in greenhouse gas emissions.
- The topic began gaining momentum again after the German government announced in 2019 its goal to become climate-neutral by 2050.

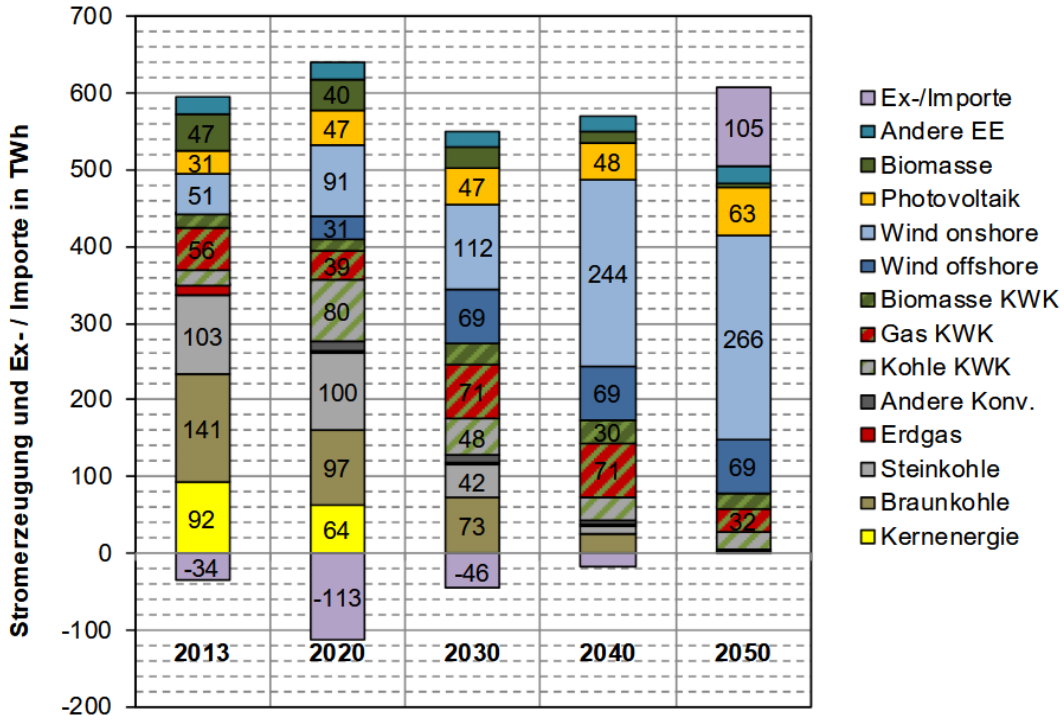

Abbildung 92: Nettostromerzeugung in Deutschland im *Basisszenario*

Sources: Pfluger et al. (2017): BMWi Langfristszenarien für die Transformation des Energiesystems

