Power-to-Gas coupling to biomethane production

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September 2013
ECN-L--13-061

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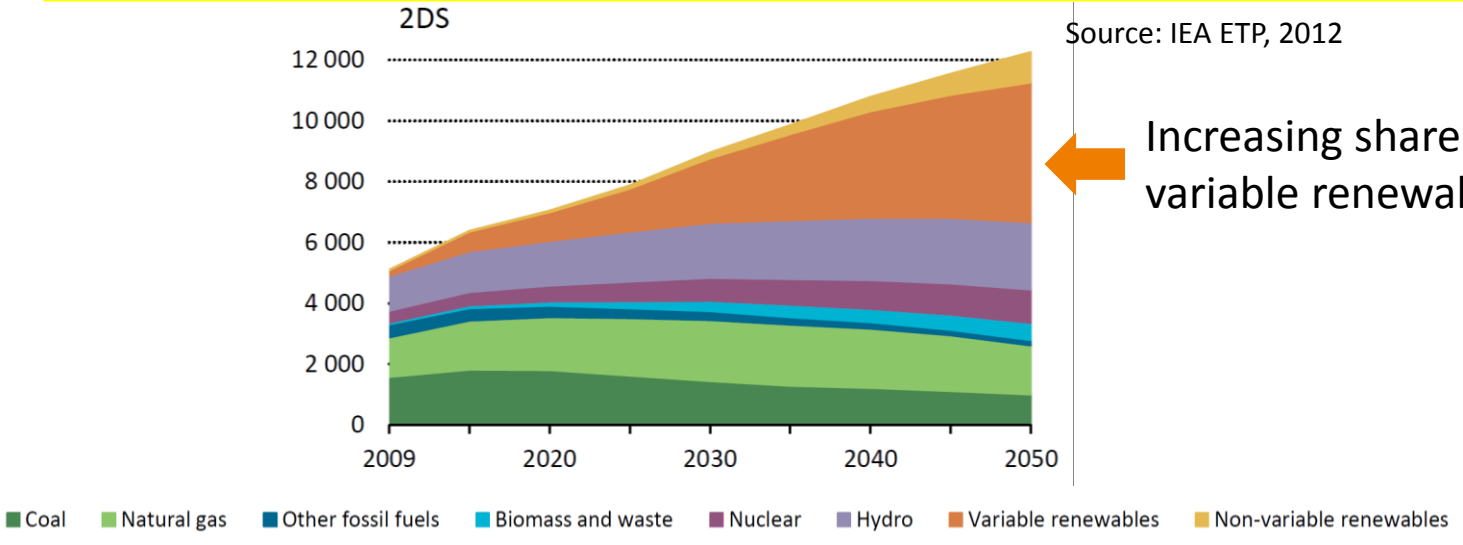
ICPS 13 International Conference on
Polygeneration Strategies

Vienna, Austria 3-5 September 2013

The future global electricity mix



Source: IEA ETP, 2012

Increasing share of variable renewables

➔ Not all green power can be fed into the electricity grid

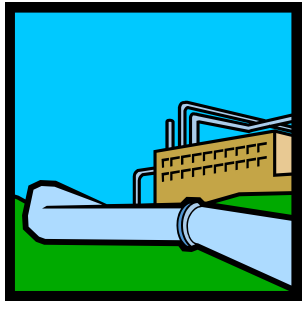
- Mismatch in time
- Mismatch in location (transport limitations)

} Excess renewable electricity

Part of the solution

Use the gas grid as a storage medium for excess electricity

- existing infrastructure
- high storage capacity

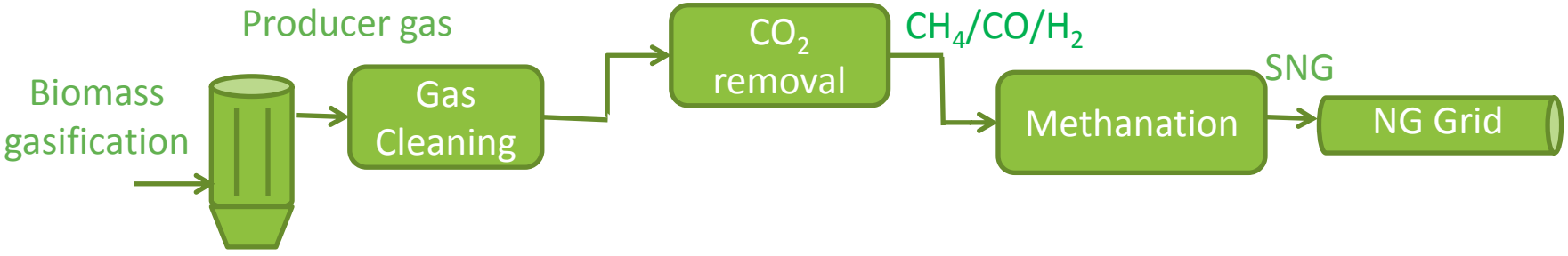


How?

