

Pathways to an efficient future energy system

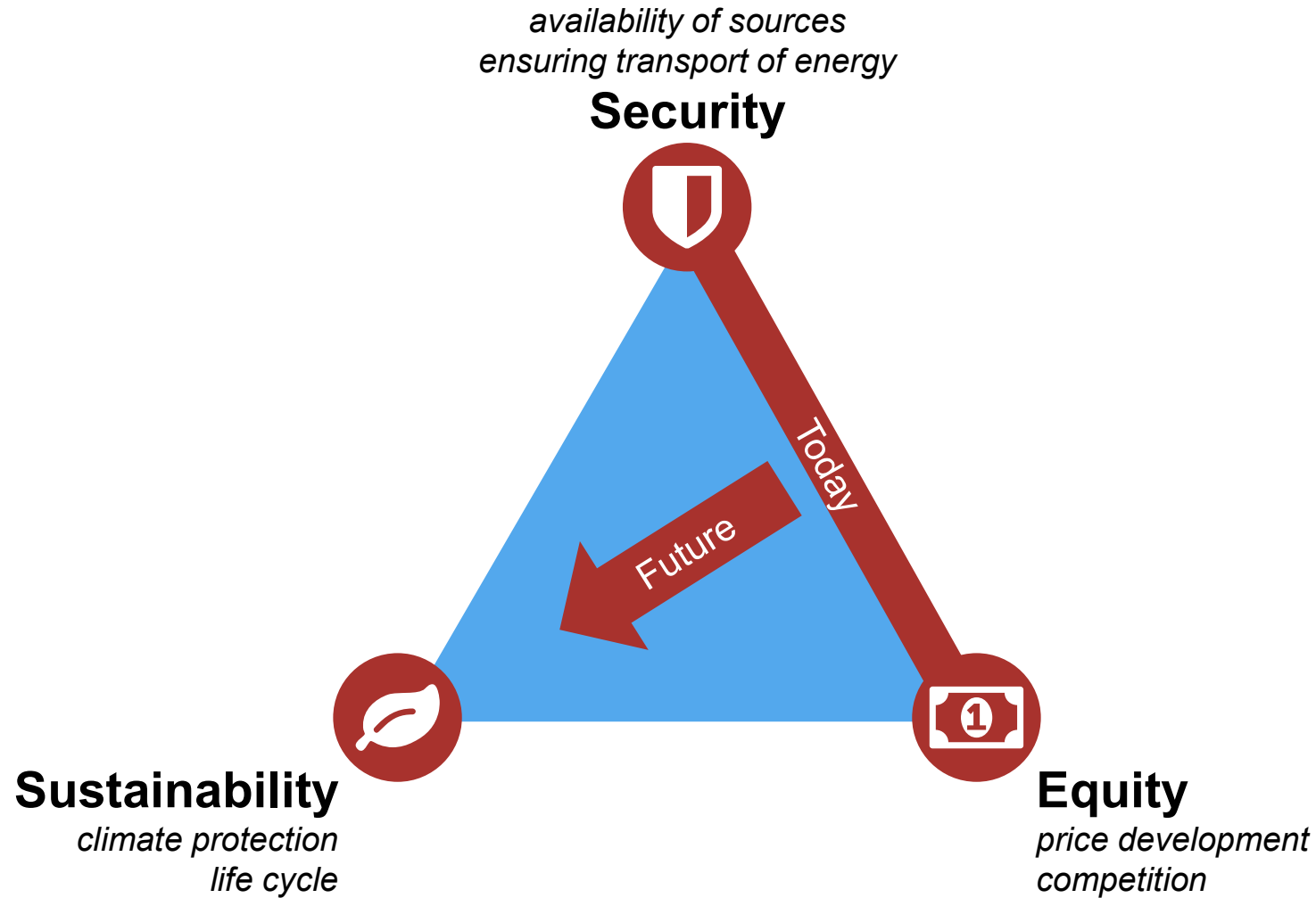
André Bardow

ETH Zurich

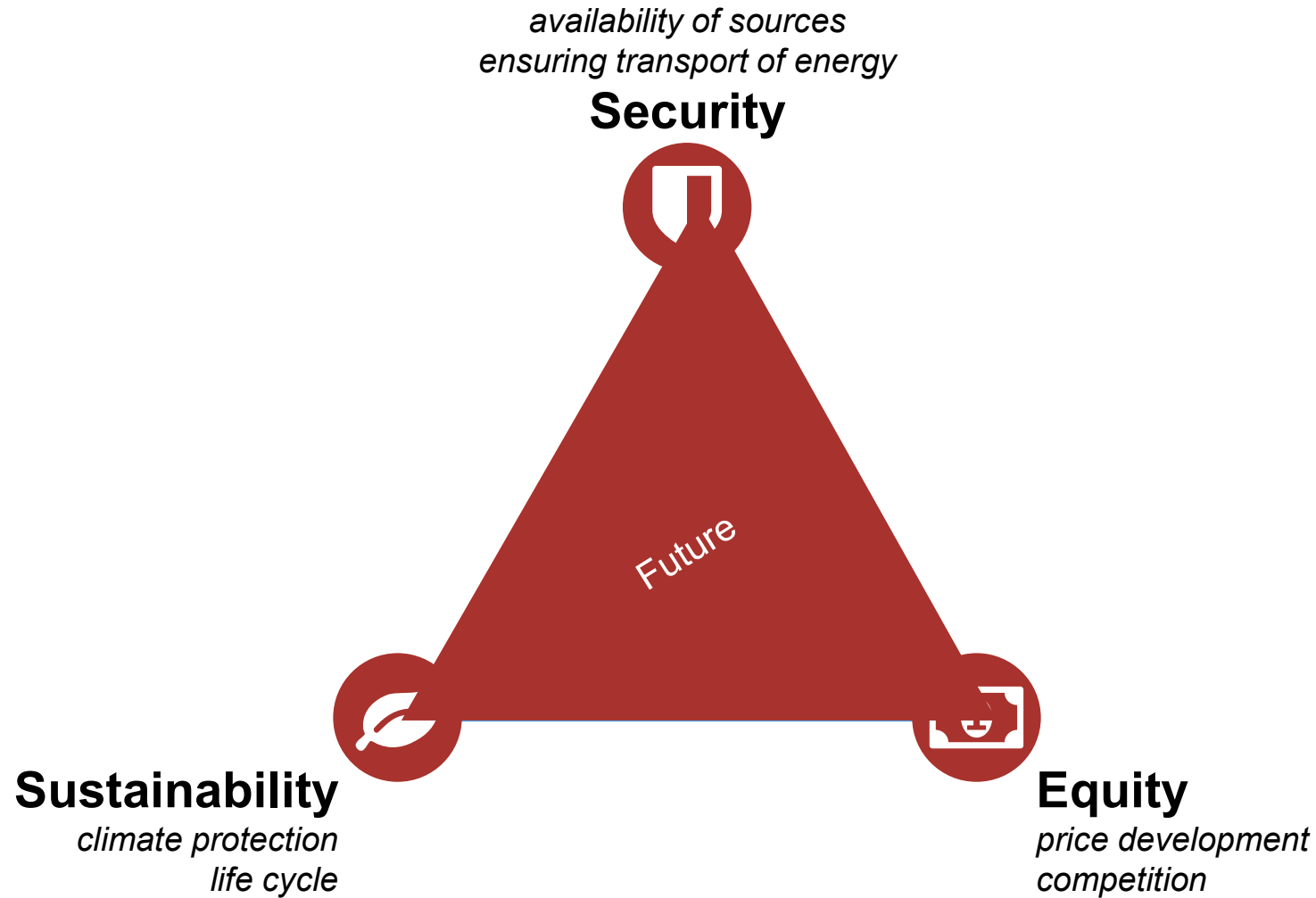
11th Swiss Symposium Thermal Energy Storage



Why a **future** energy system ? The Energy Trilemma



Why a **future** energy system ? The Energy Trilemma



Why an **efficient** future energy system ?



