Economic analysis of increased renewable methane output through CO_2 utilization

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Agenda

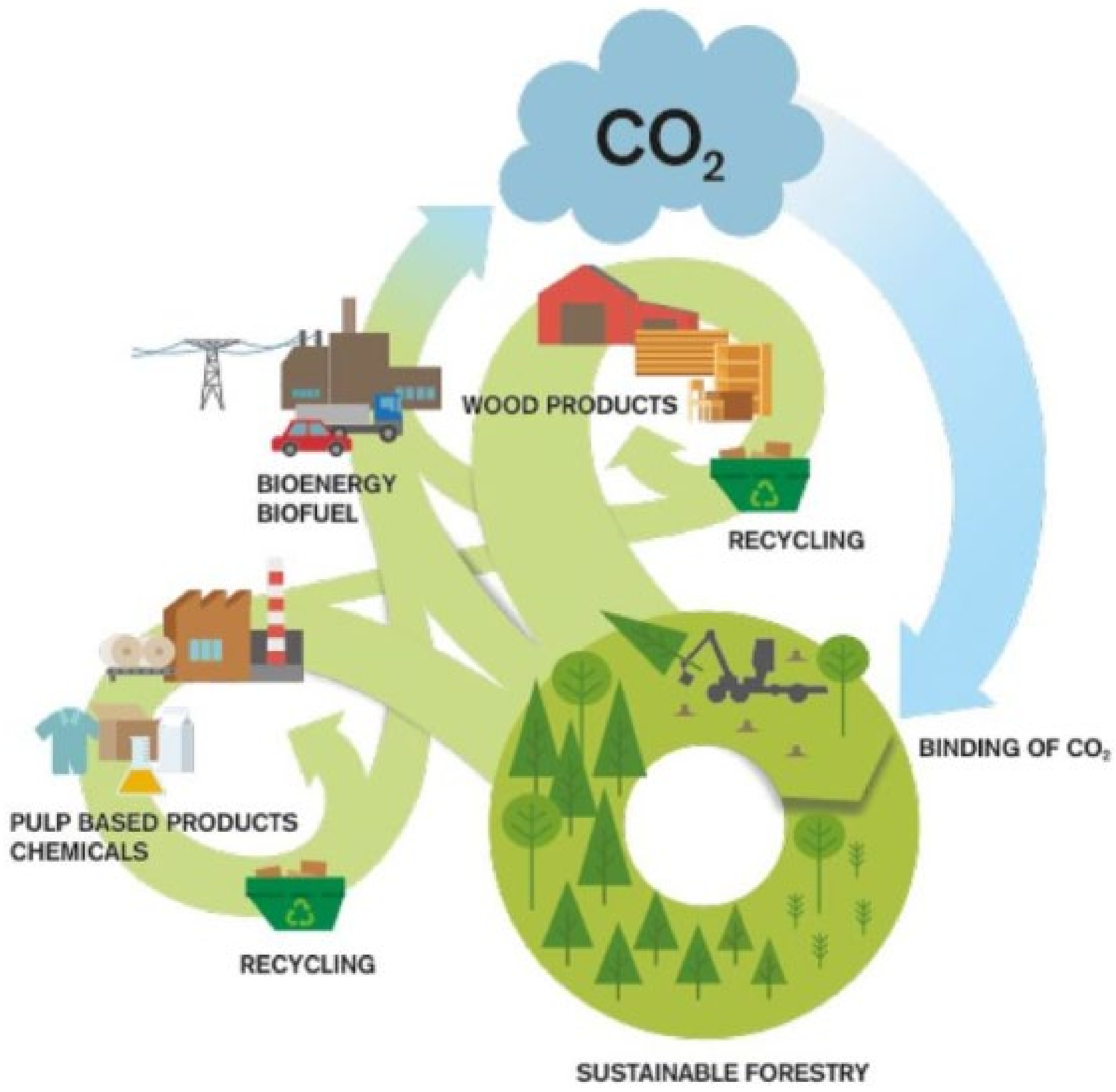
- Introduction
- Technology description
- Methodology
  - Economic assessment
- Results
- Conclusions

Motivation

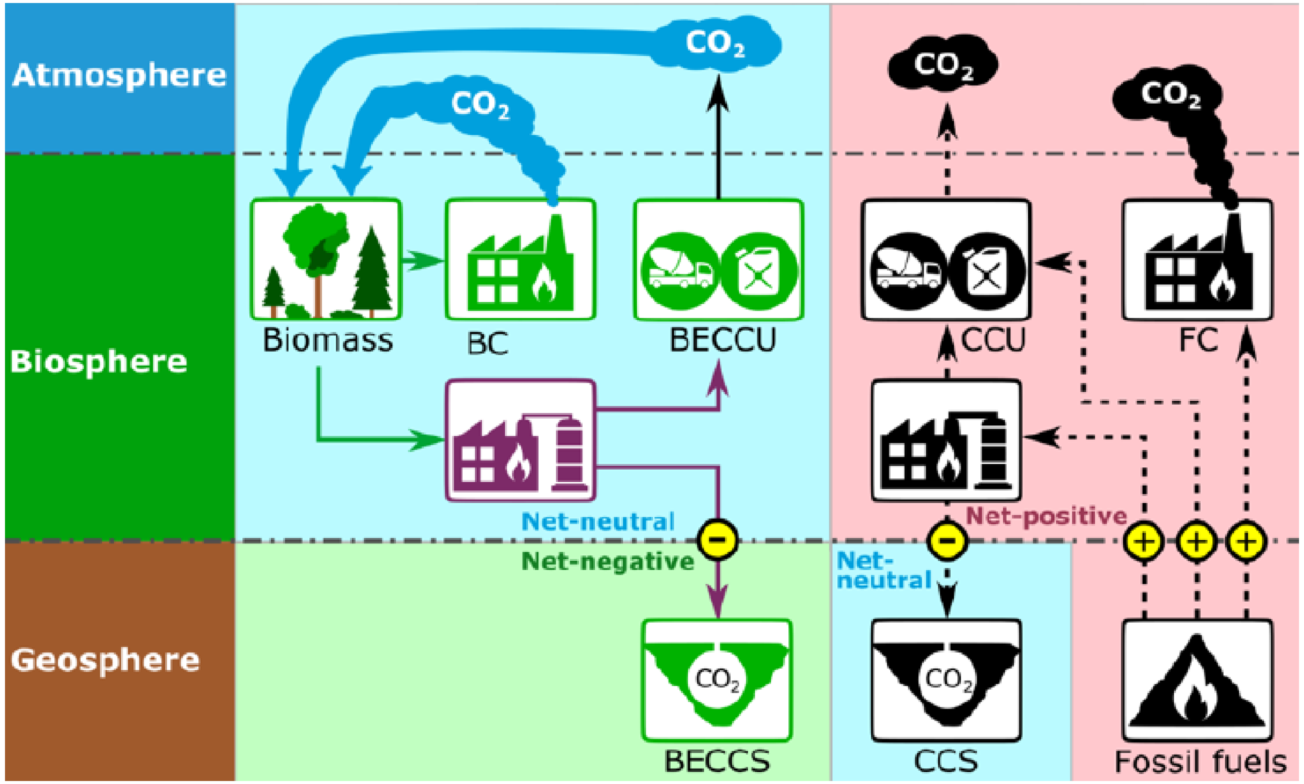
- EU depended on imports of natural gas: 82% were imported in 2020
- Gaseous energy carriers are used for many purposes
- Green gases are substitutes for natural gas (flexibility)
- Usage for processes, which are difficult to electrify
- Contribution to emission reduction
  - Agriculture: Circular economy
  - Transport: Public transport buses, heavy-duty vehicles, etc.

