Hybrid Gasification-Synthesis Process with CO2 Recycling to Improve Synthetic Fuels Yield and Carbon Efficiency – Techno-economic Assessment

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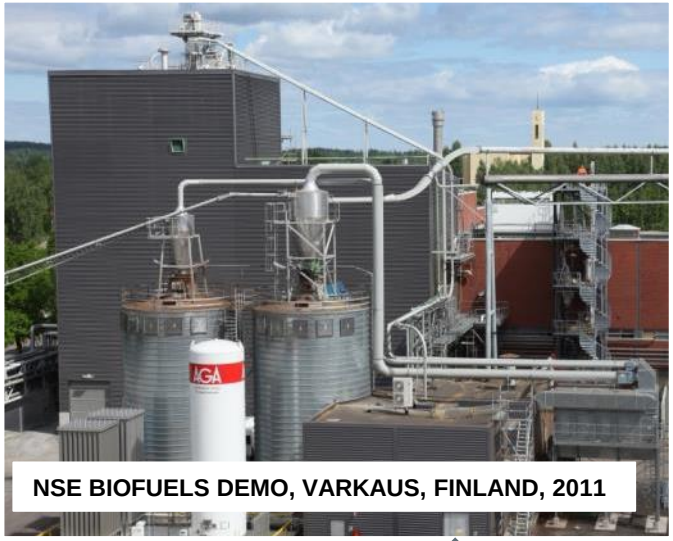
Biomass gasification for biofuels and bio-chemicals

- Long experience of medium-to-large scale synthesis gas technologies

PEAT AMMONIA PLANT
OULU, FINLAND, 1991



NSE BIOFUELS DEMO, VARKAUS, FINLAND, 2011

PILOT PLANT AT VTT BIORUUKKI, ESPOO, 2022

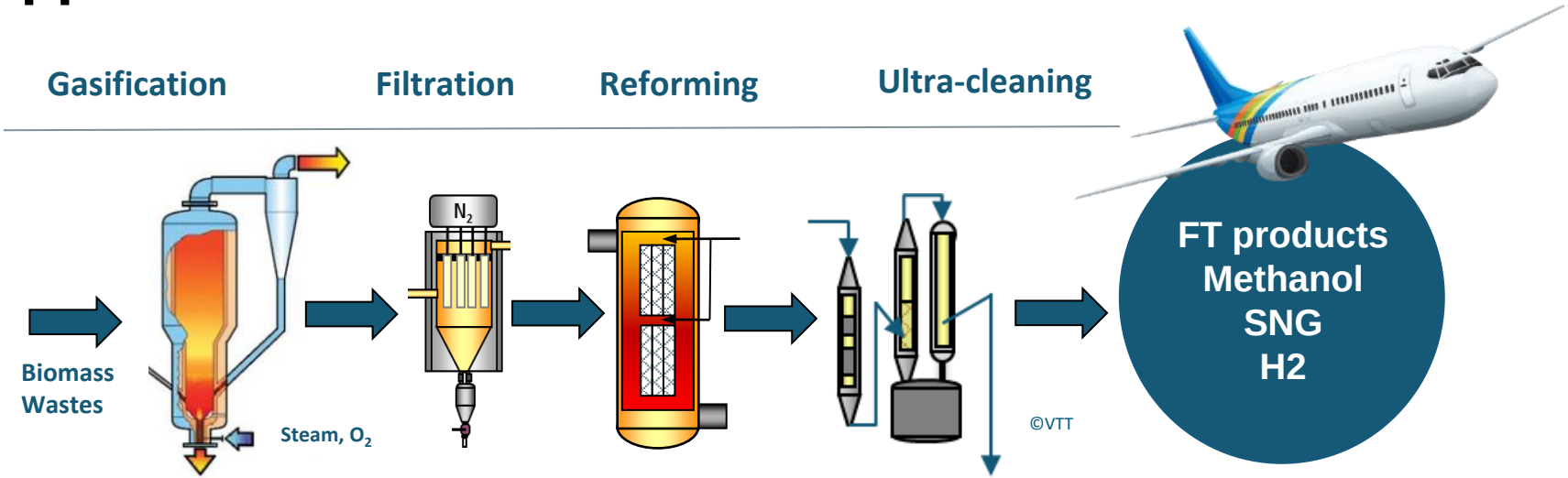
1985 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030