Christiane Reinert

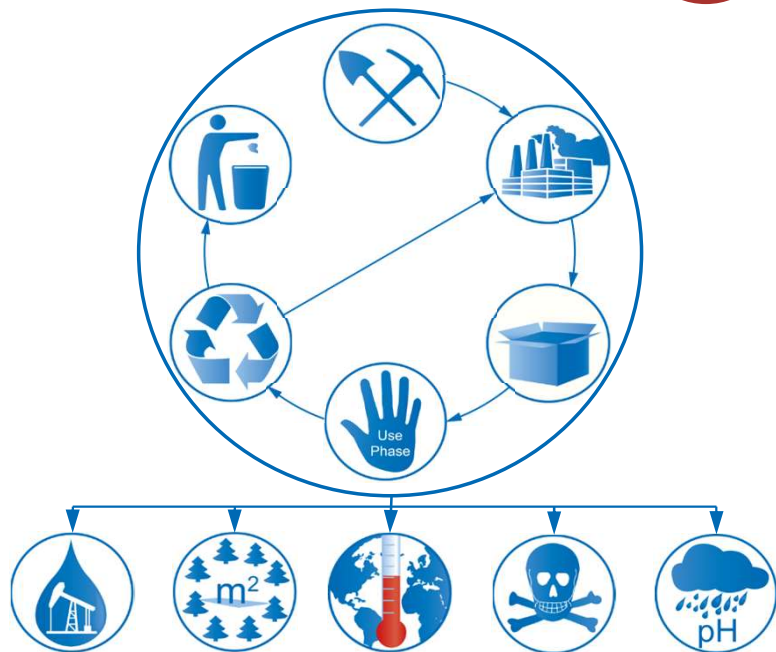


Sarah Deutz

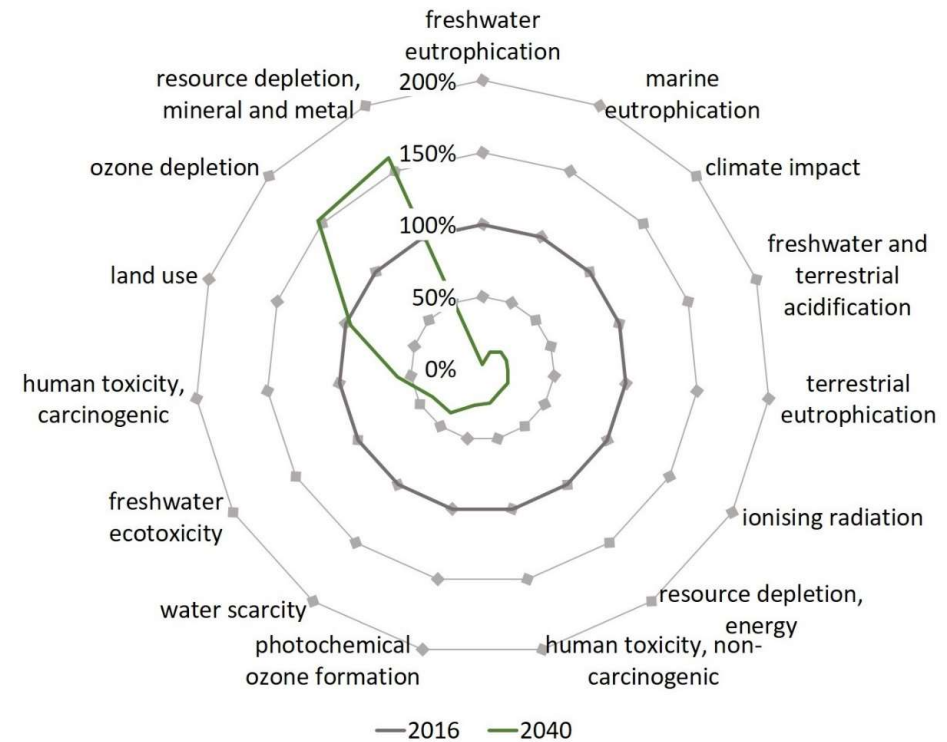


Nils Baumgärtner


Sustainability



Impacts of low-carbon energy system



- Low-carbon energy transition has many environmental co-benefits
- But also: unwanted side-effects we need to take care of
⇒ Efficiency remains key for the environment (and economics)

An aerial photograph of Zurich, Switzerland, showing the city's architecture, the Limmat river, and the ETH Zurich campus. The image is split into two horizontal sections. The top section shows a wide view of the city with the river and various buildings. The bottom section is a closer view of the ETH Zurich campus, featuring a large building with a prominent dome and a yellow construction crane in the foreground.

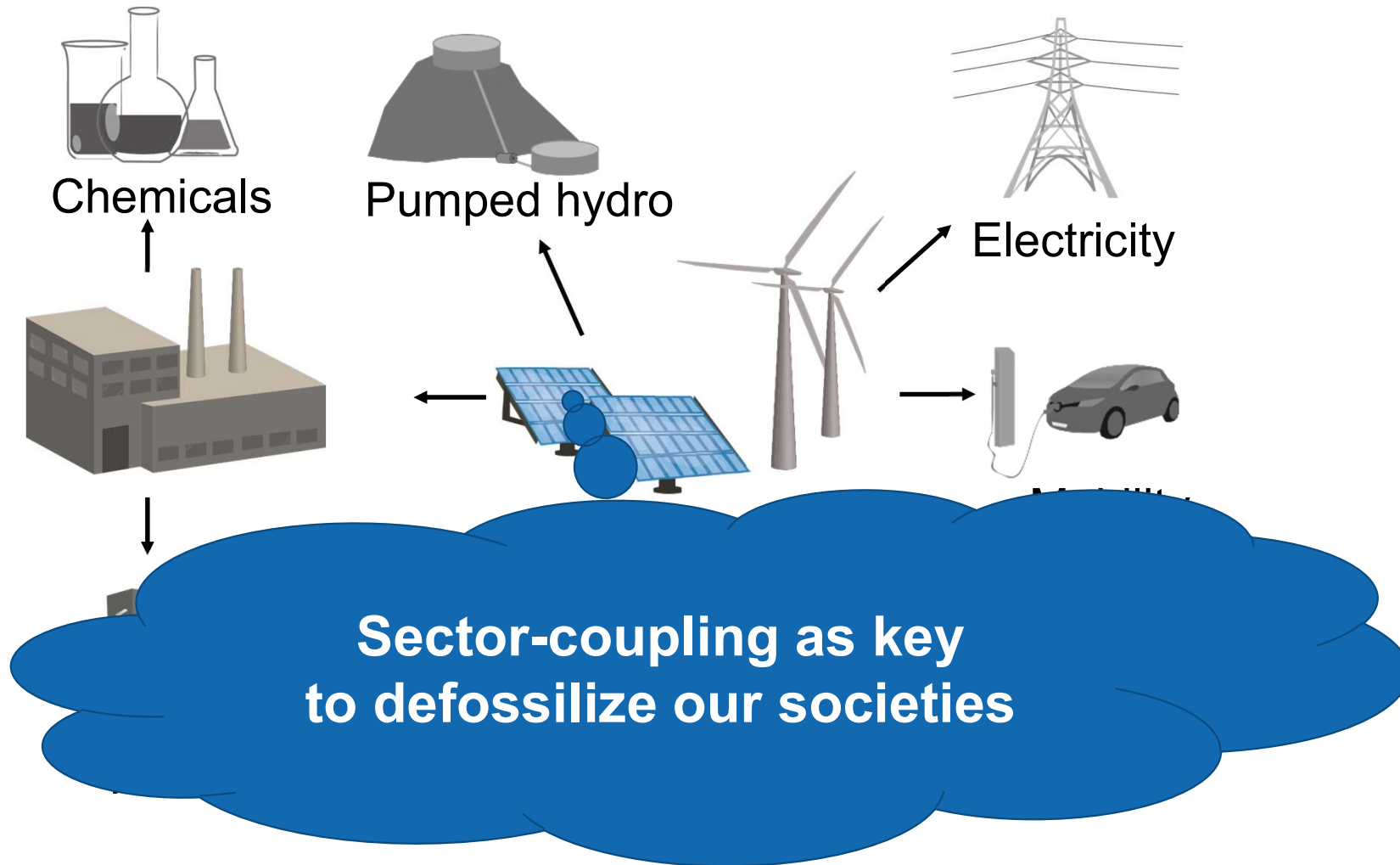
Pathways to an **efficient** **future** energy system