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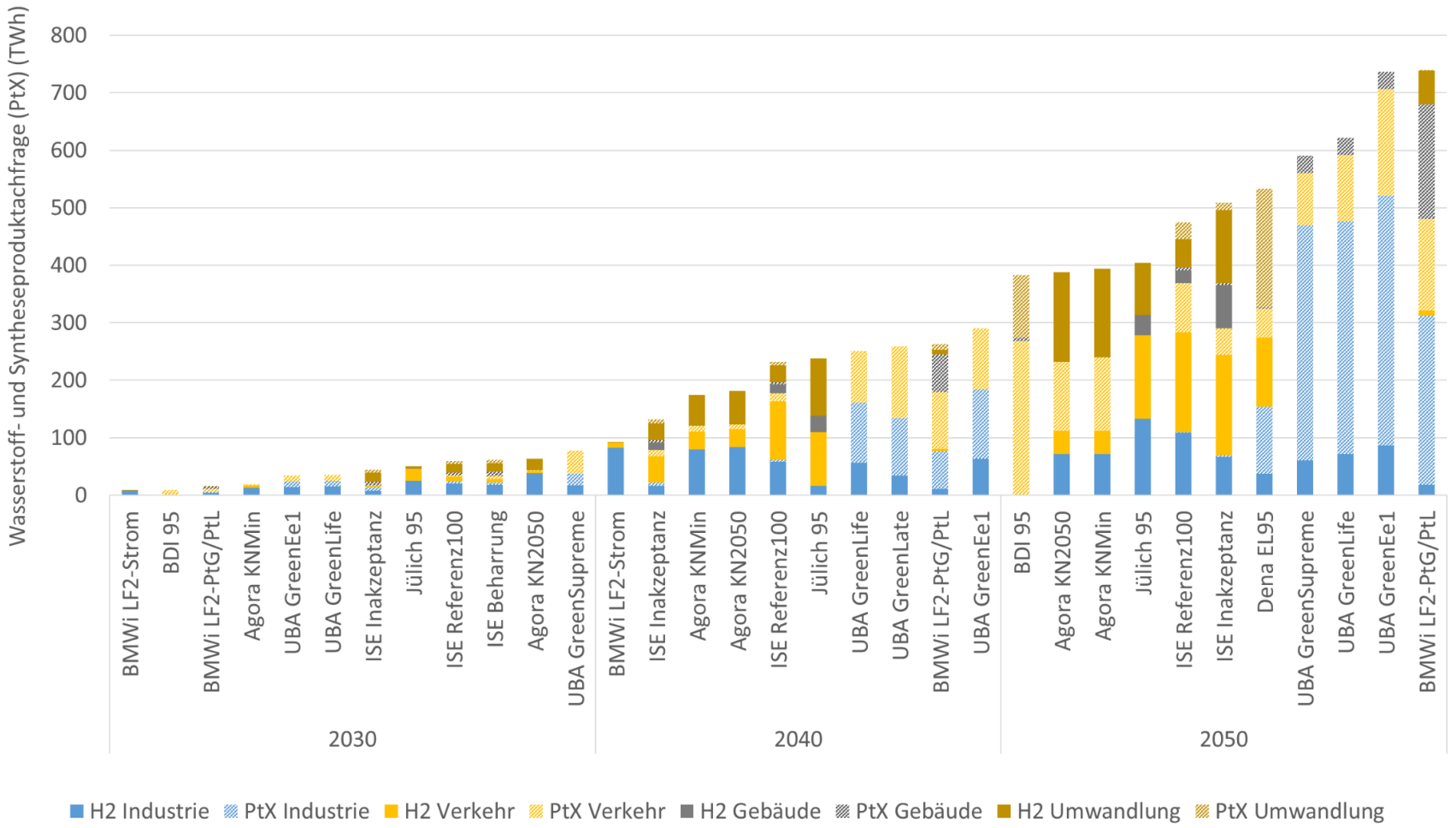
The demand for hydrogen is controversial

… for a variety of reasons



Sources: Fraunhofer (2021): Metastudie Wasserstoff im Auftrag des Nationalen Wasserstoffrats

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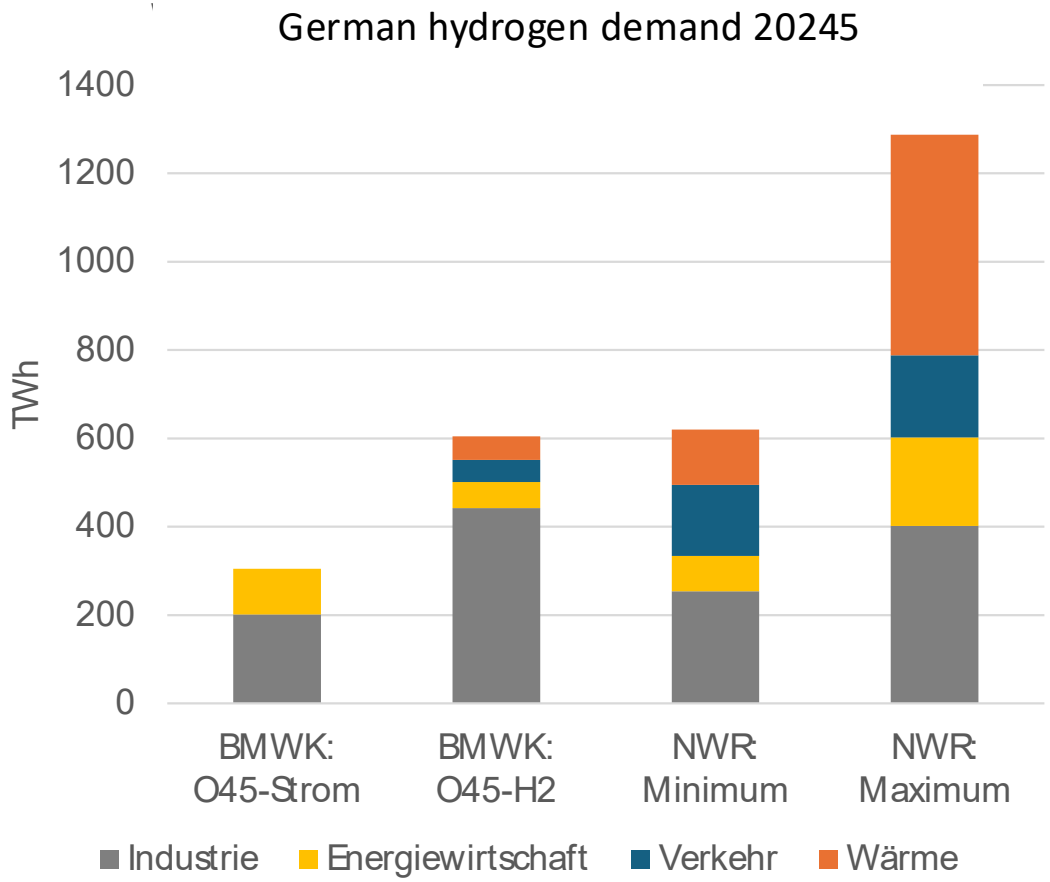
- Long-term hydrogen demand 2045/2050:
  - Estimate in 2021: 400 to 800 TWh
  - Estimate in 2025: 300 to 1,300 TWh

→ Uncertainty is increasing rather than decreasing?

