Biomass gasification and upgrading to biomethane

L.P.L.M. Rabou

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Luc Rabou
ECN

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www.ecn.nl

Let's face it: we love warmth

Renewable heat => biomass => biomethane (bioSNG)

- Large share of renewables => renewable heat
- Air quality (and other) issues => biogas or biomethane
- Limited potential for digestion => gasification route needed
- Limited amount of local biomass => import needed

=> large scale realistic option

Biomass gasification to biomethane, basics

Dry biomass + water => gaseous product

$$C_6H_9O_4 + 1.7\ H_2O \approx> 3.1\ CH_4 + 2.9\ CO_2$$

Final result similar to result of digestion, but:

- Full conversion instead of ~50%
- High temperature needed to break down biomass into biosyngas
- Catalytic process required for methane production from biosyngas

The big (3 GW coal) example

30 years experience, CO_2 used for enhanced oil recovery

Problem solved?

Coal vs biomass properties

Coal

- Centralised resource
- 70 – 90% C content
- Dense and brittle
- Limited amount of volatiles
- Coal SNG > CO_2 than coal unless combined with CCS

Biomass

- Distributed resource
- 50% C-content
- Bulky and fibrous
- 80% of volatiles
- Biomass SNG ~ CO_2 neutral or even CO_2 negative with CCS

Coal vs biomass SNG system properties

Coal	Biomass
• GW size	• 100 MW size (with local biomass)
• Gasification at 20 – 40 bar	• Gasification at ~1 bar (can be 5 – 10 bar)
• O_2/steam gasification	• Indirect (steam) gasification
• High temperature (~1200°C)	• Moderately high temperature (800 – 900°C)
• Syngas with some CH_4 and BTX	• Syngas with CH_4, C_xH_y and BTX
• Mainly inorganic contaminants (e.g. H_2S)	• Inorganic & organic contaminants (e.g. H_2S & C_4H_4S)

Biosyngas composition example MILENA

Component	Vol % (dry)	Energy %	Efficiency => CH_4 %
$CO + H_2$	60	40	77
CH_4	13	27	100
C_2H_2	0.3	1	81
C_2H_4	4.2	14	89
C_2H_6	0.3	1	96
C_3H_6	0.1	0.5	90
C_6H_6	1.0	8	90
C_7H_8	0.1	1	91
Tar	0.3	6	91
$CO_2 + N_2$	20		

$C_2H_2 + C_2H_4 + C_3H_6 + C_6H_6 + C_7H_8 \equiv \pm$ 25% of producer gas heating value

Bio-syngas cleaning (1)

Methanation catalysts are poisoned by sulphur

- Bulk H_2S removal — several options
- COS removal — $COS + H_2O \Rightarrow H_2S + CO_2$
- Deep S removal (< 0.1 ppm) — $ZnO + H_2S \Rightarrow ZnS + H_2O$
- Organic S compounds — e.g. active carbon but BTX problem

  or: org-S + $H_2 \Rightarrow H_2S$ by HDS catalyst

Bio-syngas cleaning (2)

Methanation catalysts easily deactivated by carbon.

- Aromatic and unsaturated C_xH_y are the main carbon precursors.
- Excess steam and/or H_2 suppress carbon formation

• Light C_xH_y	Hydrogenation	(by dedicated or methanation catalyst)
• BTX	Removal	(absorption by solvent or active carbon)
	Reforming	(by dedicated or methanation catalyst)
• Tar	Removal	(absorption by solvent, e.g. OLGA)
	Cracking	(by heat and/or dedicated catalyst)

Biomass-based SNG projects in Europe

Investor	Project location	Capacity (10^6 m^3/ y)	Year
EU/Repotec	Güssing (AU)	0.7	2008
Göteborg Energi	Göteborg (SE)	14	2013
EU/Göteborg Energi	Göteborg (SE)	70	2016
E.ON Bio2G	Sweden	160	?
NL consortium	Alkmaar (NL)	0.5	2016

