



University of Antwerp
iPRACS | Intelligence in Processes,
Advanced Catalysts and Solvents

Is Circularity Sustainable?

Pieter Billen



YES

but...

which?

how?

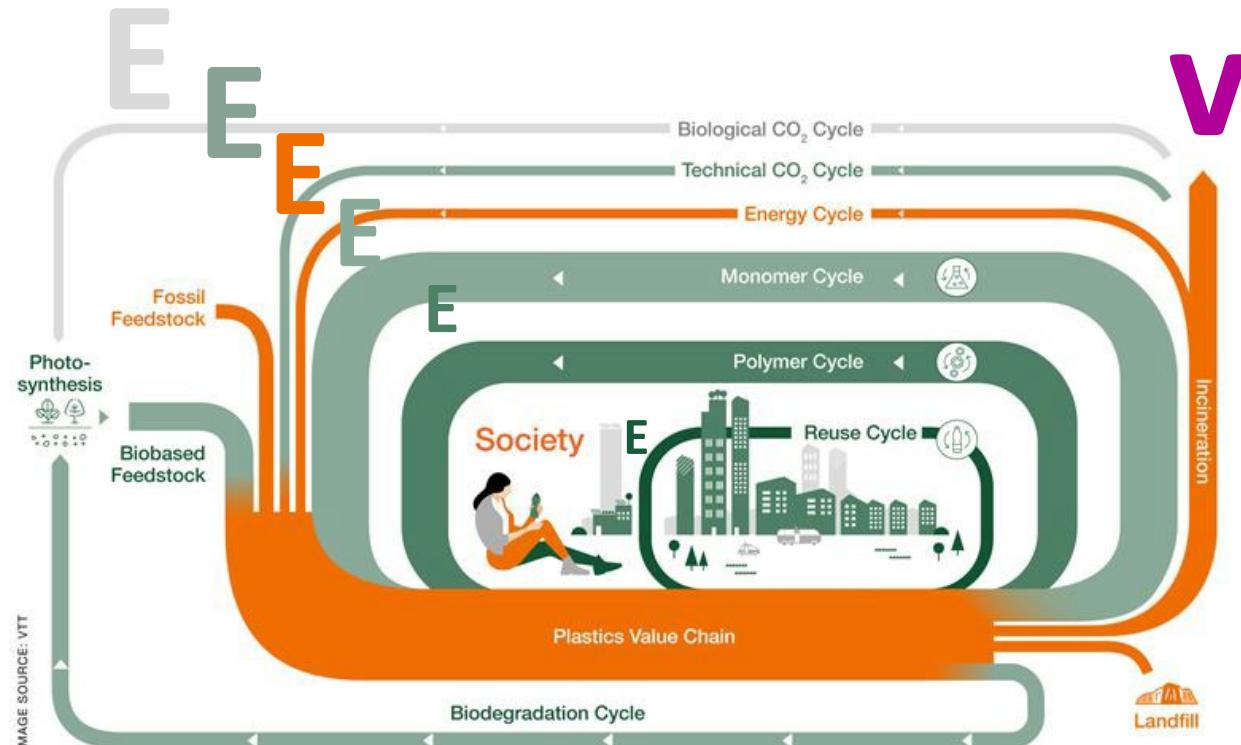
when?





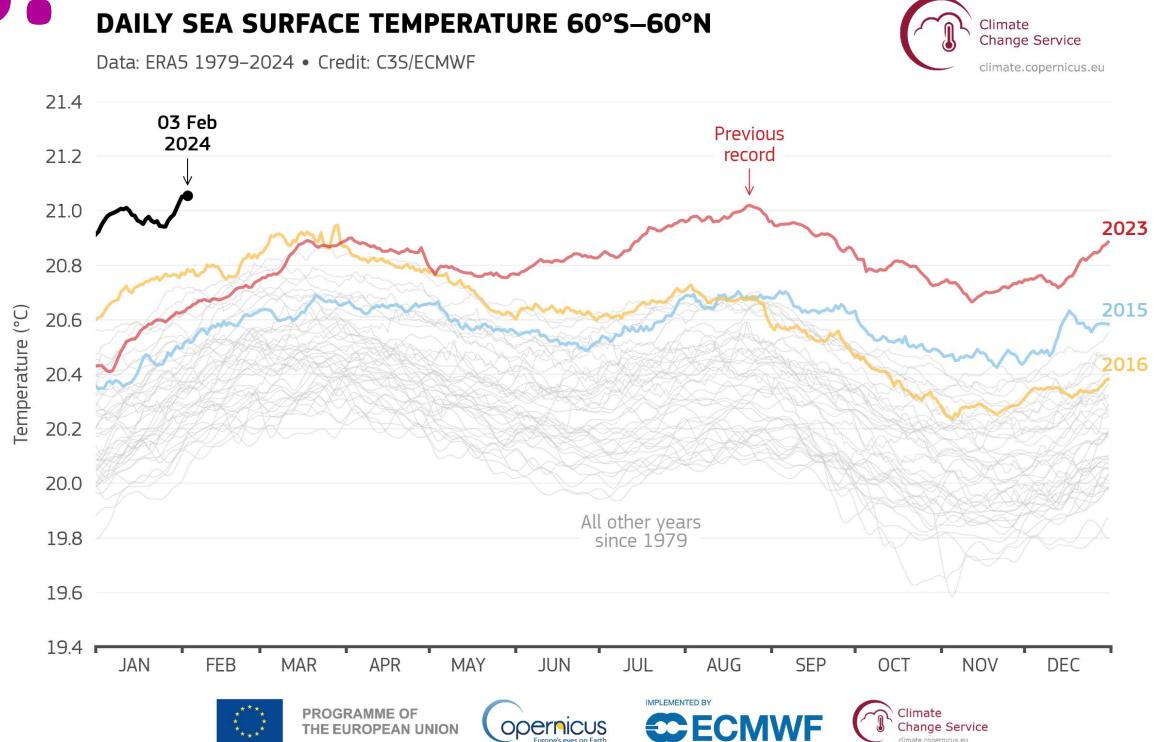
PIFF
Public Innovation Fund
for the Future

