BIOMASS GASIFICATION BEYOND STATE OF THE ART

Workshop Fuels of the Future, Trondheim Norway, 13 September 2018 | Jaap Kiel

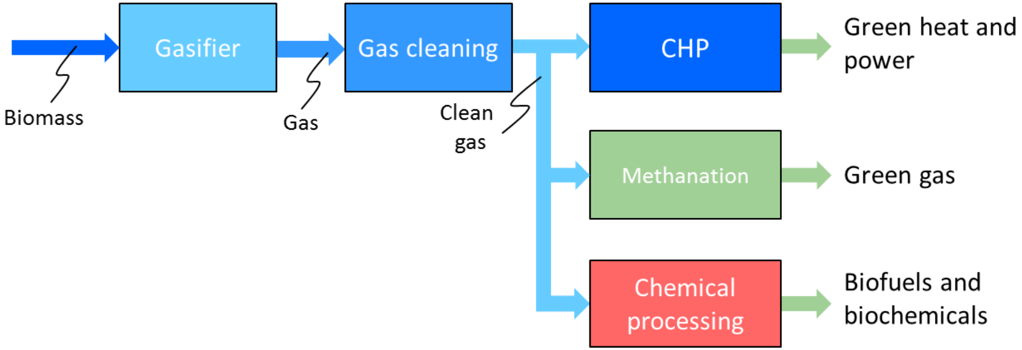
ECN › TNO innovation for life

OUTLINE

- Biomass gasification – state of the art
- New challenges
- Changing role of biomass
- Main directions in biomass gasification R&D
- Examples
- Summary conclusions

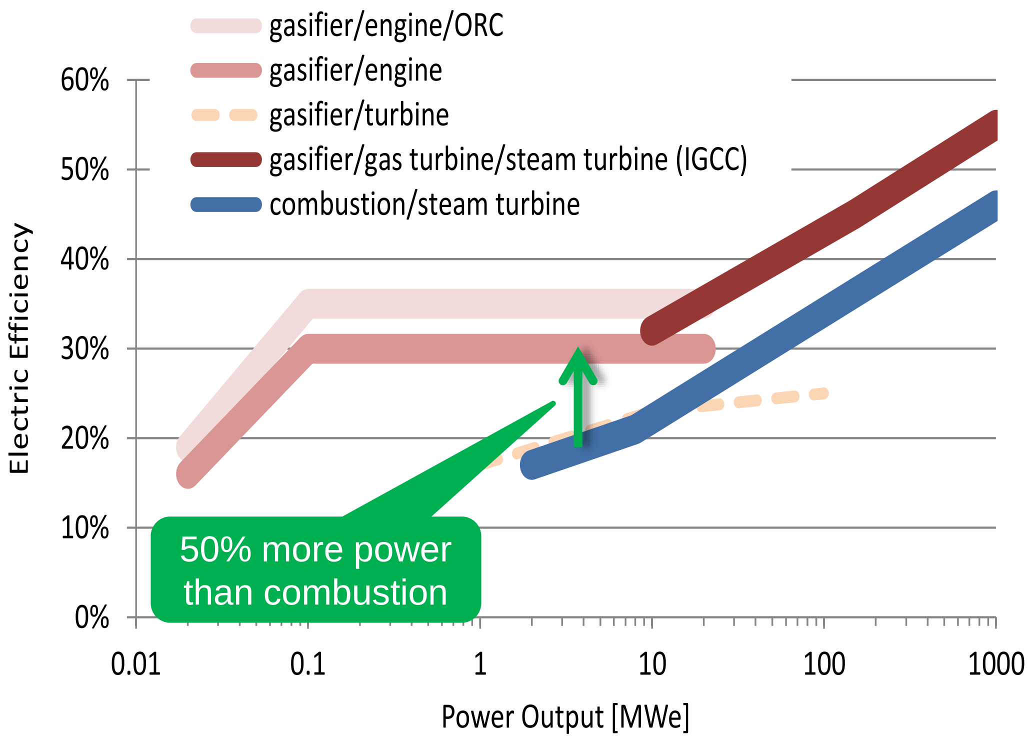
BIOMASS/WASTE GASIFICATION
A PLATFORM TECHNOLOGY FOR ENERGY AND CHEMICALS

- Gasification converts solid waste or biomass into a combustible product gas
- After cleaning, the product gas can be used for:
  - Boiler firing to replace fuel oil or natural gas
  - CHP generation using gas engines or gas turbines -> high electrical efficiency
- Via separation and catalytic conversion of the product gas a broad range of biofuels and bio-chemicals can be produced
  - BioSNG
  - Fischer Tropsch liquids
  - Methanol and higher alocohols
  - Hydrogen
  - BTX, Ethylene
  - Etc



GASIFICATION FOR POWER

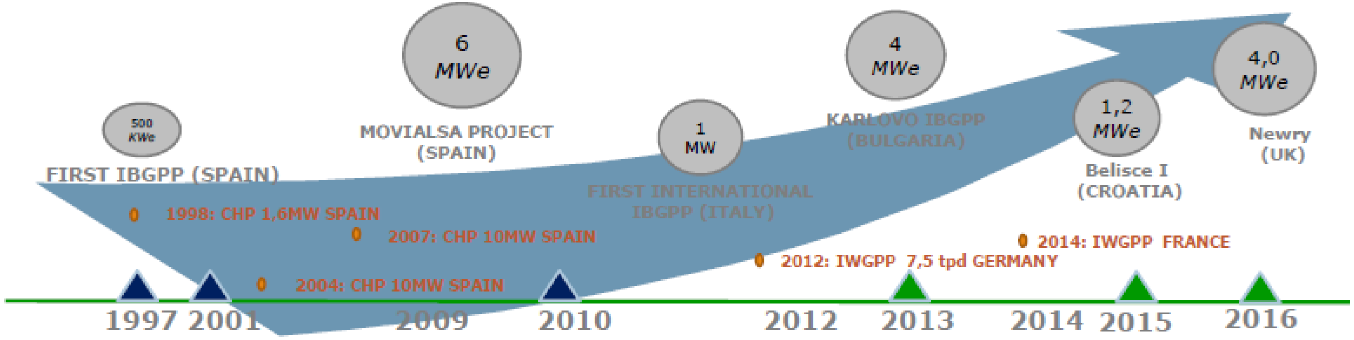
EFFICIENCY BENEFIT ON SMALL-SCALE (AND LARGE-SCALE)



BIOMASS GASIFICATION COMMERCIALLY AVAILABLE!