- The uncertainty arises particularly due to imports, which play a major role in virtually all studies.
  - Imports of PtL (Power-to-Liquid)
  - Imports of (pre-)products
- So part of the uncertainty is less about “hydrogen yes/no?” and more about “Are we doing this in Germany/Europe?”

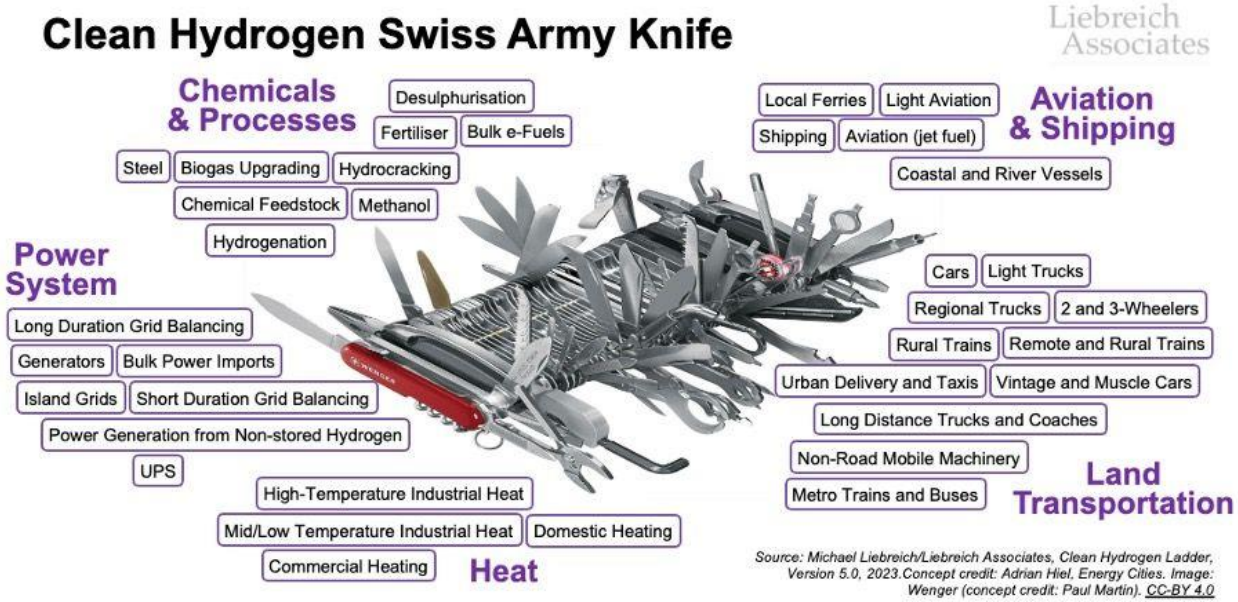


Sources: Fraunhofer (2021): Metastudie Wasserstoff im Auftrag des Nationalen Wasserstoffrats
BMWK (2024): Langfristszenarien
NWR (2024): : THG-Einsparungen und der damit verbundene Wasserstoffbedarf in Deutschland

Hydrogen is versatile

… making it difficult to plan

- Michael Liebreich came up with the clever image of a **Swiss hydrogen pocketknife**.
- Hydrogen is a **versatile energy carrier** that can be used in almost any application, or converted into something with higher energy density.
- But the core idea is this: while we could cut our hair with a Swiss Army knife, we rarely do—because there are tools more suitable for that.