- Convert excess electricity to H_2 ➔ limitations in allowable H_2 level
- **Convert excess electricity into SNG** ➔ less limitations

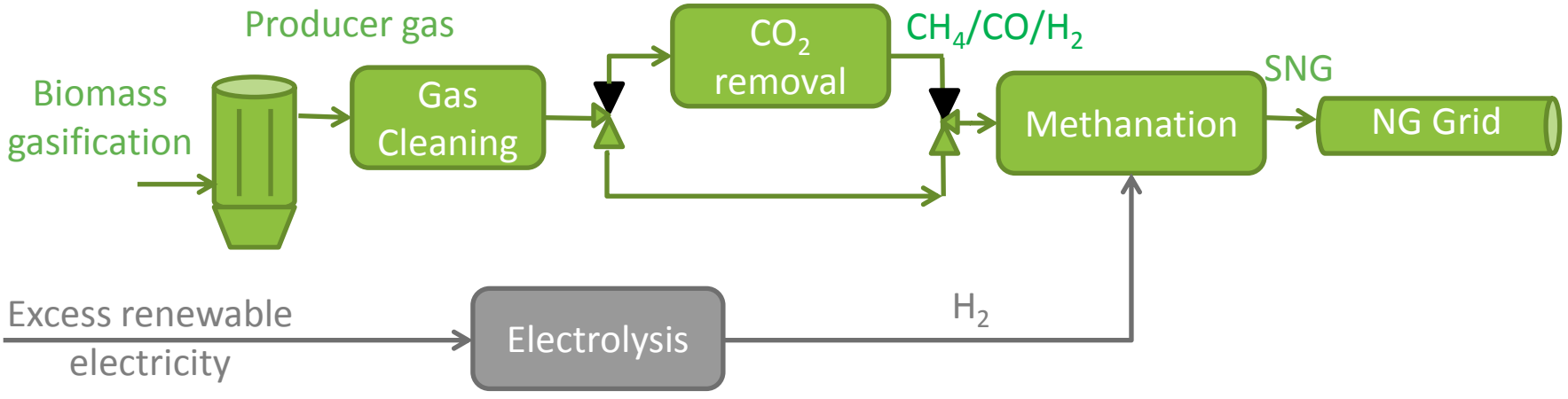
➔ Combine with biomass to SNG process

Biomass to SNG



$CO + 3H_2 \leftrightarrow CH_4 + H_2O$ $\Delta H = -217$ kJ/mol

Biomass to SNG: use CO2

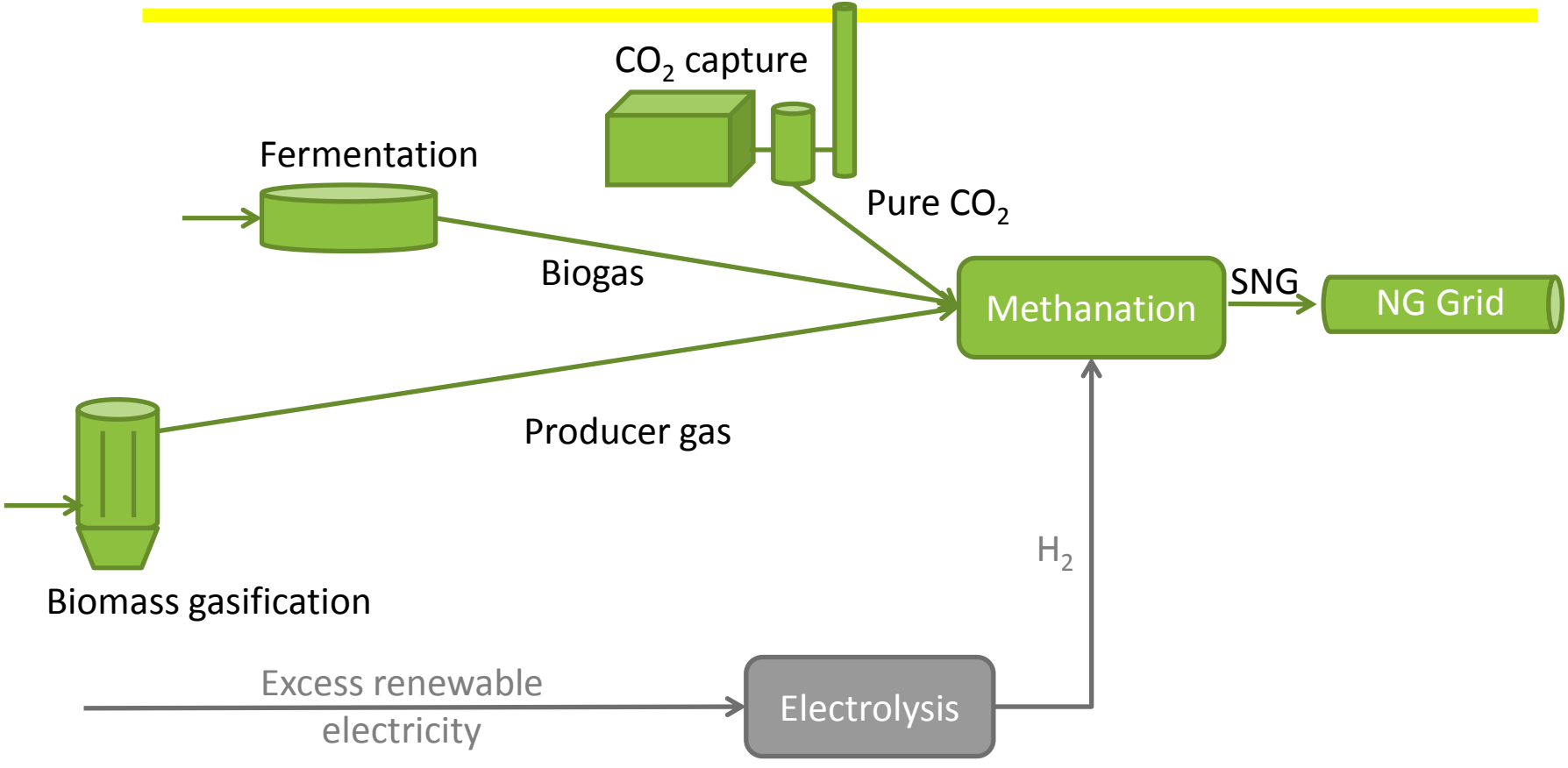


$CO_2 + 4H_2 \leftrightarrow CH_4 + 2\ H_2O$ ΔH=-164 kJ/mol

2 operating modes

CO_2 removal	No excess renewable electricity	CO_2 removal in operation, no electrolysis
H_2 addition	Excess renewabel electricity	CO_2 removal, electrolysis in operation

Power to gas (P2G)



Objective

- Assessment of a flexible process for biogas
  - Conceptual process design
  - Configurations and process conditions
- Impact of H_2 addition on gas quality
- Comparison between H_2 addition and CO_2 removal

System starting points

ECN biomass gasification technology

- MILENA indirect gasifier