COAL GASIFIER APPLIED FOR PEAT AND WOOD

LARGE-SCALE GASIFICATION SPECIALLY DEVELOPED FOR WOOD FEEDSTOCKS

PROCESS DEVELOPMENT FOR LOWER CAPEX, HIGHER CARBON UTILIZATION AND WASTES

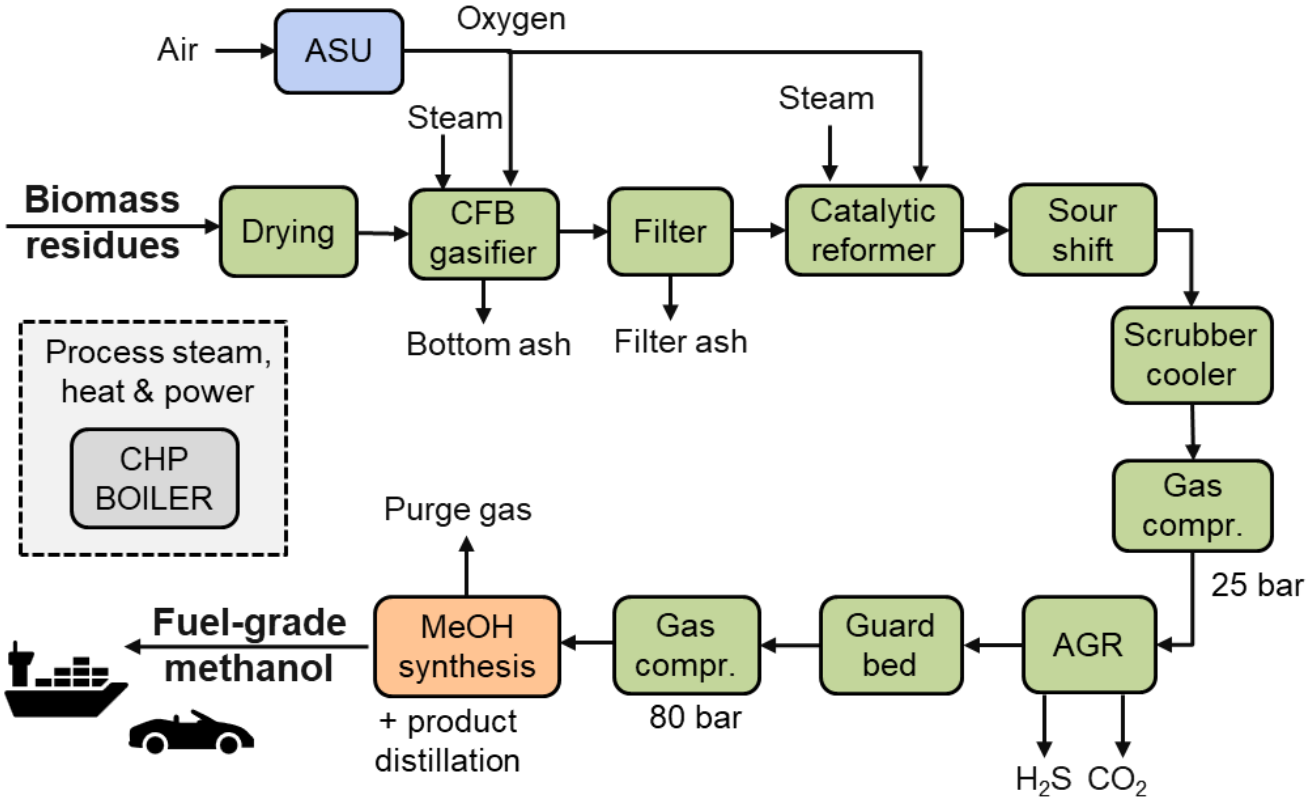
Key steps in the gasification-synfuels process of VTT



Technological basis – TRL7

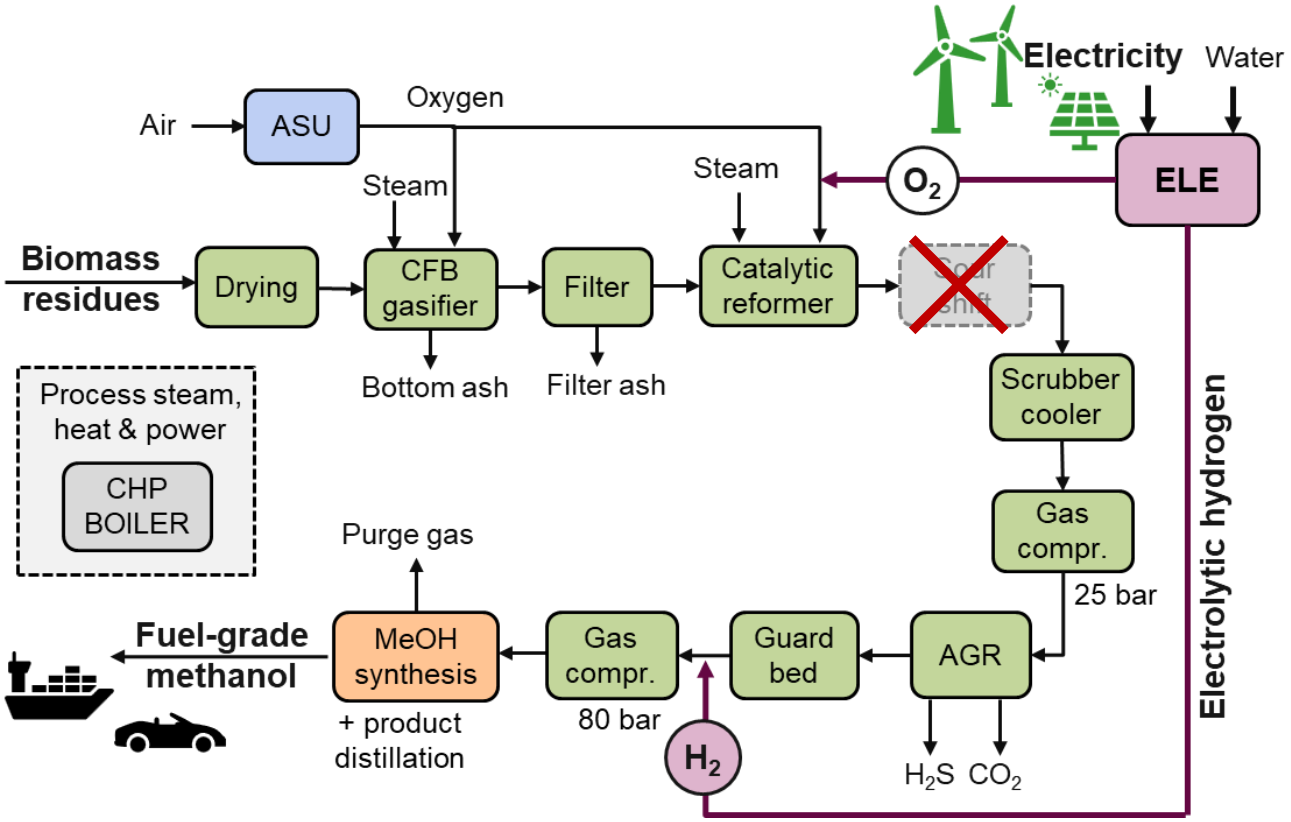
- Air-blown CFB gasifier commercial, **steam/O_2-blown demonstrated at 12 MW**
- Filtration demonstrated at 5 MW scale, commercial in air-blown gasification
- **Reforming demonstrated at 5 MW scale**
- Final gas cleaning commercial (similar to coal gasification)