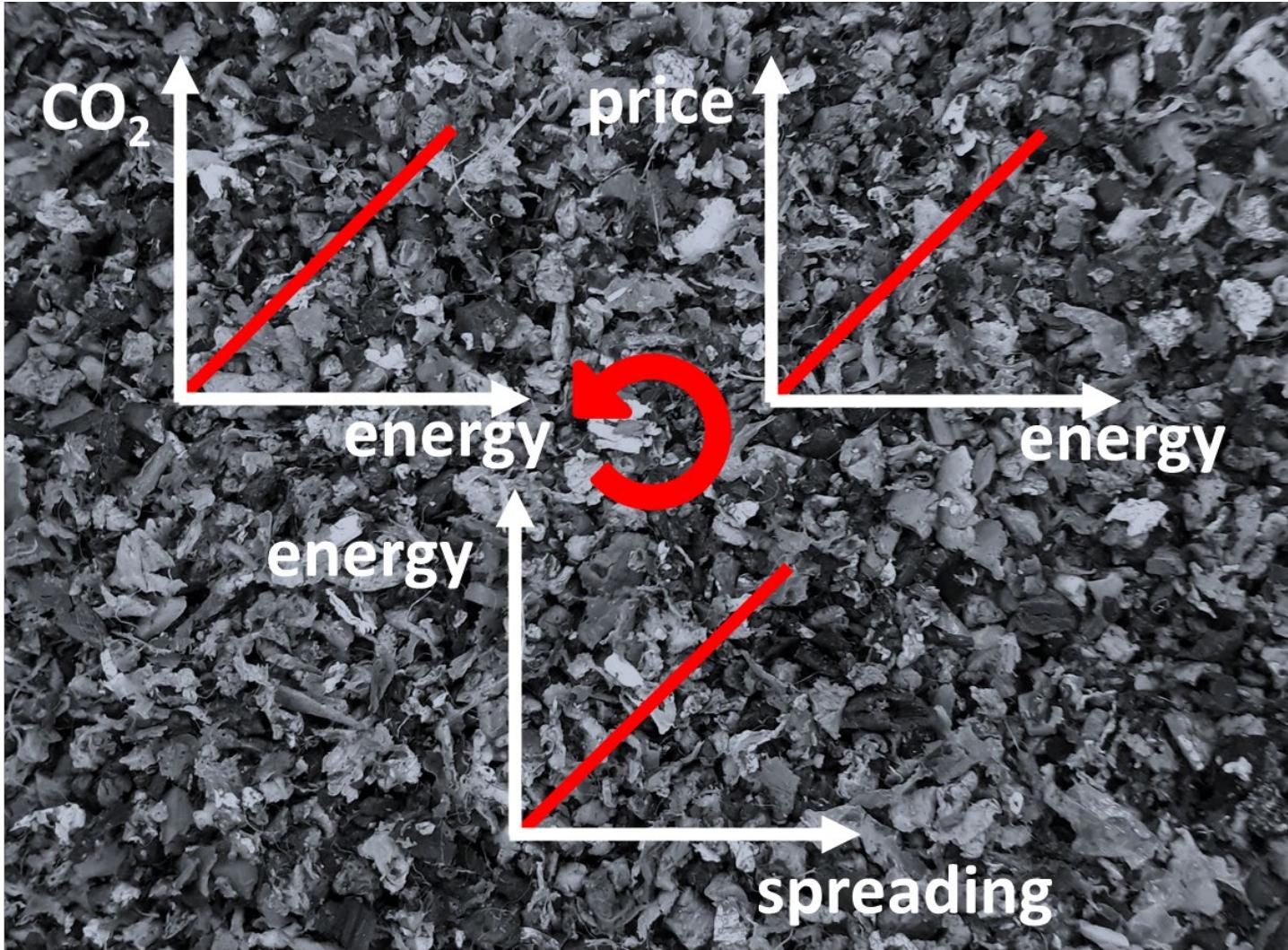
circularity



vs.

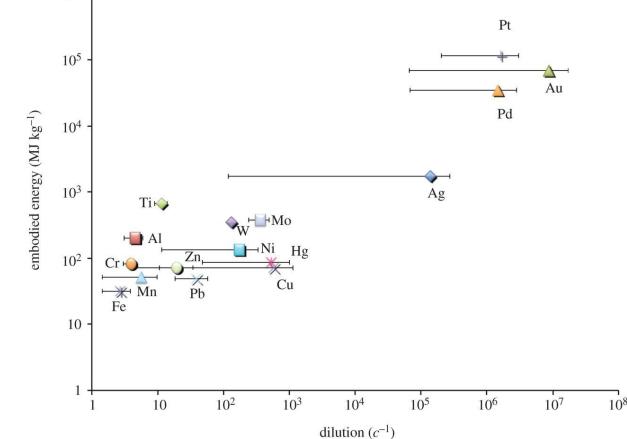
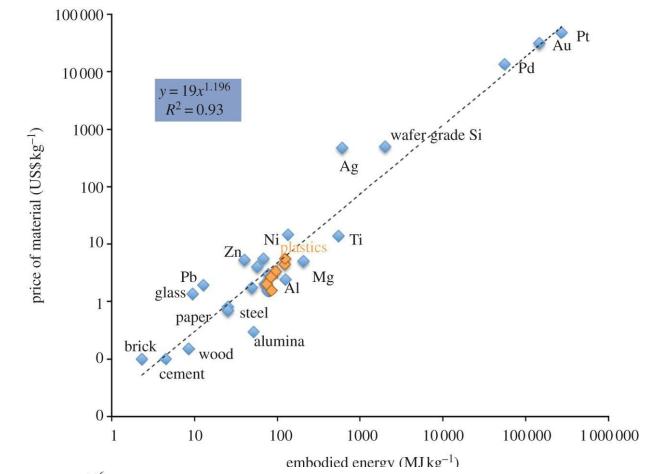
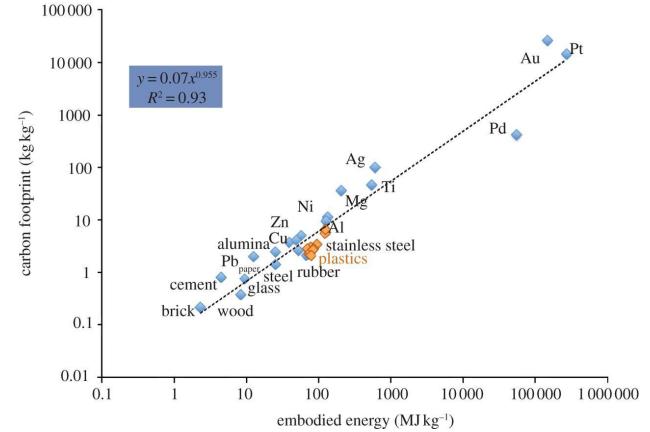
sustainability