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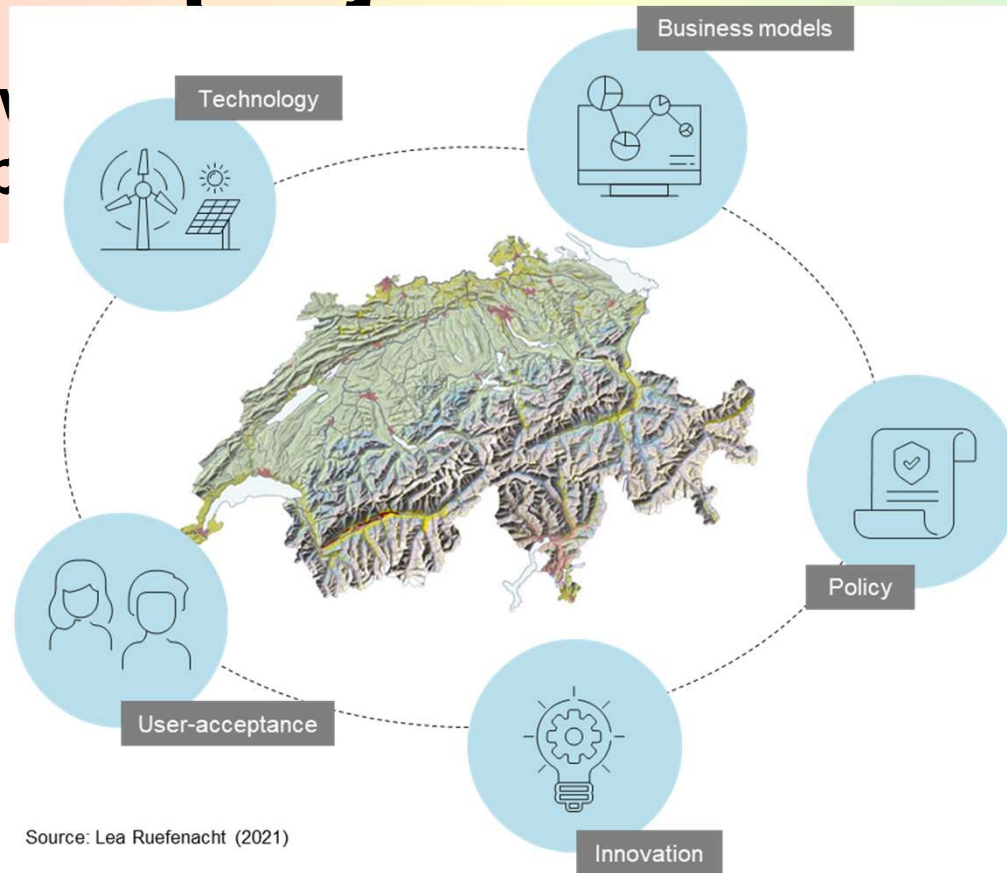
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Power-to-X: Pathways to efficient future energy systems



PATHFNR project

Improve renewable energy
through flexibility

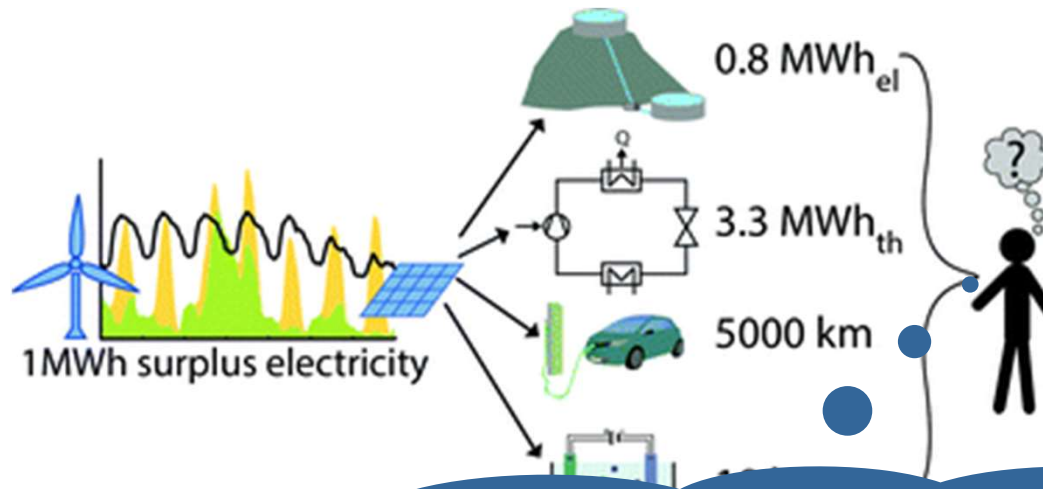


Source: Lea Ruefenacht (2021)

Power-to-What? The efficiency of sector-coupling



André Sternberg



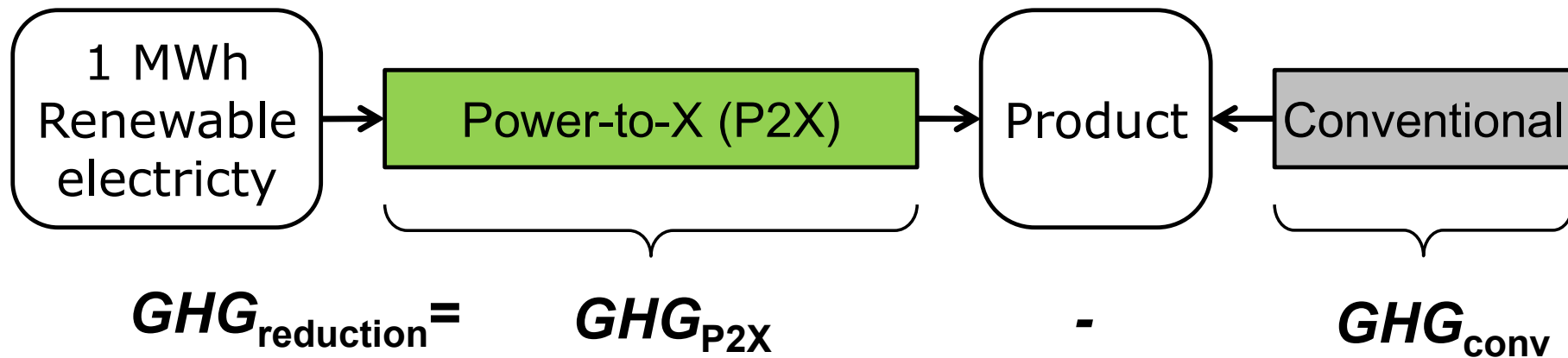
Given 1 MWh of surplus electricity,
which sector
brings the greatest environmental benefit?