Groen Gas 2.0
Milena-Olga-SNG

Biomethane upgrading

Raw product consists mainly of CH_4 and CO_2

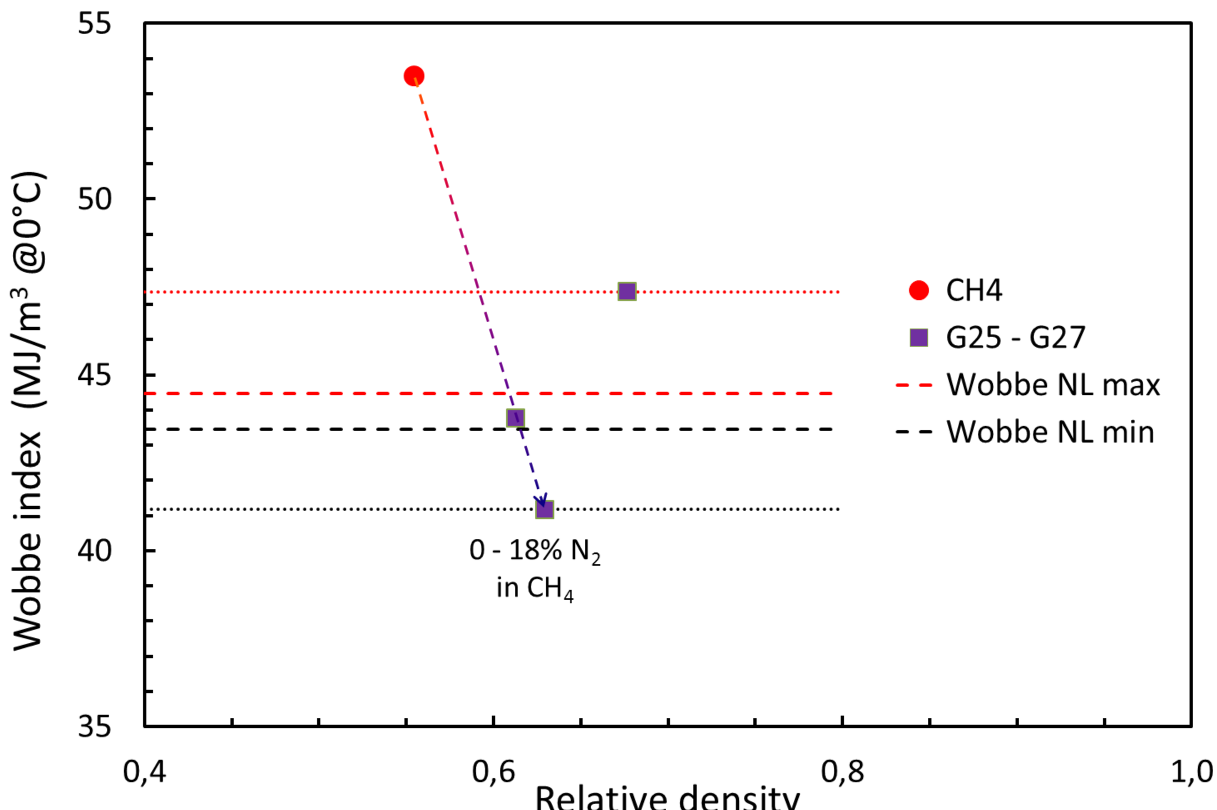
- CO_2 removal needed => CCS relatively cheap
- CO_2 removal can be avoided by H_2 addition to the process => P2G

  (H_2 addition changes heat balance in system => not trivial)