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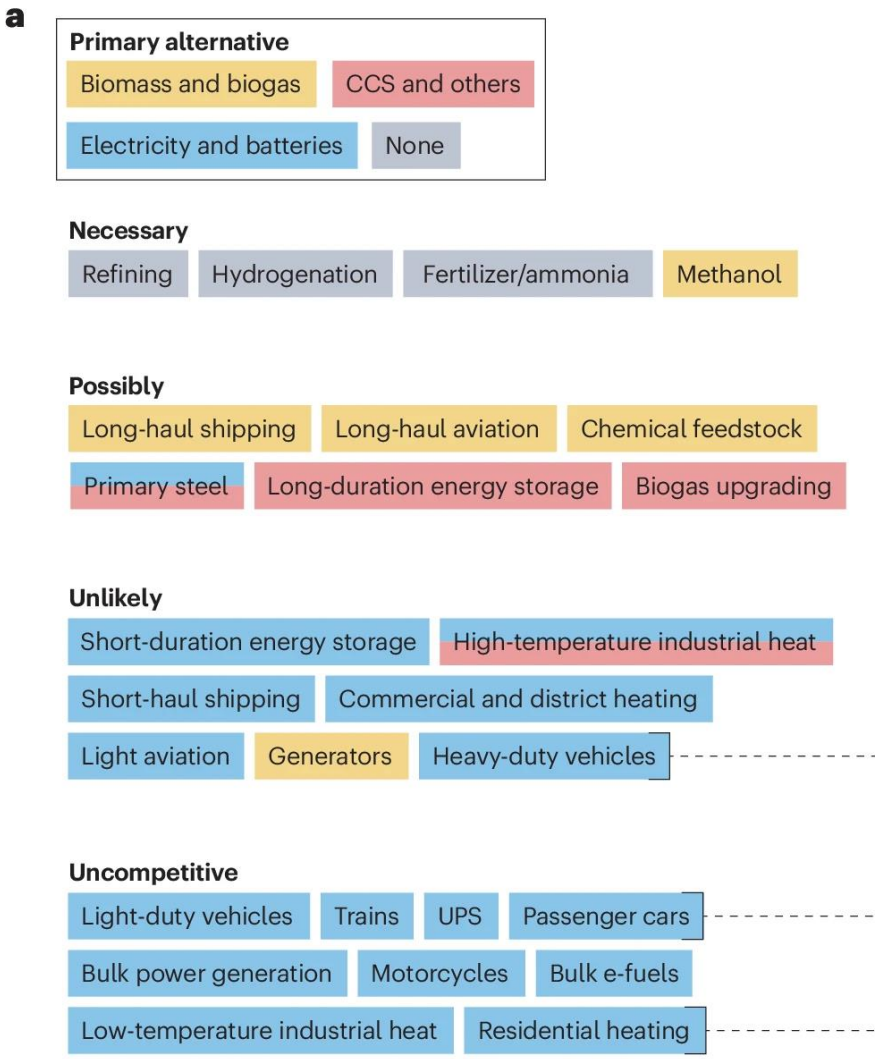
- But the core idea is this: while we could cut our hair with a Swiss Army knife, we rarely do—because there are tools more suitable for that.
- What hydrogen should be used for is more controversial among the broader group of stakeholders than it is in the scientific community.



Source: Johnson et al. (2025) Realistic roles for hydrogen in the future energy transition. Nature Reviews Clean Technology.

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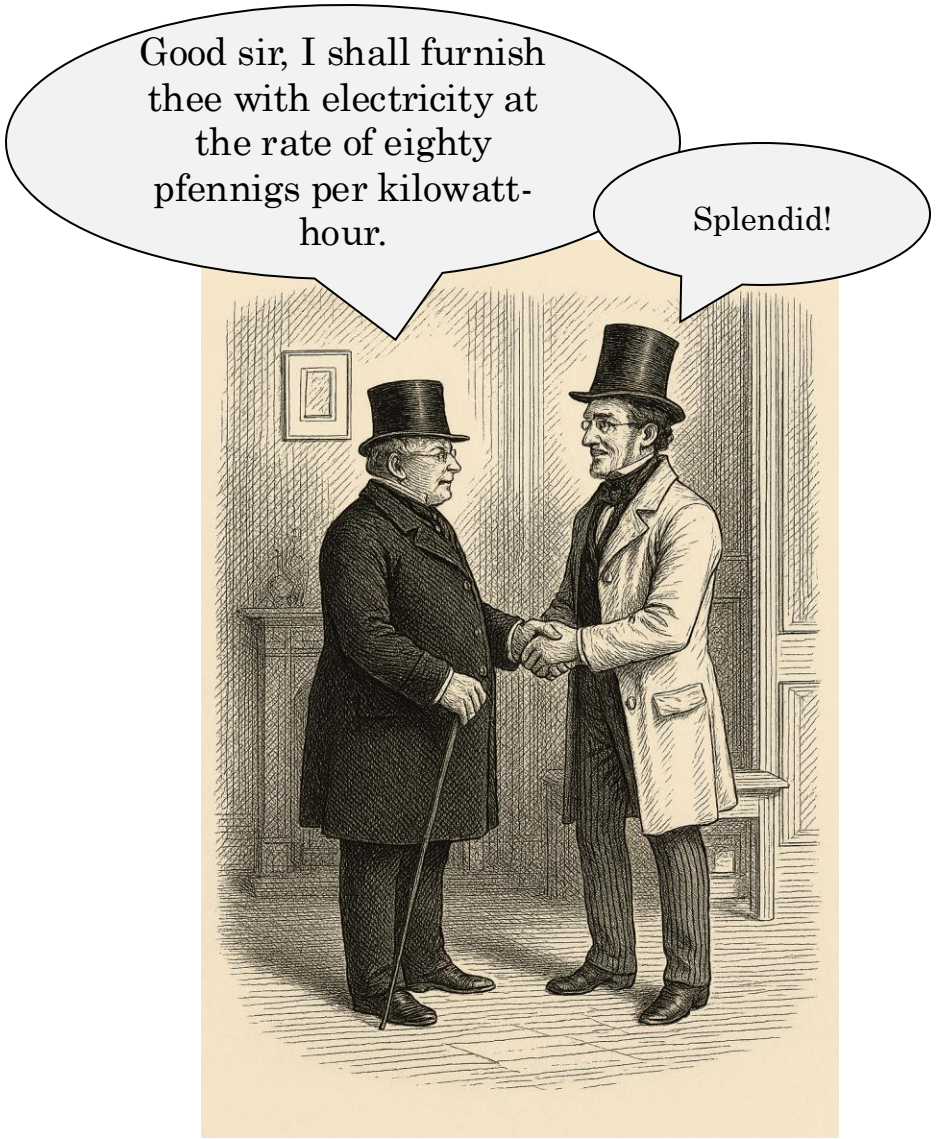
Coordinating the hydrogen ramp-up is complex

