# The role of biomass in the future EU energy system

Markus Millinger | European Bioenergy Future 2025

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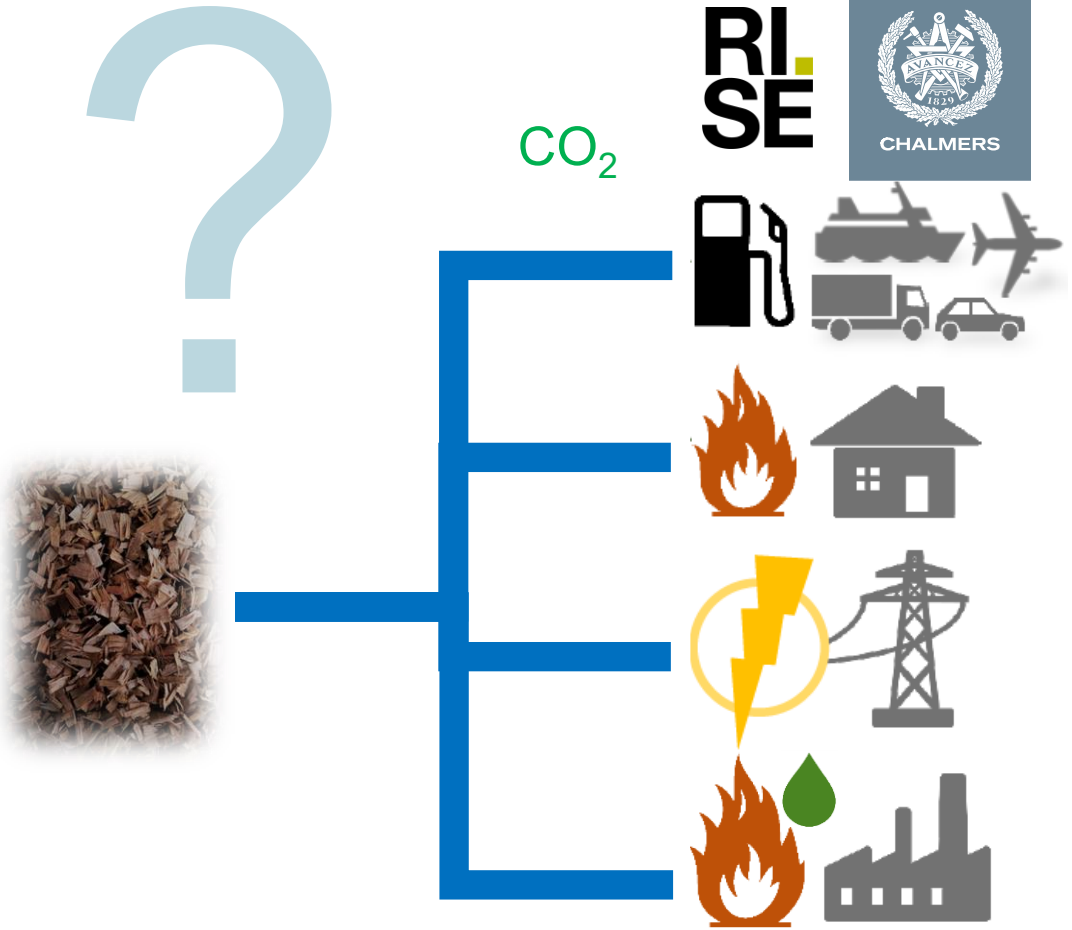
# Biomass

- Sustainable biomass is a limited resource with trade-offs
- Cost-effective use of biomass residues in the energy system?
  - Fuels?
  - Variation management / firm generation?
  - Industry?
  - Negative emissions?