ECN › TNO innovation for life

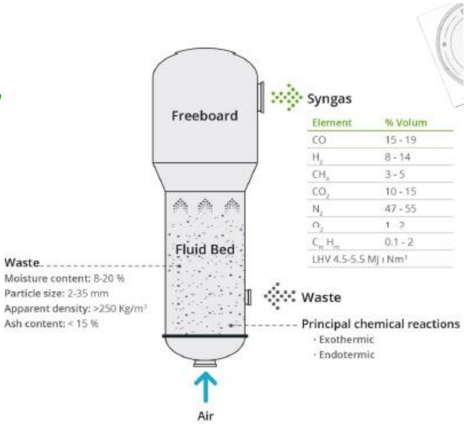
EQTEC has designed and built more than 400MWt in more than 70 different projects worldwide...



INTEGRATED WASTE/BIOMASS GASIFICATION POWER PLANTS

RELEVANT CHP PROJECTS

EQTEC BFB gasification



Source: Yoel S_Aleman Mendez, ACI Gasification 2017, Helsinki, 15 March 2017

BIOMASS GASIFICATION COMMERCIALLY AVAILABLE!

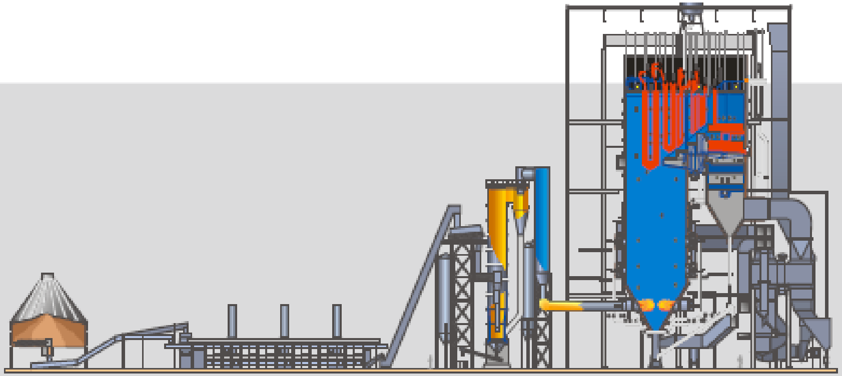
Valmet CFB gasification operational plants

VASKILUODON VOIMA

The Vaskiluoto 2 power plant

Product gas from biomass for power boilers

20,000 h+ operation

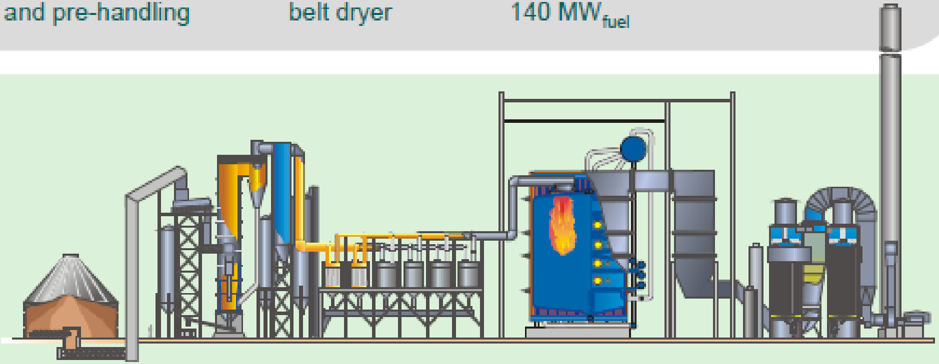


LAHTI ENERGIA

lisää tehoa

Product gas from SRF for power production

30,000 h+ operation



Source: Juhani Isaksson, ACI Gasification 2017, Helsinki, 15 March 2017

BIOMASS GASIFICATION COMMERCIALLY AVAILABLE!

ECN › TNO innovation for life

Product gas for industrial kilns

- Woody biomass, bark, peat and waste
- 20 – 110 MW_{fuel} units
- Typically includes a dryer
- Dusty product gas
- Other types of kilns also possible
- Gas cleaning if needed

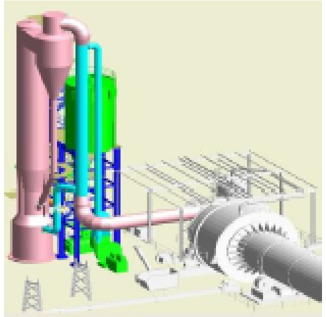
Product gas for power boilers

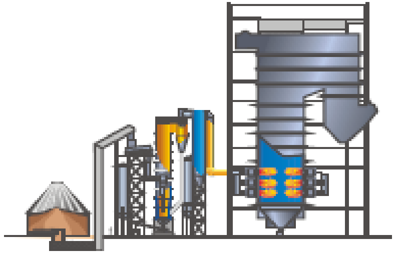
- Woody biomass, bark, peat and waste
- Superior electrical efficiency
- Existing boilers
- 50 –140 (300) MW_{fuel} units
- If needed, can include a dryer
- Gas cleaning as needed

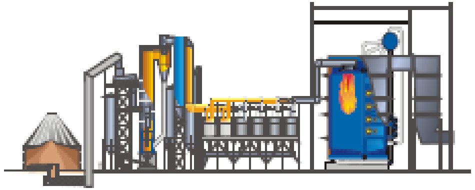
Product gas from waste for power production

- Waste-derived fuel
- 50 – 150 MW_{fuel}
- High electrical efficiency
- Typically a new gas boiler (existing boiler is also an option)
- Gas filtering -> clean product gas
- Corrosion free

Valmet
CFB gasification offering







Source: Juhani Isaksson, ACI Gasification 2017, Helsinki, 15 March 2017

BIOMASS GASIFICATION – STATE OF THE ART

- Biomass gasification commercially available (100 kWth up to 100 - 300 MWth scale)
- Market implementation limited mainly to relatively simple power and heat applications (which are at present progressing rather well)
- Biomass-gasification-based production of transportation fuels or chemicals has not yet had commercial breakthrough
- This is due to both technical challenges and non-technical issues:
  - Syngas cleaning/upgrading/synthesis processes are complex and require rather large scale in order to achieve positive economics
  - Technical uncertainties and availability risks
  - Difficulties in financing the first-of-a-kind industrial plants
  - Binding targets for renewable fuels missing
- Many possibilities for improvement in terms of overall biomass conversion efficiency, complexity, availability, reliability, CAPEX and OPEX