… and we need to develop new processes for this

- In the past: **Vertically integrated companies** planned and operated infrastructure through which they supplied customers with energy.
- **Hydrogen is the first scale-up of a new energy carrier in an unbundled energy market.**



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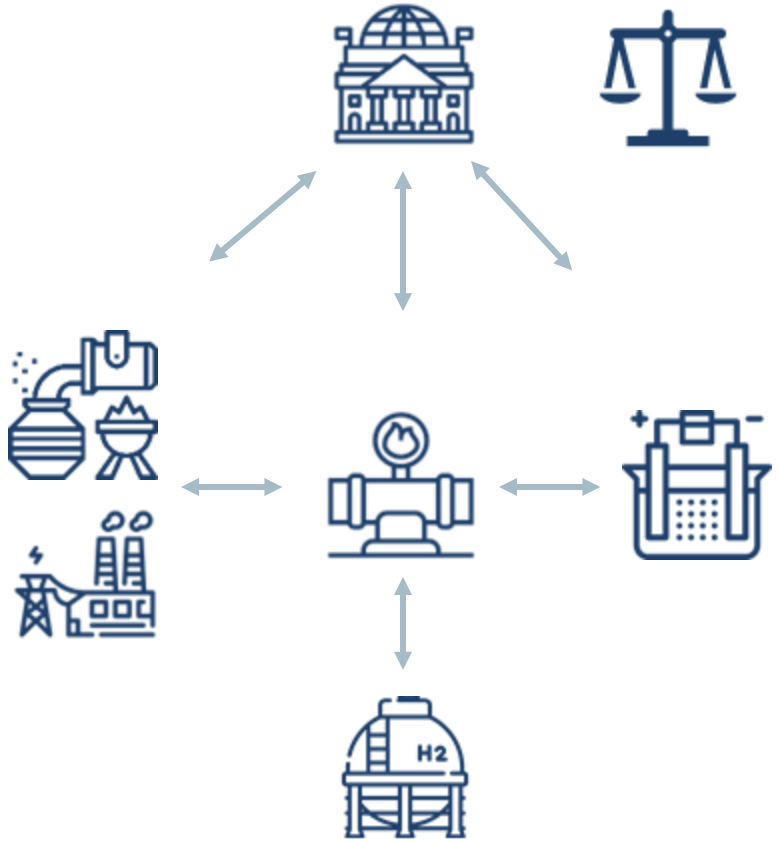
- **Hydrogen is the first scale-up of a new energy carrier in an unbundled energy market.**.
- Today: Many actors need to coordinate their decision:
  - Suppliers
  - consumers
  - infrastructure operators
  - public authorities
- Without subsidies, there would be no investment in scaling up hydrogen over the next 10 years**.**
- European regulations and structures are primarily designed to further develop fully established infrastructures and markets.