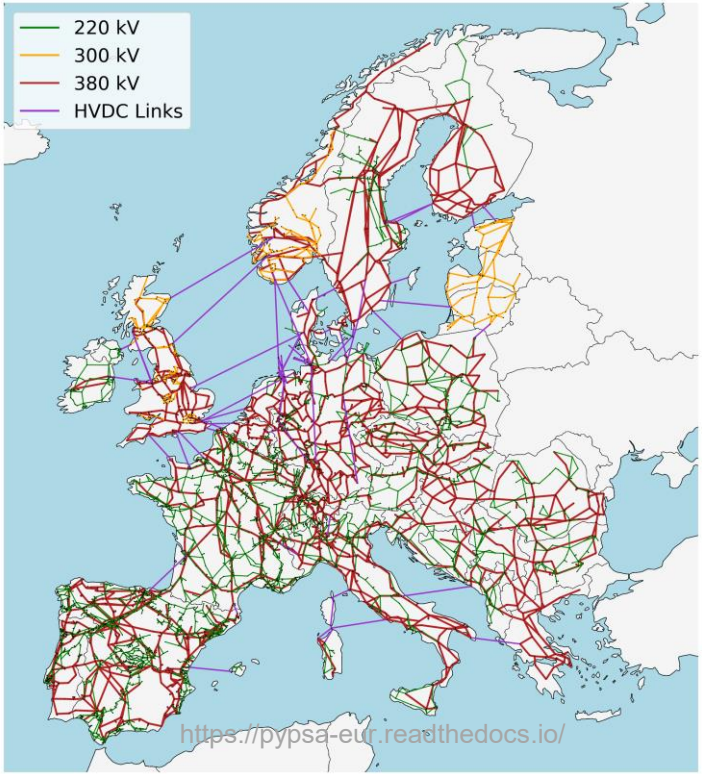

Millinger et.al. 2021:
https://doi.org/10.1039/D0SE01067G

# Model

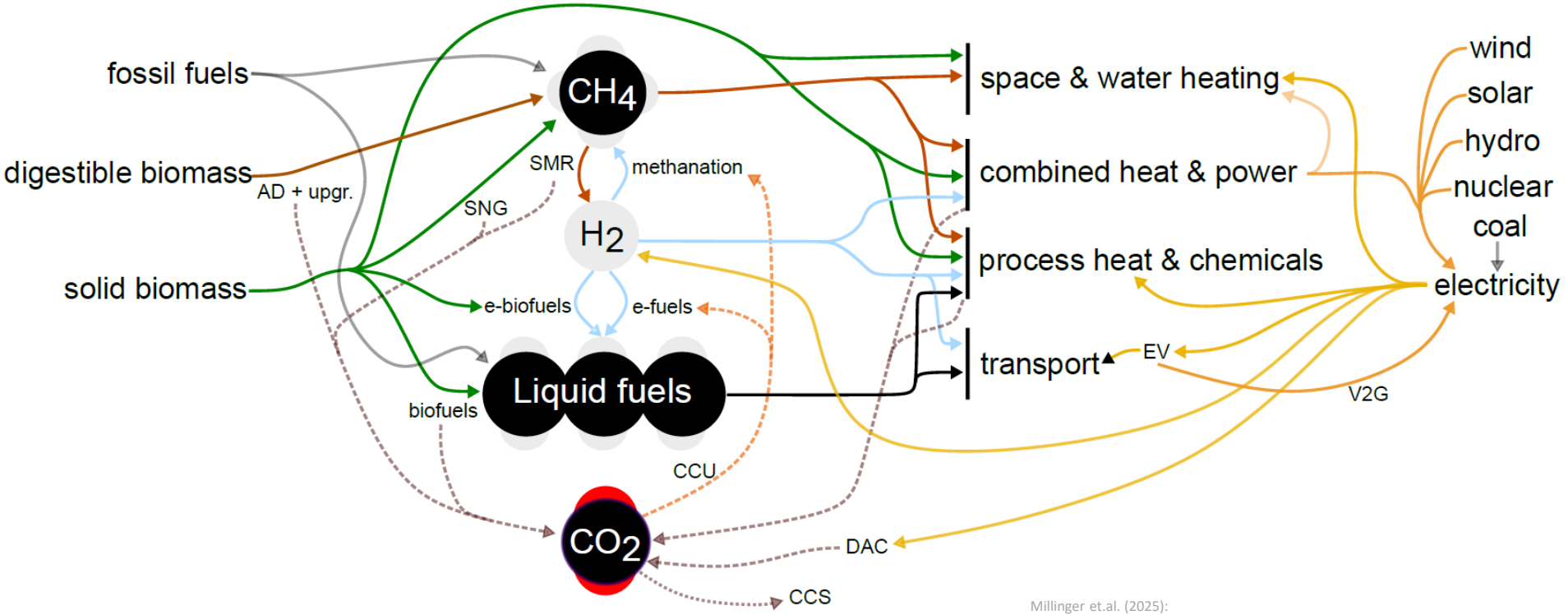
- **PyPSA**-Eur-Sec. Optimisation of capacity and dispatch across all sectors. Open source.