Methanol production from biomass



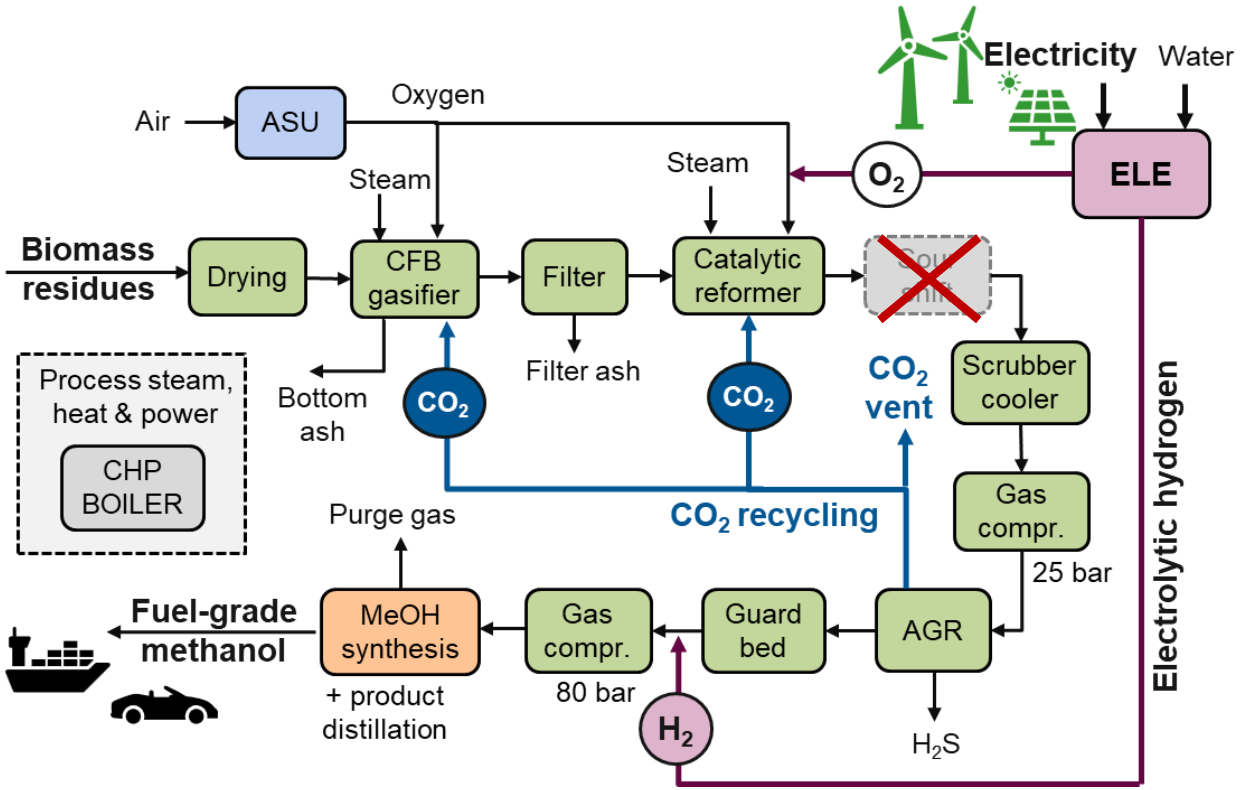
BASE CASE – Biomass alone, H_2/CO molar ratio adjusted with a shift unit