GOBIGAS PROJECT

FROM SHOWCASE PROJECT TO “UNFORTUNATE EXAMPLE”

Phase 1: 20 MW/ 160 GWh/y in operation 2014 – about 160 million €

- Project start: 2006
- Investment decision: 2010
- Start 2013
- First delivery of Biogas to the Grid dec 2014
- Demonstration supported by the Swedish energy agency with – 23 miljon €
- Assesment of the process during 7 years (until end of 2019)

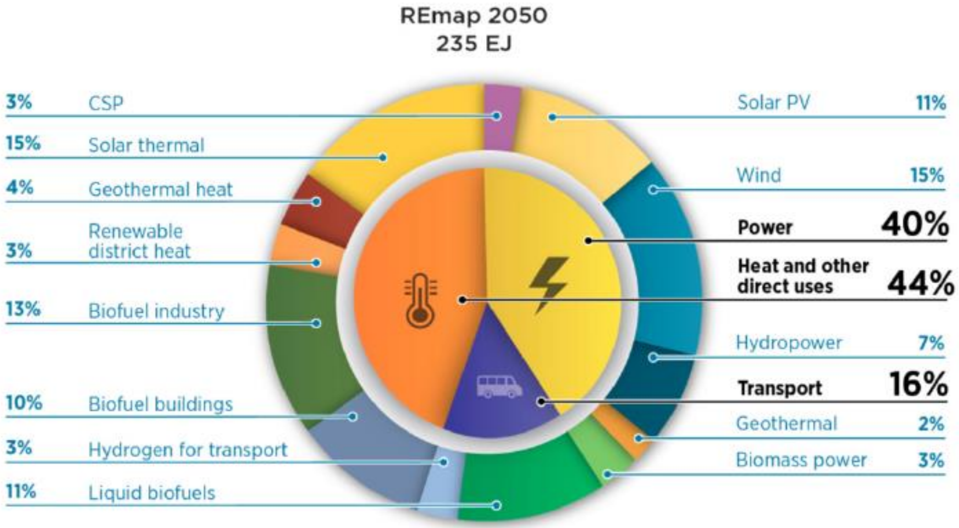
Phase 2: 80-100 MW/ 640-800 GWh/y

- Decision after demonstration of the technology and profitable
- Sponsored by the EU program NER-300 with about 53 million €
- With current prices of the biogas, phase 2 (100Mw) is not profitable and the project is therefore on hold

ON HOLD

Source: Anton Larsson, ACI Gasification 2017, Helsinki, 15 March 2017

IN VIEW OF THE PARIS AGREEMENT:
› BIOMASS ESSENTIAL TO MAKE CHEMISTRY AND ENERGY FULLY SUSTAINABLE
› ALL ENERGY SCENARIOS SHOW A MAJOR ROLE FOR BIOMASS



"Perspectives for the energy transition", IEA/IRENA, 2017

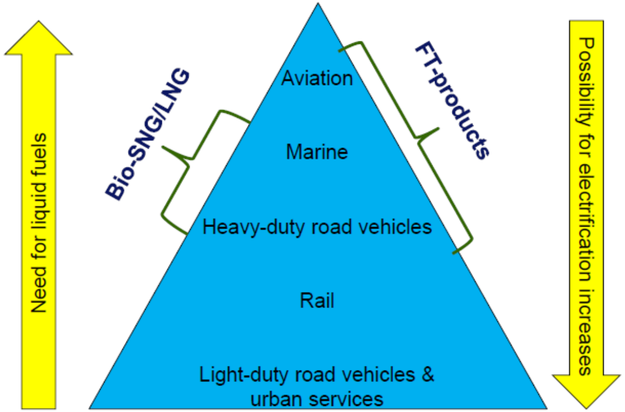
- 20-50% bioenergy in the sustainable energy mix needed for 80-95% GHG emission reduction in 2050
- Development of synthetic fuels and feedstock uncertain and not in time

CHANGING ROLE BIOMASS TOWARDS 2050

USE BIOMASS PREDOMINANTLY IN SECTORS, THAT CANNOT BE COVERED (ENTIRELY) BY OTHER SUSTAINABLE SOURCES (NL FOCUS)

- High value feedstock for the biobased economy
  - Production of chemicals and materials
  - Connect agro and chemistry sectors
- Sustainable fuel
  - Aviation and shipping
  - Heavy duty road transport
  - High-temperature heat
  - Residential heating (e.g. gas in old cities)
  - Back-up power supply and to cover intermittency problems
  - In combination with CCS enable negative GHG emissions (CO_2 sink)