- OLGA tar removal

Gas cleaning

- Water scrubbing
- H_2S removal by ZnO
- Pre-reforming
- Pre-compression

CO_2 removal (MEA) [with bypass]

Methanation

- Pure H_2 available a at required pressure

SNG upgrade

- Water removal
- Final compression to grid pressure [60 bar]

Battery limits

Design variables

Methanation configuration

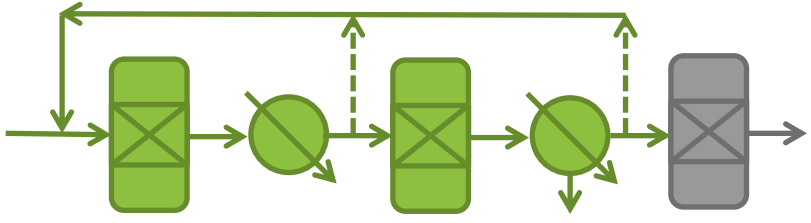
Variation in number or stages and location of recycle

- 1st: high temperature T_{max}=650°C, 3 stage, recycle after 1st stage
- 2nd: high temperature T_{max}=650°C, 3 stage, recycle after 2nd stage

Lurgi HT

- 3rd: low temperature T_{max}=450°C, 2-stage recycle after 1st stage

Great plains



Methanation section pressure

- 20-60 bar

Criteria

Wobbe index

$$W = \frac{HHV}{\sqrt{(\rho_g / \rho_{air})}}$$

W> 43.5 MJ/m^3_n Dutch gas grid standard

SNG molar H_2 Content

- Max1 <0.5% H_2 — Dutch gas grid standard
- Max2 < 10% H_2 — Possible future limit