Methanol production from biomass



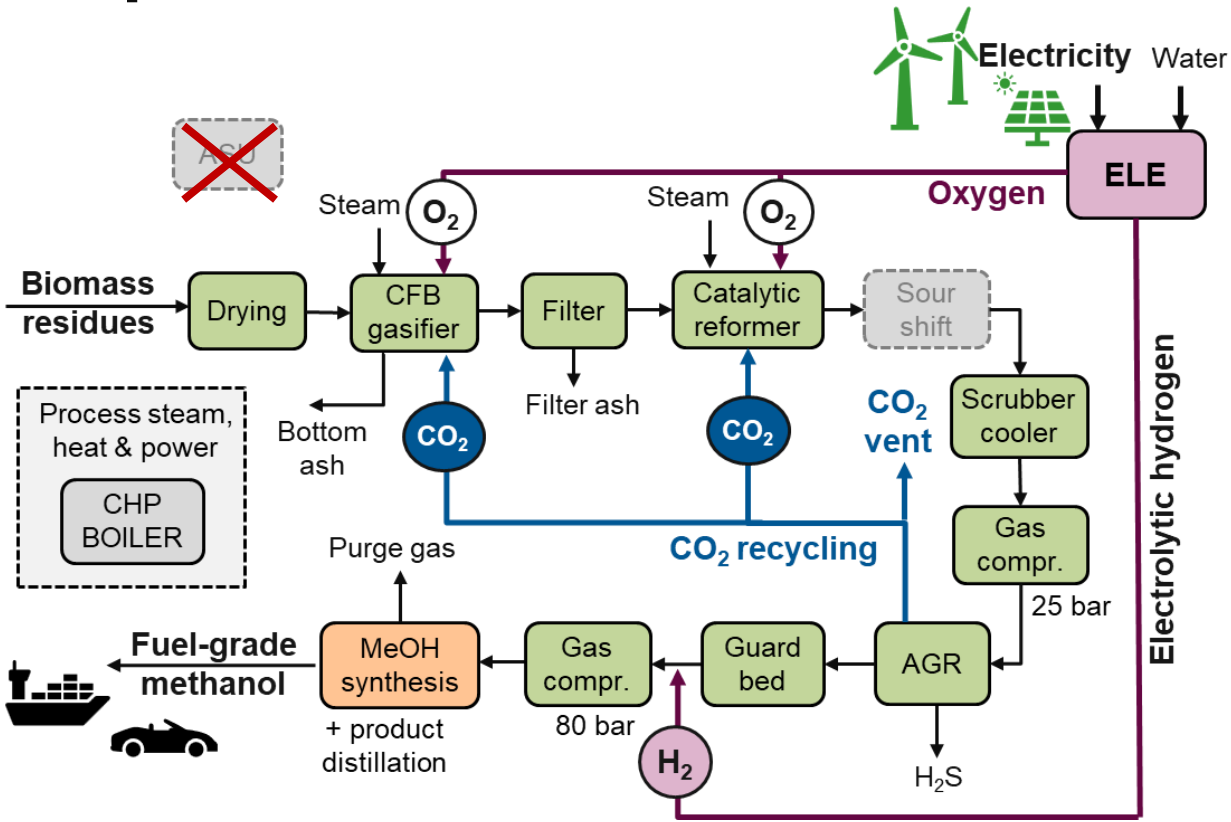
HYBRID 1 – CO shift replaced with electrolysis H_2

Methanol production from biomass



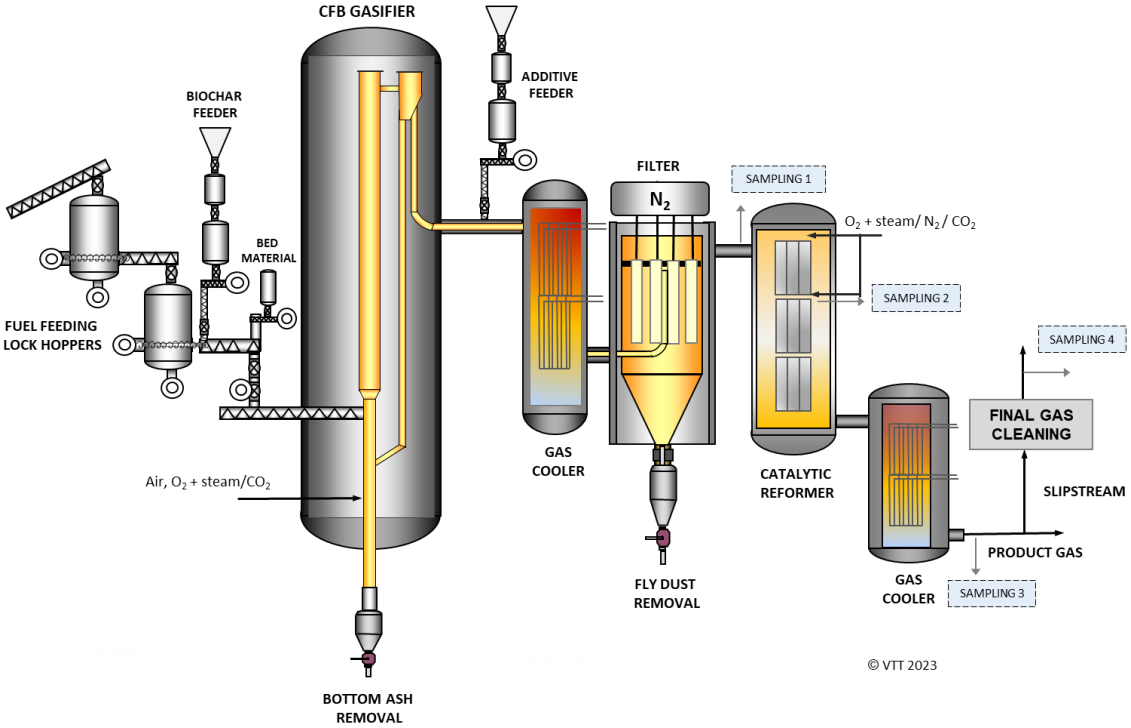
HYBRID 2 – CO_2 recycling to increase the use of external H_2