Sternberg, Bardow, *Energy Environ. Sci.*, 2015, 8, 389

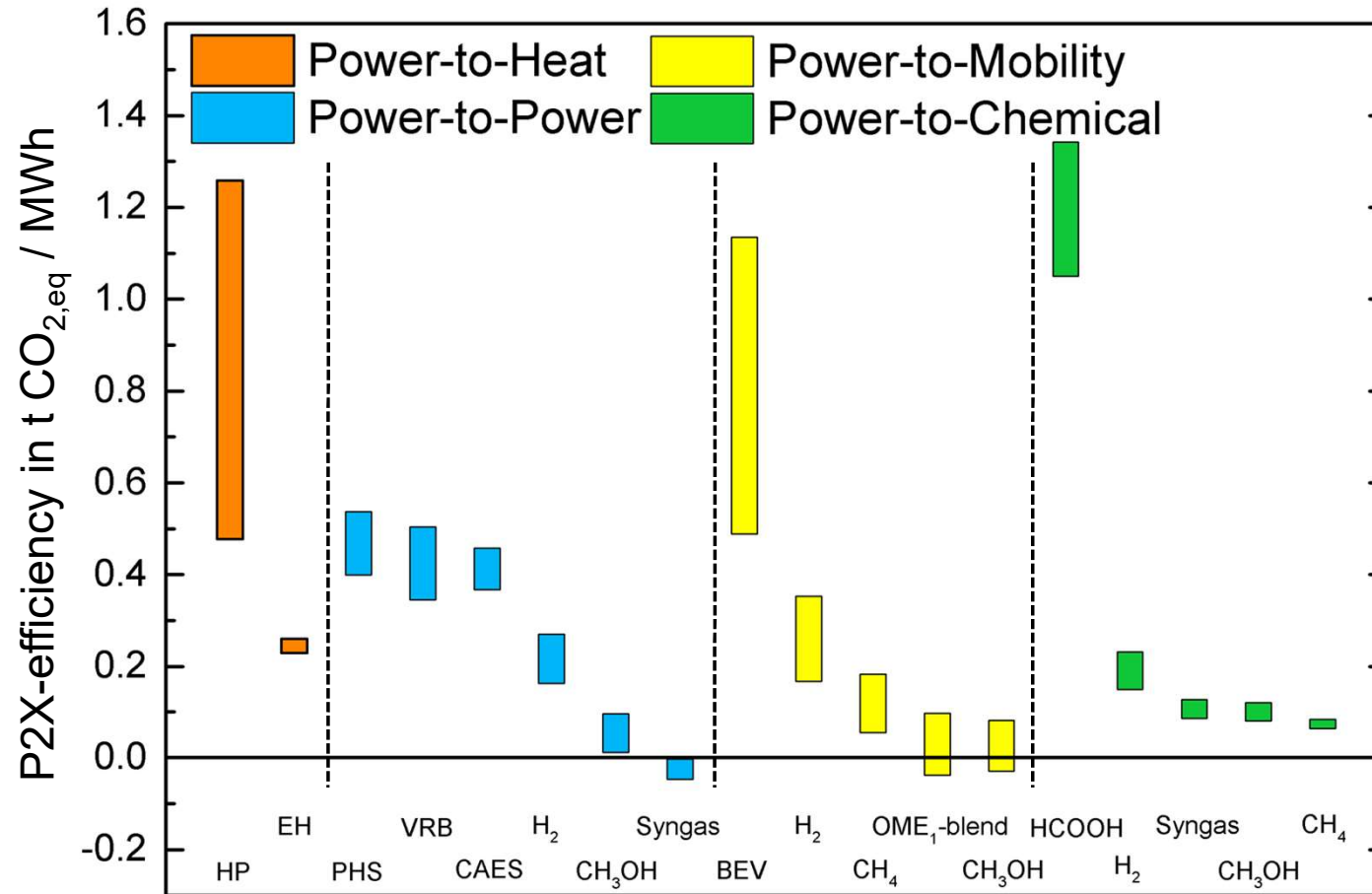
Efficiency is

Given 1 MWh of surplus electricity,
which sector
brings the greatest environmental benefit?

$$\text{P2X efficiency} = \frac{\text{reduction in GHG emissions}}{\text{per MWh renewable electricity}}$$

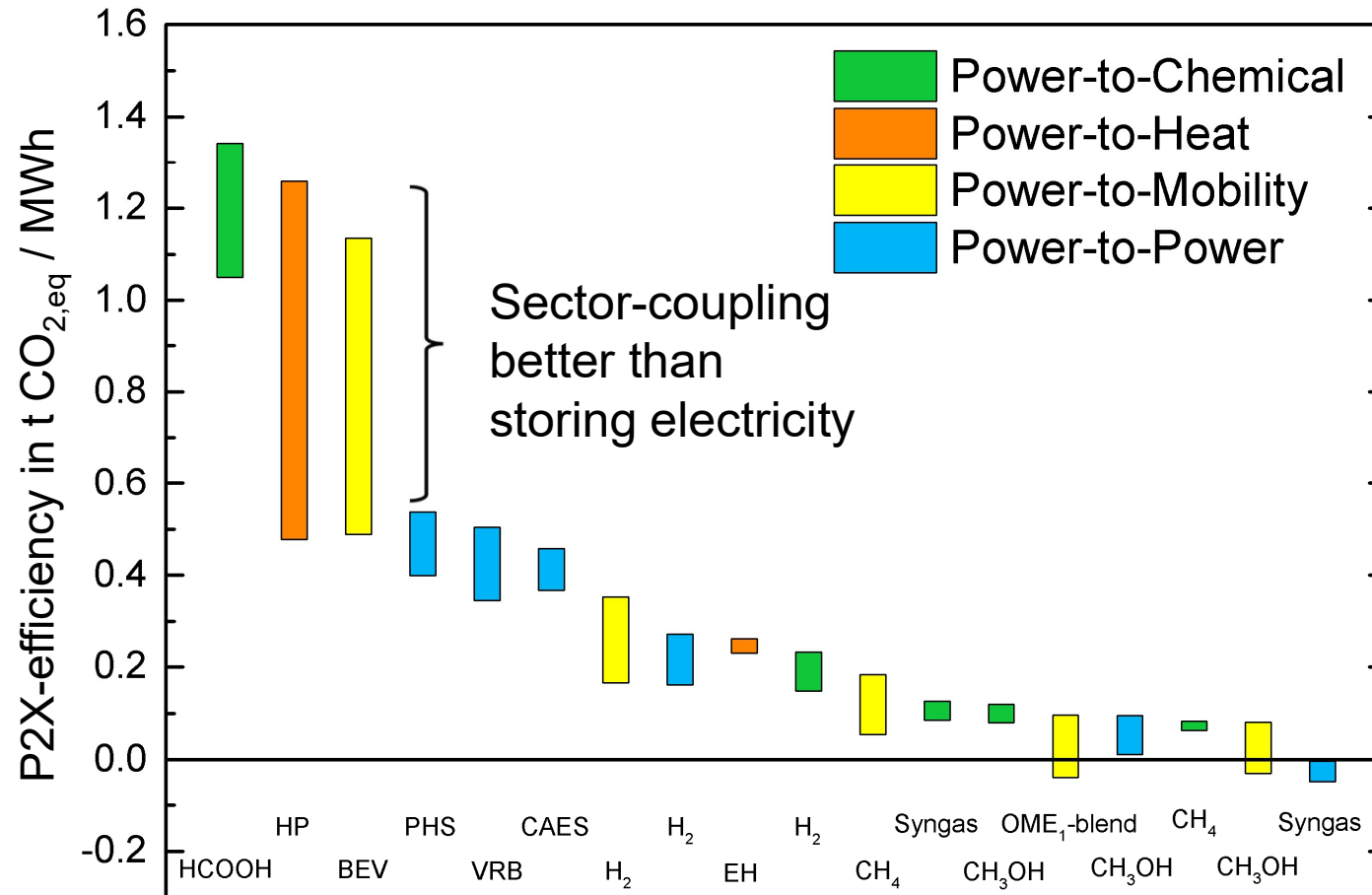


Power to What?