SWOT-analysis Renewable methane

Strengths	Weaknesses
Easier to store than H_2 with lower storage costs Applicability in different industries	Offset of emission reduction in case of methane leakages Low overall process efficiency Currently high production costs
Opportunities	**Threats**
Gas storage capacities for long-term storage CO_2 utilization Usage of current infrastructure Industry is heavily based on methane as feedstock	Lock-in effects of natural gas infrastructure Energy input for compression

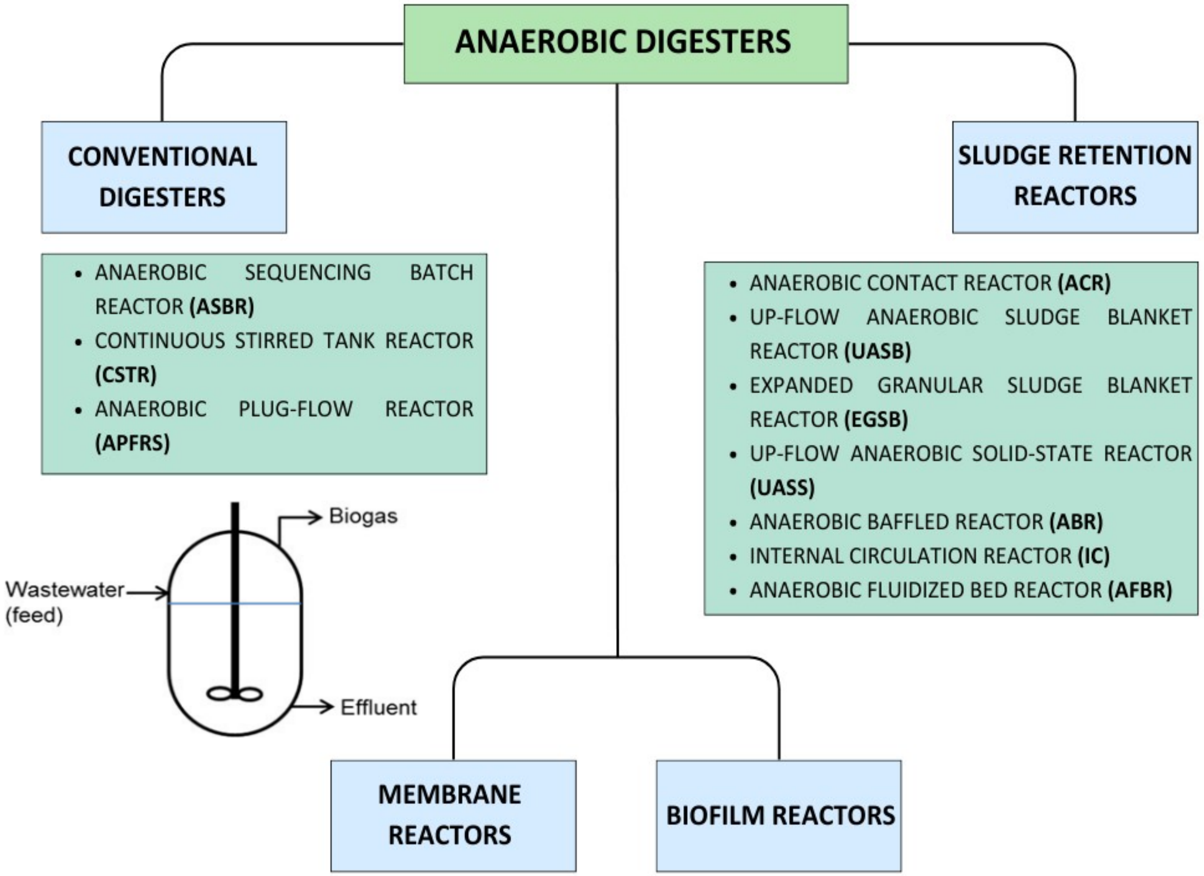


https://www.ieabioenergy.com/iea-publications/faq/woodybiomass/

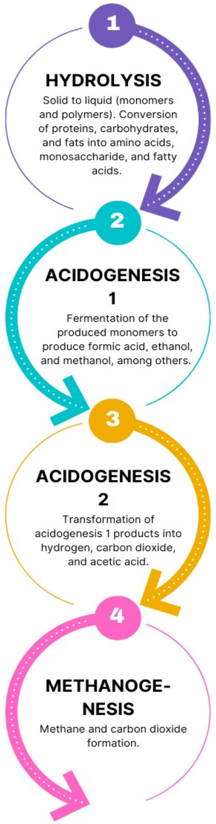


Olsson et al. 2020

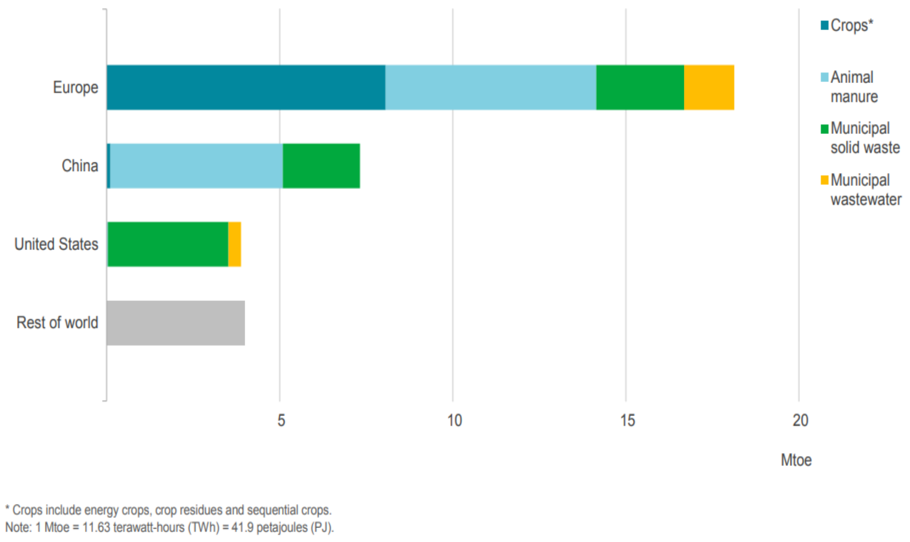
Anaerobic digestion



Gupta and Tuohy 2019

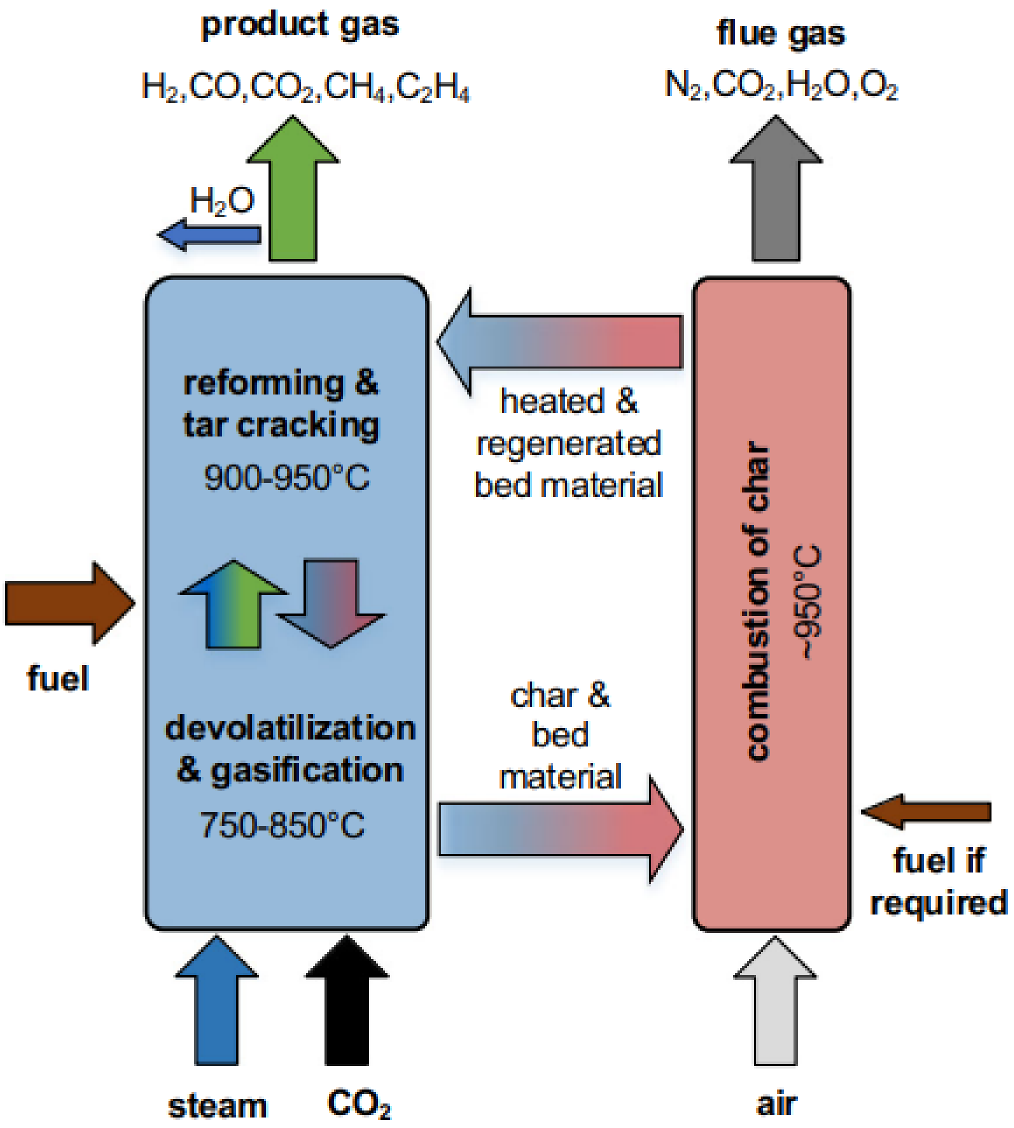


Negi et al. 2019



IEA 2020

Biomass gasification



Mauerhofer et al. 2021

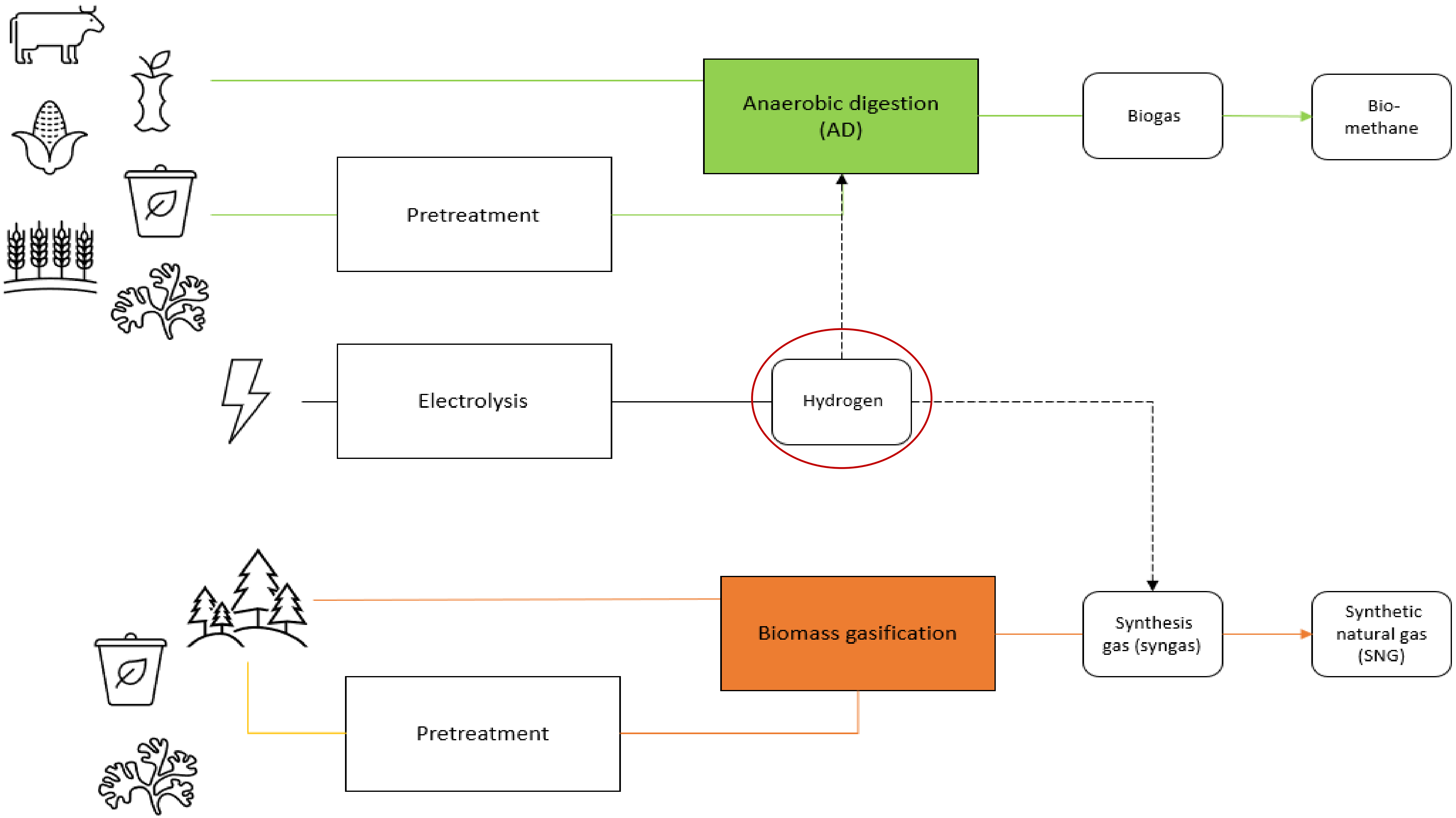
Methanation

$CO_2 + 4H_2 \leftrightarrow CH_4 + 2H_2O$

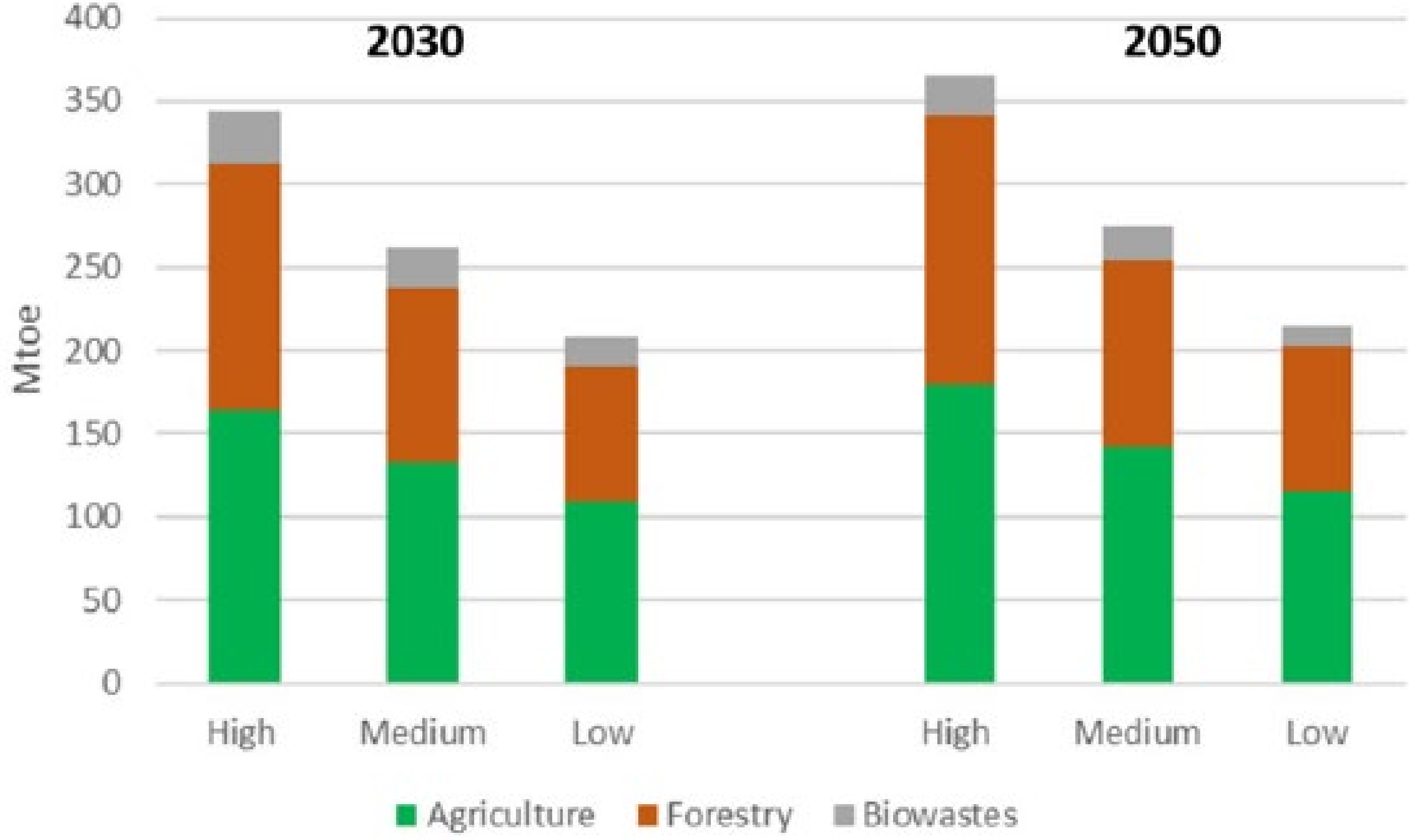
$CO + 3H_2 \leftrightarrow CH_4 + H_2O$

Carbon utilization
~ 35-40%

Technologies



Biomass resources



Feedstock potentials in the former EU-28 with focus on biomass waste and residues. Source: Imperial College London 2021

Advanced biofuels
2030: 46-97 Mtoe
2050: 71-176 Mtoe

Increase to approximately:
2030: 92 – 194 Mtoe
2050: 142 – 352 Mtoe
with **CO_2 utilization**

Economic assessment

- How will the costs change in the case of CO_2 utilization now and by 2050?
- Which variables have the strongest influence on the costs?