Methanol production from biomass



HYBRID 3 – Electrolyser dimensioned to produce all oxygen consumed at the plant

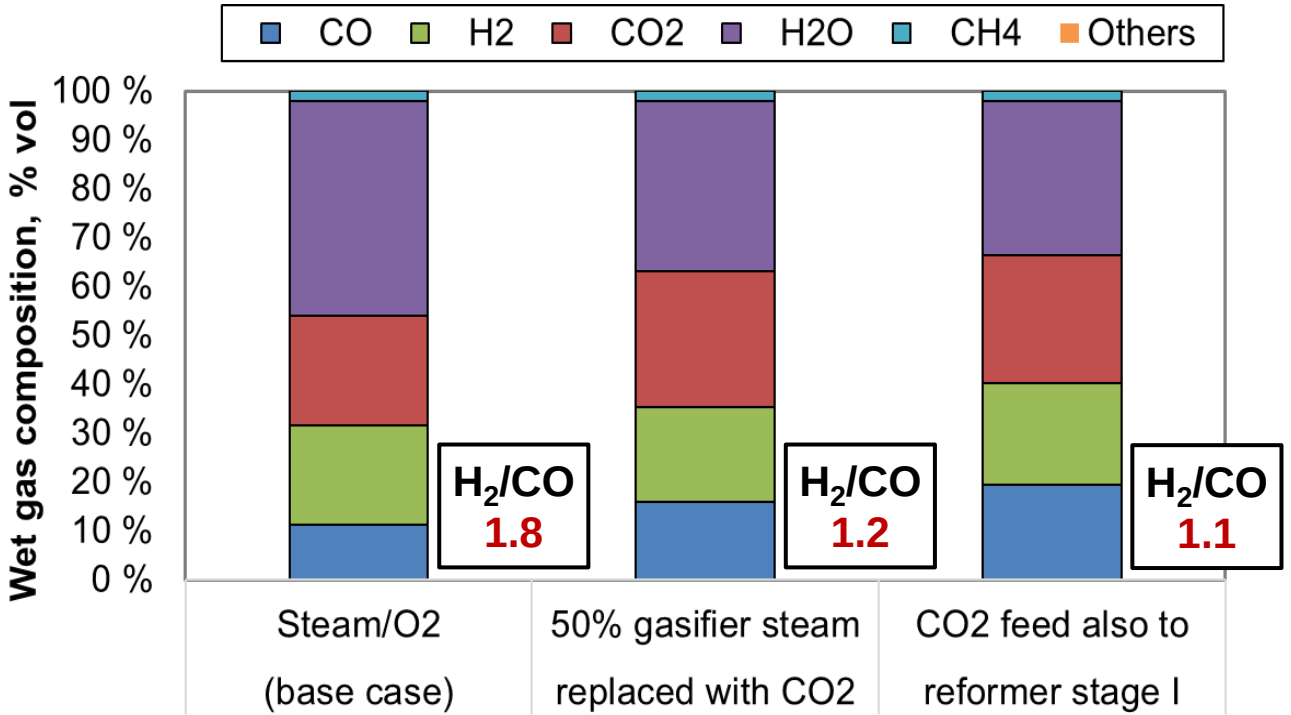
VTT's pressurized O_2/steam-blown CFB gasification pilot plant at Bioruukki



CFB gasifier "UCG2021"	
Plant capacity, MW	0.2-0.5
Operation pressure, bar	1 - 8
Temperature range, °C	750 - 920
Gasification agents	Air, O_2 + Steam/CO_2
Feedstocks	Biomass residues, wastes
Feed rate, kg/h	max. 100 kg/h
Gas velocities, m/s Fluidizing velocity at the bottom of bed Gas velocity at the top of reactor	 1 - 3 1.5 - 3
Reactor (i.d.), mm Lower part Upper part	 150 225
Reactor height, m Total height	 7.5

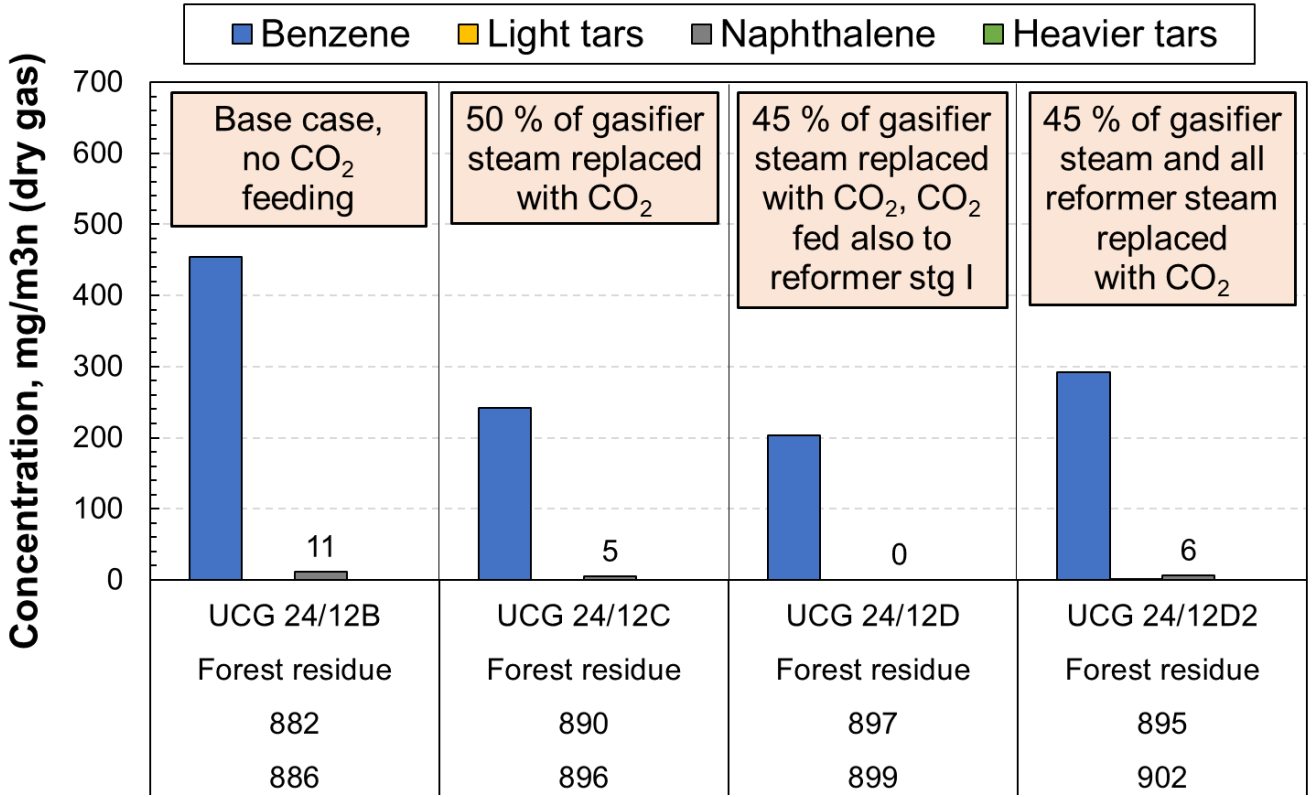
Total gasification hours ~5000 h (CFB gasification, hot filter and reformer)