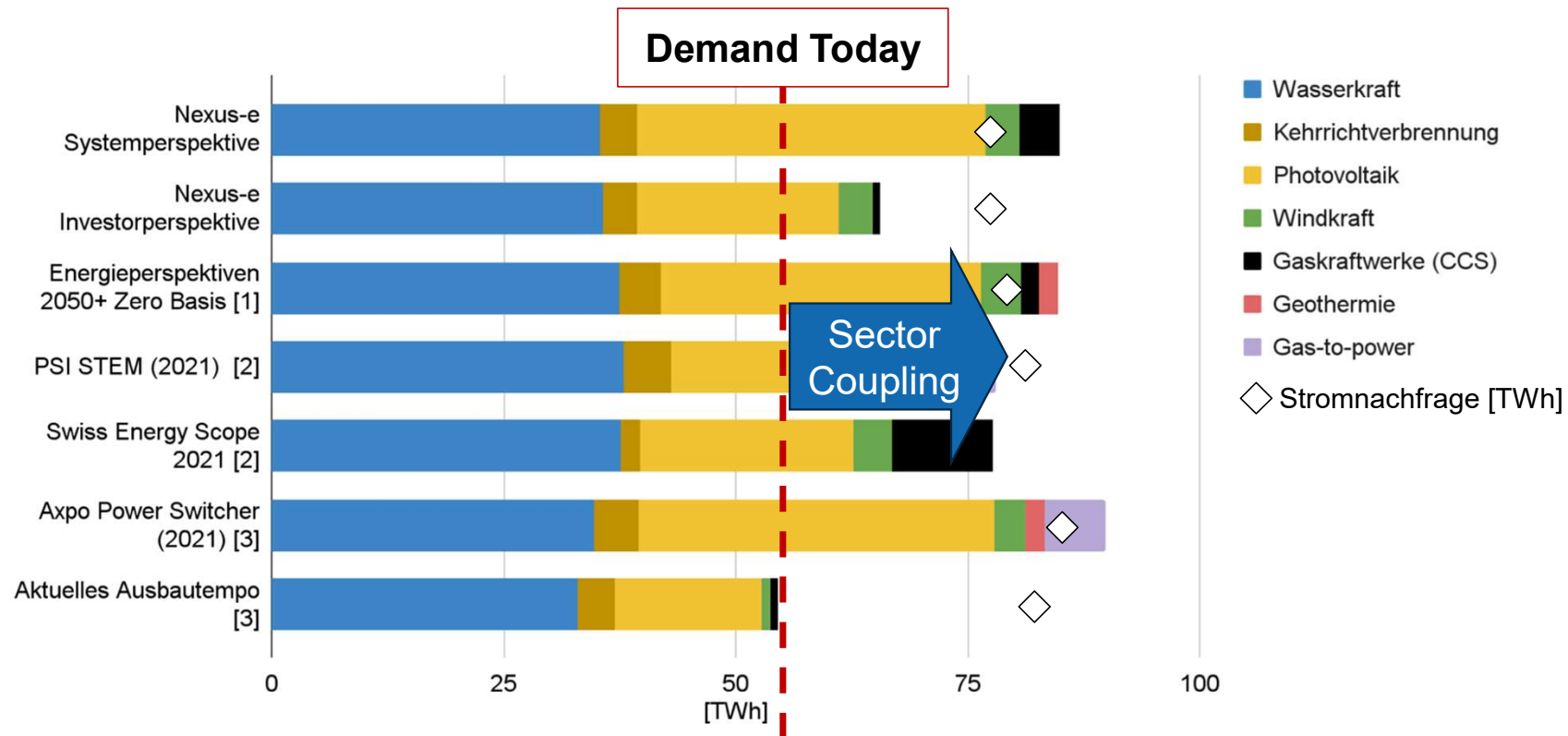
Sternberg und Bardow, *Energy Environ. Sci.*, 2015,8, 389-400.

Power to What?



Sternberg und Bardow, *Energy Environ. Sci.*, 2015,8, 389-400.

Future Electricity Production in CH

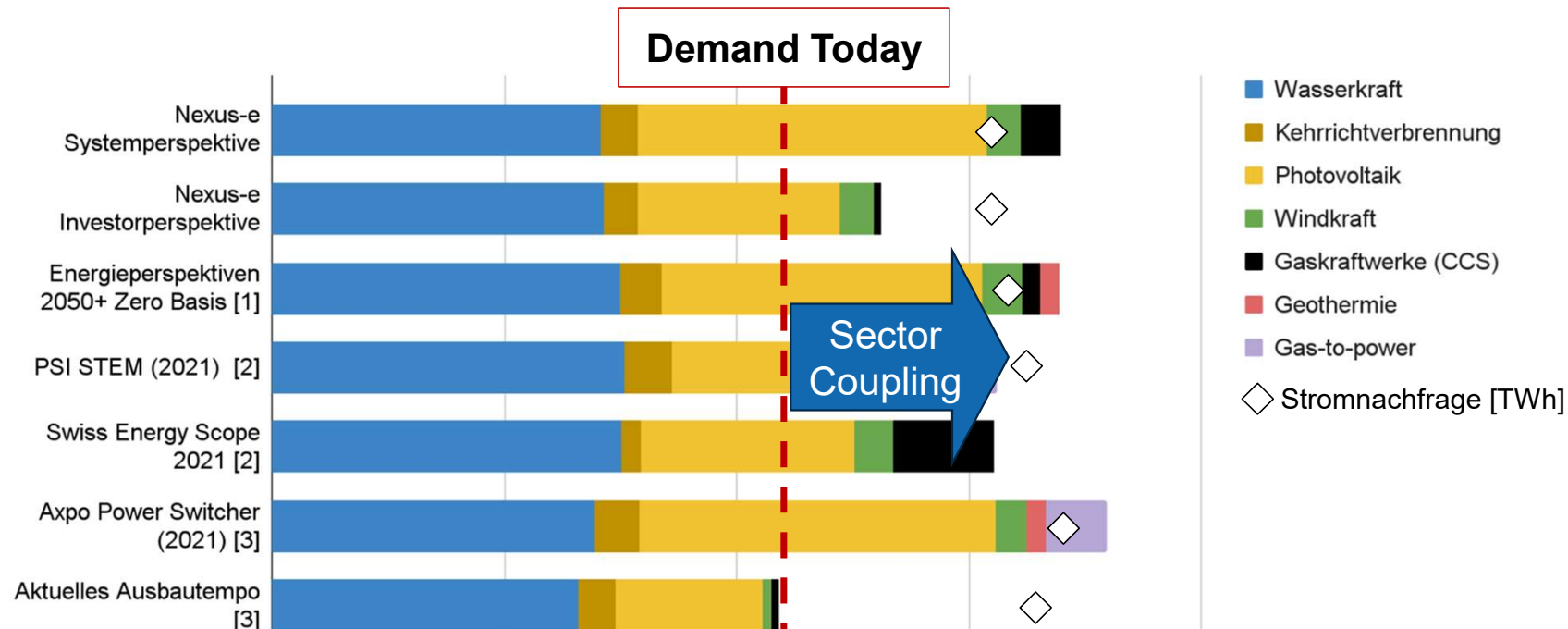


[1]: BFE Energieperspektiven 2050+, Szenario Zero Basis, <https://www.bfe.admin.ch/bfe/en/home/policy/energy-perspectives-2050-plus.html>

[2]: JASM (2021). Transformation of the Swiss Energy System for a Net-Zero Greenhouse Gas Emission Society. JASM synthesis report.

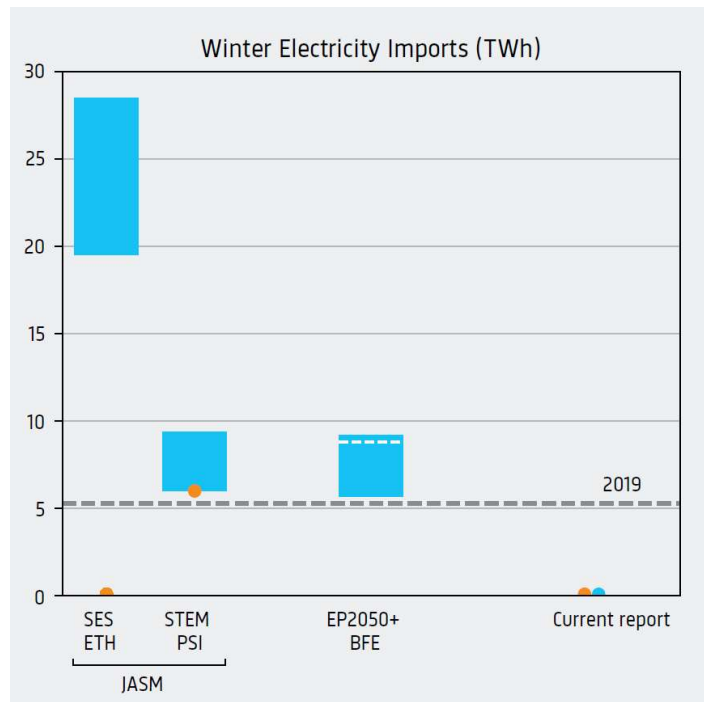
[3]: Axpo Power Switcher (2021). <https://powerswitcher.axpo.com/>

Future Electricity Production in CH



- Sector coupling can be better than electricity storage
... and will increase electricity demand