Set-up:

- Europe in 37 nodes, 5H temporal resolution, **overnight**
- **Net-negative** (-110%) or net-zero $CO_2$ emissions vs 1990, with limited carbon storage. The exact year when this target is achieved is not specified.
- Biomass competes with electricity- and fossil-based options in all sectors



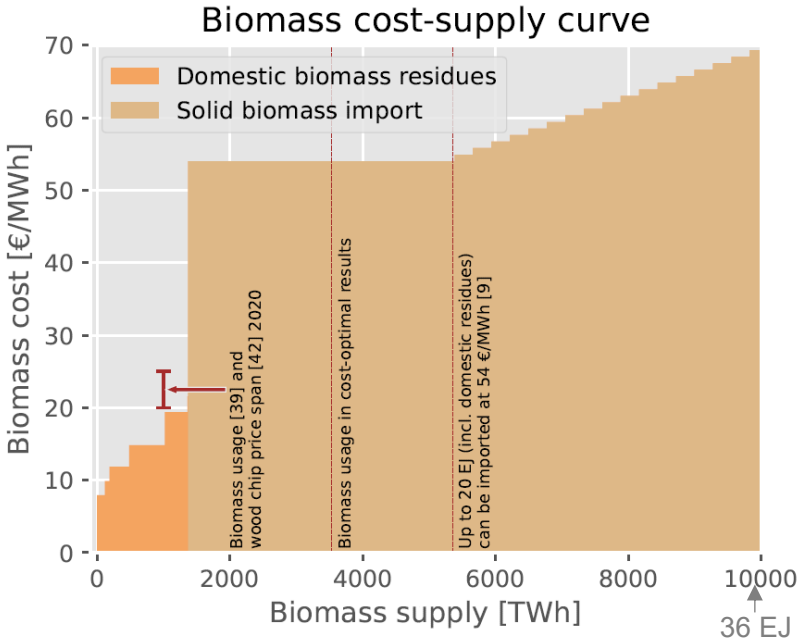
# Biomass options and competition




Millinger et.al. (2025): https://doi.org/10.1038/s41560-024-01693-6

# Biomass

- Domestic residues and more expensive biomass ”imports” (can also be e.g. a higher extraction of domestic residues)
- All biomass processes can choose to add carbon capture (except small-scale heating)
- Carbon capture: energy penalty for added heat demand + substantial infrastructure cost

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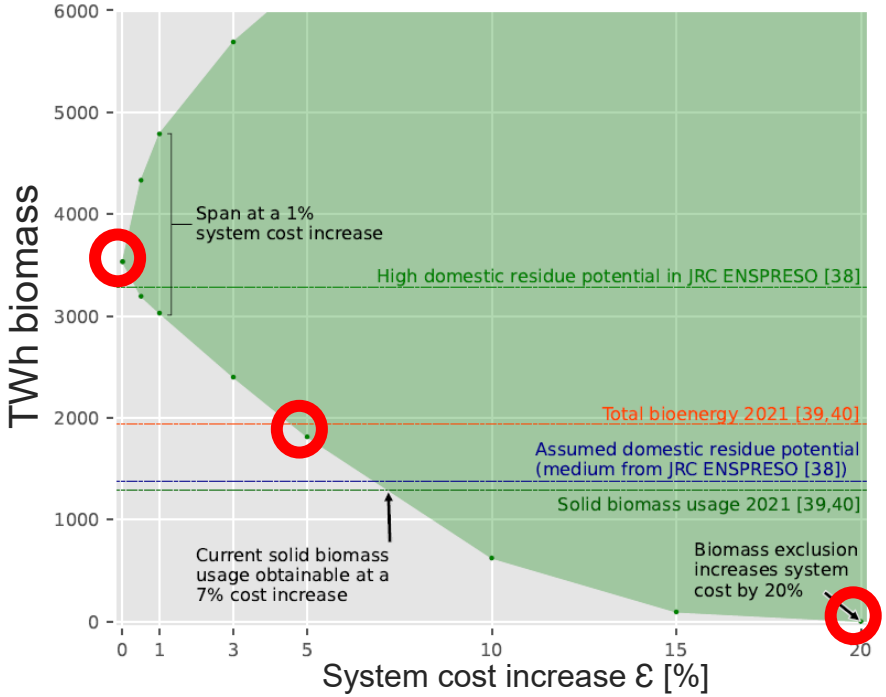
# RESULTS

# Biomass in the energy system

- 3500 TWh biomass cost-optimal (29% of primary energy; the rest wind, solar and some hydro)
- Biomass limited to current amounts corresponds to ~5% higher system cost.
- Can be excluded at ~20% higher system cost (170 B€, or ca total defense spending in EU). Similar to wind power and electrolysers!
- Biomass usage sensitive to biomass upstream emissions