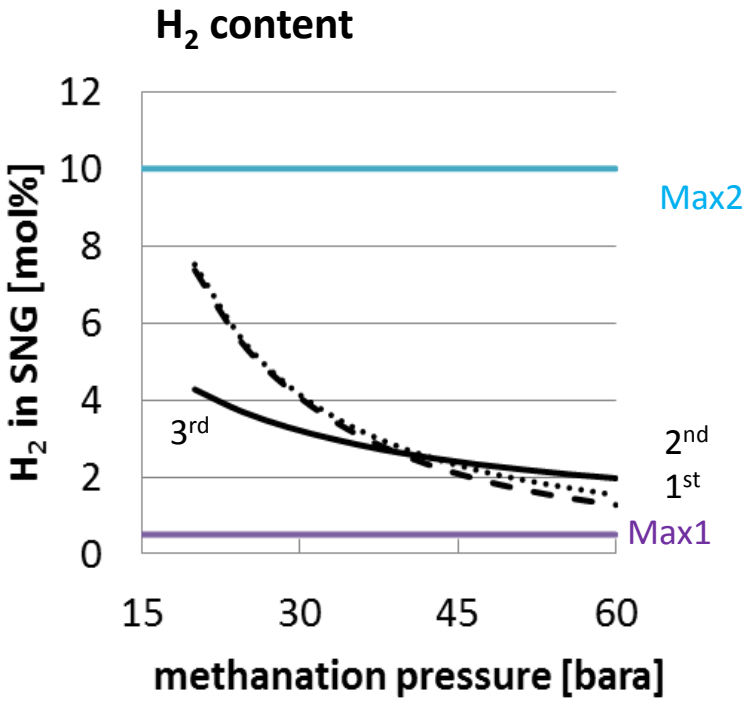
Energy balance

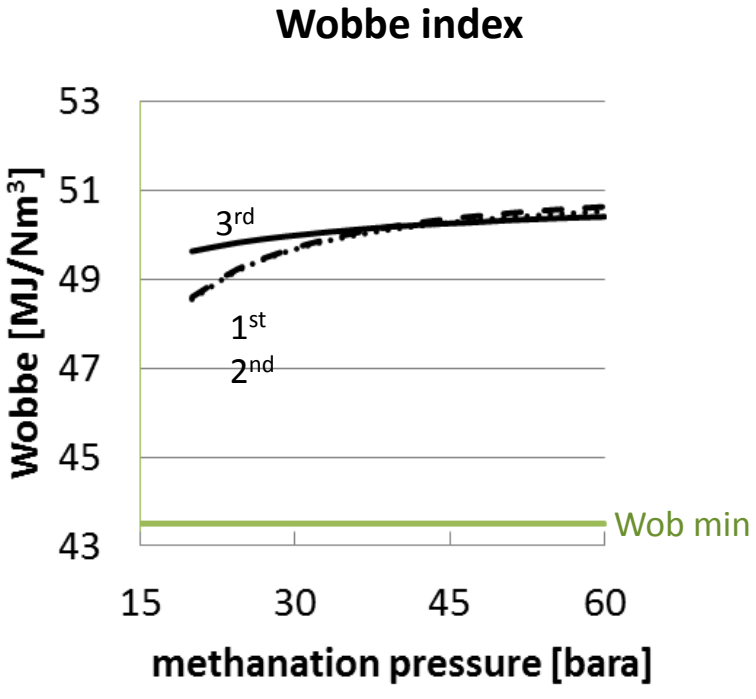
- Steam balance
- Total power use

Cold gas efficiency

- Based on gas inlet/outlet combustion values