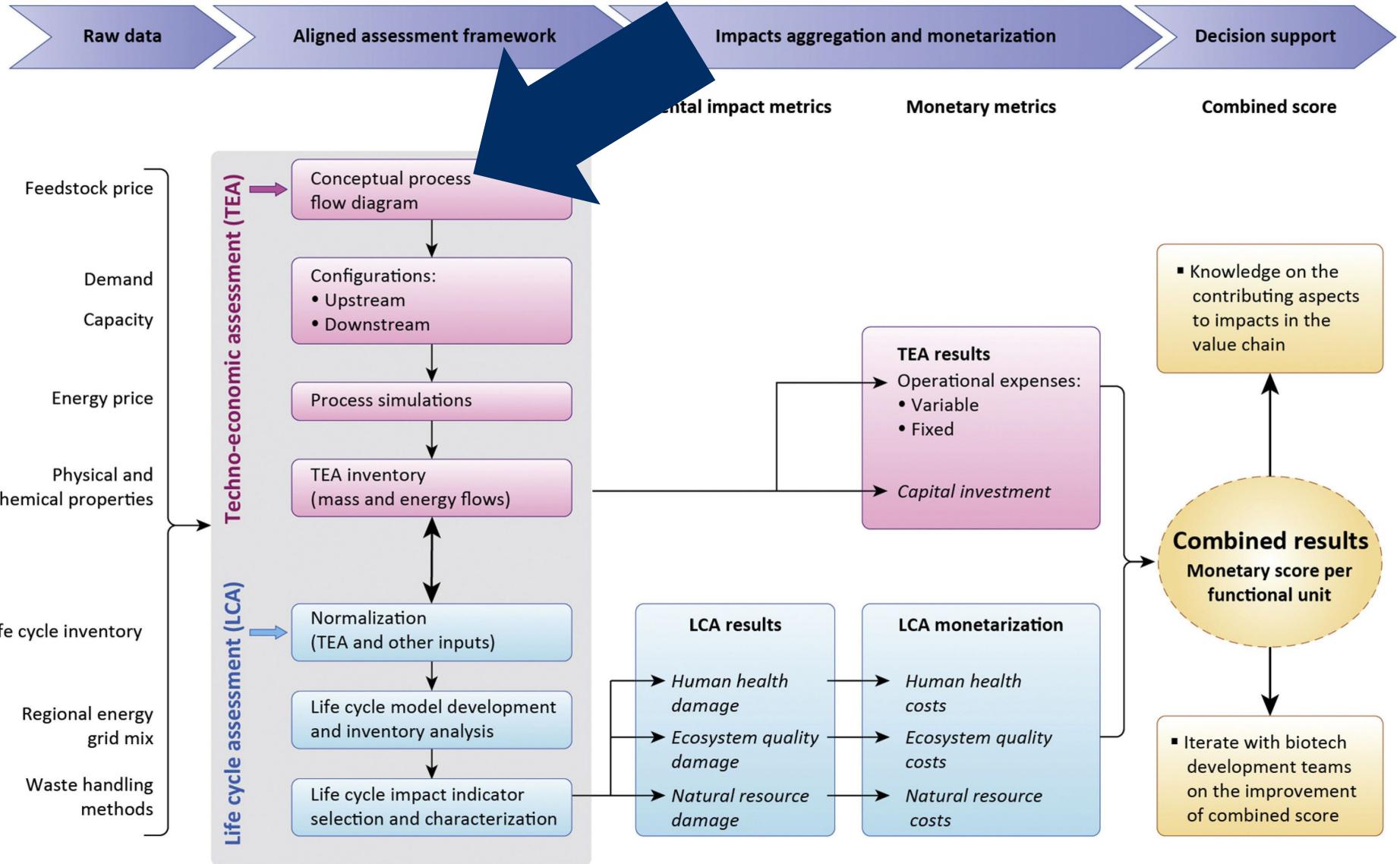




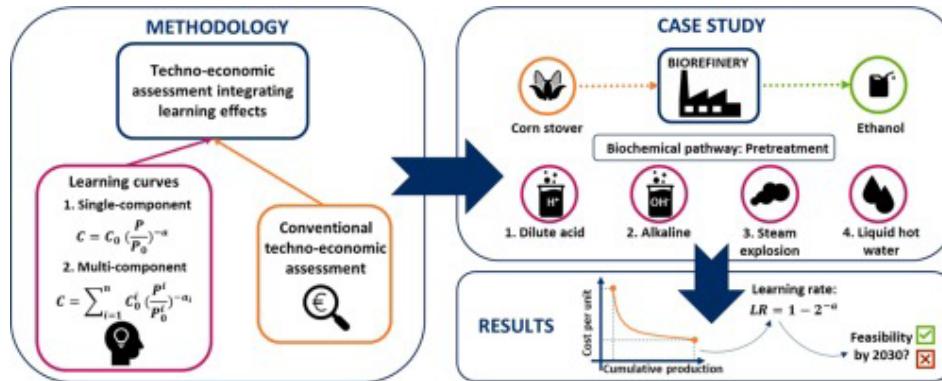
Simplified scheme based on the work of
T. Gutowski et al., and own work
Published in Knack 1857889 (2022)

All about ENERGY (and entropy)



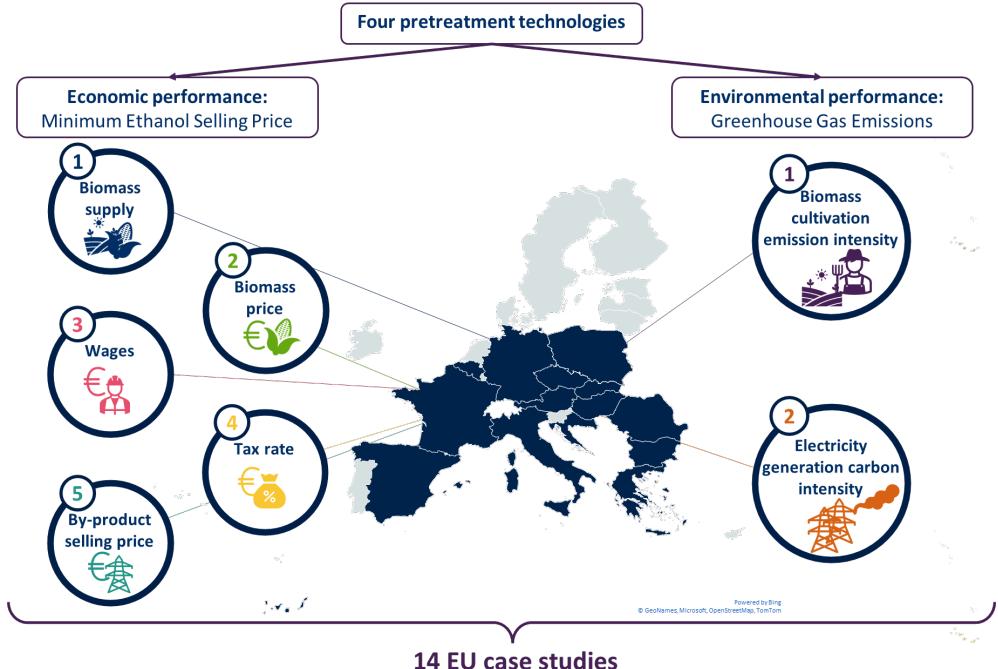


Technological learning: apples and oranges



Vasilakou K., Nimmermeier P., Thomassen G., Billen P., Van Passel S. Applied Energy 2023; 344, 121263

