Biomass gasification – development of attractive business cases

J.H.A. Kiel

April 2015
ECN-L--15-032

Biomass gasification – development of attractive business cases

Gasification: a versatile technology converting biomass to produce synfuels, heat and power
The BRISK Open Workshop / TOTEM 40

Jaap Kiel

Delft, the Netherlands
22 April, 2015

Biomass – a difficult energy source

- In view of:
  - Logistics (handling, transport and feeding)
  - End-use (production of power, heat, biofuels and /or chemicals)

- Difficult properties are:
  - Low energy density (LHV_{ar} = 10-17 MJ/kg)
  - Hydrophilic
  - Vulnerable to biodegradation
  - Tenacious and fibrous (grinding difficult)
  - Poor “flowability”
  - Heterogeneous

Gasification

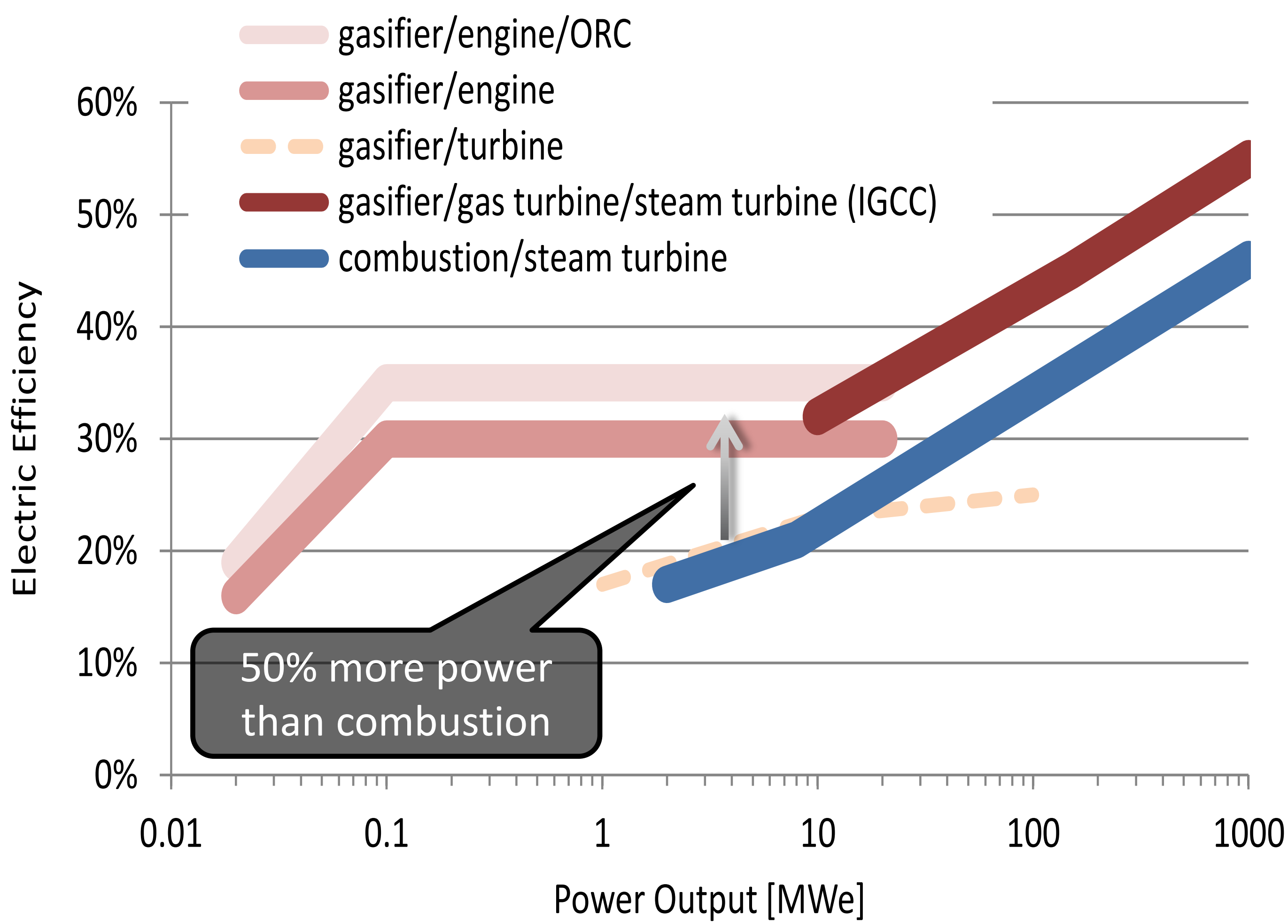
wood, agricultural residues, sewage sludge, waste, coal, …

- Gasification converts solid fuel to gaseous fuel
- Opens the door to existing energy systems:
  - Boilers
  - Engines
  - Turbines
  - Chemistry
  - Fuels
  - Refineries
  - Steel industry

H_2, CO, CH_4, …

Gasification for Power

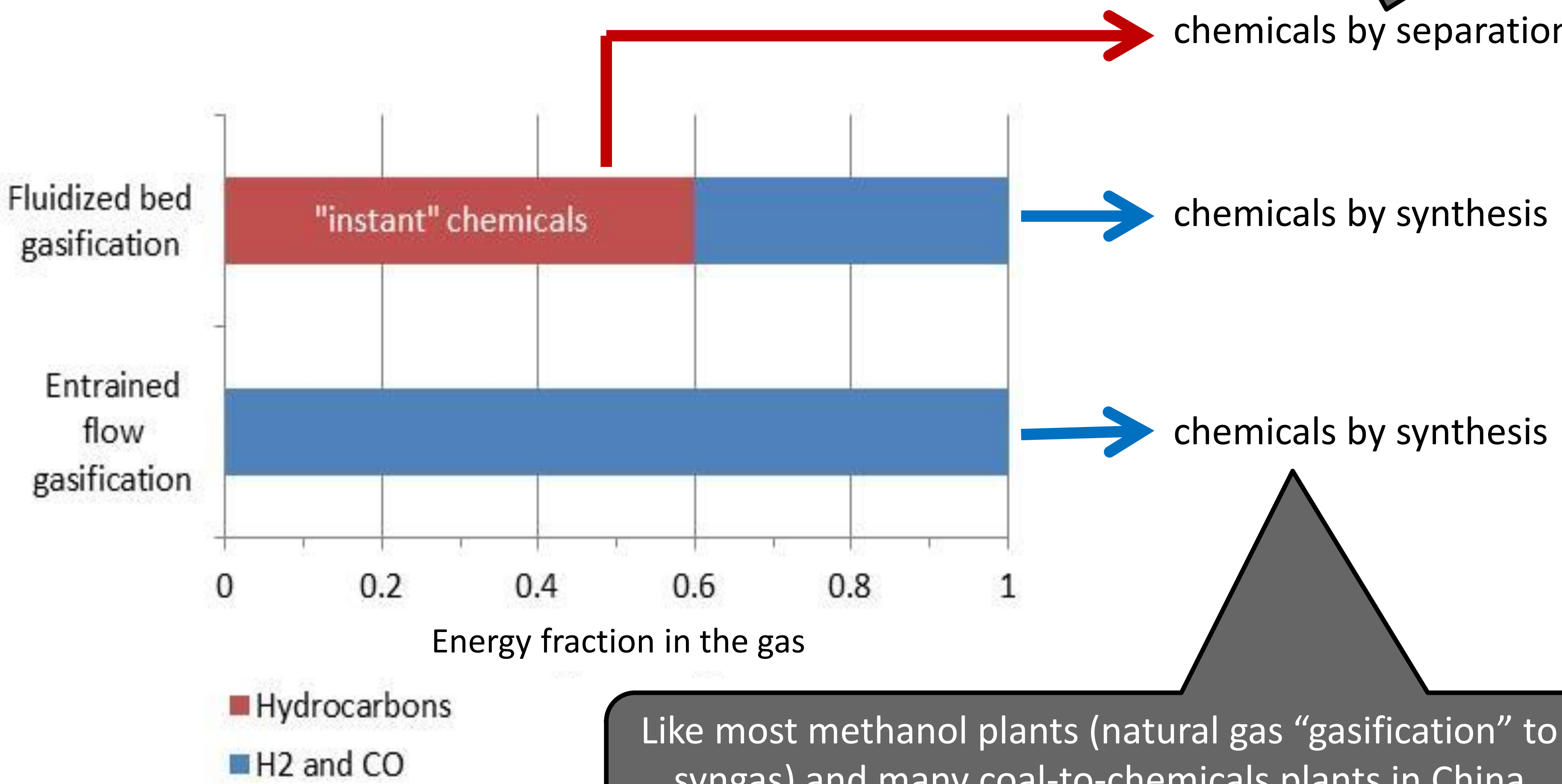
Efficiency benefit on small-scale (and large-scale)



Gasification for Chemistry

Two options

Like naphtha cracking (to ethylene, propylene, BTX, ...)