H2 addition : Impact of configuration and pressure

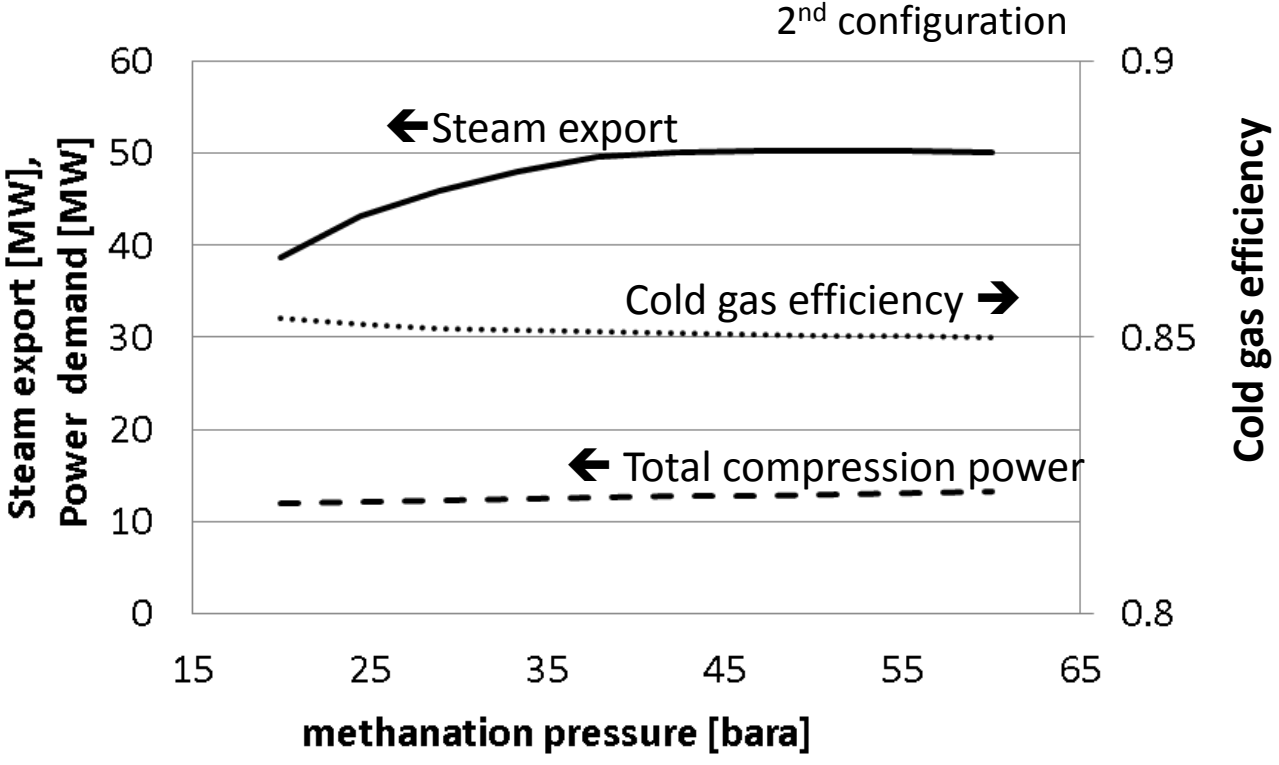




1st config 2nd config 3rd config

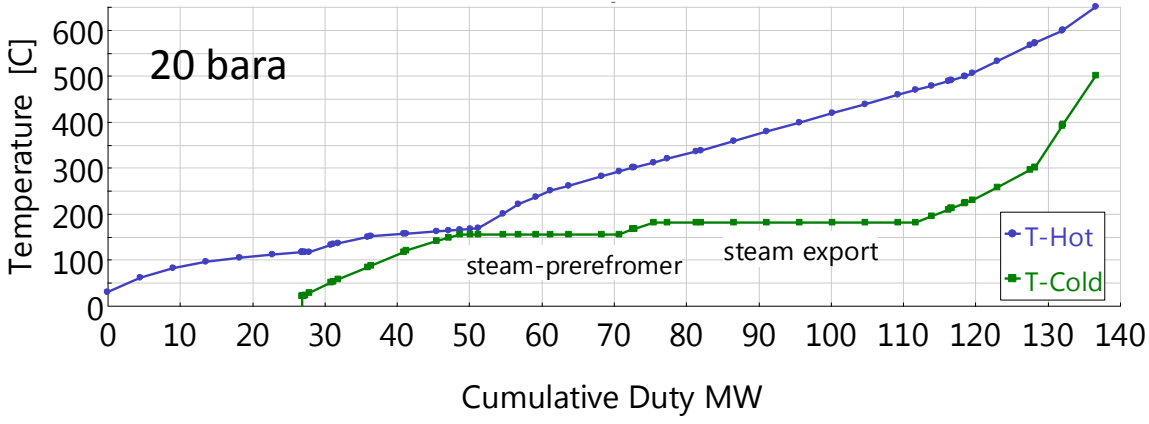
3 configurations give similar gas quality