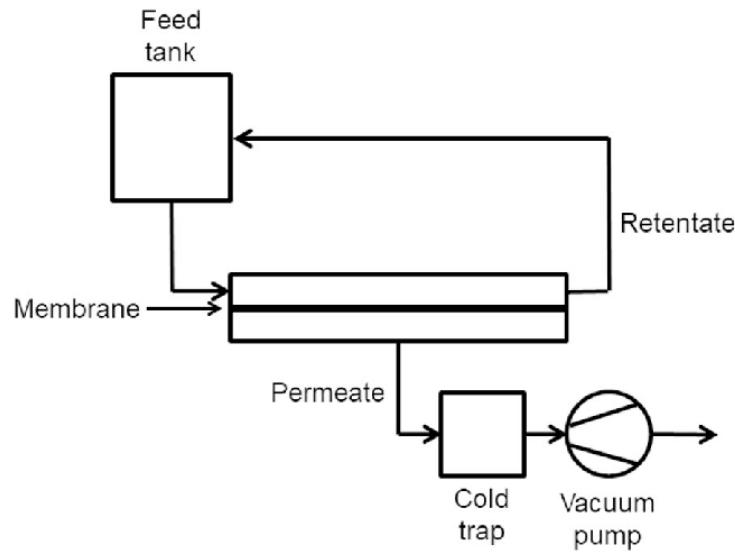
Location: oranges and ... beets



Vasilakou K., Nimmermeier P., Billen P., Van Passel S. Renewable and Sustainable Energy Reviews



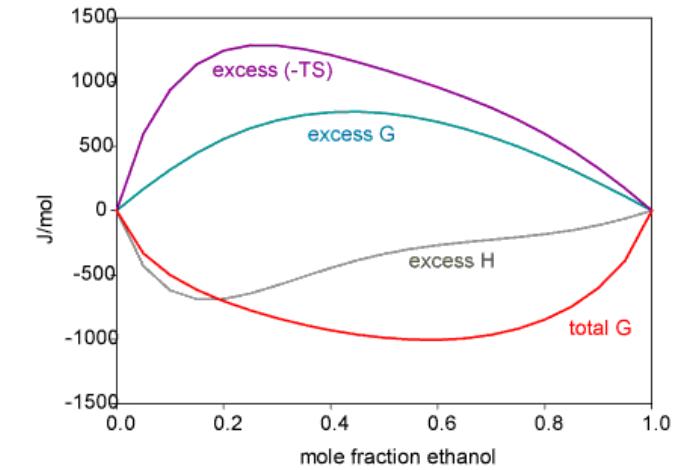
From process-based...



detailed and specific



Simplified but generic

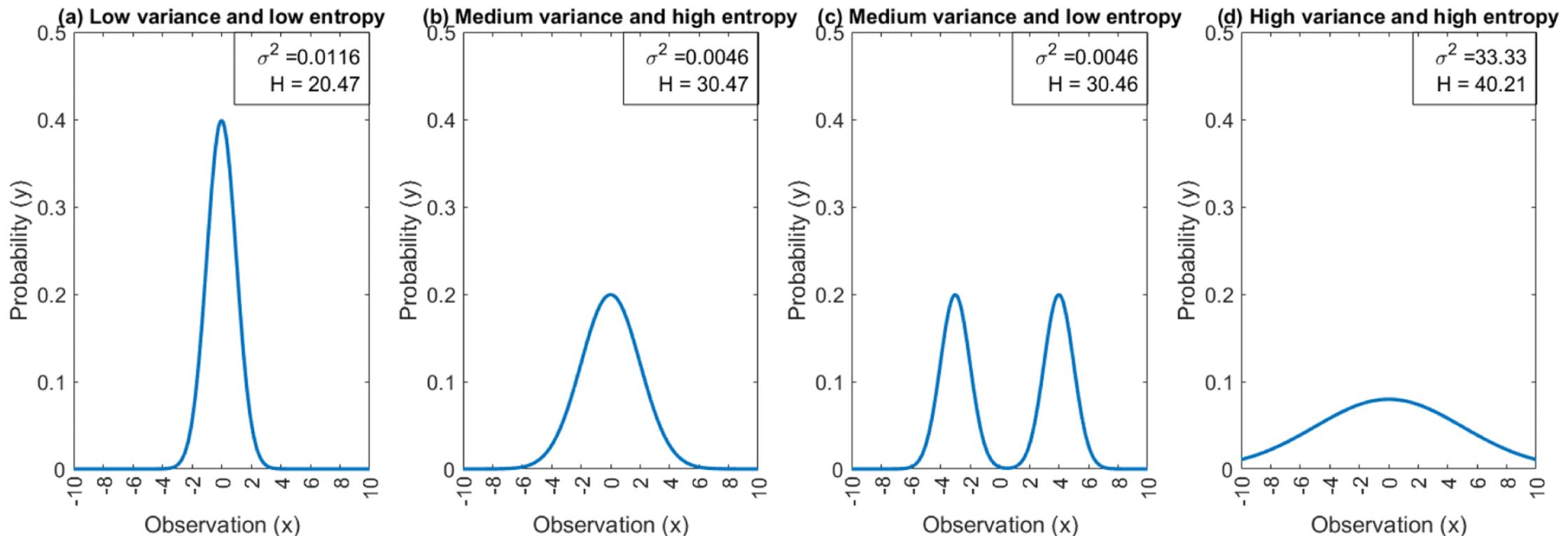


...to state based

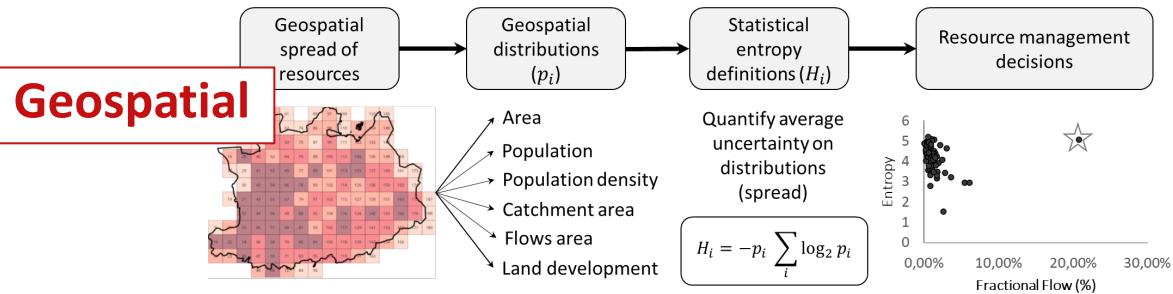
Entropy as a state variable and estimator for energy consumption