- Production costs
  - $c_{fuel} = \frac{CRF*I_0+C_{OF}+C_{misc}}{FLH} + \frac{P_B}{LHV*\eta} + c_{var}$
  - $c_{H_2} = \frac{CRF*I_0+C_{om}}{FLH} + \frac{c_{ele}}{\eta}$
  - $C_1 = C_0 * \left(\frac{S_1}{S_o}\right)^f$

c_{fuel} = levelized cost of fuel production, CRF = capital recovery factor, C_{OF} = fixed operating cost [€/ kW], C_{misc} = other capacity related cost, P_f = feedstock price, LHV = lower heating value, η = energy efficiency, c_{var} = variable cost [€/ kWh], C_0 = reference price for scale 0, S_o = base scale, f = scaling factor

Scenarios

- Biomass gasification
  - 2 Feedstocks: residual wood and wheat straw
- Anaerobic digestion:
  - 5 Feedstocks: Energy maize, grasses, biowaste, manure, wheat straw

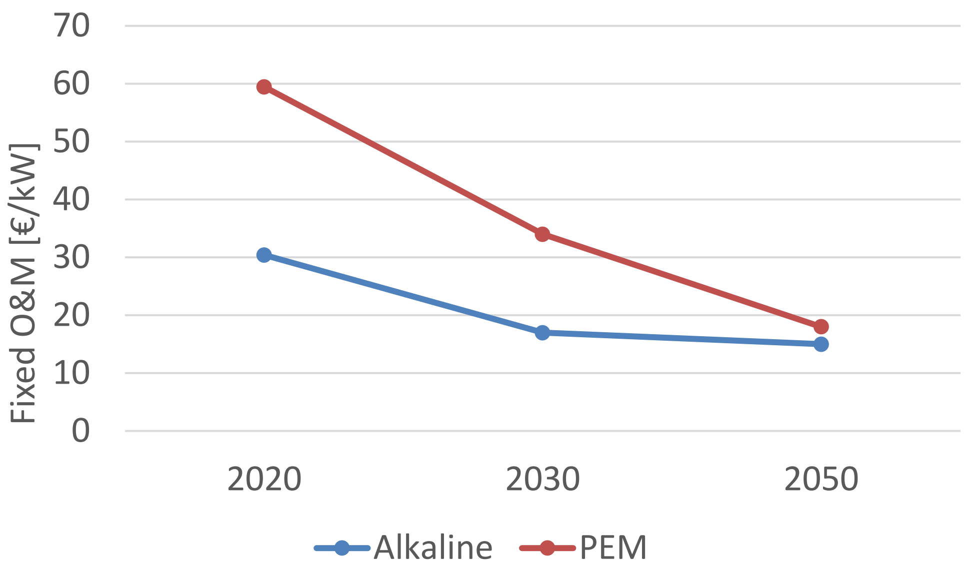
- Alkaline electrolyzer powered by grid electricity
  - Average AT historic electricity prices 2012-2021 = 4.3 ct/ kWh
  - 8.9 ct/ kWh
- PEM electrolyzer
  - Wind power
  - PV

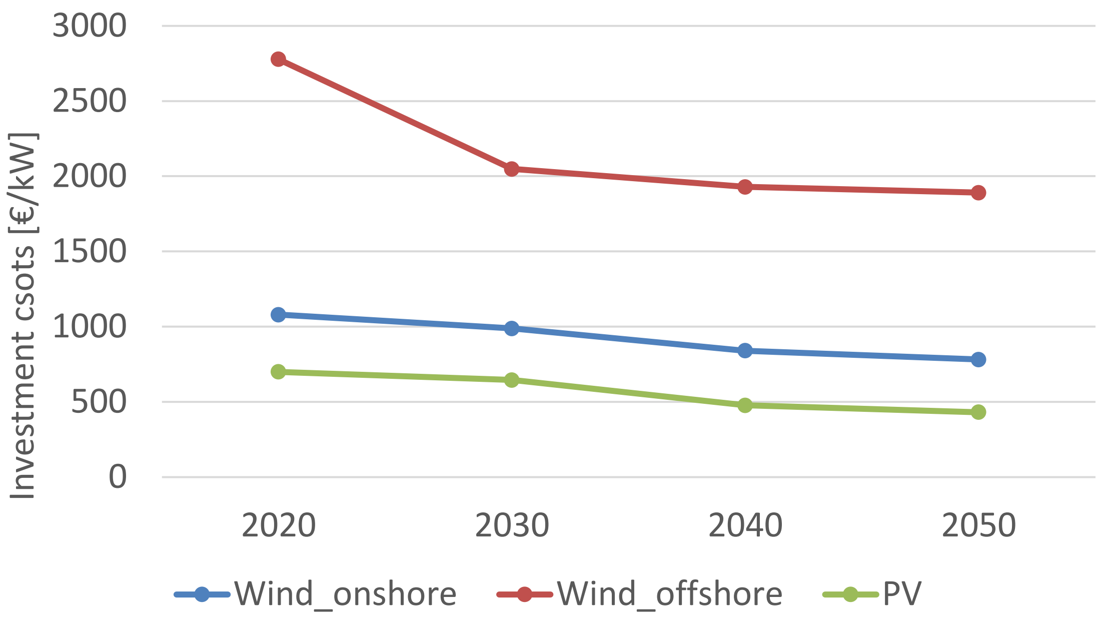
- Overall process efficiency
  - Biomass gasification + H2: 59%
  - Anarobic digestion + H2: 51- 67%

Parameters	Gasification	Anaerobic digestion	Alkaline electrolyzer		PEM electrolyzer	
Year			2020	2050	2020	2050
Discount rate	5%	5%	5%	5%	5%	5%
Transport distance	75 km	10 km	/	/	/	/
Energy efficiency	63%	42-69%	42-**67** %	> 74 %	40-**67** %	> 74%
Plan/electr. Capacities [MW]	200 MW	8 MW				
kWh H2/ kWh product gas (biogas)	**1.24**	**0.7-1**				
Investment cost €/kW	3765	1842-3672	437-875	< 200	613-1225	<200

Sources: Hofbauer 2020, Holmgren 2015, Billig und Thraen 2017, Thunman 2018, IRENA 2020