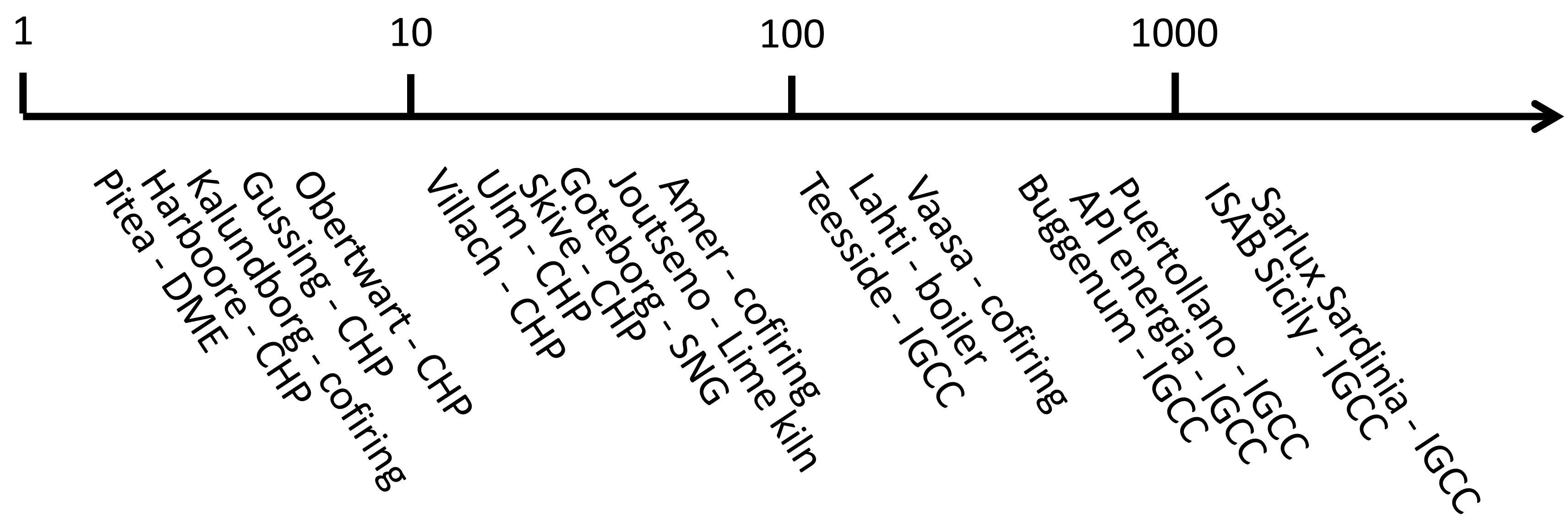


Like most methanol plants (natural gas “gasification” to syngas) and many coal-to-chemicals plants in China (methanol, DME, NH3, SNG, ... MtO)

Gasification plants in Europe

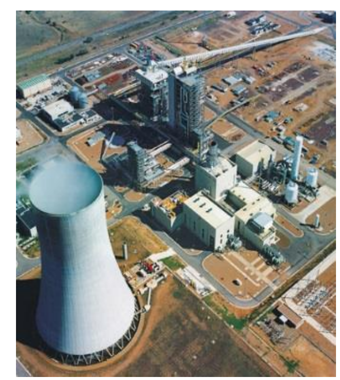
Existing

Scale (MW input capacity)





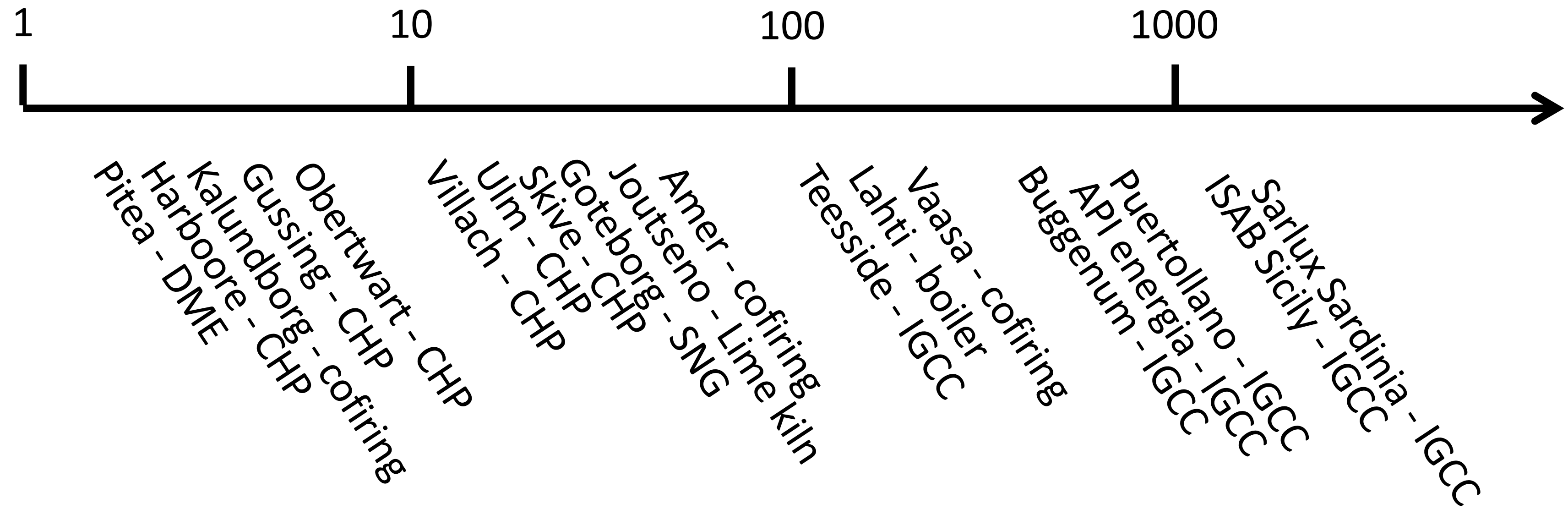


Gasification plants in Europe

Existing – feedstock

Scale (MW input capacity)