Energy balance



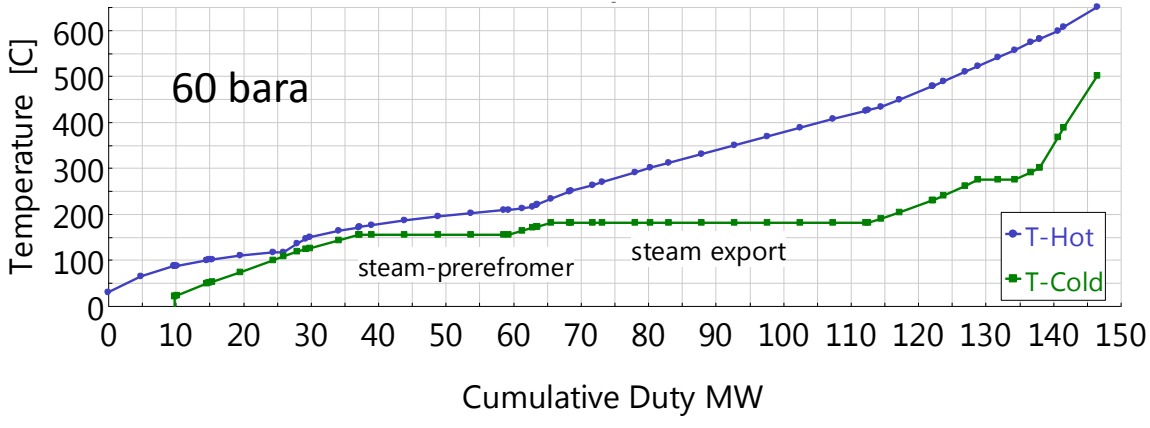
➔ Only steam export significantly affected by pressure

Heat levels



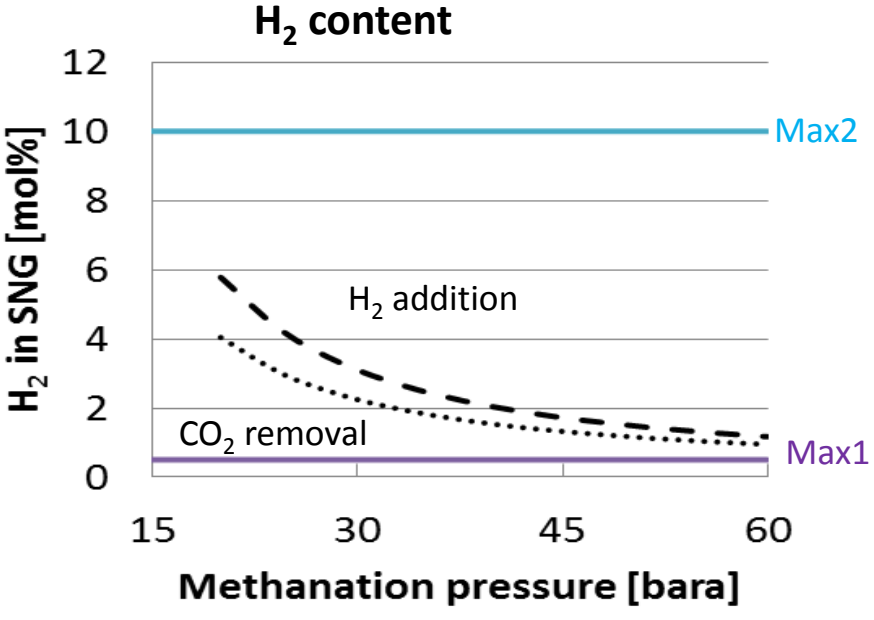
2nd configuration

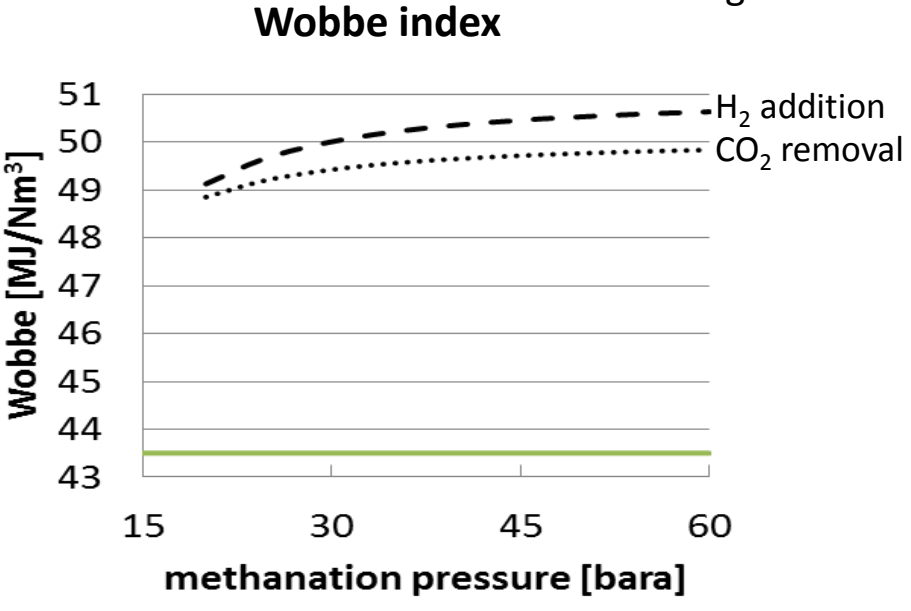
Better alignment of Q-T corves for the 60 bar case