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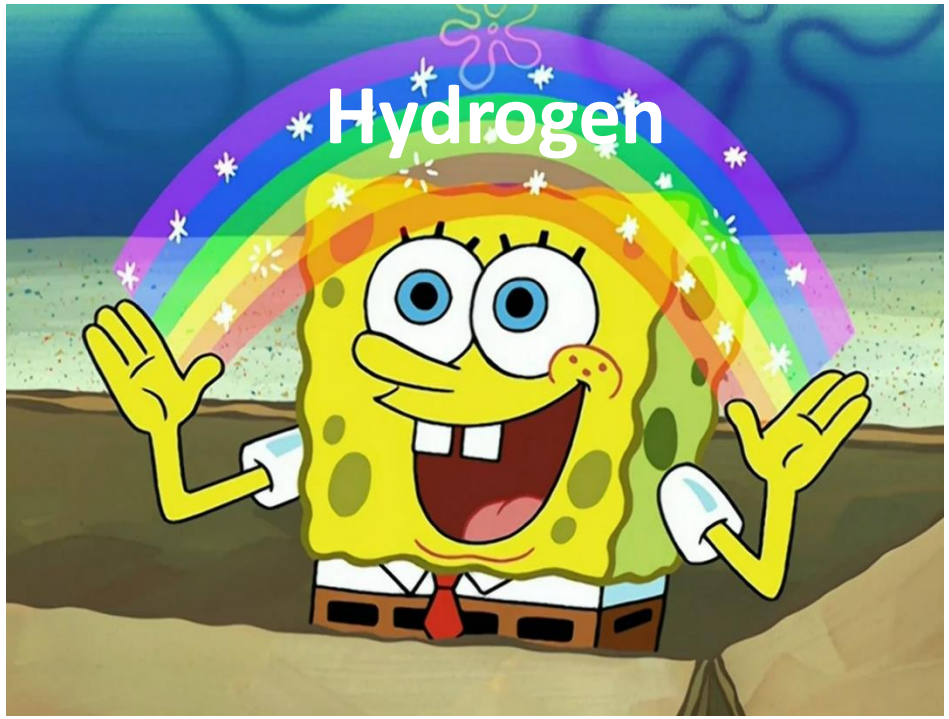
Hydrogen is colourful

…. one molecule, but very different demands regarding its production

Grey hydrogen	from natural gas via steam reforming
Green hydrogen	Electrolysis with renewable electricity
Pink hydrogen	Electrolysis with nuclear power
Yellow hydrogen	Electrolysis with grid electricity
Blue hydrogen	From natural gas with CO_2 capture (CCS)
Turquoise **hydrogen**	Methane pyrolysis: Splits natural gas into H_2 and C
White hydrogen	Naturally occurring geological H_2
Orange hydrogen	Partially used for hydrogen from biomass
Low carbon hydrogen	70% fewer GHG emissions than grey H_2



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Hydrogen is expensive

… and we have to address this fact head-on

- EEX Hydrogen Index HYDRIX current level:
  - Prices for green hydrogen range from approximately **7 to € 8.5 €/kg.**
- **End customer prices** will depend on many factors, especially the **load profile**, including:
  - Market prices,
  - grid fees,
  - storage costs

Source: https://www.eex-transparency.com/de/wasserstoff

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  - Market prices,
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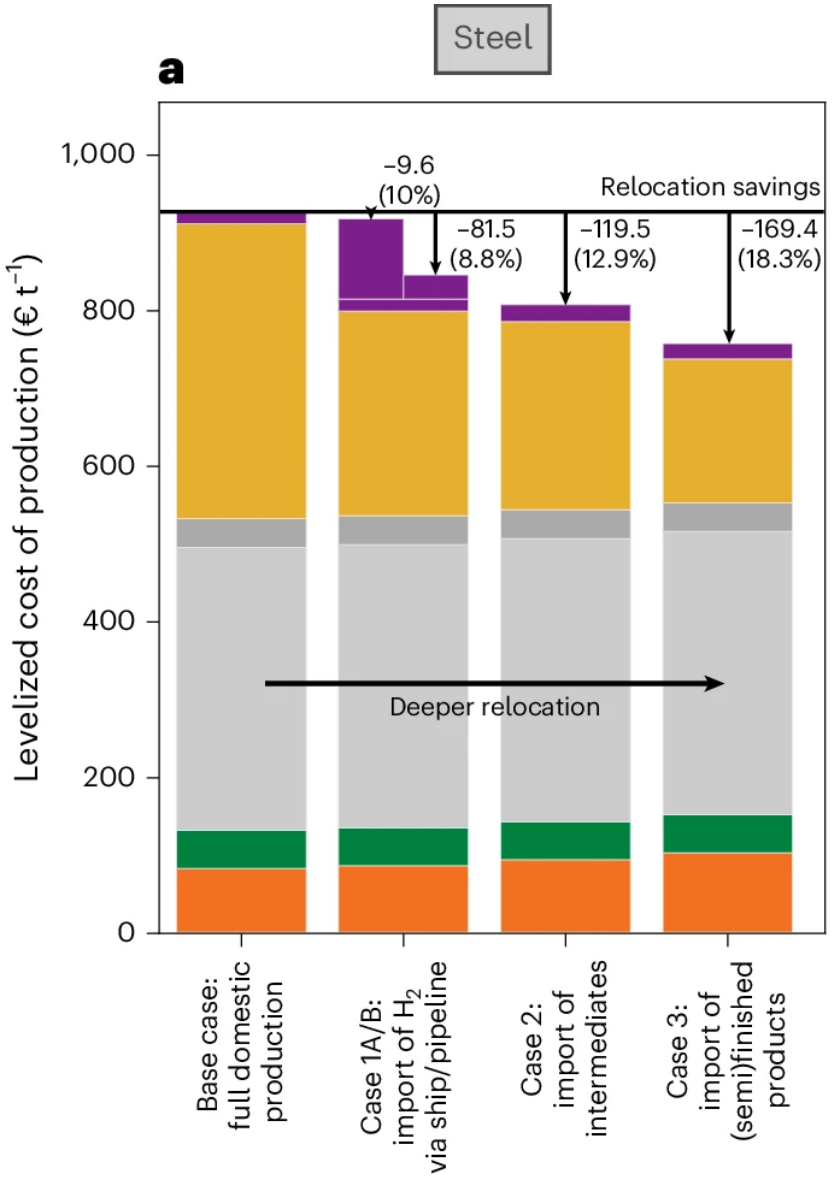
  - storage costs
- Blue hydrogen is (presumably) cheaper to produce, but the actual prices will be a different matter.
- The ETS will only achieve price parity with natural gas rather in the 2040s than 2030s.
- Knowing the best option for something is not enough; We must ask our energy optimization models better questions or handle the results better.