Efficiency effects of sector coupling



Radio SRF 1 >

Möglicher Mangel

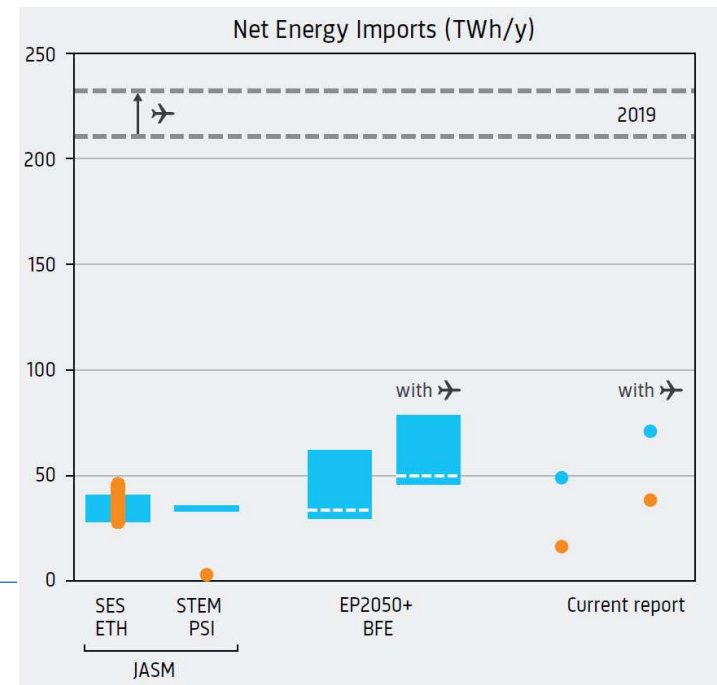
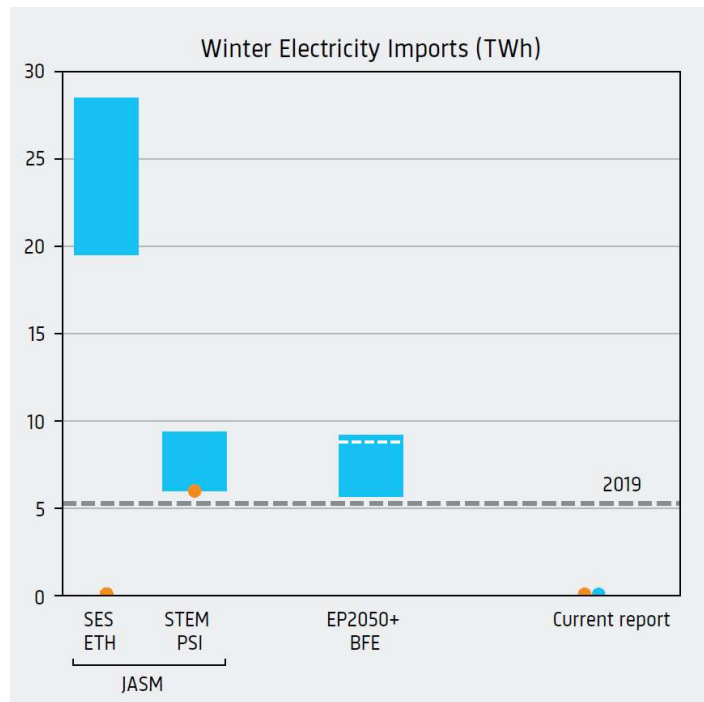
Risiko einer Stromlücke in der Schweiz: Das sind die 8 Gründe

Vor allem im Winter droht uns in Zukunft eine Strommangellage.

- Increased electricity demand might require more winter imports

[4]: Swiss Academies of Arts and Sciences. 2022. Swiss Energy System 2050: Pathways to Net Zero CO2 and Security of Supply

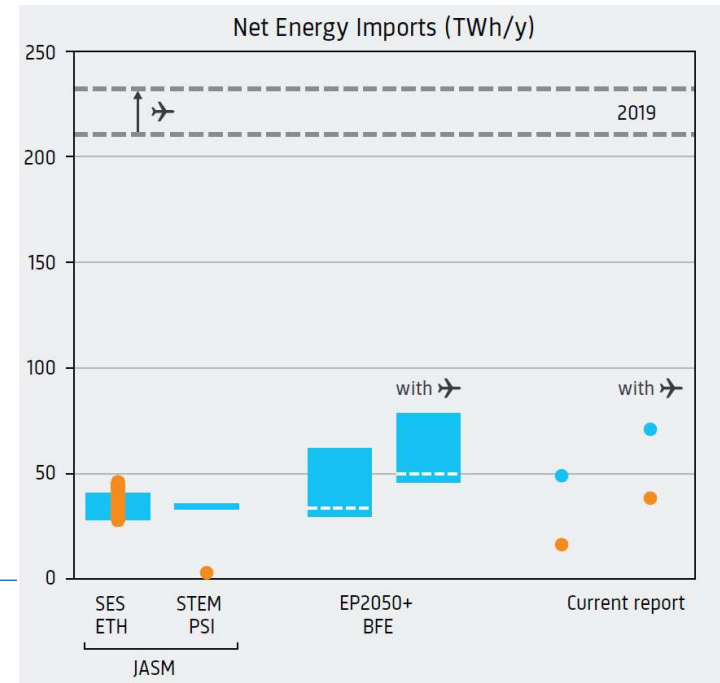
Efficiency effects of sector coupling



- Increased electricity demand might require more winter imports

[4]: Swiss Academies of Arts and Sciences. 2022. Swiss Energy System 2050: Pathways to Net Zero CO2 and Security of Supply

Efficiency effects of sector coupling



- Increased electricity demand might require more winter imports
- Sector coupling more than halves energy imports

[4]: Swiss Academies of Arts and Sciences. 2022. Swiss Energy System 2050: Pathways to Net Zero CO2 and Security of Supply

Sector coupling yields new flexibility



Patricia Mayer



David Shu



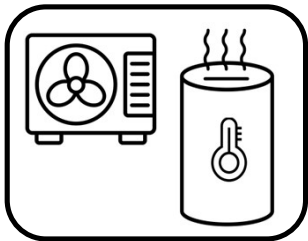
Ludger Leenders



Florian Baader

Flexibility in Industry

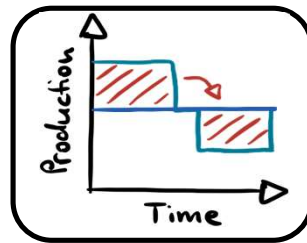
Power-to-Heat + Thermal energy storage (TES)



Cheap, Efficient

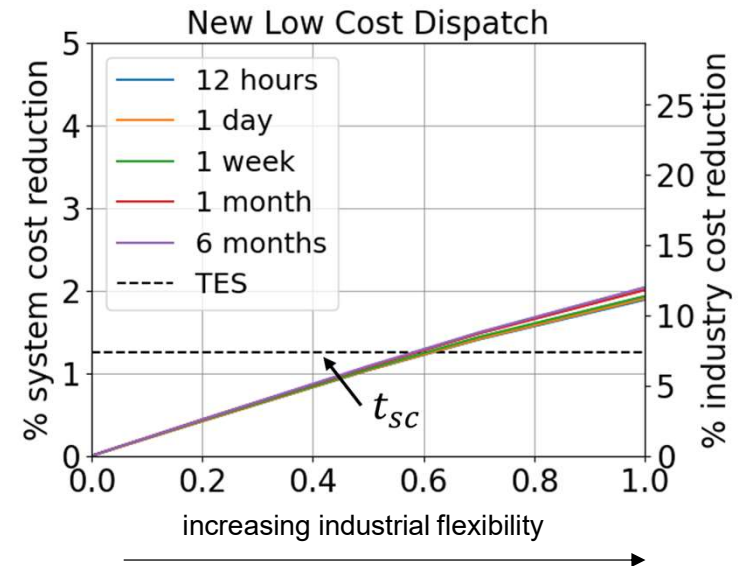
Additional components, Space

Shift in production



No additional components

Adaption of production process



- Swiss industry could reduce its energy cost by up to 20%
- Thermal Energy Storage could harvest up to 60% of this potential



Pathways to an efficient ✓
future ✓ energy system

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Saying **No** means saying **Yes** to something else