$$H(X) = - \sum_i P(x_i) \log P(x_i)$$

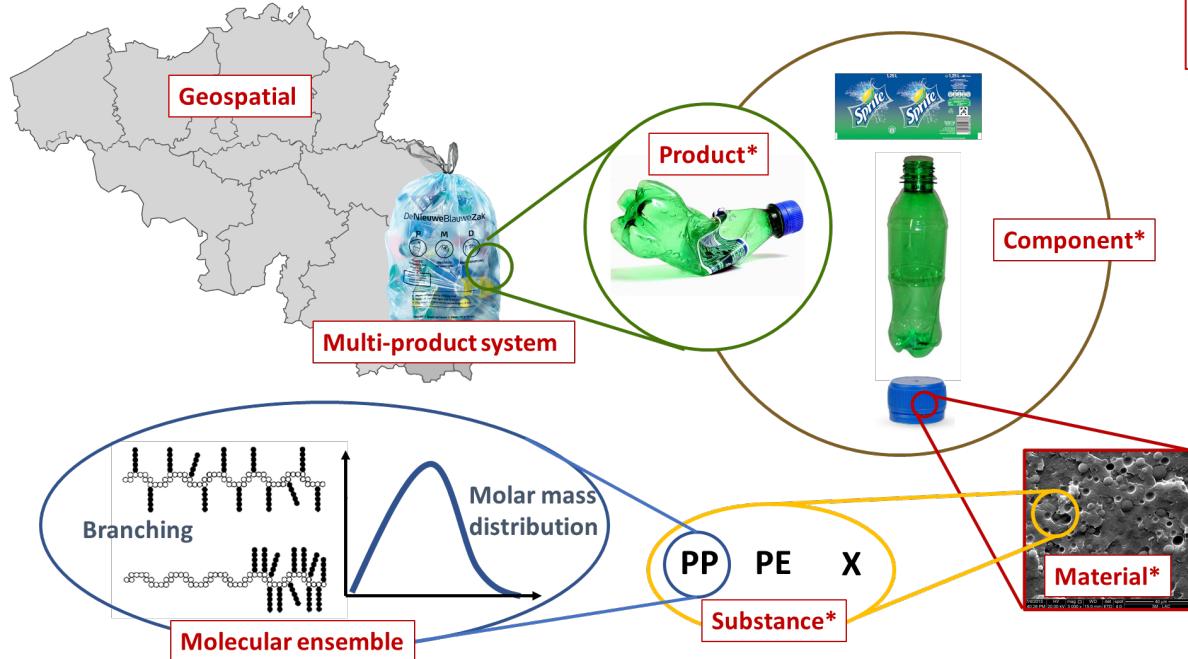
Claude Shannon



Entropy at various levels

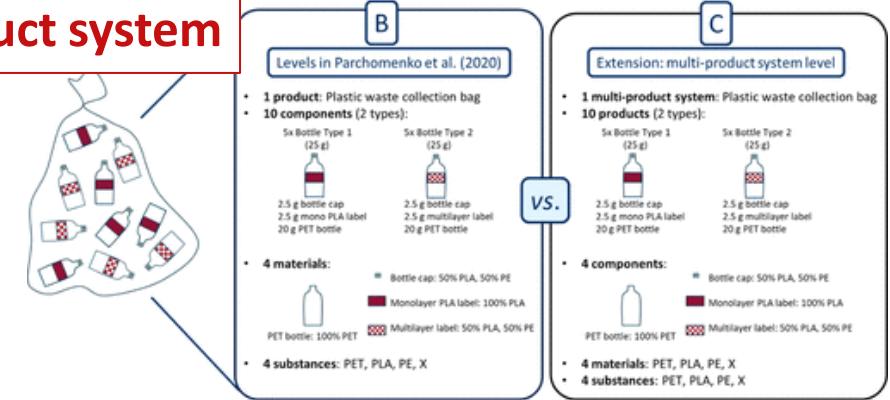


Moyaert, C., Nimmemeers P., Mellouk, B., Voordeckers, D., De Meulenaere, P., Billen P. Environmental Science: Advances 2024: 3, 314-331



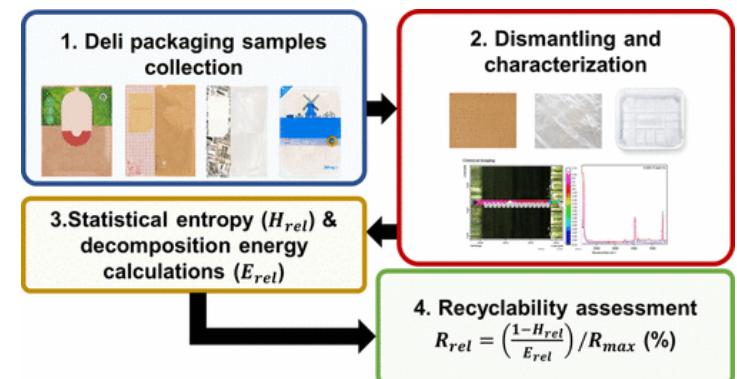
Nimmemeers P., Parchomenko, A., De Meulenaere, P., D'hooge, D., Van Steenberge, P., Rechberger, H., Billen P. Sustainability 2021: 13(6), 3553

Multi-product system



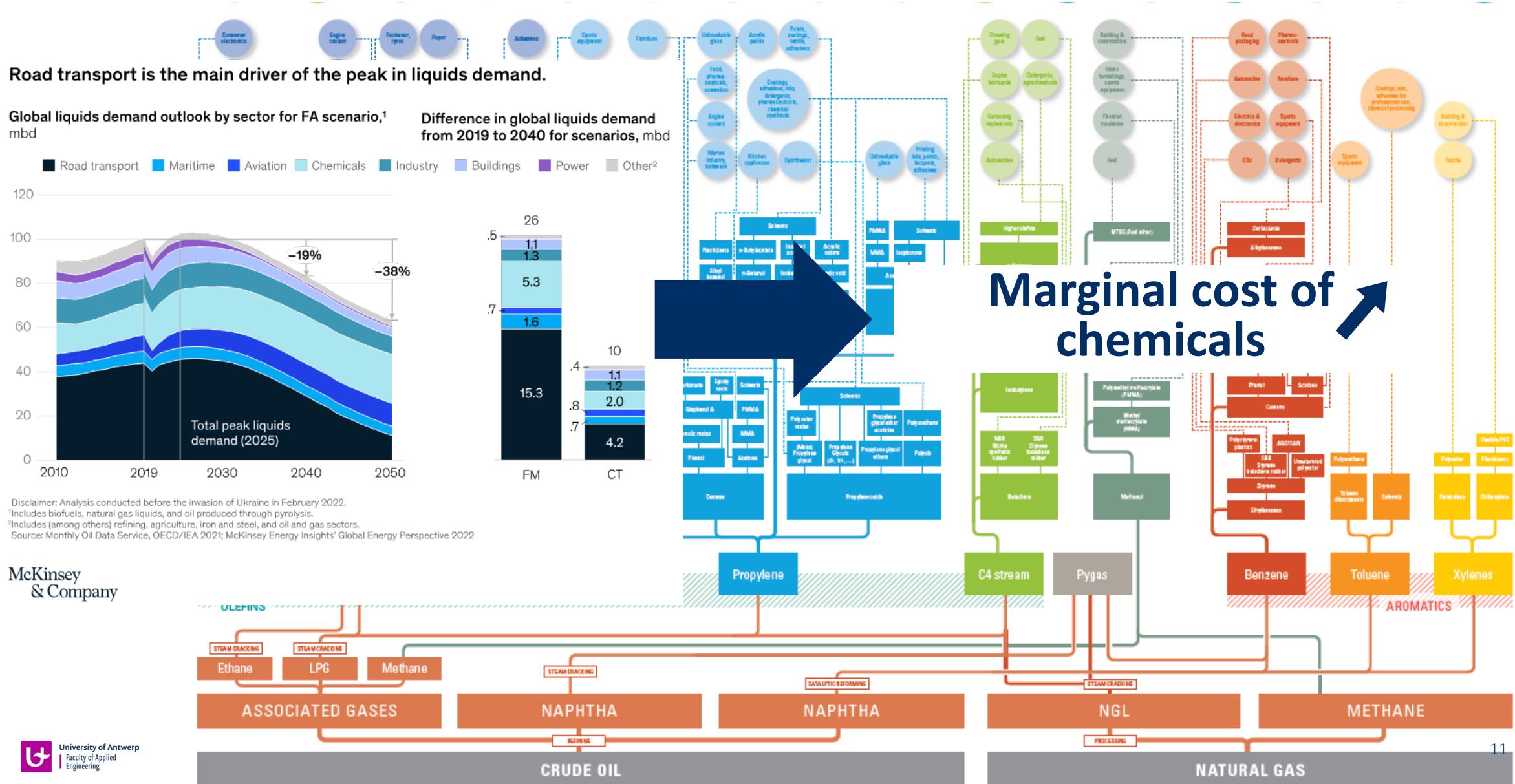
Nimmemeers P., Billen P. ACS Sustainable Chemistry & Engineering 2021: 9(29), 9813-9822