Preliminary testing of CO_2 recycling in VTT's gasification pilot with forest residues



Wet gas composition after catalytic reforming

Preliminary testing of CO_2 recycling in VTT's gasification pilot with forest residues



Tar and benzene concentrations after reforming

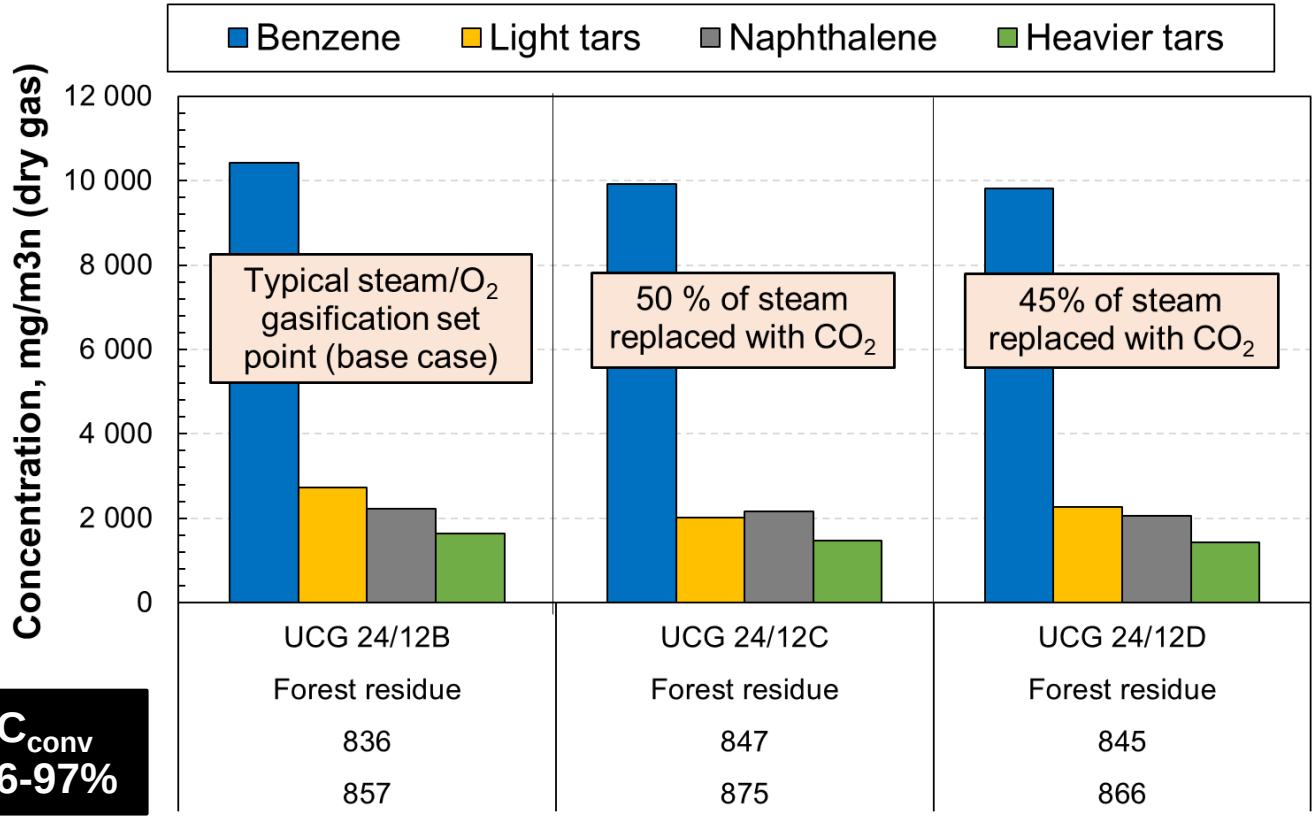
Set point

Feedstock

Reformer II (out), °C

Reformer III (out), °C

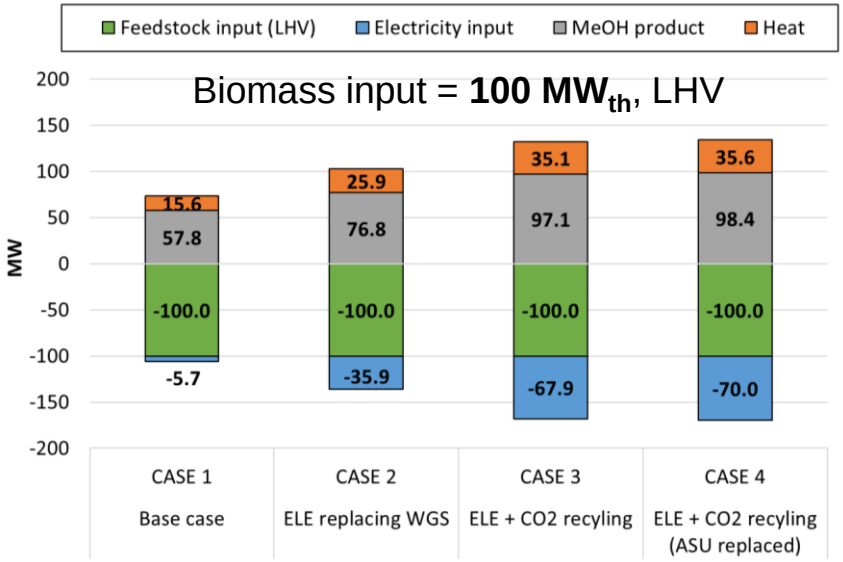
Preliminary testing of CO_2 recycling in VTT's gasification pilot with forest residues