Hierarchy in biofuels

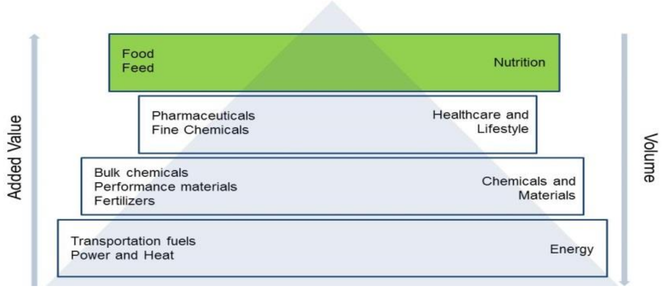


Source: Nils-Olof Nylund, IMECHE Future Fuels, 2016

BIOMASS USE – MAXIMISE ADDED VALUE

PRODUCTION OF BIOCHEMICALS/-MATERIALS AND BIOENERGY GO HAND IN HAND

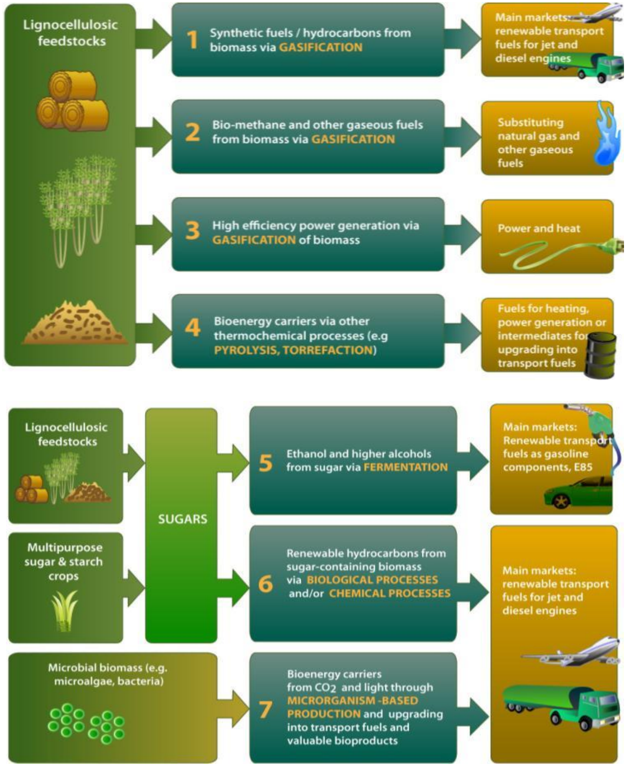
- Maximum added value creation through:
  - Use of molecular capital (e.g. proteins, sugars, aromatic structures)
  - Use biomass as a carbon source



- Smart co-production strategies based on cascading and biorefinery concepts lead to attractive business cases and cost-effective bioenergy
  - High-added-value application of the entire biomass often not possible
  - Concept not new, in oil refining chemicals (typically 10% = 50% value added), fuels (up to 90%) and low-value asphalt/bitumen fractions
  - Existing biomass utilisation practice: e.g., paper industry and beer production
- Energy sector more than an order of magnitude larger than chemical sector and not all biomass qualifies for high-added-value application – also direct energy applications

EU POLICY ON BIOENERGY (R&D)

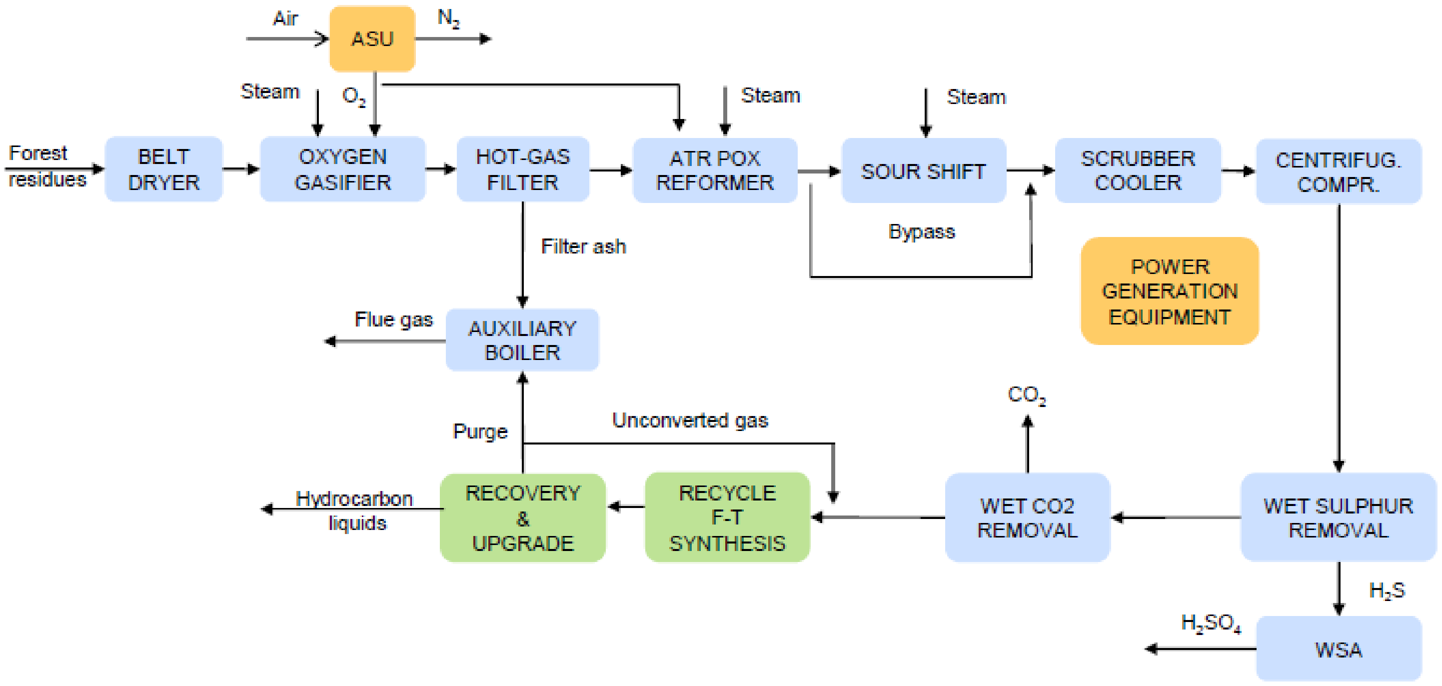
- Renewable Energy Directive II (RED II)
  - Target for renewable transport fuels (14% in 2030, of which 3.5% advanced biofuels = 300-400 plants)
- SET plan and Action 8 Implementation Plan
  - Gasification key technology in 3 out of 7 SET plan value chains
  - 2030 targets on cost reduction, efficiency increase and GHG savings, for advanced biofuels production:
    - Net process efficiency improvement for biomass conversion to end biofuels products of at least 30%
    - At least 60% GHG savings from the use of advanced biofuels (including biomass feedstock contribution)
    - Cost reduction for advanced biofuels to <50 €/MWh in 2020 and <35 €/MWh in 2030, excluding taxes and feedstock cost



MAIN DIRECTIONS IN BIOMASS GASIFICATION R&D

- Process simplification and intensification
  - Significant cost dimension (CAPEX, OPEX and plant availability, reliability and higher net plant efficiency)
  - Consider smaller scale? (easier financing, more integration options, use of local biomass)
- Increasing feedstock flexibility and allowing application of (cheaper) biomass low-quality feedstock
  - Mainly aiming at cost reduction
- Co-production of chemicals/materials
  - Energy-driven biorefinery; to boost the business case for energy products (with higher added value for chemicals/materials)
- Combining thermochemical and biochemical processing
  - E.g. , thermochemical conversion of residues of biochemical processing (e.g., lignin gasification), biochemical product gas cleaning, syngas fermentation
- Maximizing resource efficiency
  - E.g. by combining biomass processing with other sources like renewable hydrogen produced from solar and wind
- Creating negative GHG emissions
  - Involving concepts like BioEnergy + Carbon Capture & Storage (BECCS) and biochar co-production
- Coupling with other industrial activities (sector coupling)
  - Industrial symbiosis, e.g. exchange of utilities and residues/feedstock, heat integration