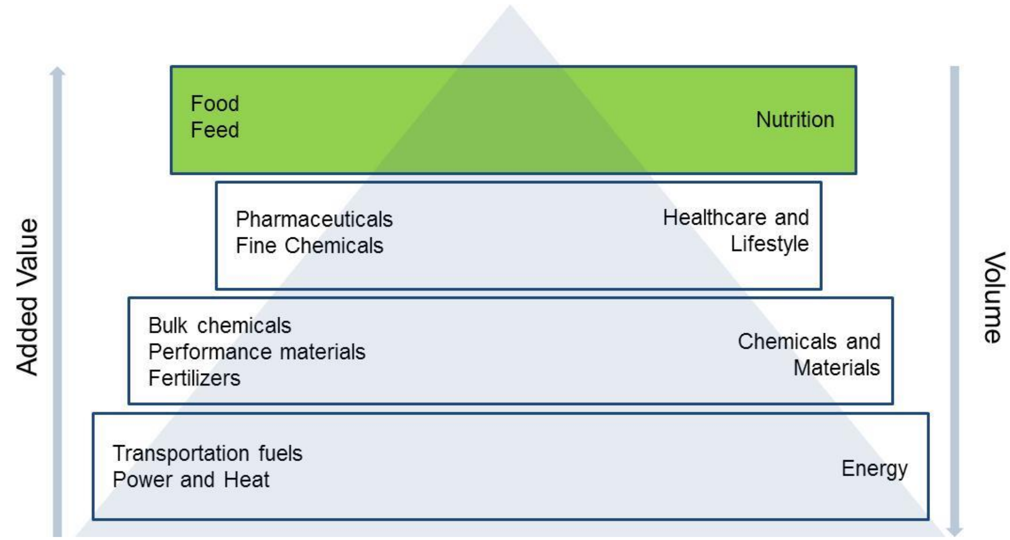
Wood pellets – Waste wood – Black liquor – Straw – SRF – MSW – Coal (plus wood)

ECN

Biomass under debate

Biomass use – markets and preferred options

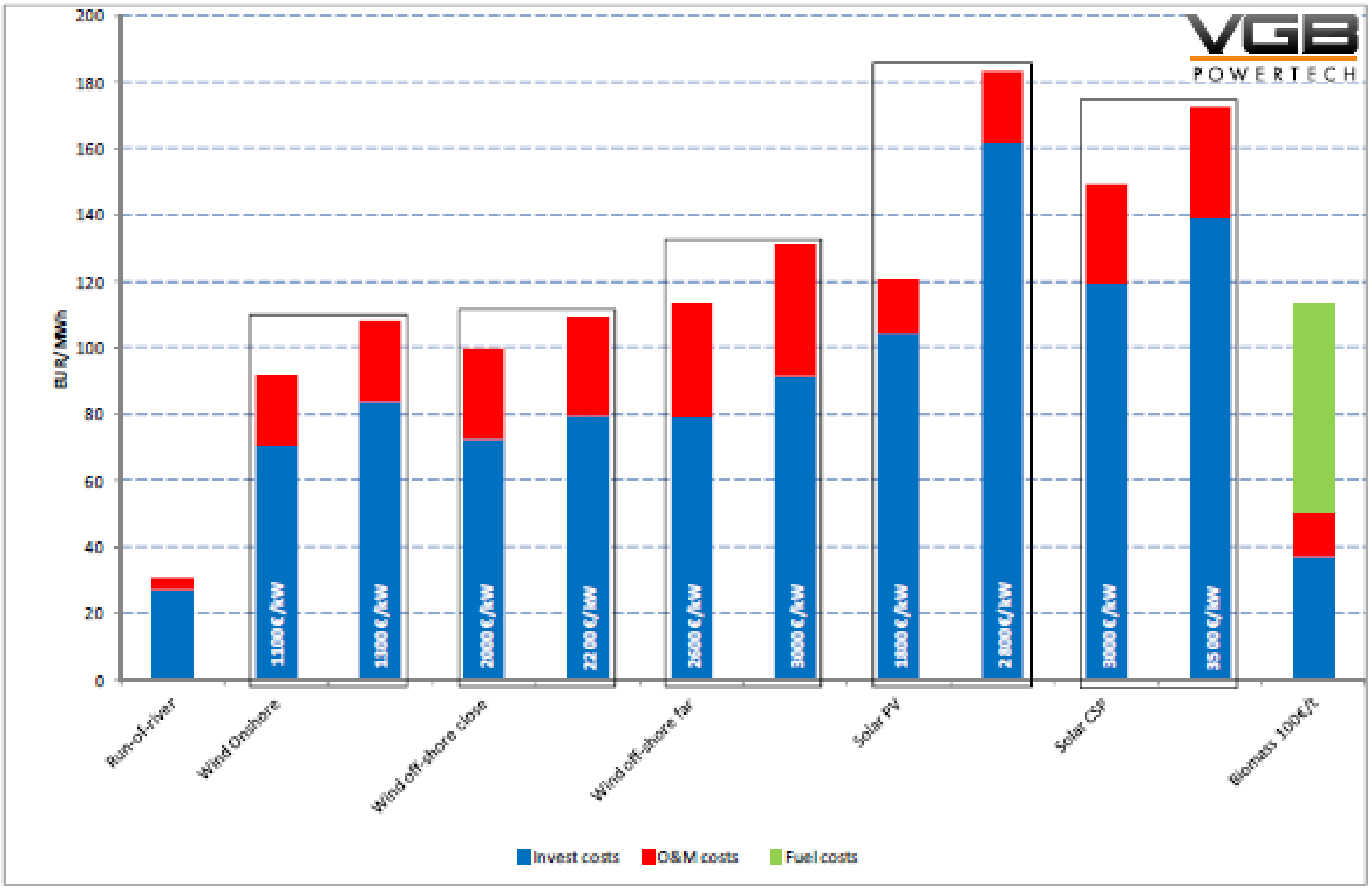
- Shift from focus on bioenergy to focus on biobased economy
- Use C and molecular capital
- Aim for maximum added value



- But:
  - Energy sector more than an order of magnitude larger than chemical sector
  - We need all renewable energy options, we cannot exclude major ones
  - There is enough sustainable biomass to make biomass a major renewable energy option (1/4 – 1/3 of future global energy use)
  - Some parts of the energy sector difficult to cover with other renewables (e.g., HT process heat, biofuels for heavy vehicles, aviation and marine applications)
  - Not all biomass qualifies for high-value applications (e.g., heterogeneous and/or contaminated streams)

Renewables cost comparison

For bioenergy, feedstock cost is a major cost factor



Graph 2: Levelised Costs of Electricity 2011 – Renewables

VGB survey 2012, Investment and operation cost figures, September 2012

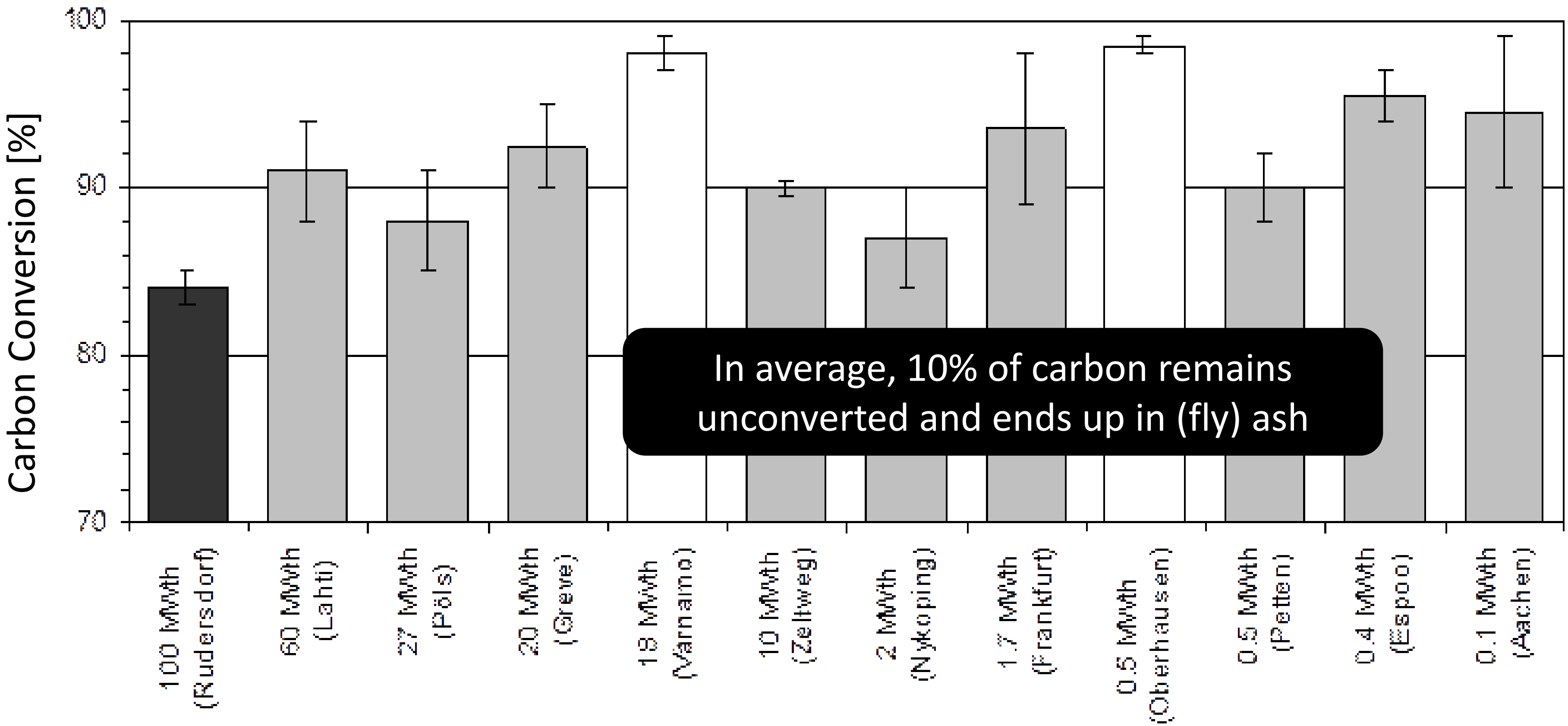
More attractive business cases?