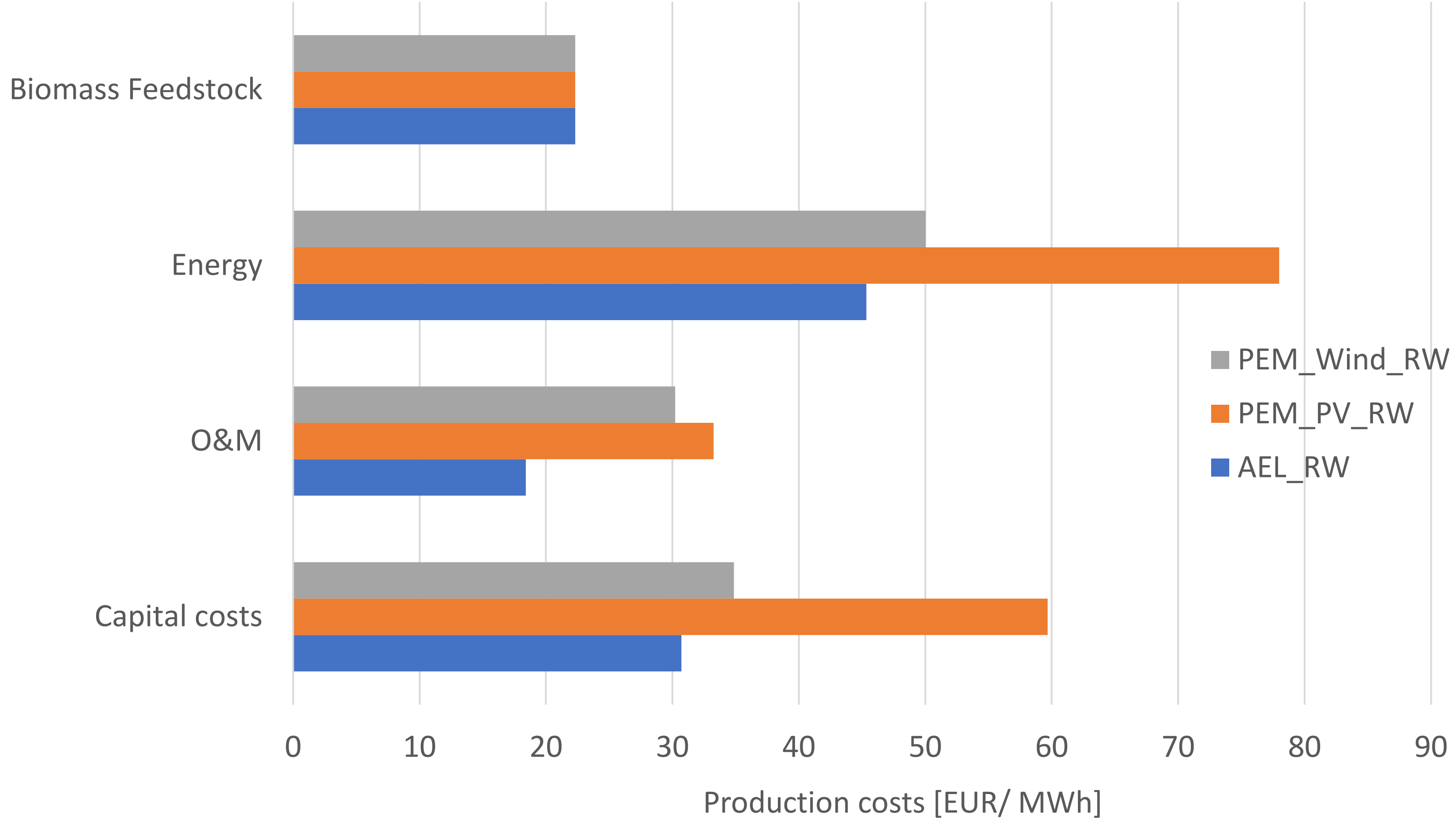
Decline in H2 production costs





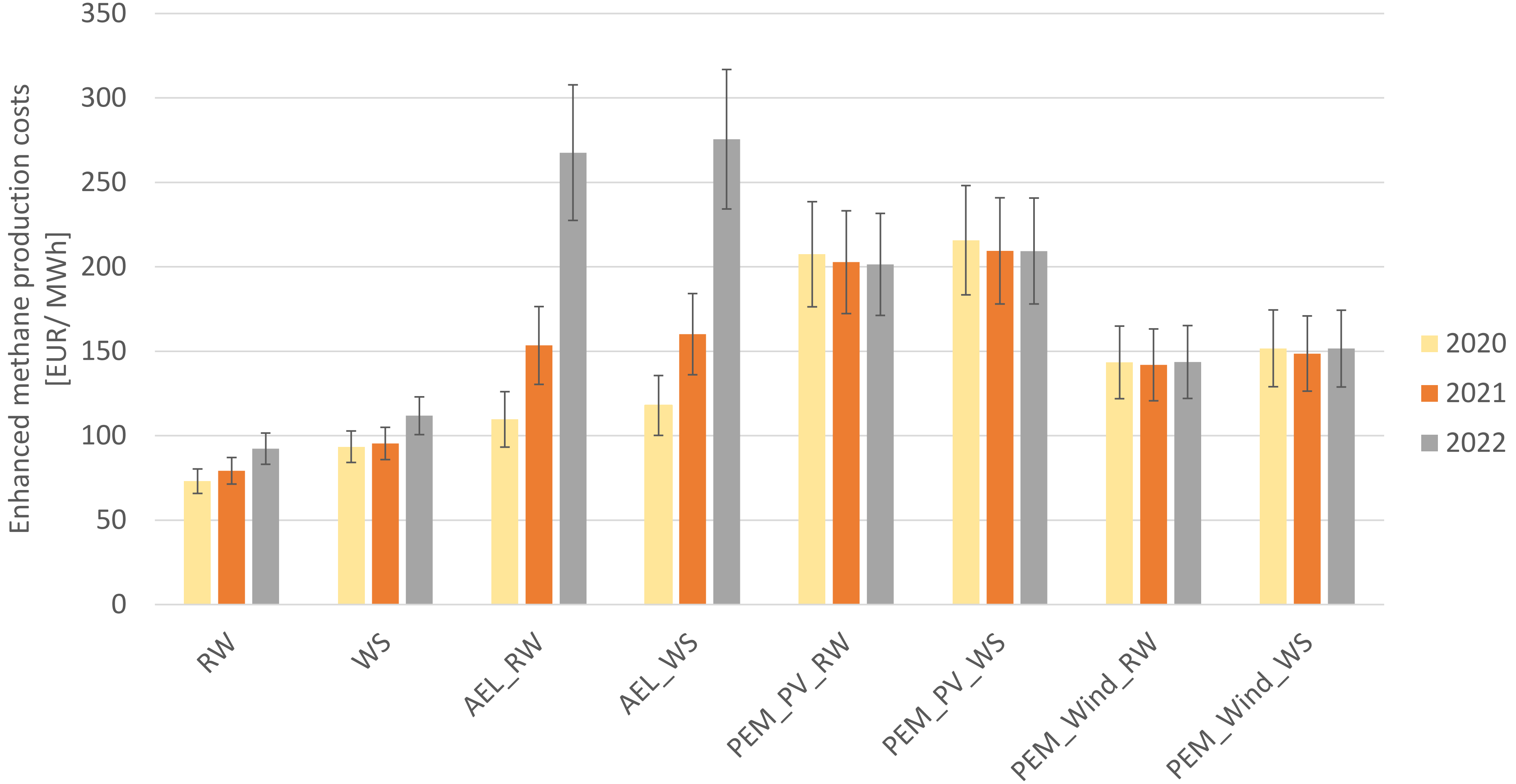
Source:
Technology pathways in decarbonisation scenarios (Asset 2018)