Product Component

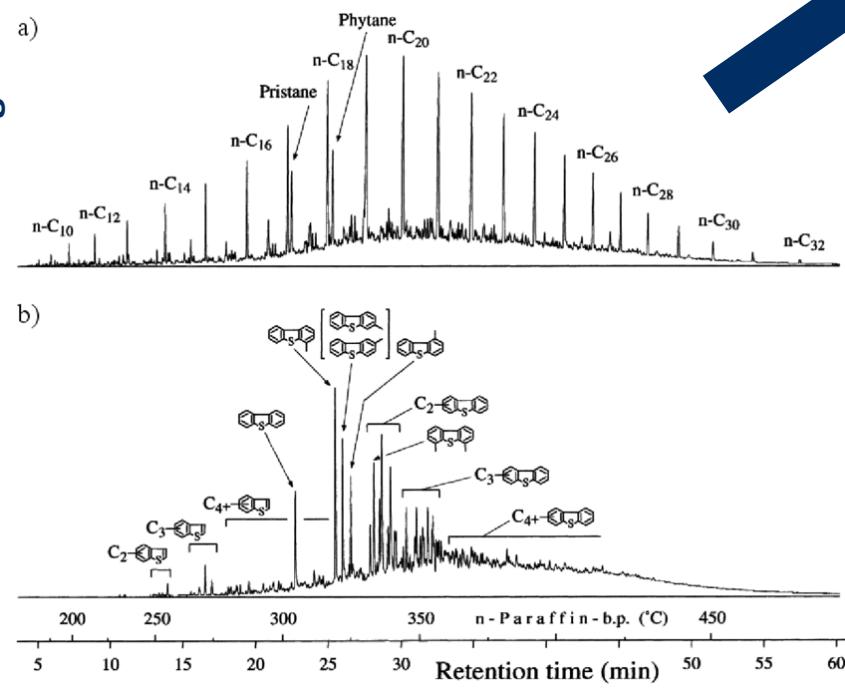


Moyaert, C., Fishel, Y., Van Nueten, L., Cencic, O., Rechberger, H., Billen, P., Nimmemeers P. ACS Sustainable Chemistry & Engineering 2022: 10(36), 11719-11725

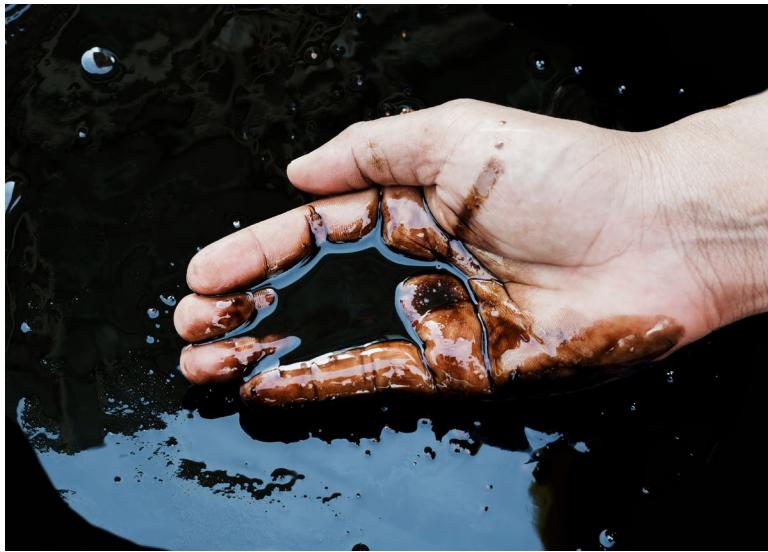
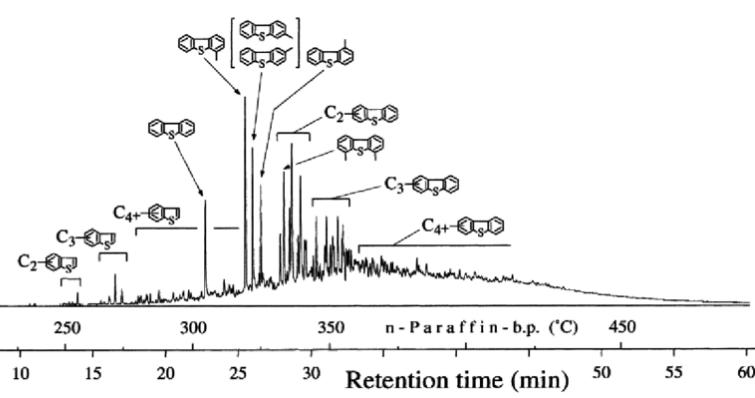
Sustainability is also strategy