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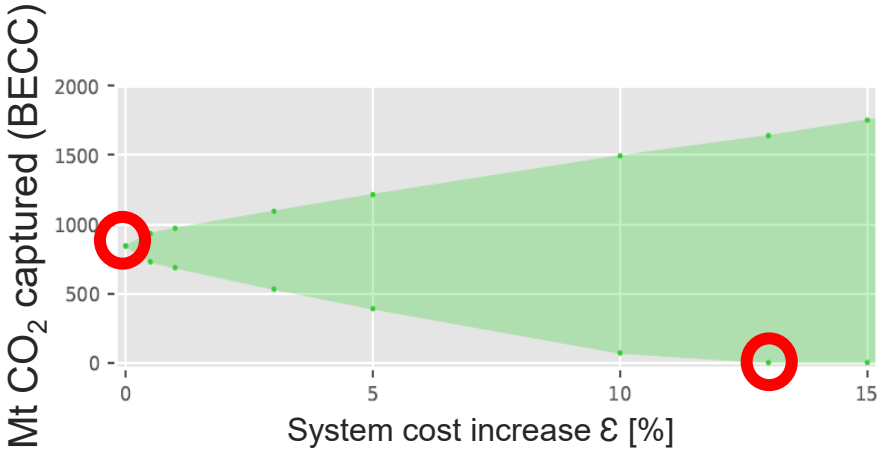
# Bioenergy with carbon capture

- Around 900 $MtCO_2$ biogenic capture cost-optimal (21% of total **GHG** emissions in 2021)
- Most biomass usage linked to CC
- Can be excluded at a 13% higher system cost
- BECC (and/or e-biofuels) strongly enhances carbon efficiency and value of biomass
- BECC is competitive to DAC also given very low DAC cost → may inhibit DAC deployment

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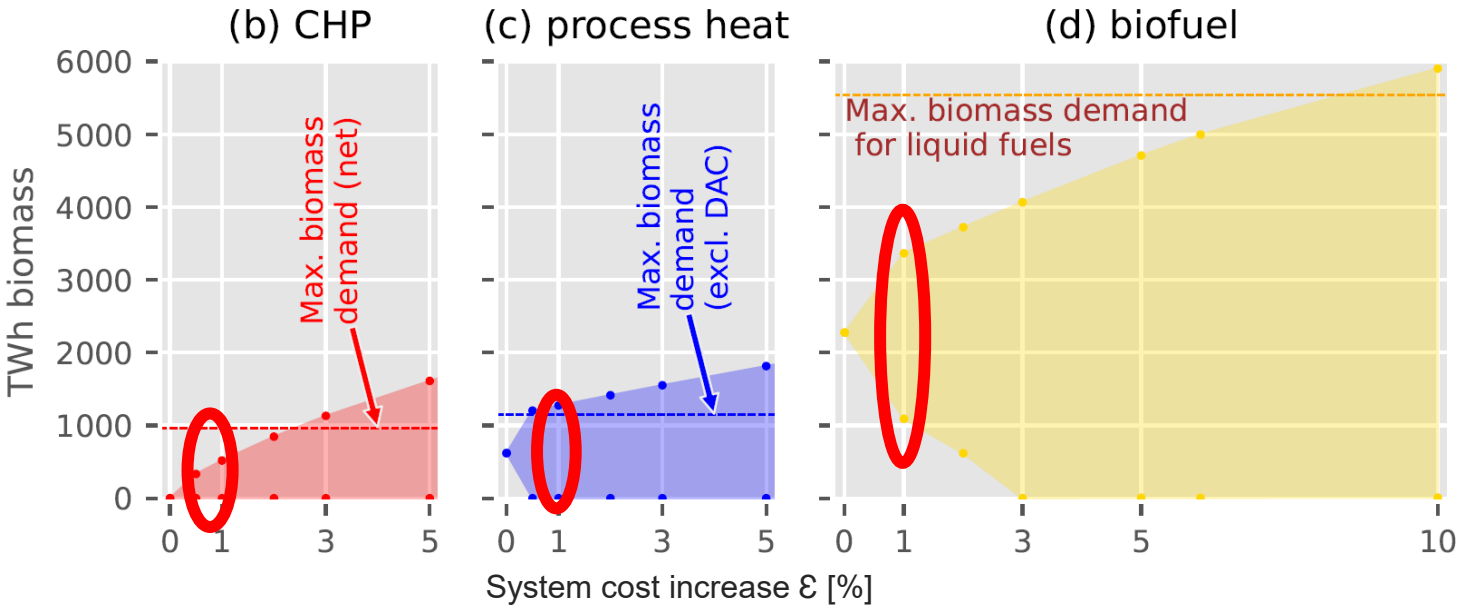
# Use of solid biomass