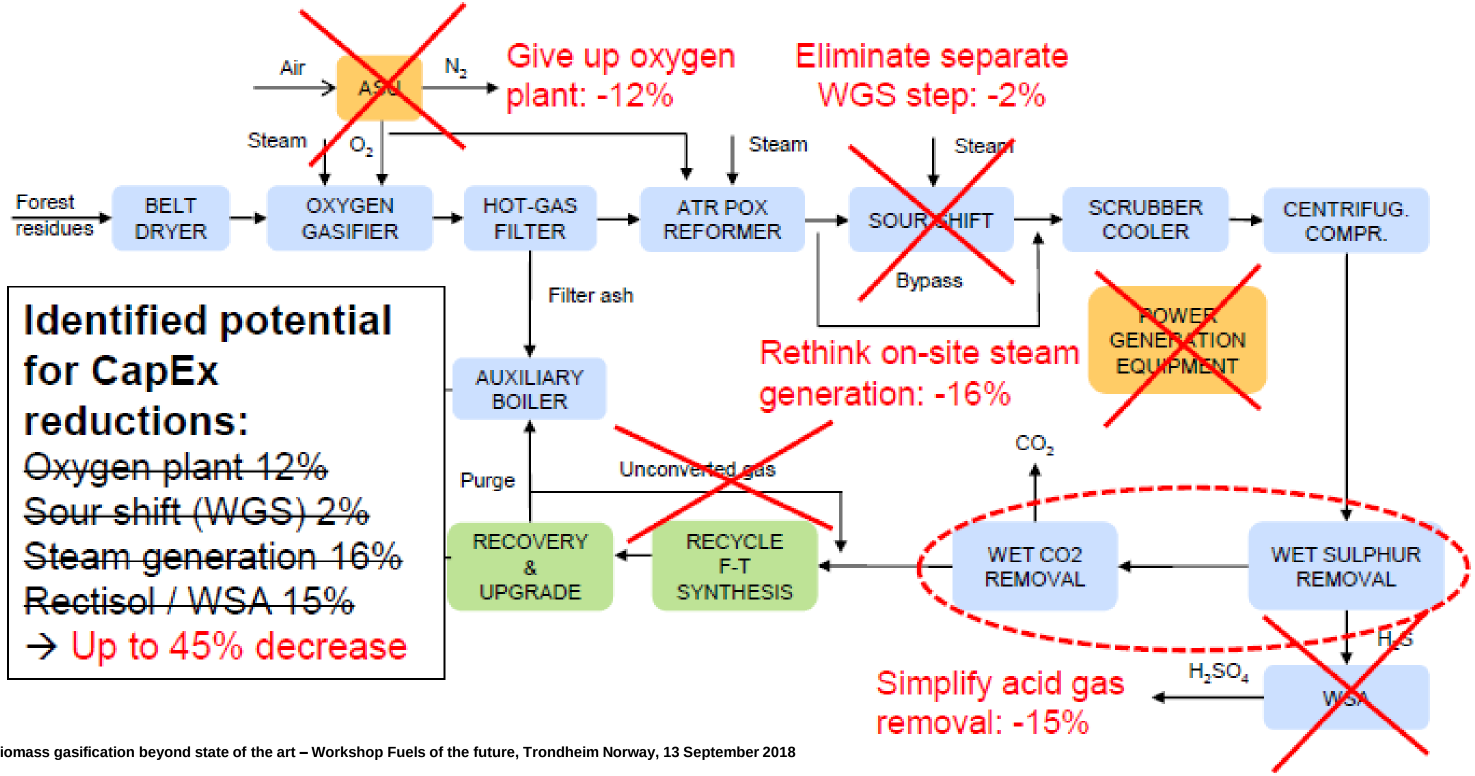
VTT MEDIUM SCALE LOW-CAPEX BIOMASS-TO-LIQUIDS PROCESS



Source: Esa Kurkela, ACI Gasification 2017, Helsinki, 15 March 2017

VTT MEDIUM SCALE LOW-CAPEX BIOMASS-TO-LIQUIDS PROCESS

ECN › TNO innovation for life



Identified potential for CapEx reductions:

~~Oxygen plant 12%~~

~~Sour shift (WGS) 2%~~

~~Steam generation 16%~~

~~Rectisol / WSA 15%~~

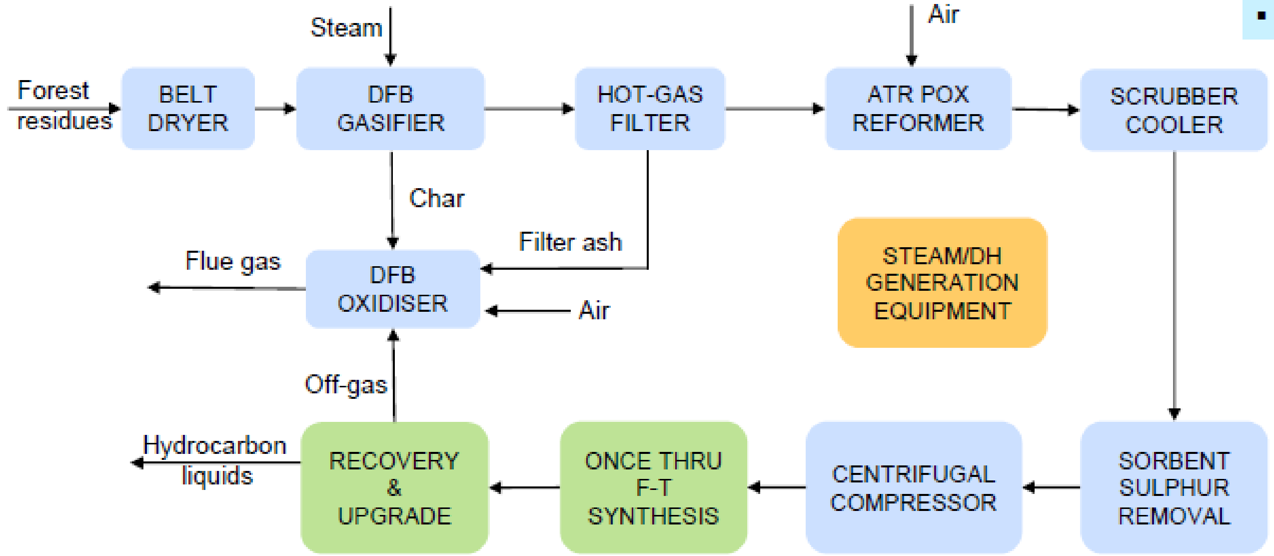
→ Up to 45% decrease

Source: Esa Kurkela, ACI Gasification 2017, Helsinki, 15 March 2017

VTT MEDIUM SCALE LOW-CAPEX BIOMASS-TO-LIQUIDS PROCESS

Typical process attributes:

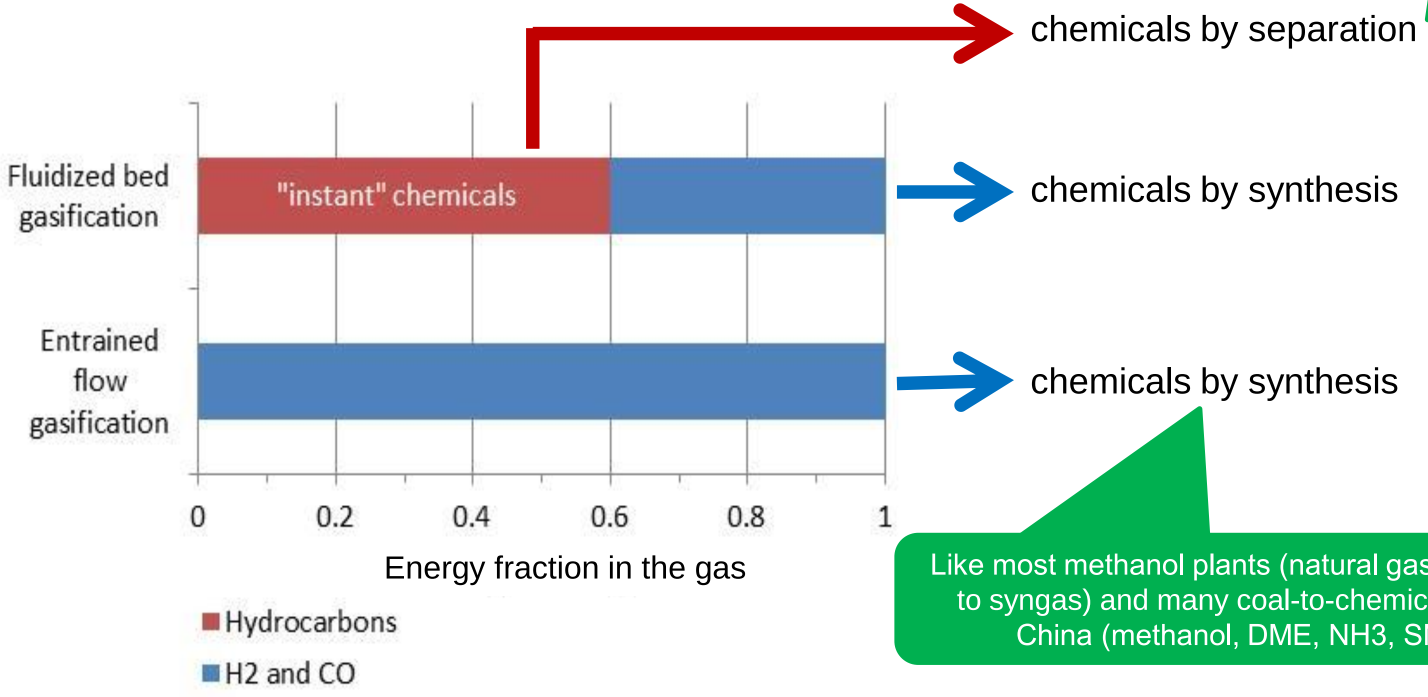
- Biomass input: 100 MW
- FT-wax output: 50-55 MW (35 ktoe/a)
- Steam/district heat output: 15-25 MW
- Target size: 100-200 MW biomass