(from a bioenergy perspective)

- More attractive in view of cost, sustainability, and public acceptance
- Options to reduce cost / develop more attractive business cases:
  - Reduce CAPEX (e.g., scaling up)
  - Maximise energy efficiency / heat utilisation (CHP)
  - Use less expensive biomass (residues)
  - Co-produce high added value products
  - …….

Circulating fluidised-bed gasifiers

Carbon conversion of CFB gasifier plants (2002)



Fluidised-bed gasification

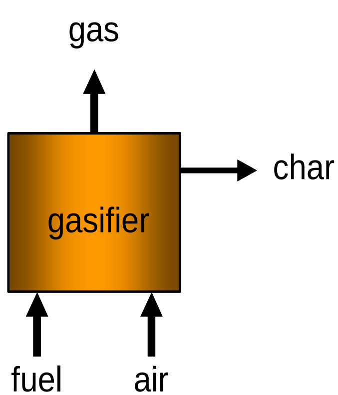
Generations

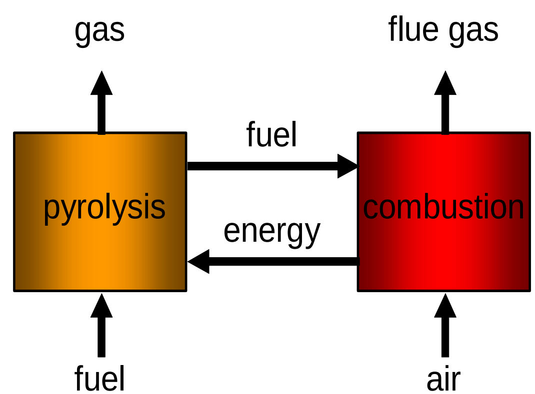
First generation

- 50% N_2 in gas
- Incomplete carbon conversion
- Acceptable conversion (>90%) requires high temperature, much steam, small fuel size, large residence time

Second generation

- N_2-free gas without ASU
- Complete carbon conversion
- Additional degree of freedom: temperature, steam, fuel size, residence time

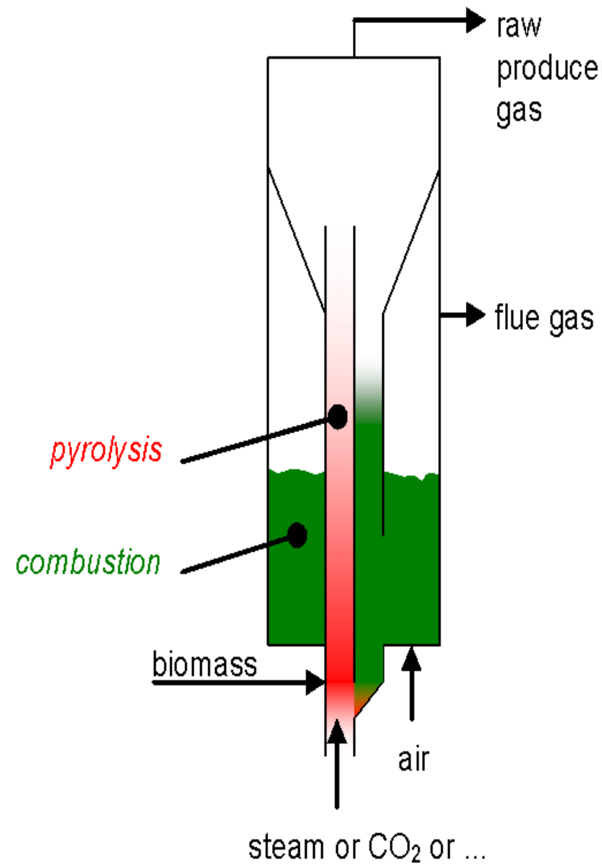




2G Fluidised-bed gasification

Coupled fluidized beds

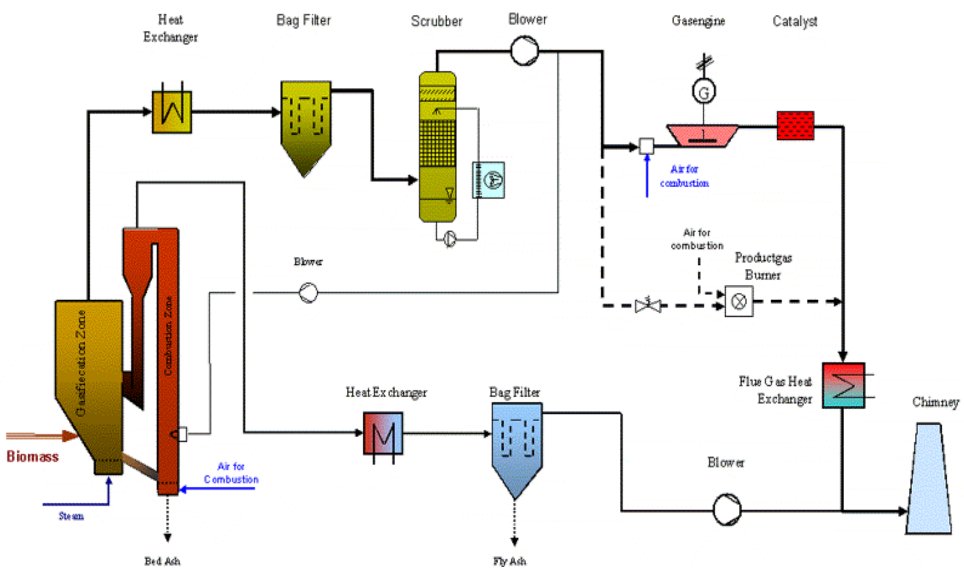
- Energy production and energy consumption processes in separate reactors
- Also called indirect gasifiers
- Char serves as fuel for combustion reactor
- Complete conversion
- Air-blown, yet essentially N_2-free gas
- 5-200 MW_{th}
- Medium tar (10-50 g/Nm^3)
- Examples: Batelle/Rentech/SilvaGas (US), FICFB/Repotec (A), ECN/MILENA (NL)