Saying **No** means saying **Yes** to something else



Florian Baader

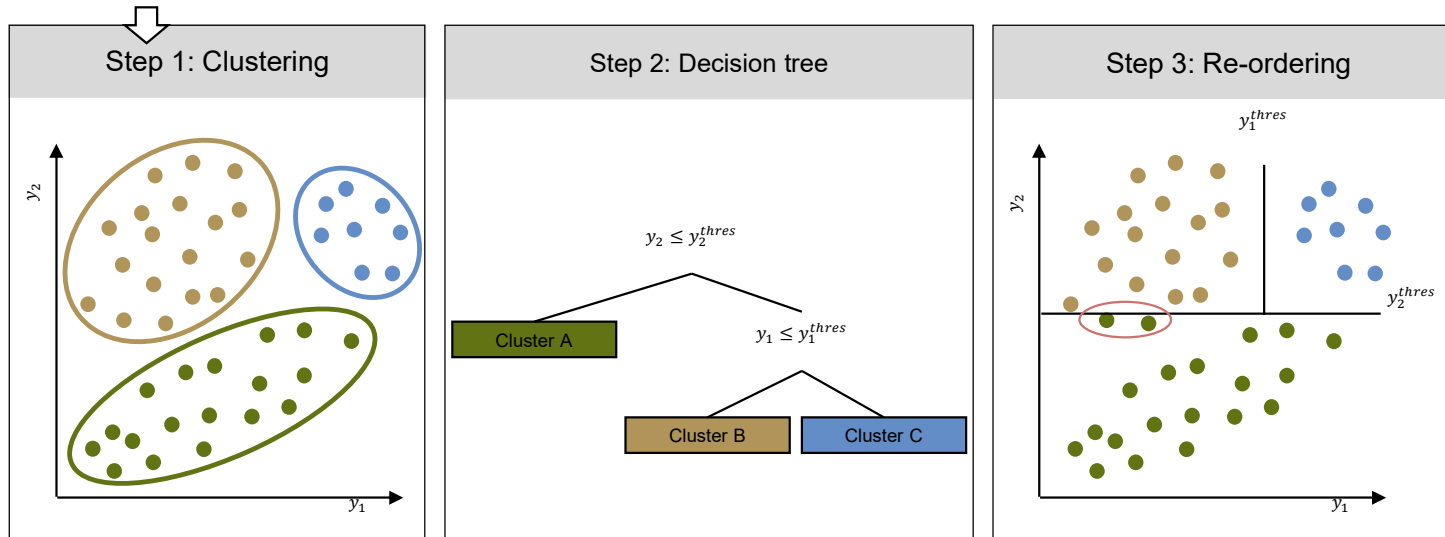


Stefano Moret

Run	y_1	y_2	[...]	y_m
1				
2				
3				
...				
N				

Table with m Outputs of Interest y_j for N runs (compare to Figure 3)
Steps are shown for the case of $m = 2$

1000's scenarios with varying assumptions on prices, availabilities, etc.

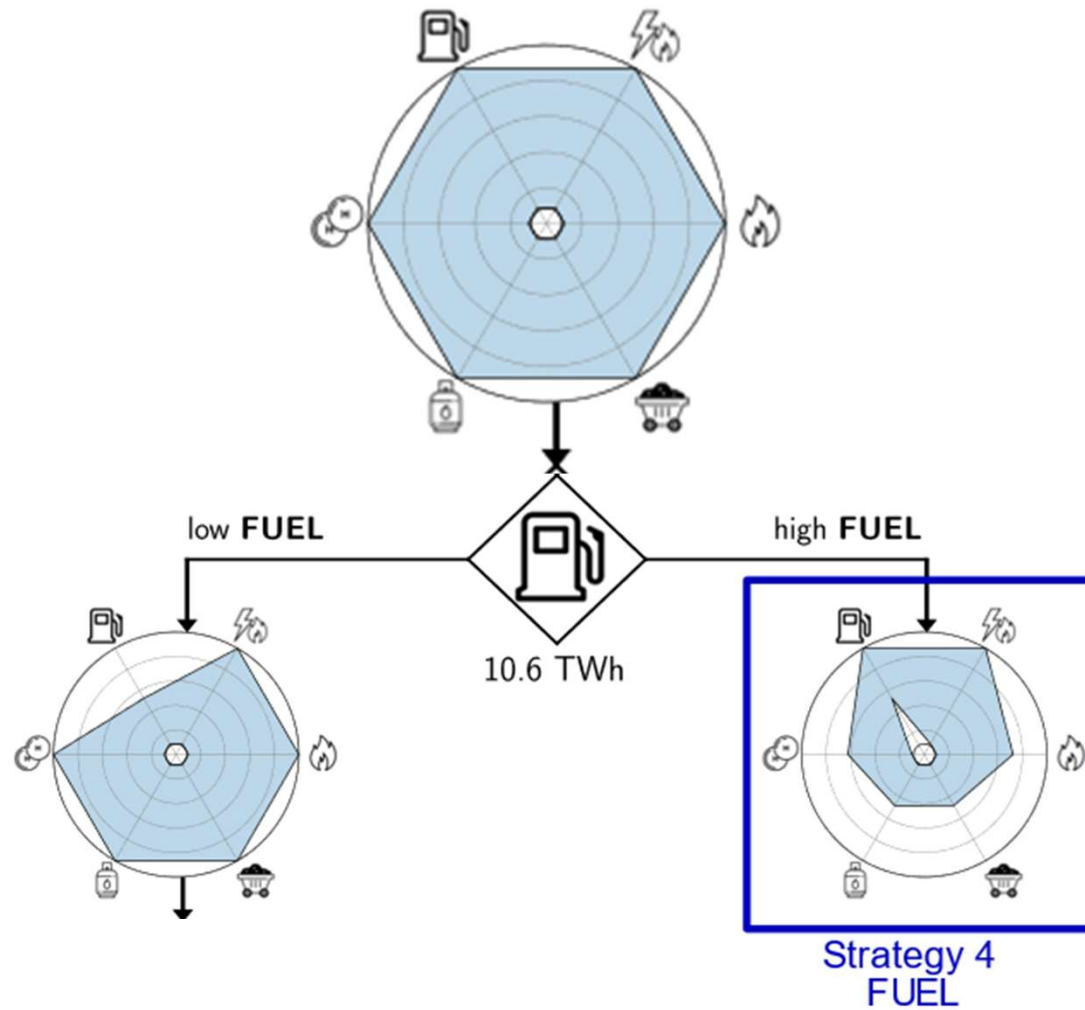
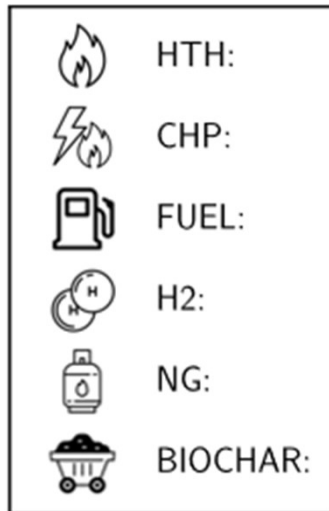


Decision trees for the Energy Transition

Software Available on GitHub: <https://www.gitlab.ethz.ch/epse/systems-design-public/decide/>