Source: Esa Kurkela, ACI Gasification 2017, Helsinki, 15 March 2017

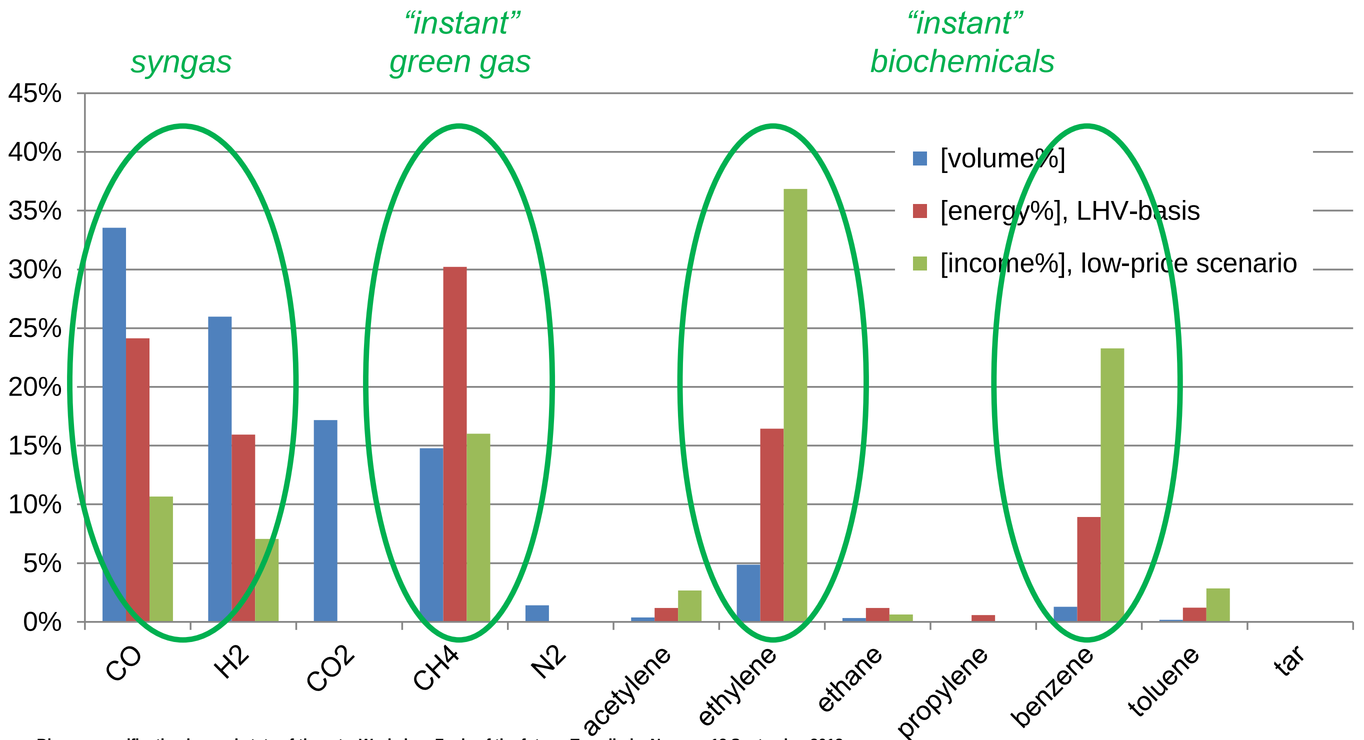
GASIFICATION FOR CHEMISTRY
TWO OPTIONS

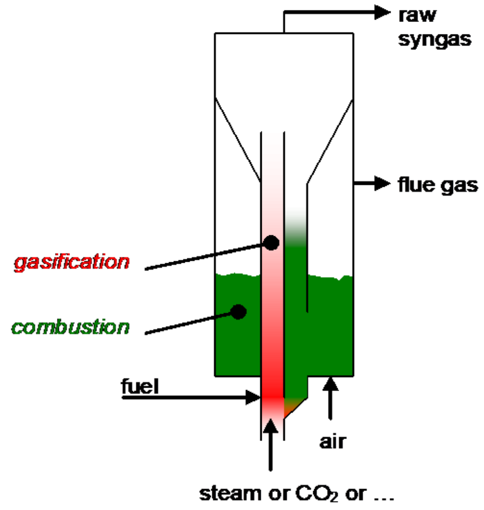
Like naphtha cracking (to ethylene, propylene, BTX, …)



Like most methanol plants (natural gas "gasification" to syngas) and many coal-to-chemicals plants in China (methanol, DME, NH_3, SNG, …)

ENERGY-DRIVEN BIOREFINERY
VIA GASIFICATION TO BIOFUELS, BIOCHEMICALS, HEAT AND POWER



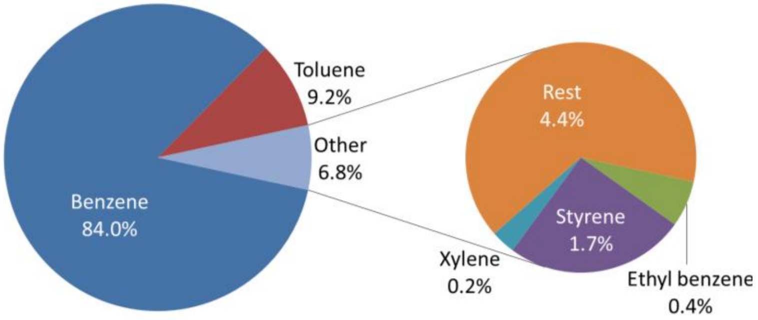


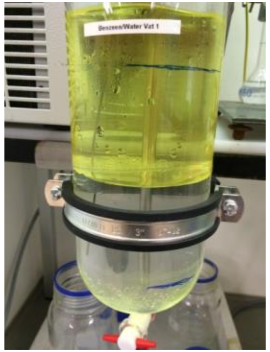
Tar-free gas from MILENA wood residues gasification

BTX SEPARATION (AND ETHYLENE AROMATISATION)
(BTX = BENZENE, TOLUENE, XYLENES)

- First step after (OLGA) tar removal
- Simplifies downstream processing and improves business cases
- Proof of Concept: >95% separation, B/T/X = typically 90/9/1
- Continuous long duration testing December 2017
- Next step: Process optimisation and piloting

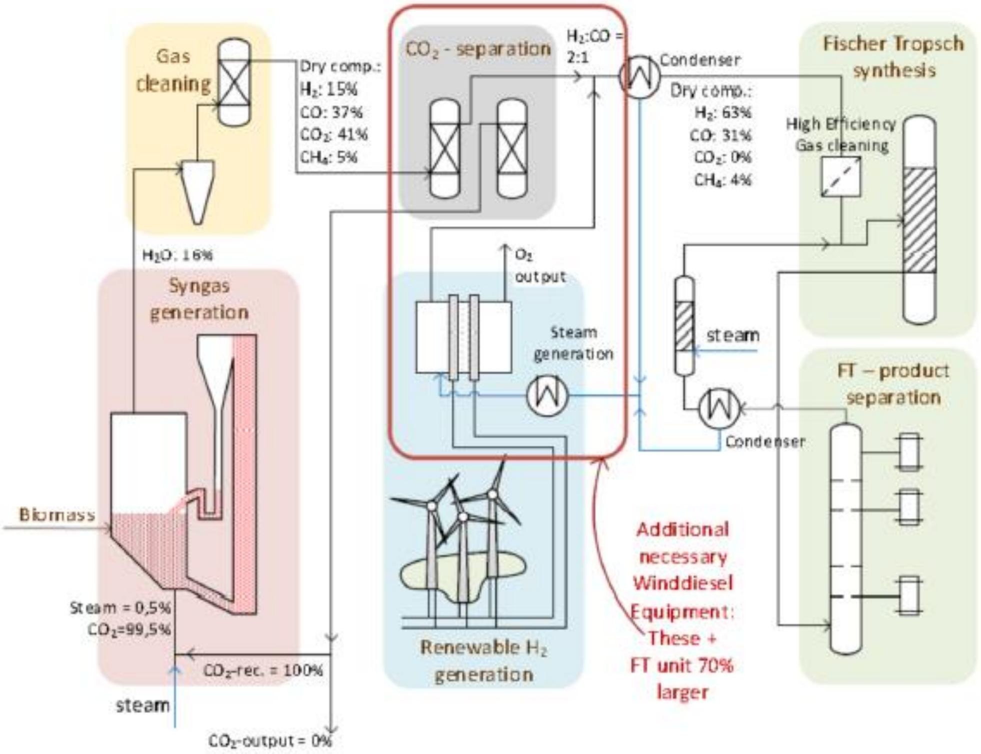
Biorizon
The way to aromatics
www.biorizon.eu