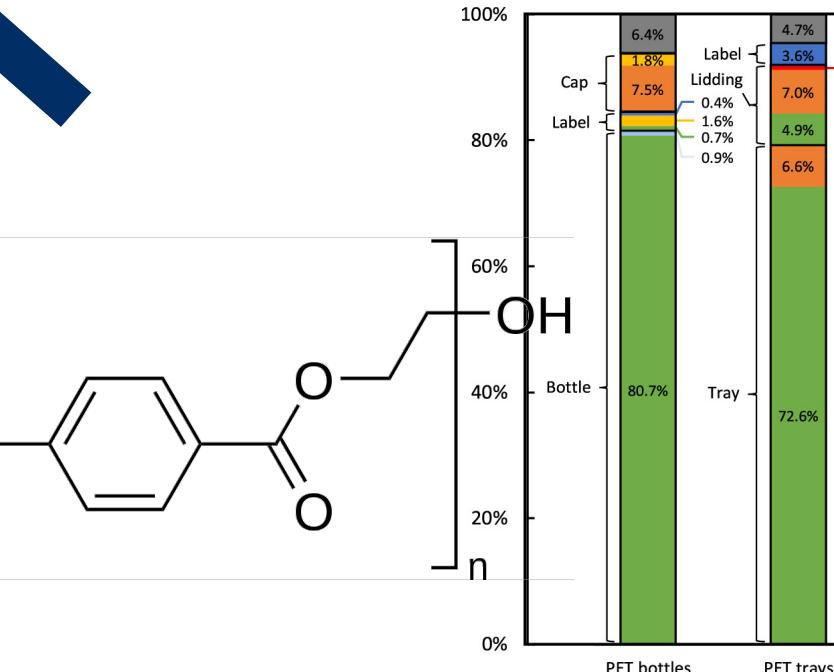
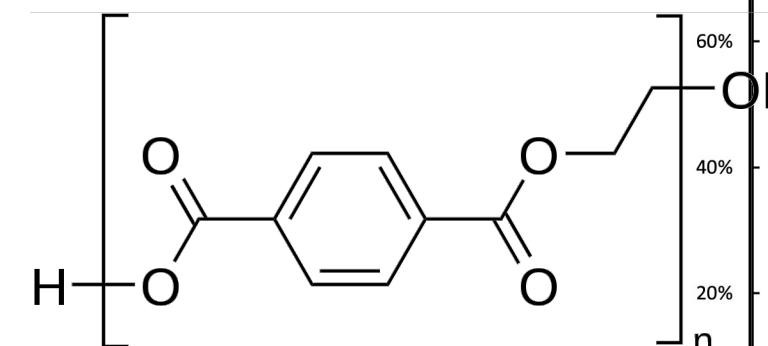
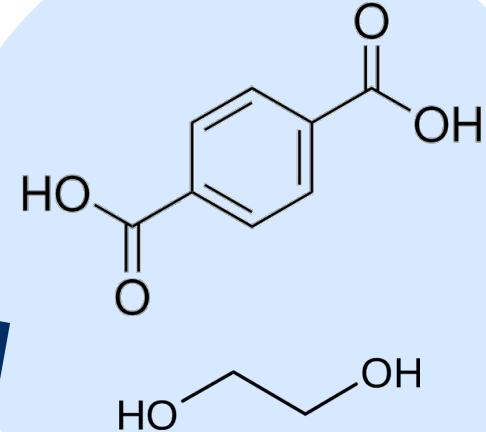
a)



b)



the choice
is yours

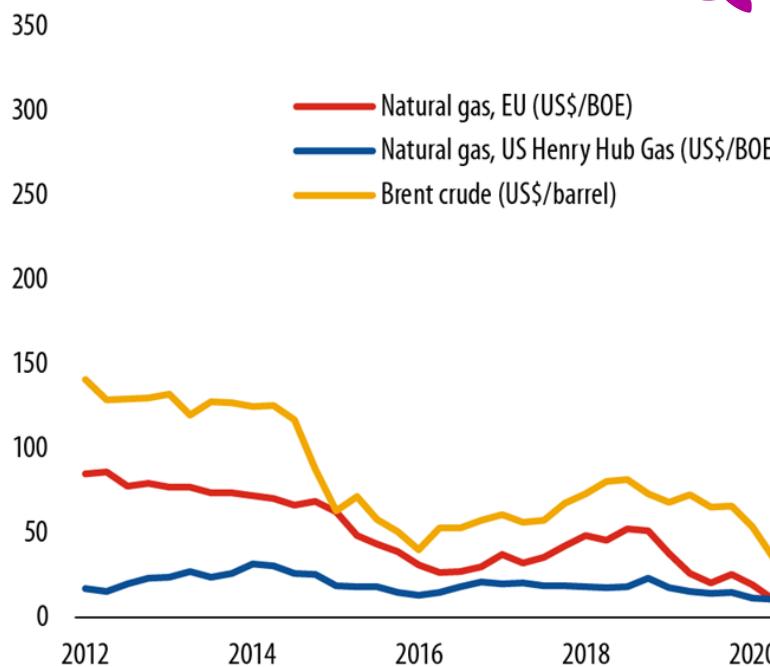


All about ENERGY but

Chart 1

European gas hit hardest

The recent rise in global oil prices and US natural gas prices is relatively modest compared with the gas price increases in Europe.
(real prices, quarterly average, US\$ a barrel)