2G Fluidised-bed gasification

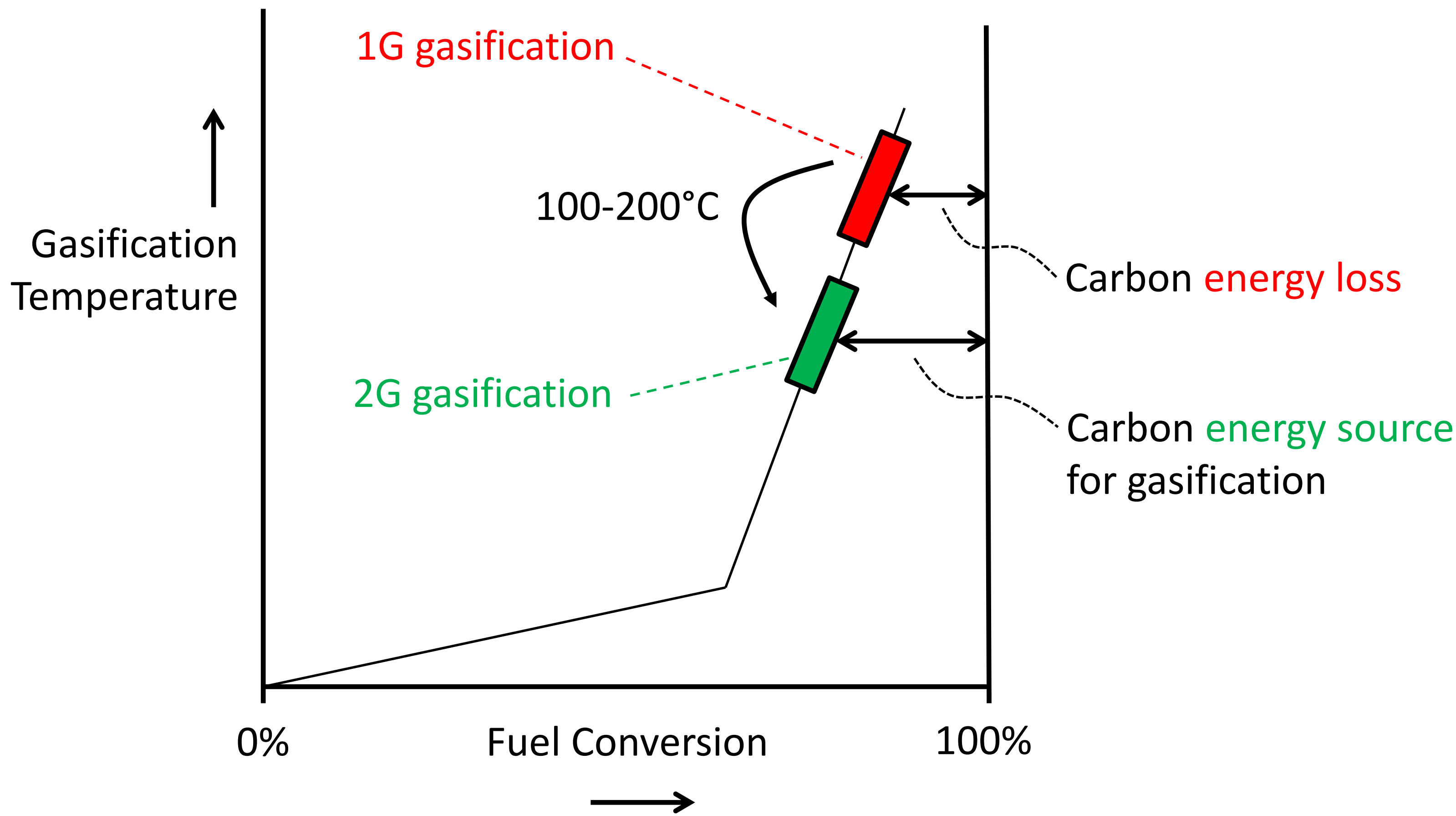
FICFB concept (Repotec)

- First plant 2 MW_e in Güssing (Austria)
- Since 2001
- Olivine bed material for catalytic tar reduction
- Other plants (wood input capacity): Oberwart (8 MW), Senden (9 MW), Göteborg (32 MW)



2G Fluidised-bed gasifiers

Lower temperature, better efficiency, higher conversion

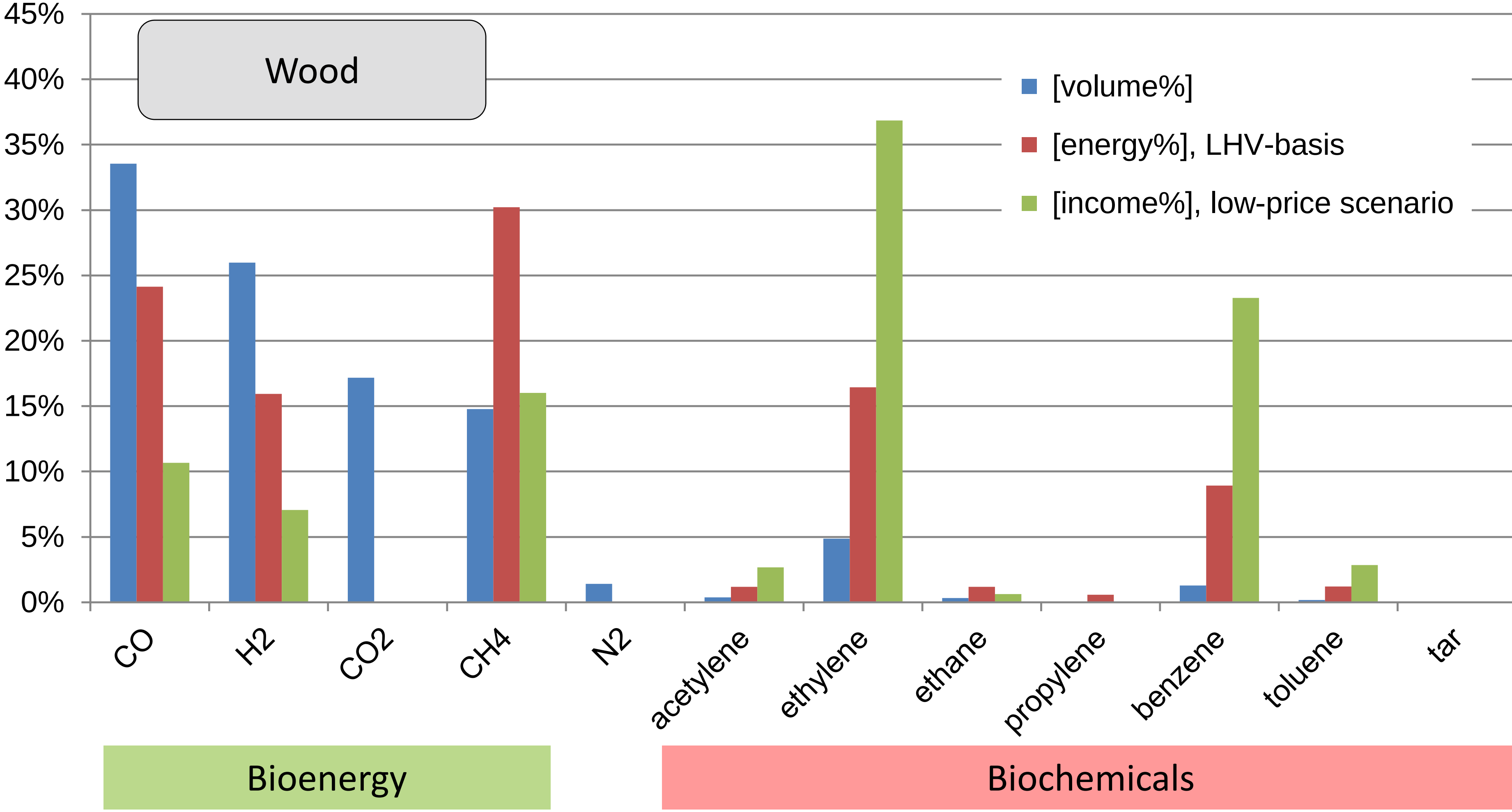


2G Fluidised-bed gasification

- 2G Fluidised-bed gasification has higher efficiency, because:
  - 100-200°C lower temperature
  - No carbon loss
- 2G Fluidised-bed gasification has higher fuel flexibility, because:
  - 100-200°C lower temperature: less melting risk
  - 100-200°C lower temperature: less inorganic volatiles in syngas (to boiler)
  - Relaxed carbon conversion requirement
- 2G Fluidised-bed gasification produces more valuable gas, because:
  - No N_2 dilution, syngas applications possible
  - High yield of hydrocarbons: mainly methane, ethylene, benzene