BTX scrubber, 2 Nm^3/h

REPOTEC WINDDIESEL PROCESS



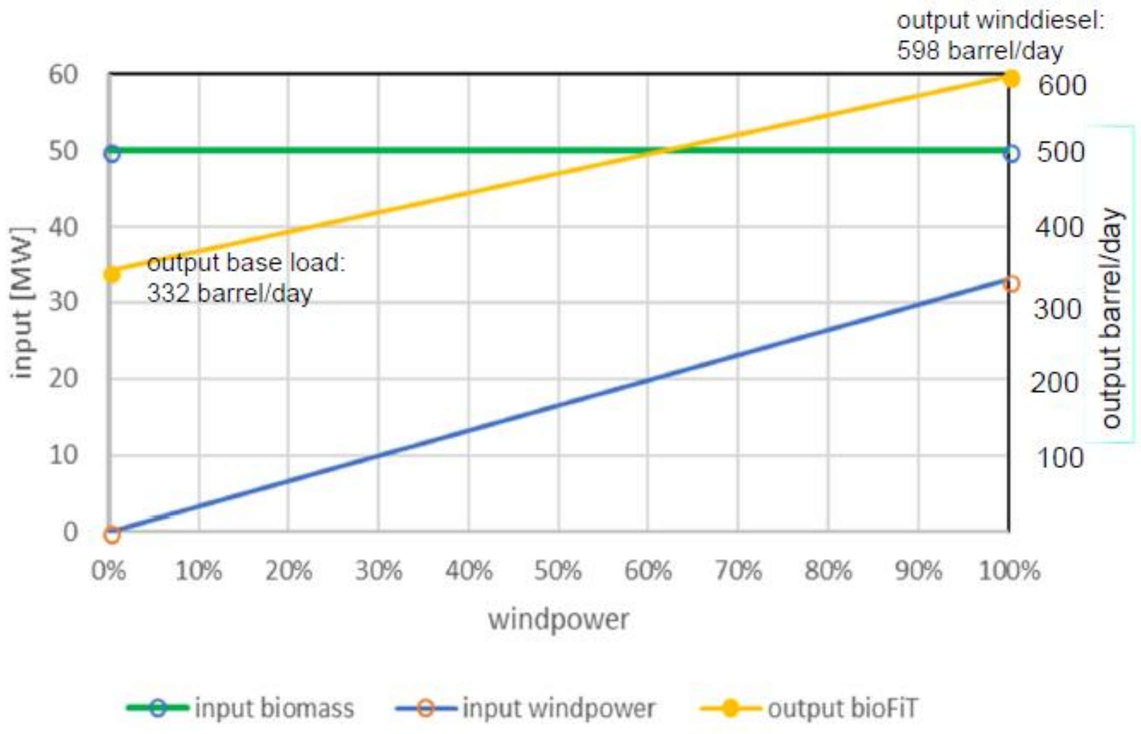
www.winddiesel.at

Source: Christian Aichernig, ETIP Bioenergy workshop Emerging Technologies, Brussels, 4 June 2018

ECN › TNO innovation for life

REPOTEC WINDDIESEL PROCESS

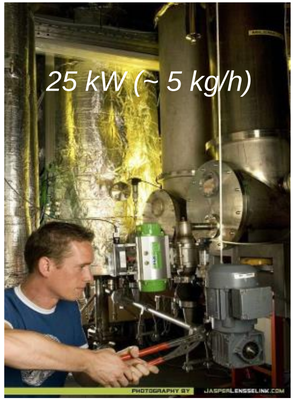
www.winddiesel.at



Source: Christian Aichernig, ETIP Bioenergy workshop Emerging Technologies, Brussels, 4 June 2018

AMBIGO
BIOMASS-TO-SNG DEMO IN ALKMAAR, NL

- Consortium of Synova/DRT, Gasunie, ENGIE, PDENGH and ECN part of TNO to demonstrate and commercialize bioSNG technology
- 4 MW_{th} input, 300 Nm^3/h bioSNG production, based on MILENA/OLGA technology



ECN › TNO innovation for life

SYNOVA

DAHLMAN renewable technology member of SYNOVA Power

gasunie new energy

engie

PDENH

ECN › TNO innovation for life

ambigo

INVESTA

EXPERTISE CENTRE FOR GREEN GAS AND BIOMASS GASIFICATION

- Accelerator of innovation for large-scale production of biobased chemicals and fuels through biomass gasification
  - Bring technology to market through large-scale demonstrators
  - Shared infrastructure, facilities and services
  - World-class Shared Research Programs
- Connect research institutes, education and private companies to enable further innovation
- Strengthen the energy cluster in North-Holland North and the Energy Valley region by creating additional employment and an attractive location

SUMMARY CONCLUSIONS

ECN › TNO innovation for life

- Biomass gasification commercially available, market implementation limited to relatively simple power and heat
- Gasification-based production of biofuels or biochemicals has not yet had commercial breakthrough due to both technical challenges and non-technical issues, e.g.:
  - Processes complexity, large scale, technical uncertainties and availability risks, difficulties in financing the first-of-a-kind industrial plants, binding targets for renewable fuels missing
- Biomass gasification is a key technology for the transition to a sustainable economy
- Biomass gasification R&D should focus on reducing cost, increasing (resource) efficiency and maximizing GHG savings, through:
  - Process simplification and intensification, increasing feedstock flexibility, co-production of chemicals/materials, combining thermochemical and biochemical processing, maximizing resource efficiency, creating negative GHG emissions, coupling with other industrial activities (sector coupling)
- Firm incentives needed to ensure R, D&D up to high TRL and timely wide-scale commercial role out (taking into account required time intervals)

Time is of the essence! We should step up our activities!

THANK YOU FOR YOUR ATTENTION

TNO.NL/ECNPARTOFTNO