Results
Production cost structure



RW= residual wood, AEL = alkaline electrolysis, PEM = proton exchange membrane electrolysis, PV= photovoltaics

Effect of high energy prices



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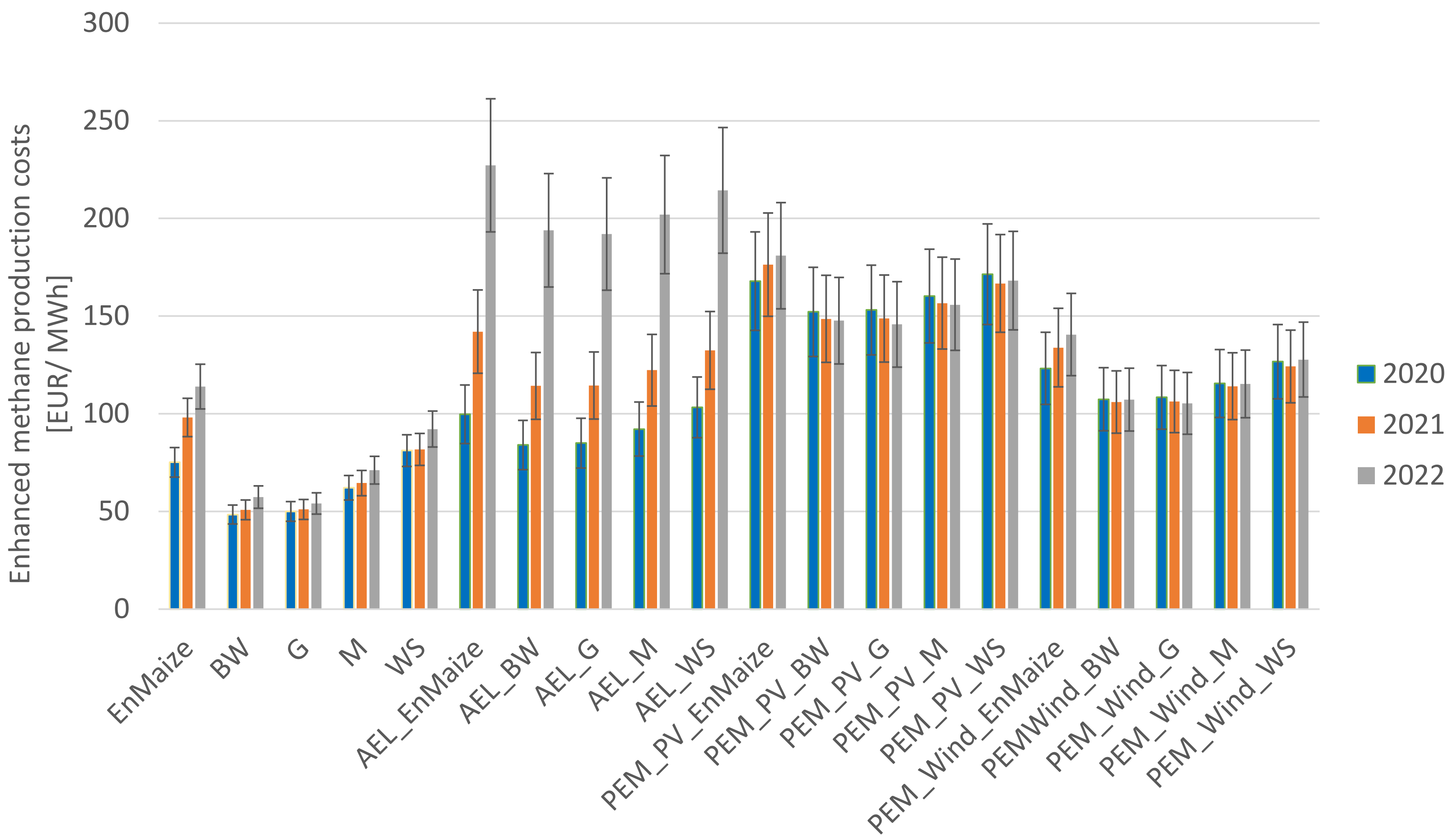
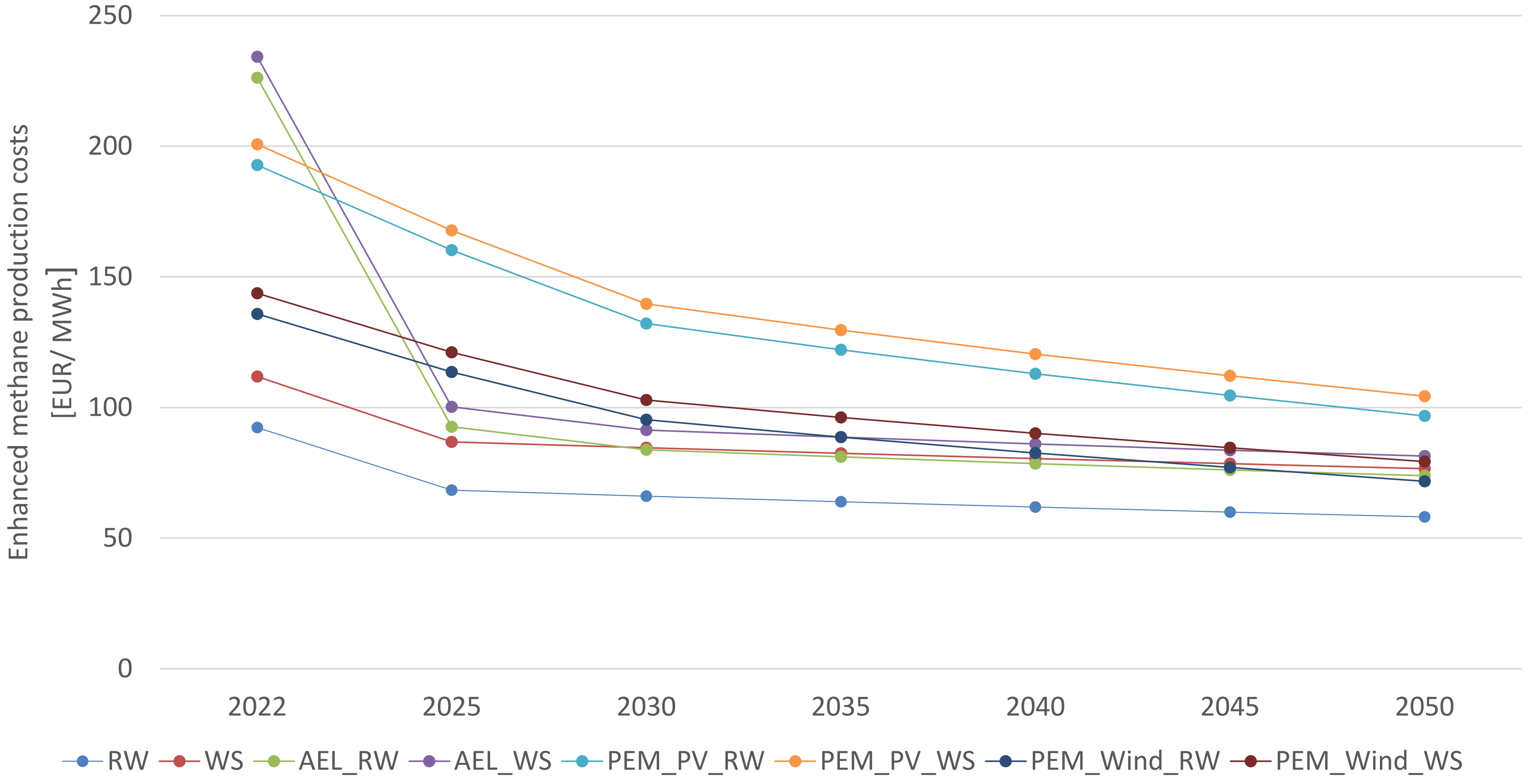