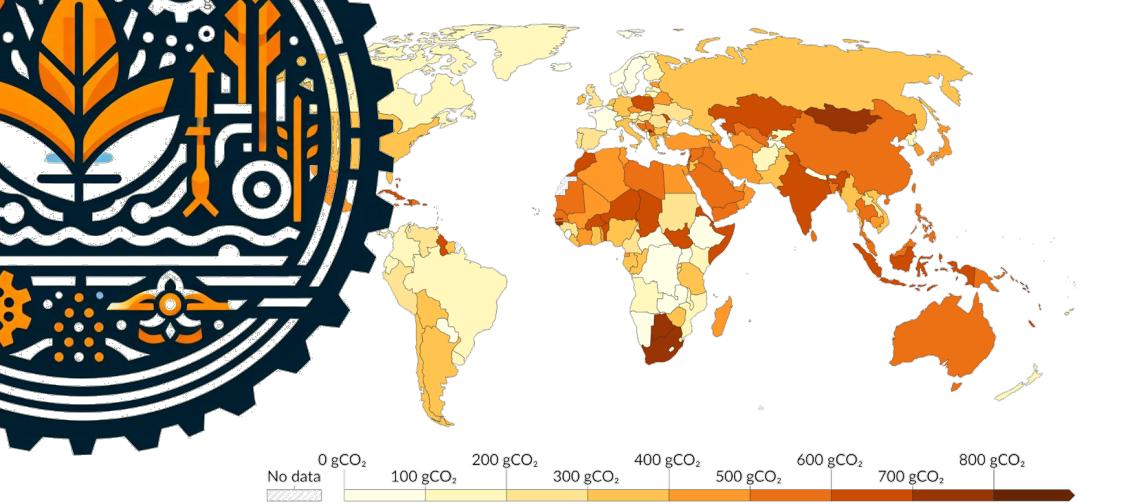
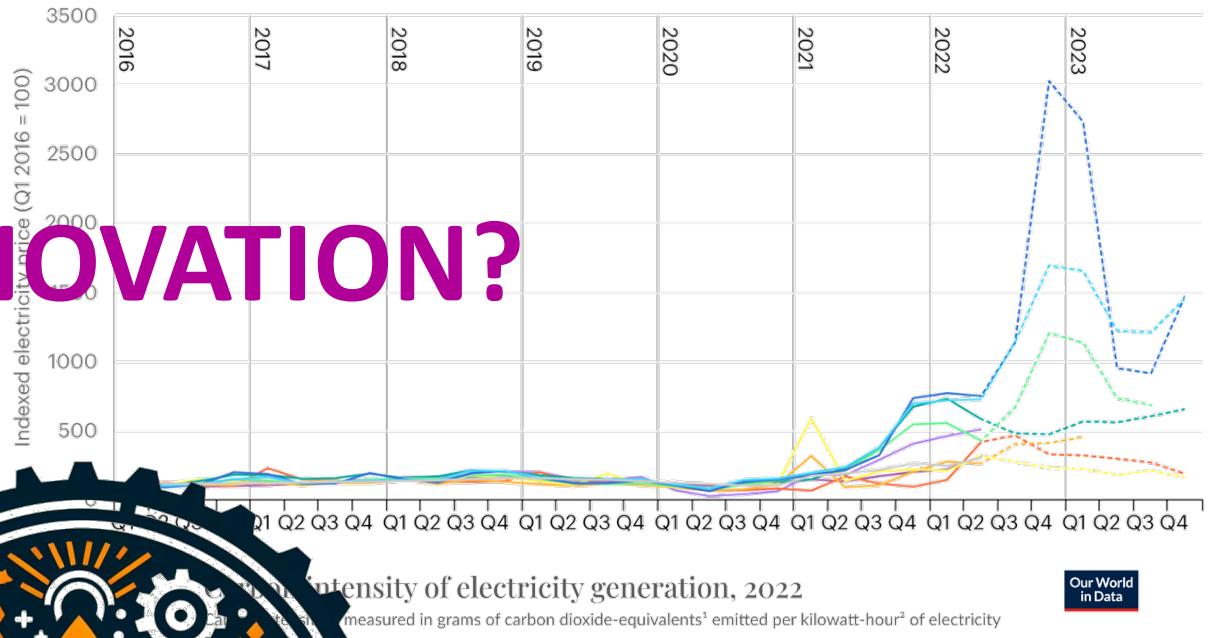


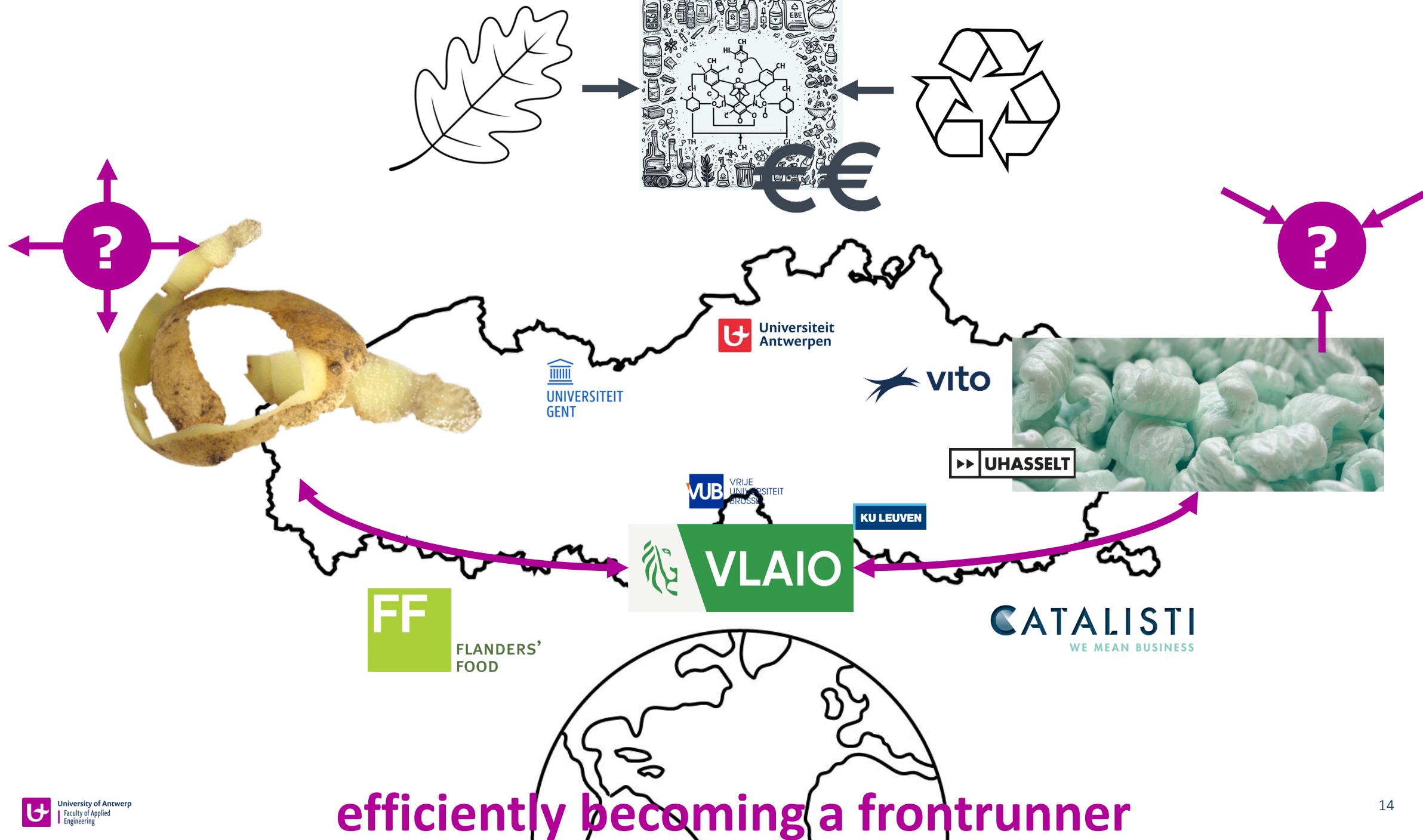
Sources: IMF PCPS; US Bureau of Labor Statistics; and IMF staff calculations.

Note: The consumer price index is rebased as 2021=100. BOE = barrel of oil equivalent.

Quarterly average wholesale prices and futures prices estimates for selected regions, 2016-2023
Electricity Market Report - July 2022

● Germany ● France ● United Kingdom ● Spain ● United States ● Japan ● Australia ● Nord Pool ● India ● Price index





Is Circularity Sustainable?

- The size of the cycle matters (a lot) – ENERGY
- Faster decision making can be done on the basis of energy and entropy
- There is no sustainability if our industry leaves – ENERGY
- Collaborative efforts and derisking lead to more efficient R&D roadmaps



Acknowledgement

Philippe Nimmemeers, Cristina Moyaert, Konstantina Vasilakou, Steven Van Passel, Britt Segers



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