Biomass gasification (fluidised-bed)

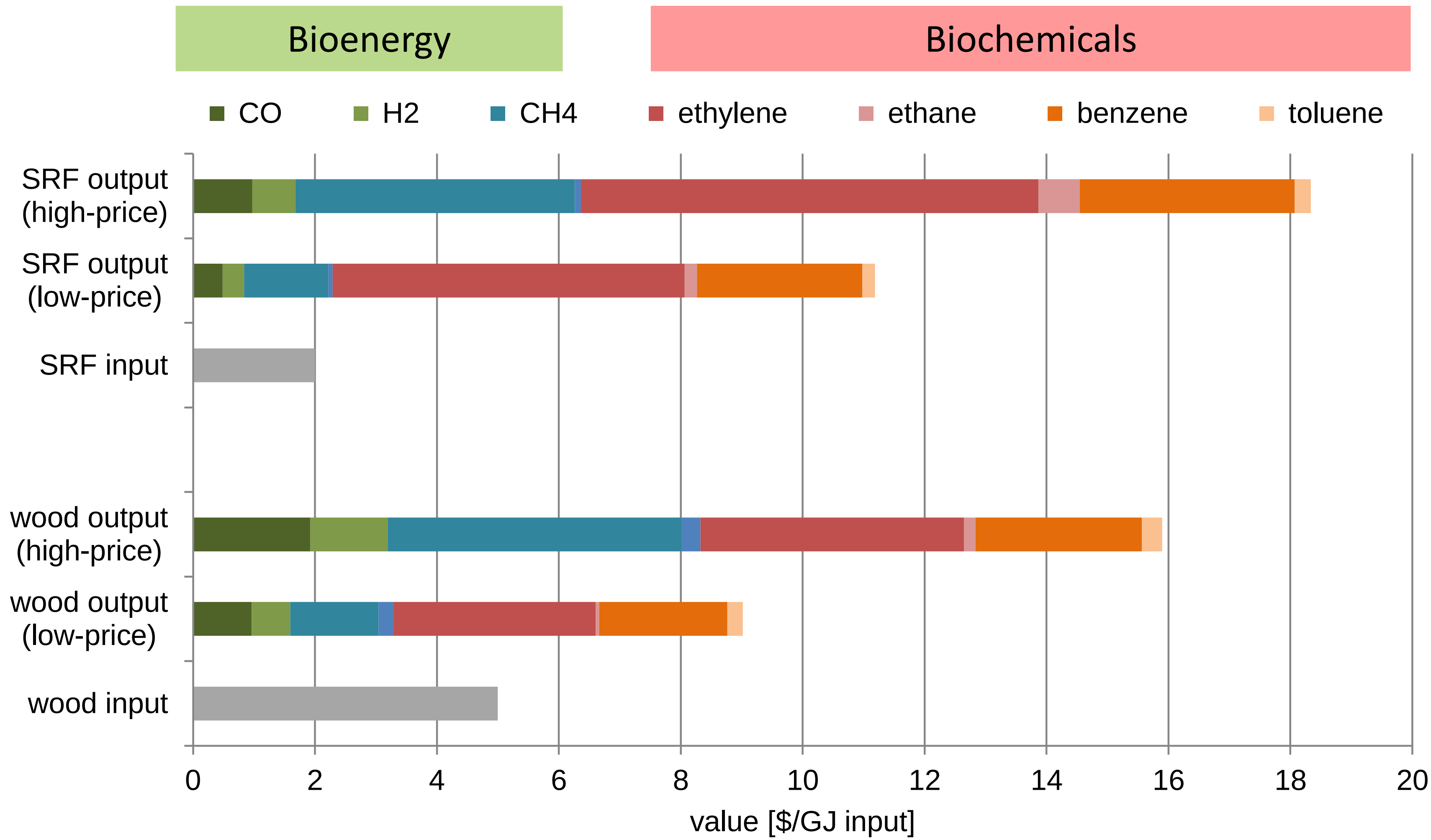
Gas composition: small concentrations, high value



Economics of bioenergy

Impact of feedstock cost and chemicals co-production

(low-price = based on fossil prices; high-price = 100% premium on syngas, 200% premium on methane, 30% premium on biochemicals)



SRF = Solid Recovered Fuel = standardised paper-plastic residue

Example: (ECN) Green Gas production

Natural Gas quality gas without the CO_2

Green Gas = bio-SNG = Renewable Natural Gas = bio-Methane

For power
For (high-T) heat
For chemistry
For transport

Using existing infra
Including gas storage
With quality system
And security of supply

Cost of (ECN) Green Gas production

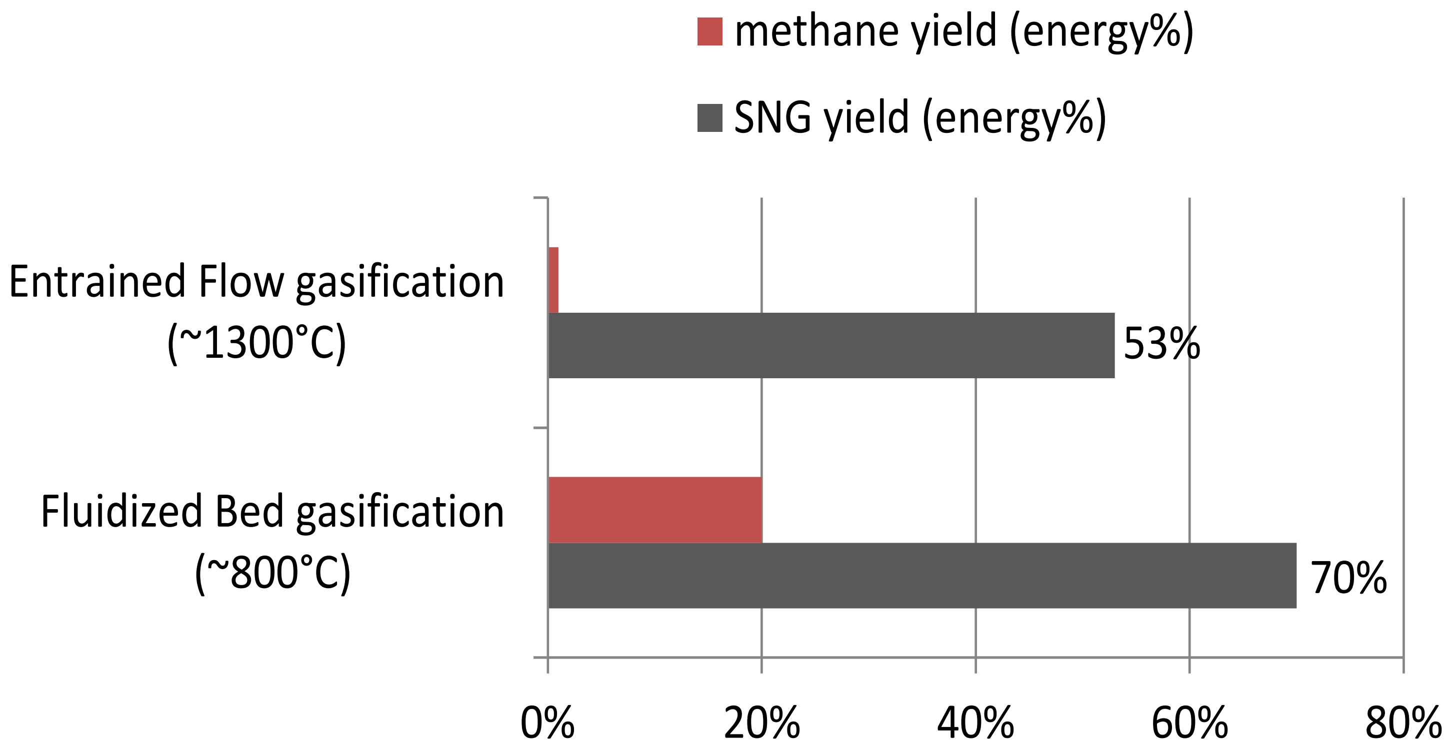
Long-term perspective (say 2030)