Comparison:
H2 addition vs. CO2 removal

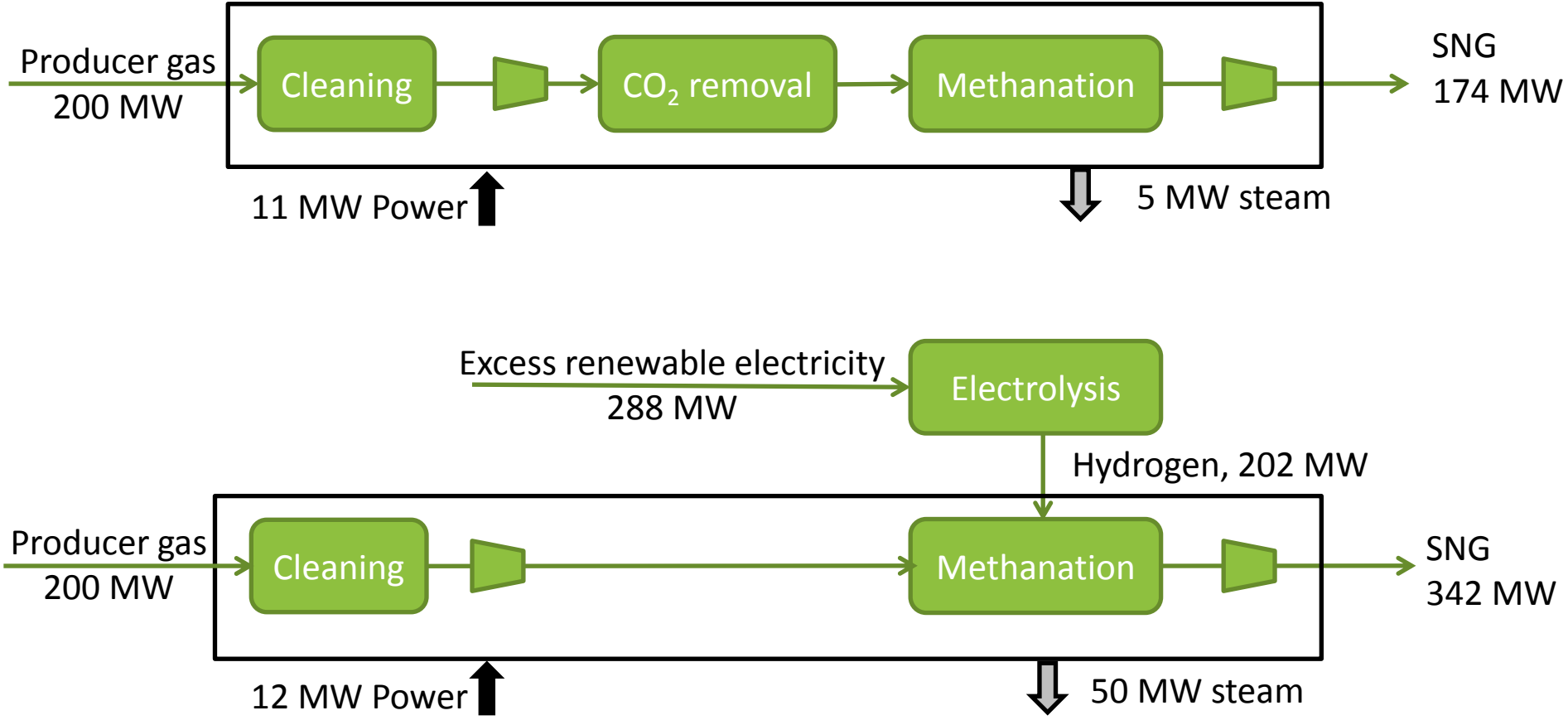
2nd configuration



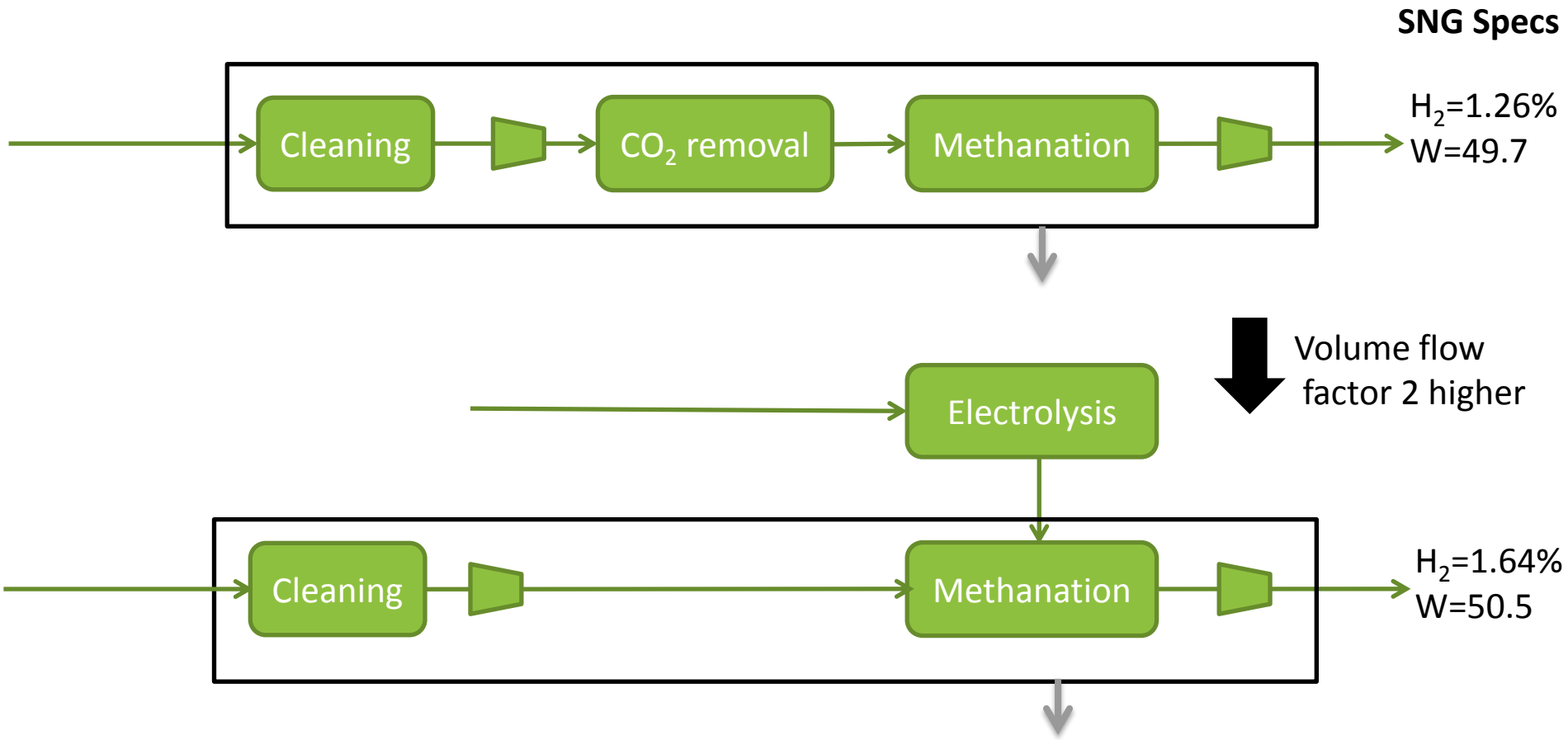


➔ Similar gas quality for H_2 addition and CO_2 removal (Good news)

Comparison:
H2 addition vs. CO2 removal



Comparison:
H2 addition vs. CO2 removal



Conclusions and outlook

- Feasible and flexible process
  - Produce 100% green SNG from biomass gasification and intermittent solar/wind
  - Significant flexibility impact: H_2 addition nearly doubles the SNG output
- Only limited gas quality fluctuations when switching to H_2 addition
  - Absolute H_2 content a point of attention, depending of the gas grid requirements
- Outlook:
  - Explore innovative concepts, such as sour methanation
  - Study integration with the high temperature electrolysis
  - Other CO_2 sources: fermentation and captured CO_2

Full conference paper details:
Marija Sarić, Jan Wilco Dijkstra, Stéphane Walspurger, Power-to-Gas coupling to biomethane production: a feasibility study, IPCS13, International Conference on Polygeneration Strategies, September 3-5 2013, Vienna, Austria

Acknowledgements

The research program EDGaR acknowledges the contribution of the funding agencies: The Northern Netherlands Provinces (SNN). This project is co-financed by the European Union, European Fund for Regional Development and the Ministry of Economic Affairs, Agriculture and Innovation. Also the Province of Groningen is co-financing the project.

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