Source: https://www.eex-transparency.com/de/wasserstoff

Verpoort et al. (2024) Impact of global heterogeneity of renewable energy supply on heavy industrial production and green value chains. Nature Energy.

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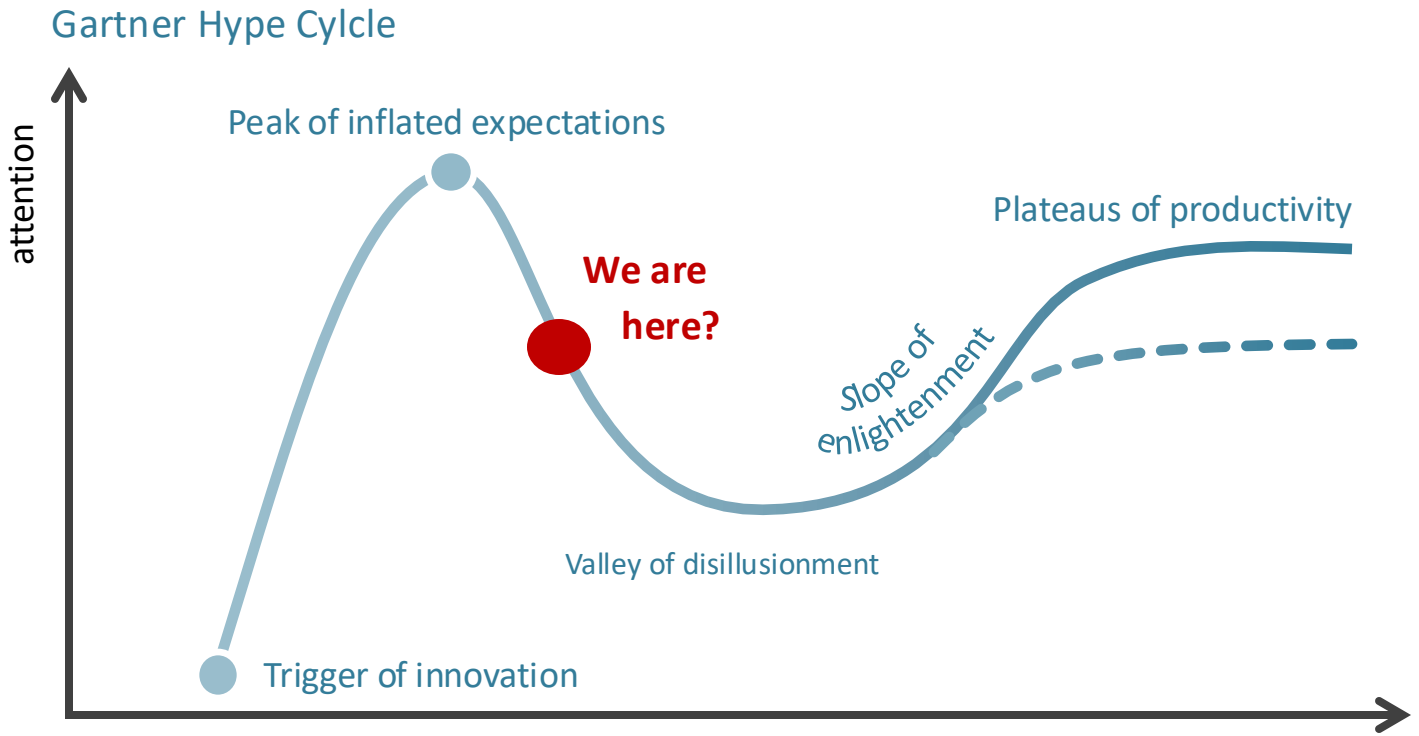
Hydrogen is hype