- Large variation within small cost span → less crucial what biomass is used for if it is connected to carbon capture
- Use for biofuels is more robust to uncertainty of e.g. renewable hydrogen or carbon capture scaling

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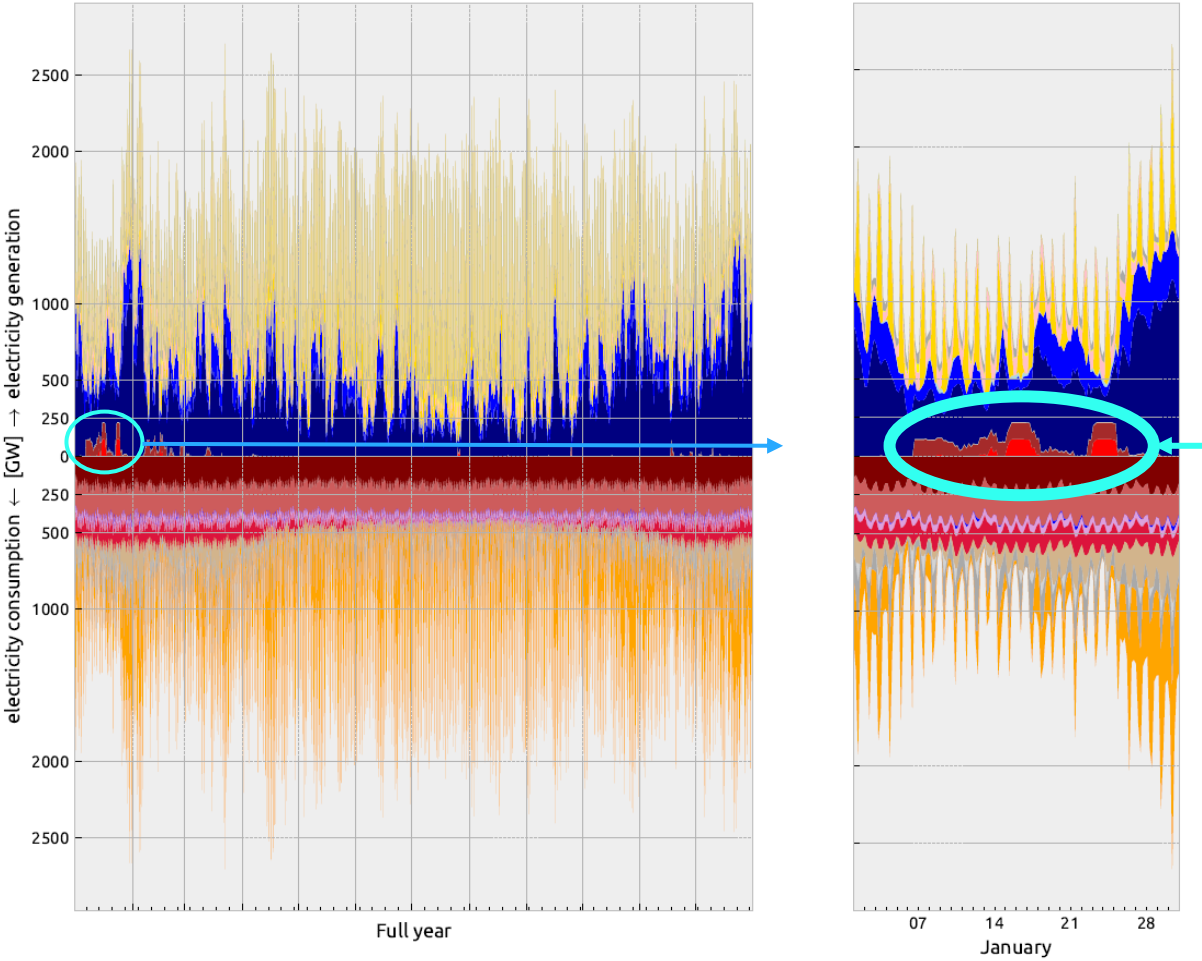
# Flexible electricity back up




- Flexible back-up needs to have low investment cost, it is ideally only used a few hundred hours/year
- Fuelled by biomethane (w/o carbon capture), and surprisingly valuable to the system!

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# Key take-aways

- Removing biomass residues results in **~20%** higher energy system cost
- Main value of biomass is **carbon provision** for chemicals, fuels and negative emissions
- High **carbon efficiency** enhances biomass value. Adding hydrogen to make more direct use of carbon (**e-biofuels**) and carbon capture are key options
- Except for some dispatchable back-up power, it is **less crucial what biomass is used** for if carbon efficiency is high
- Renewable chemicals and **liquid fuels most challenging** part of the energy system


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