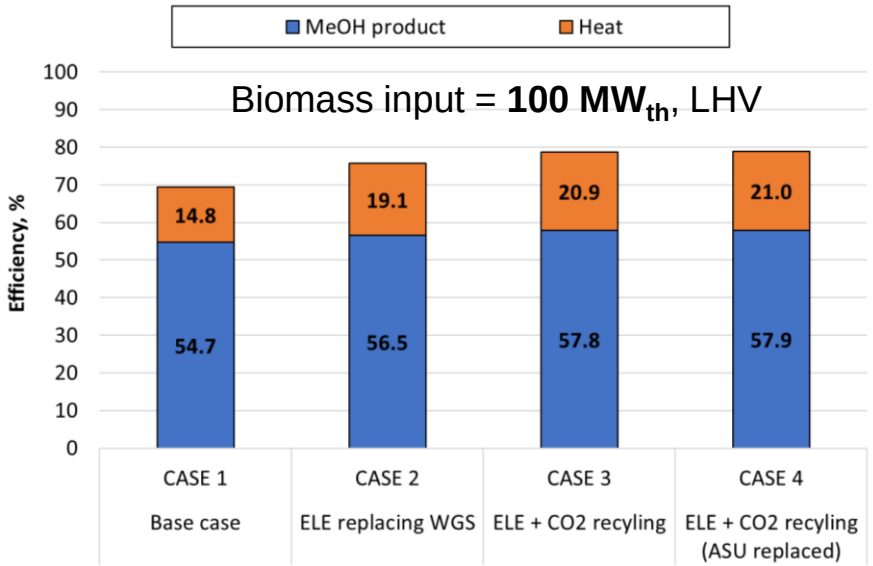


Tar and benzene concentrations after gasifier

C_{conv} 96-97%

Estimated energy balances and efficiencies for MeOH production from forest residue feedstock