Baader, Moret et al., *submitted*

Biomass in the Swiss energy transition



Gabriel Wiest



Gianfranco Guidati

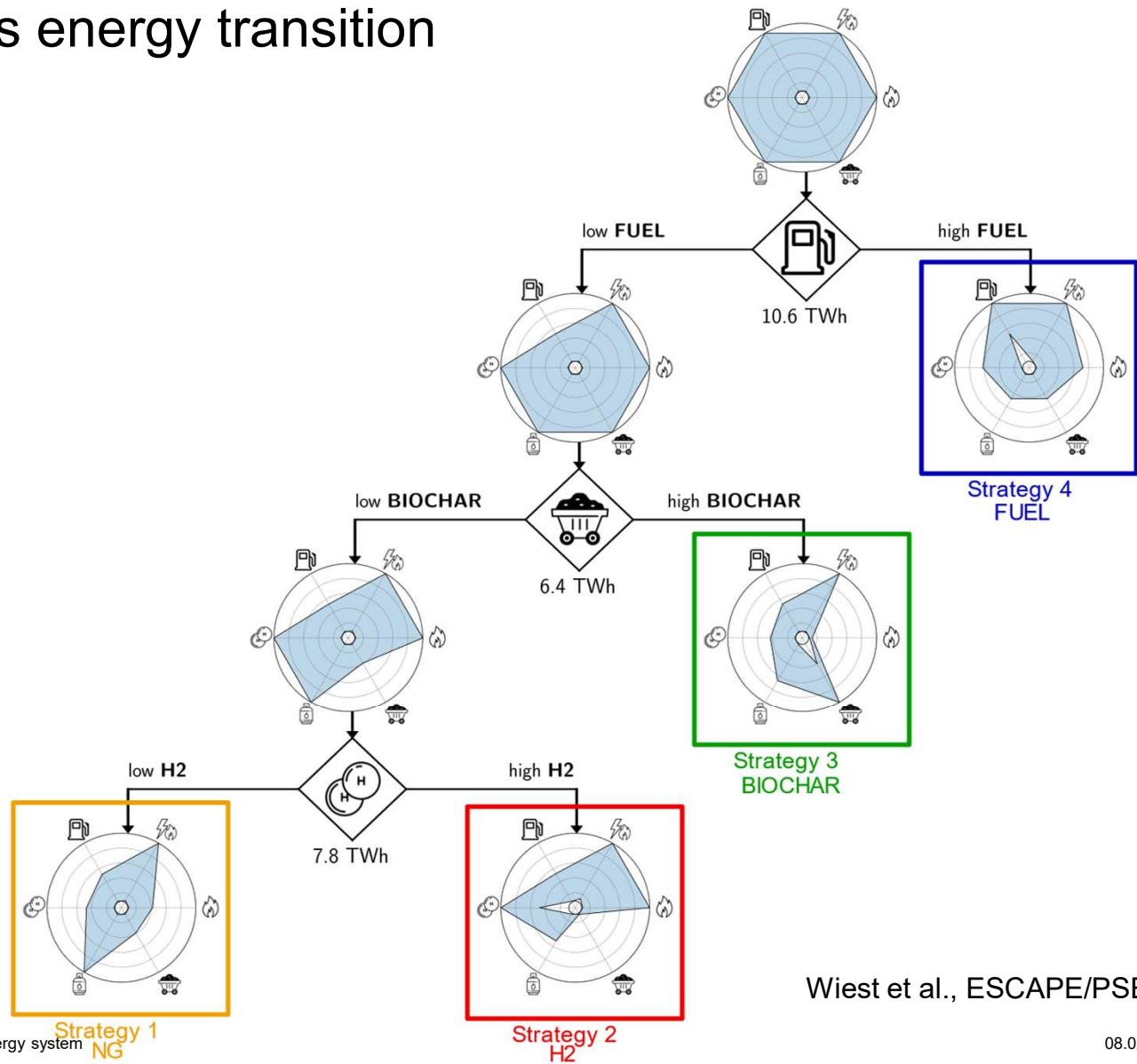
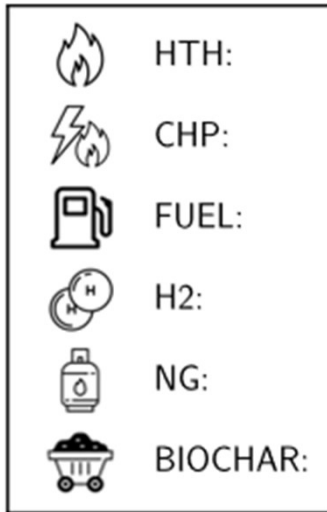


Adriana Marcucci



Stefano Moret

Biomass in the Swiss energy transition



Gabriel Wiest



Gianfranco Guidati



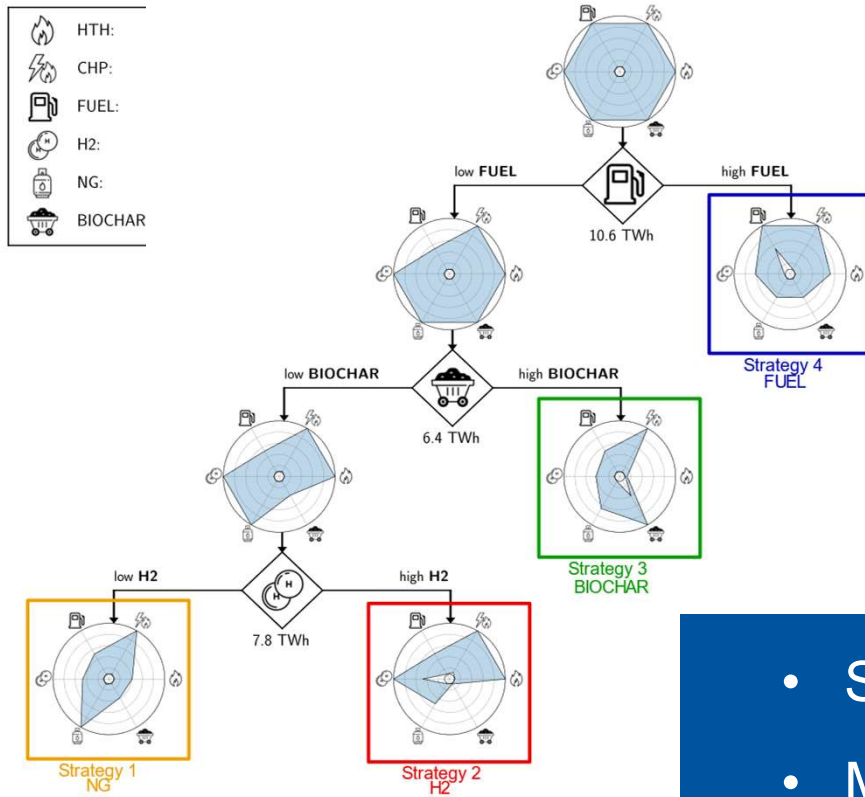
Adriana Marcucci



Stefano Moret

Wiest et al., ESCAPE/PSE 2024, accepted

Low-regret Pathways for the Energy Transition



• Beautiful unpublished data

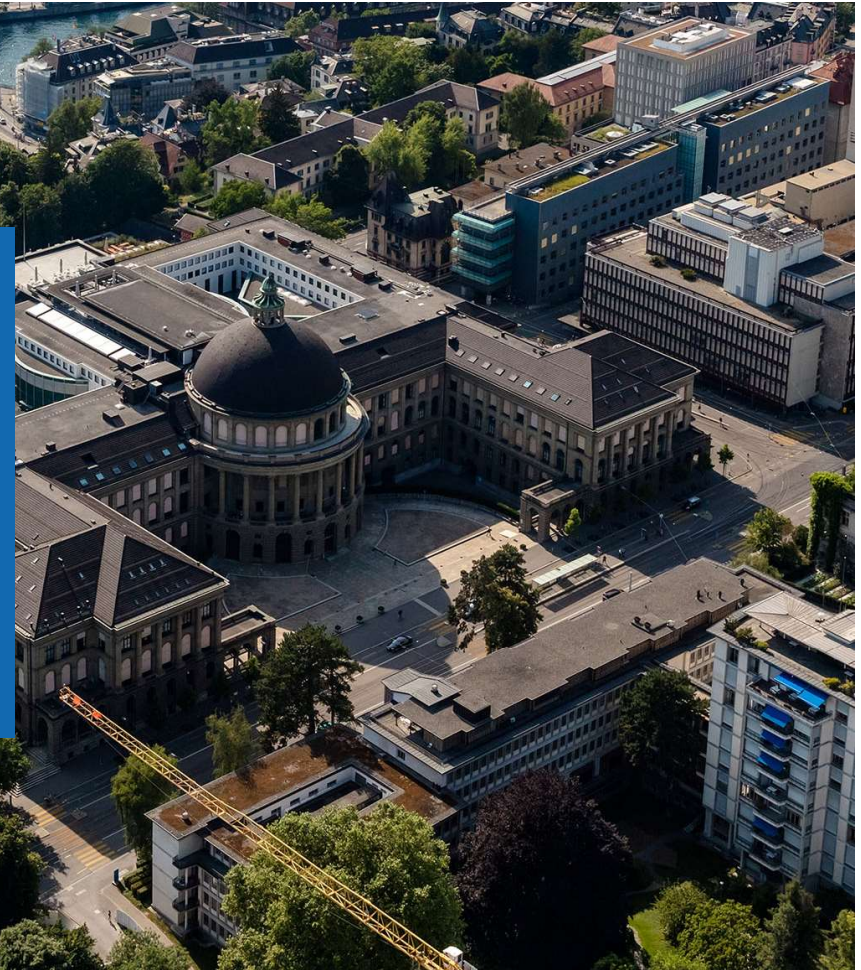
- Several low-regret uses of biomass
- Must avoid: biomass for low-temperature heat

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future ✓ energy system

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