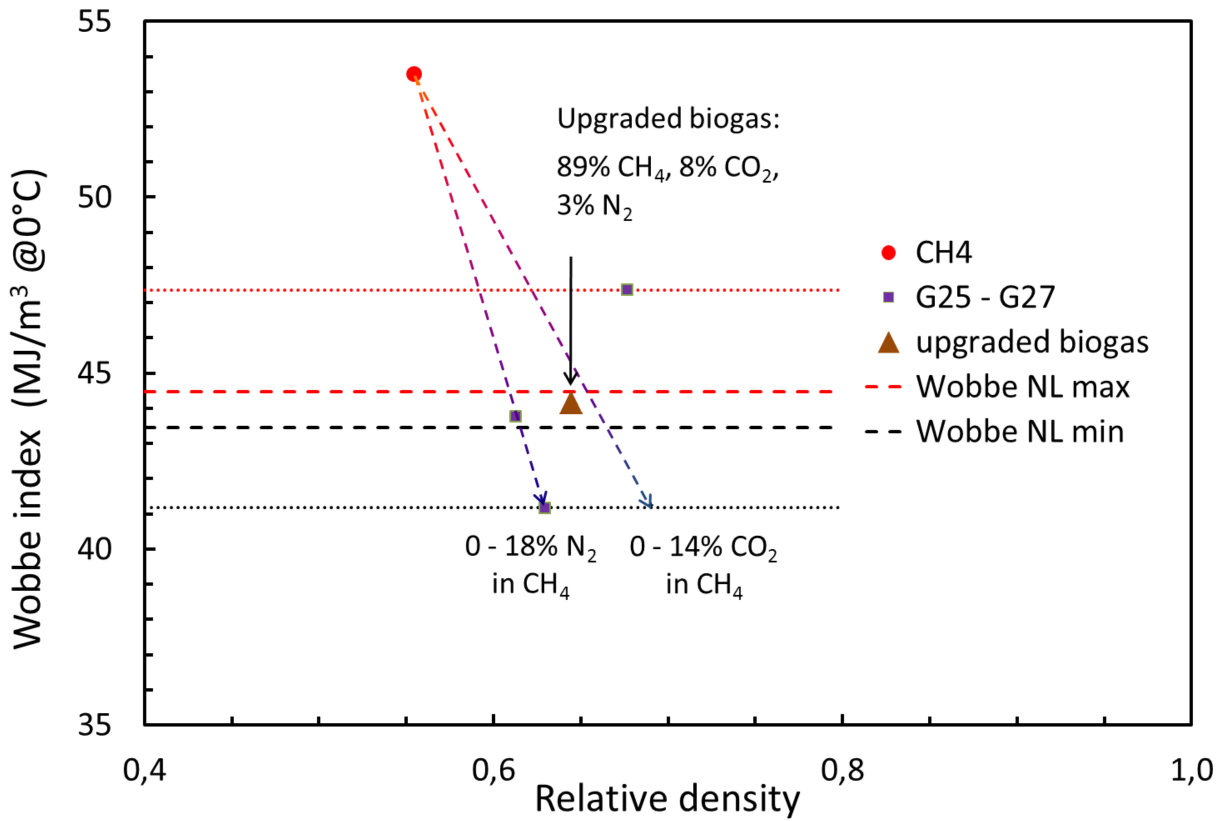
(Coal-)SNG composition

	Tremp™ Haldor Topsøe (3 reactors + recycle)	**Vesta** Foster Wheeler / Süd-Chemie (4 reactors)	**Vesta** Foster Wheeler / Süd-Chemie (5 reactors)
CH_4	94 - 96	94 - 98	99.1
CO_2	0.5 - 1	0 - 1.5	0.7
H_2	0.5 - 1	2 - 4	0.13
CO	trace	0 - 0.2	-
N_2 + Ar	2 - 3	traces	traces