EnMaiz= energy maize, BW= biowaste, G= grass, M= manure, WS= wheat straw, AEL = alkaline electrolysis, PEM = proton exchange membrane electrolysis, PV= photovoltaics

Scenario results



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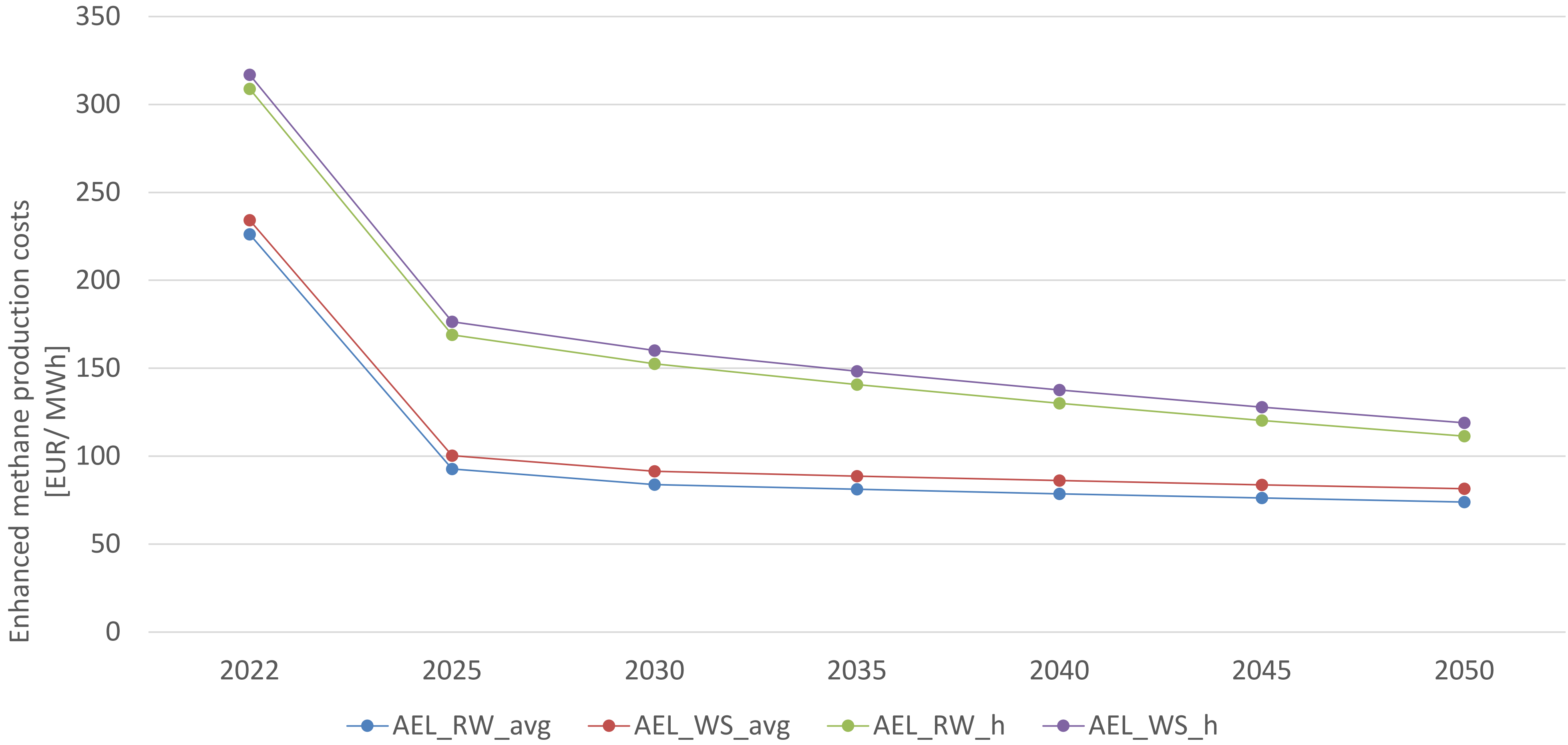

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Conclusions

- Choice of feedstock has a significant influence on the production costs
- A high number of full load hours is beneficial for the costs
- Cost reductions of hydrogen in the future
  - will lead to cost reductions for CO_2 utilization

- Uncertainties regarding the costs
  - Electricity availability and costs
  - Effects of learning rates

- Life cycle assesment needs to be conducted

Thank you for the attention!