… but we have to make it a productive part of the energy transition

- The topic of hydrogen has (and still does) clear characteristics of a bubble:
  - Global electrolysis announcements for 2030 exceed 422 GW
  - Former EU electrolysis target: 10 Mt domestic production plus 10 Mt imports
  - Prediction of “cost parity with grey hydrogen by 2030” by many actors
- The hydrogen hype created FOMO in many actors’ minds.



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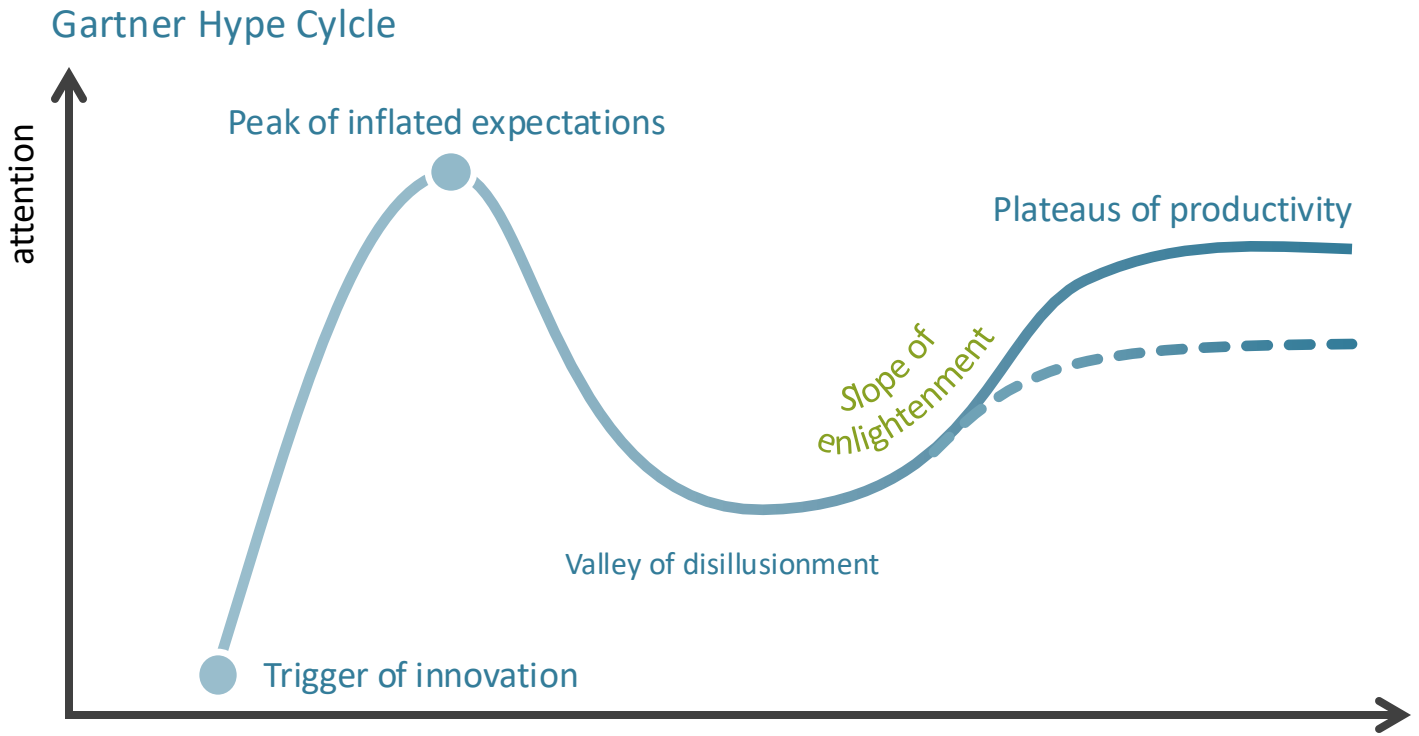
- The “path of enlightenment” leads through:

1. **Scaling back** expectations,
2. **understanding** where hydrogen has potential and where not. (e.g. through energy systems modelling),
3. developing a robust **long-term strategy**, that handles uncertainty and includes honesty about who pays for the extra costs at the different stages.
4. managing the ramp-up through policies and regulation focused on **efficiency and effectiveness**.

- **If this succeeds, hydrogen can become a key technology of the energy transition.**



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Thank you for your attention!