	Biomass at 2 $/GJ	Biomass at 9 $/GJ
Biomass	2.9 $/GJ	12.9 $/GJ
Capex	7.5 $/GJ	
Opex	1.7 $/GJ	
Other	1.2 $/GJ	
Power	0.7 $/GJ	
Total [$/GJ]	**14 $/GJ**	**24 $/GJ**
Total [$ct/m³ NG-eq]	**45 $ct/m³**	**77 $ct/m³**

Source: https://www.ecn.nl/publications/ECN-E--14-008

Gasification: not too hot

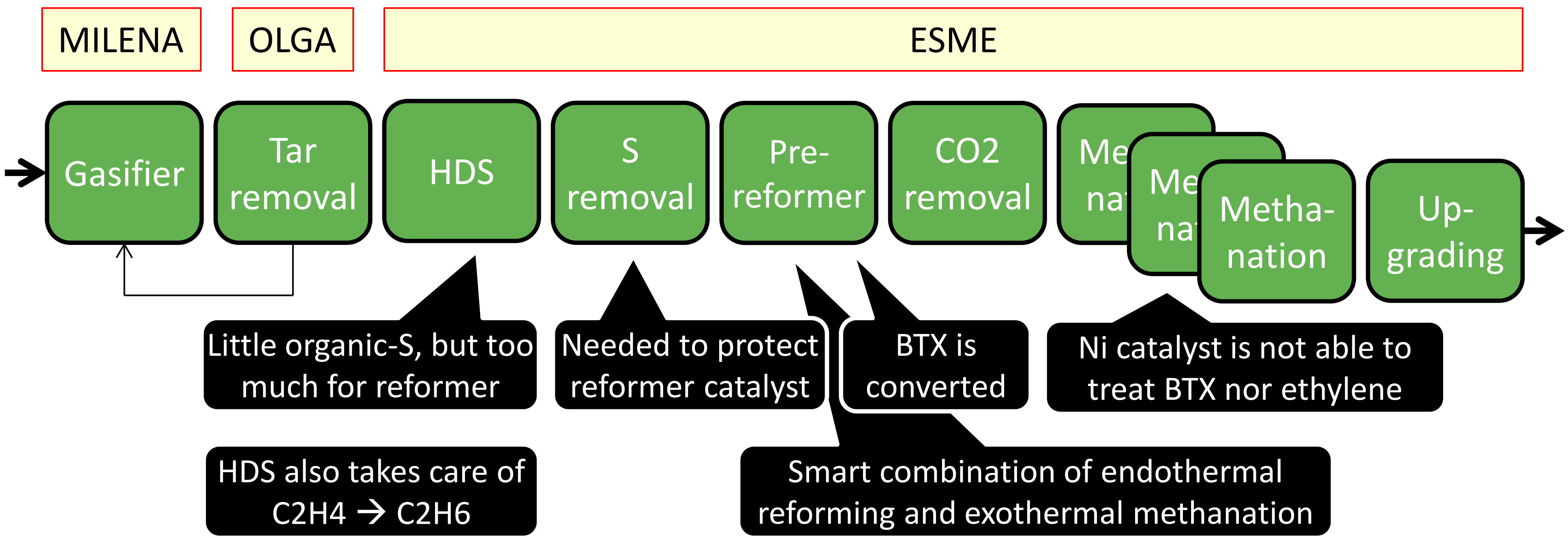
Instant methane is good for efficiency



Source: C. M. van der Meijden et.al., Biomass and Bioenergy 34, pp 302-311, 2010

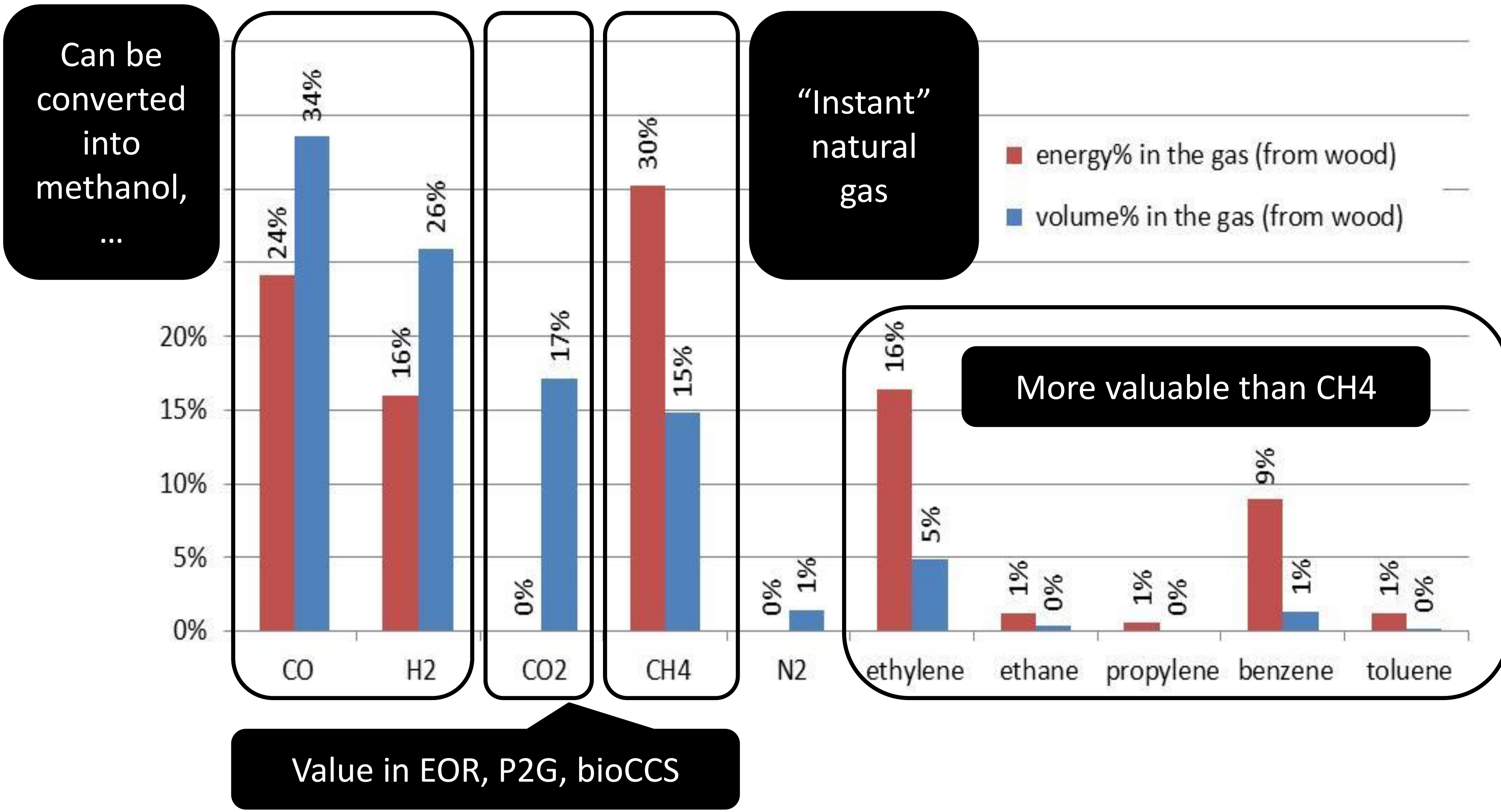
ECN Green Gas process

Base case: everything converted into methane



Gasifier: *Fluidized Bed Gasifier operating at ~800°C*
HDS: *HydroDeSulphurization (converting organic S molecules into* H_2S*)*
BTX: *Benzene, Toluene, Xylene (~90%/9%/1% in case of fluidized bed gasification at ~800°C)*

… but the Green Gas business case can be further improved!