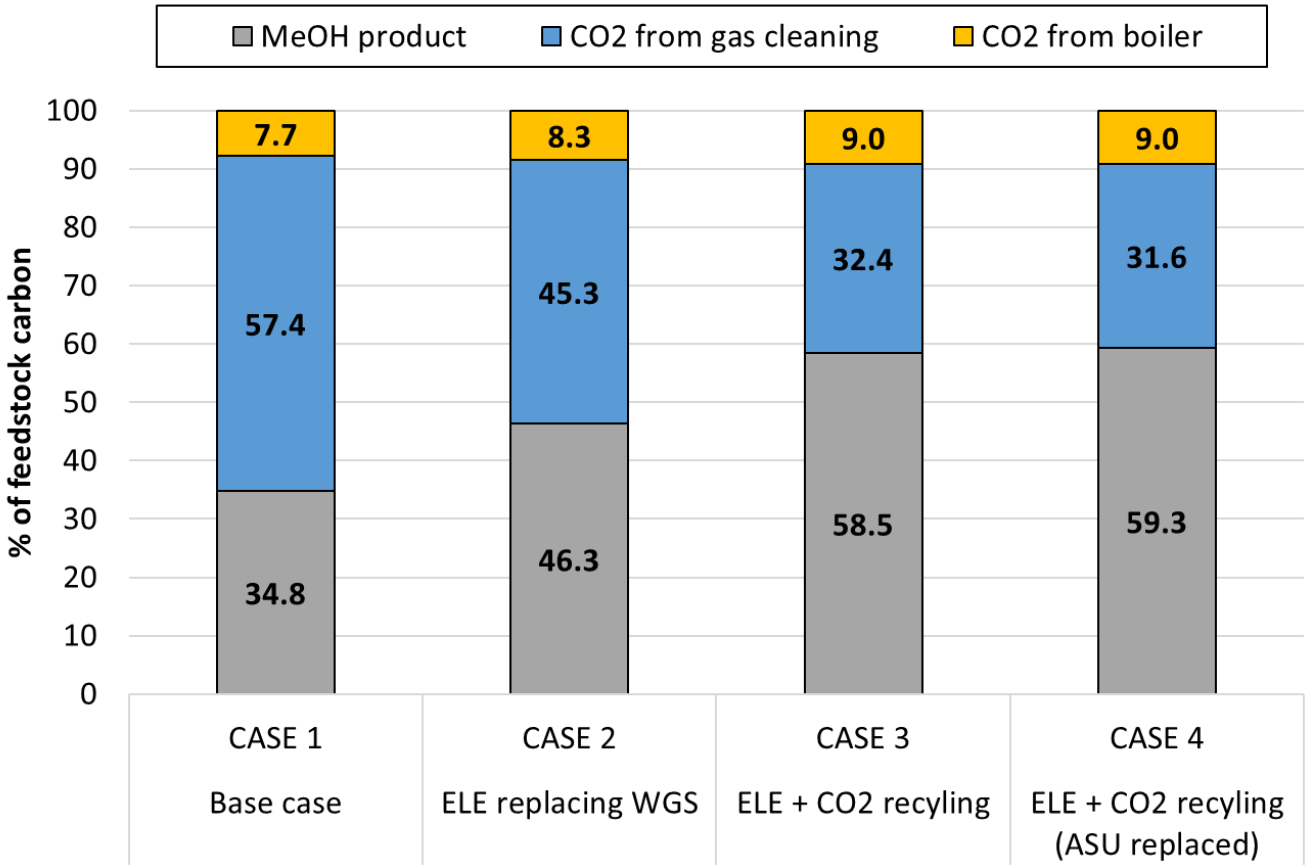




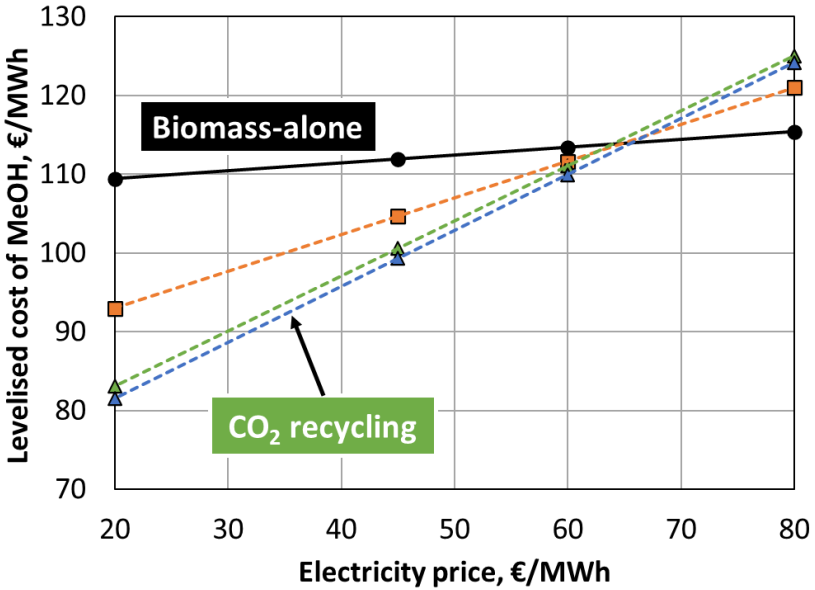
ELE, MW	-	**32.9**	**67.7**	**69.9**
CO_2 rec, %	-	-	**33**	**35**
Steam repl, %	-	-	**50**	**53**

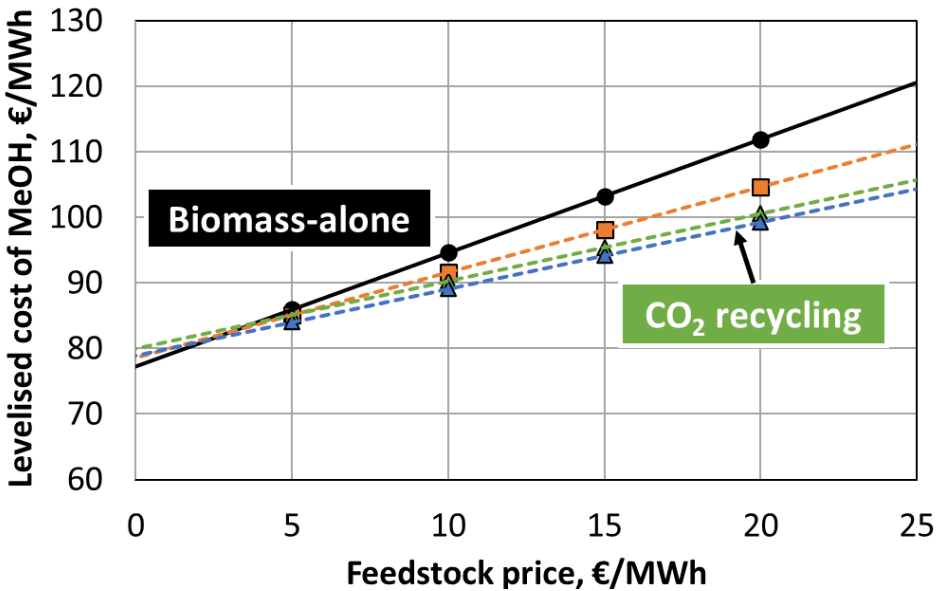
- **Feedstock:** Forest residues (50 wt-% moisture as received, dried to 12 wt-%)
- **Steam/O_2 CFB gasification**: 880 °C, 4 bar
- **Filtration**: 550 °C
- **Catalytic reforming**: outlet temperature 900 °C
- **MeOH synthesis**: 260 °C, 80 bar

Estimated distribution of feedstock carbon



Estimated production cost of methanol





- CASE 1 (Base case)
- CASE 2 (ELE replacing WGS)
- CASE 3 (ELE + CO2 recyling)
- CASE 4 (ELE + CO2 recyling, ASU replaced)

Price of feedstock	20 €/MWh
Price of electricity	45 €/MWh
Value of heat	40 €/MWh
Interest rate	7%
Economic life of plant	20 a

Conclusions

- Hybrid gasification-synthesis process with CO_2 recycling to the gasifier and the reformer (to replace part of the steam feed) is estimated to have significant potential in improving synthetic fuels yield, process efficiency and carbon efficiency.
- Preliminary experimental work in steam/oxygen-blown CFB gasification conditions would suggest that replacing 50% of the steam feed in the gasifier and the catalytic reformer would not compromise gasifier/reformer performance. However, more extensive testing and especially long-term runs are needed to verify this assumption and the technical limitations for CO_2 recycling.
- In methanol production from biomass, hybrid concepts that couple gasification with electrolysis are estimated to be economically attractive already with current electricity price levels. CO_2 recycling has the potential for further cost reductions especially with lower electricity prices.

beyond the obvious

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