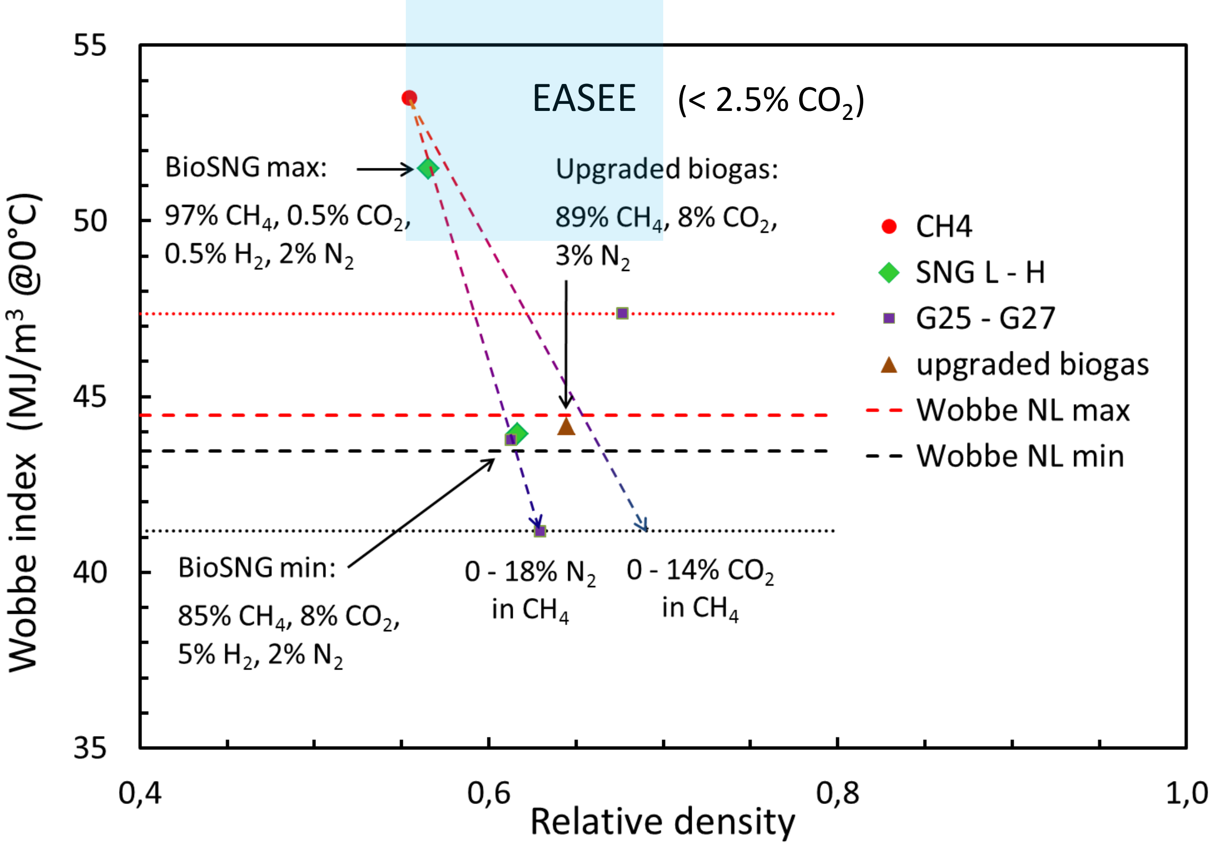
L-gas properties



Upgraded biogas

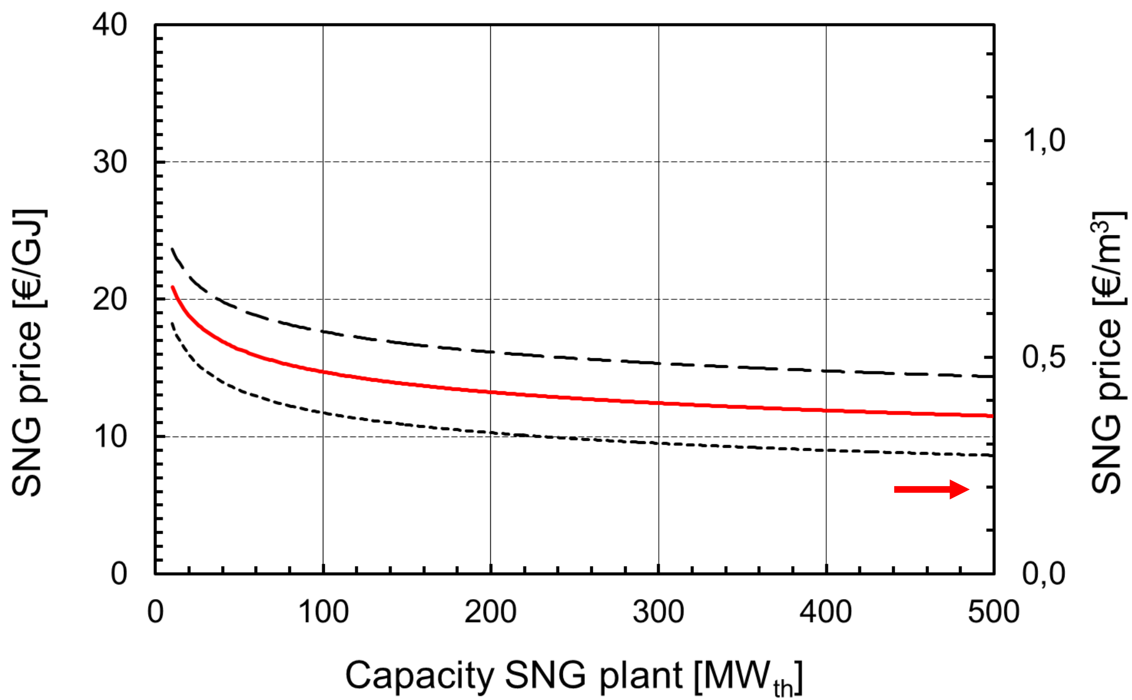


BioSNG



CO	traces
H_2	0.2 - 4%
CO_2	0.5 - 8%

Biomethane cost estimate



BioSNG price =

1.5 x Biomass price

+

Plant cost

Assumed biomass price:

2, 4 or 6 €/GJ

+

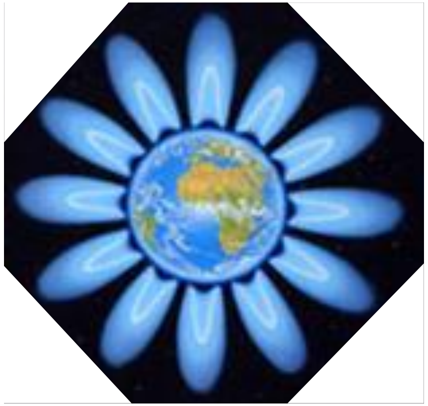
Mature technology

Conclusions

- Biomethane by gasification can be made to natural gas standards
- Technology at 1 – 20 MW demonstration stage
- CO_2 storage possible, for maximum CO_2 reduction
- CO traces are to be expected => acceptable limit e.g. 200 ppm
- 0.2 – 4% H_2 unavoidable => to be accepted or removed
- Integration with Power-to-Gas possible
- Price will not be competitive with fossil equivalent

  => subsidy or obligation

Gas + bioSNG future



Luc P.L.M. Rabou
ECN
P.O. Box 1
1755 ZG Petten
The Netherlands
T +31 88 515 44 67
rabou@ecn.nl

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ECN

Westerduinweg 3
1755 LE Petten
The Netherlands

P.O. Box 1
1755 LG Petten
The Netherlands

T +31 88 515 4949
F +31 88 515 8338
info@ ecn.nl
www.ecn.nl