The DAKOTA example

- Lignite to SNG in North Dakota
- 1.1 bcm SNG/year
- And several co-products: naphtha, phenols, oil, CO_2
- The co-products pay the process

	Energy output [%]	Revenue [%]
SNG	79%	41%
Naphtha, phenol, oil, CO_2	21%	59%

…. and the same holds for shale gas!

Source: www.dakotagas.com

Source: http://www.ogfj.com/articles/2013/01/the-ethane-asylum-big-time-ethane-rejection-in-the-shale-gas-world.html

Gasification-based green gas production

Potential cost reductions (base-case 14-24 $/GJ)

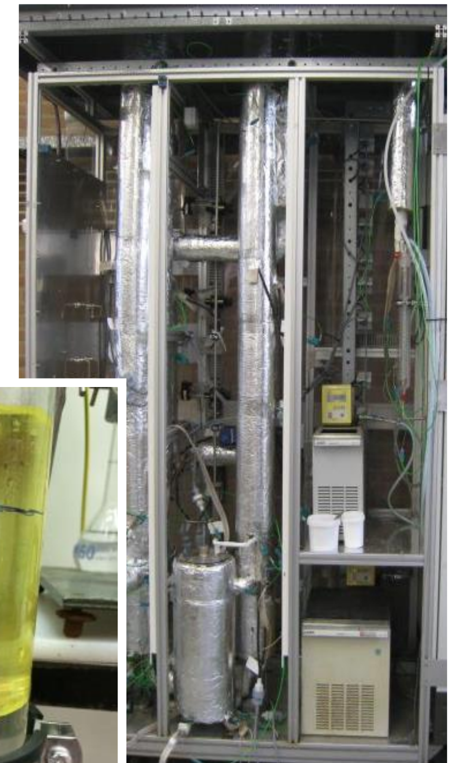
- -3 $/GJ by bio-BTX
- -5 $/GJ by bio-ethylene (either separated or converted into aromatics)
- -5 $/GJ by bio-$CO_2$
- And more:
  - H_2/CO for bio-chemicals
  - Increasing bio-BTX yield
  - Increasing bio-ethylene yield
  - Accommodate excess (renewable) H_2 to make methane and solve the renewable power intermittency (P2G)

Green Gas can become cheaper than natural gas!

ECN BTX separation process

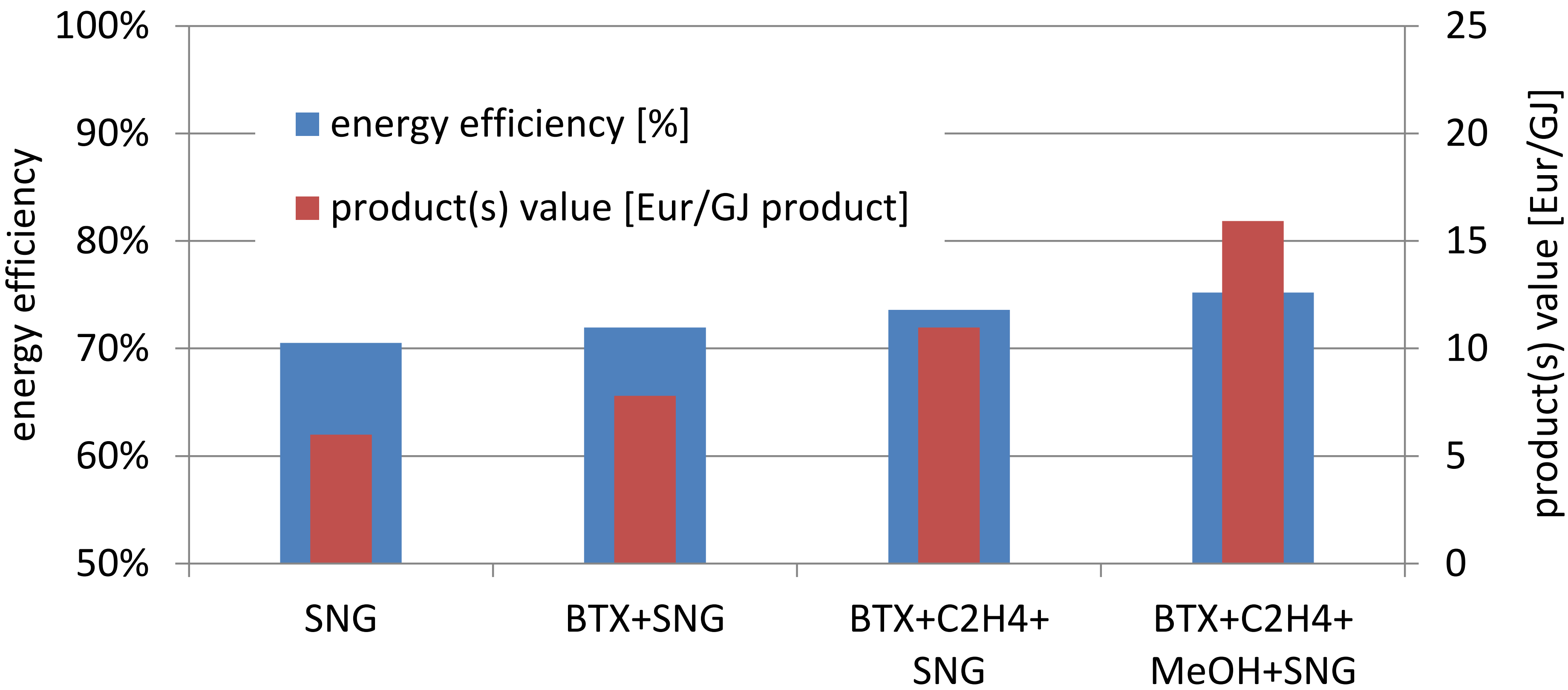
Benzene, toluene, xylenes

- First step after OLGA tar removal
- Liquid BTX product: first liter in 2014
- >95% separation
- BTX = 90/9/1
- Simplifies downstream process to SNG



Co-production has potential

In view of product prices, energy efficiency and process complexity



SNG: Synthetic Natural Gas; BTX: mainly benzene; C2H4: ethylene; MeOH: methanol

Conclusion

- Gasification is a versatile biomass conversion technology indeed
  - Facilitates logistics and end-use
  - Wide feedstock range
  - Many possible products
- Even more (co-production) options than anticipated thus far
- Many gasification technologies: choose the right one in view of feedstock, scale and product(s)
- Learn from fossil examples (DakotaGas, shale gas)
- More attractive business cases can be created through scale-up, higher efficiency, low- cost biomass residues, high-added-value co-products
- Example: Green Gas can become cheaper than natural gas

Thank you for your attention!

Publications: www.ecn.nl/publications
Fuel composition database: www.phyllis.nl
Tar dew point calculator: www.thersites.nl
IEA bioenergy/gasification: www.ieatask33.org
Milena indirect gasifier: www.milenatechnology.com
OLGA: www.olgatechnology.com / www.renewableenergy.nl
SNG: www.bioSNG.com /www.bioCNG.com
BTX: www.bioBTX.com

For more information, please contact:

Jaap Kiel
Programme Development Manager
Biomass

T +31 88 515 45 90
F +31 88 515 84 88
kiel@ecn.nl

P.O. Box 1, 1755 ZG PETTEN
The Netherlands
www.ecn.nl

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