Biomass gasification for the production of SNG: a practical route through available and new technologies

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Agenda

- **Introduction and Plant overview**
- **Technology review**
  - Gasification
  - Tar removal
  - Syngas conditioning
  - Methanation
- **Case study**
- **Conclusions**

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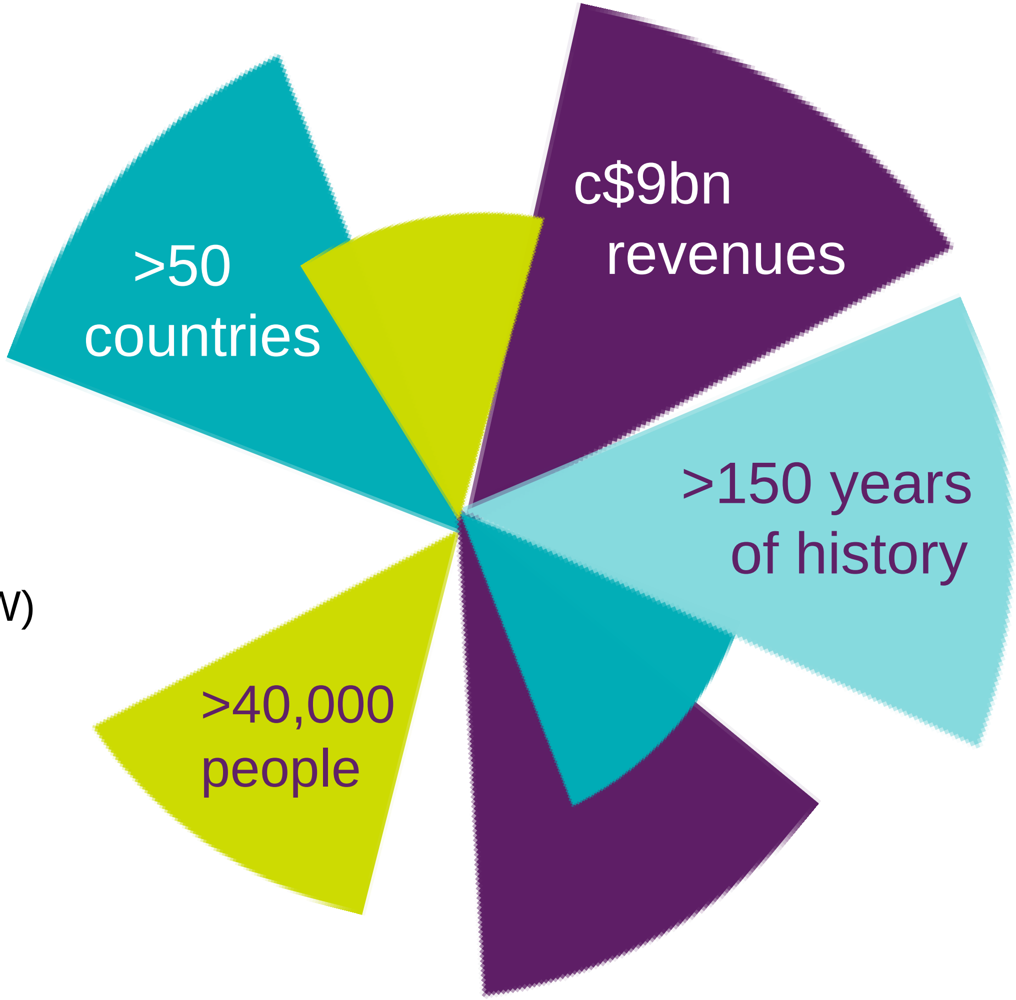
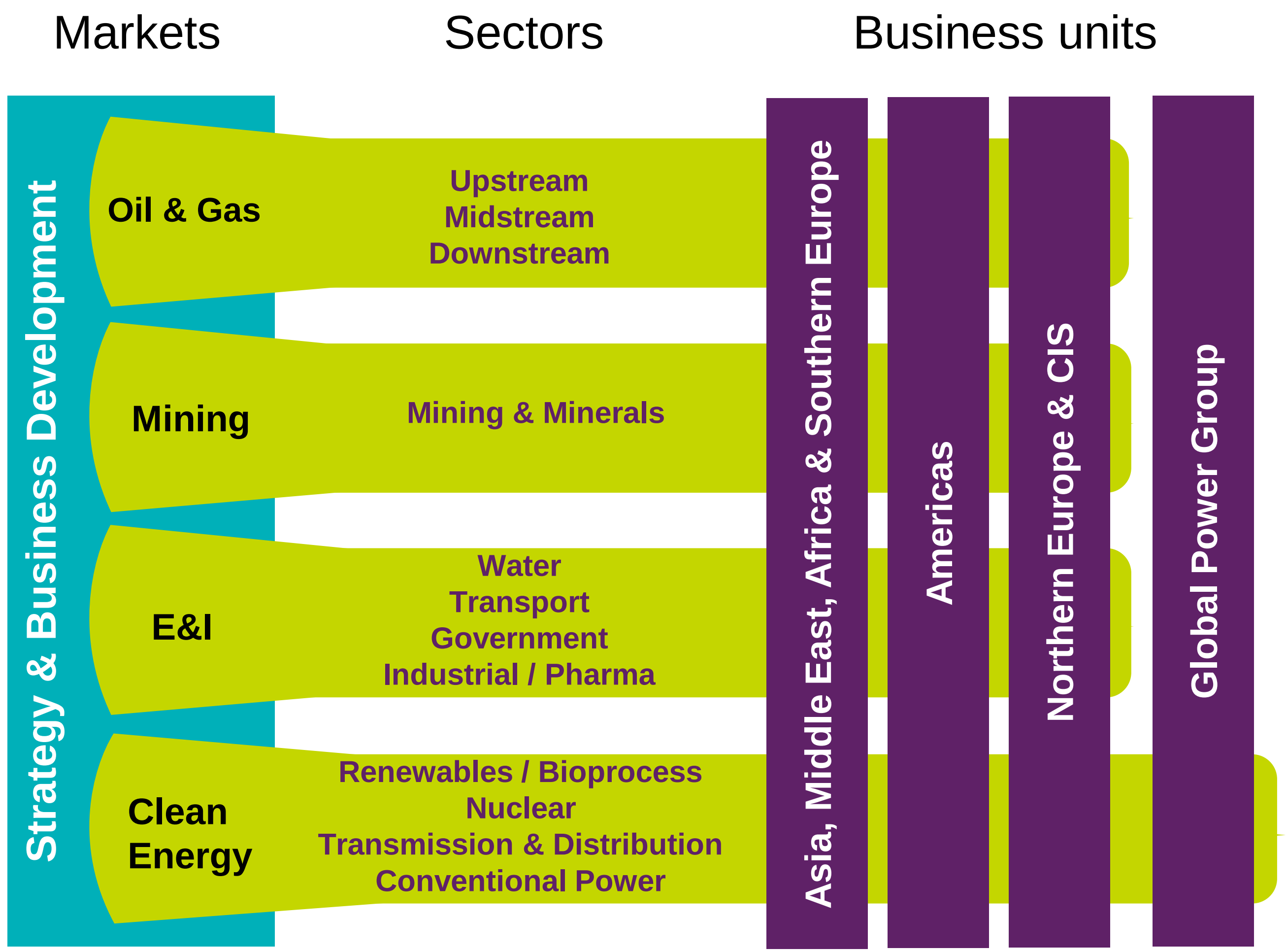
Who we are

- Headquartered in London
- Listed on
  - London Stock Exchange (AMFW)
  - New York Stock Exchange (AMFW)

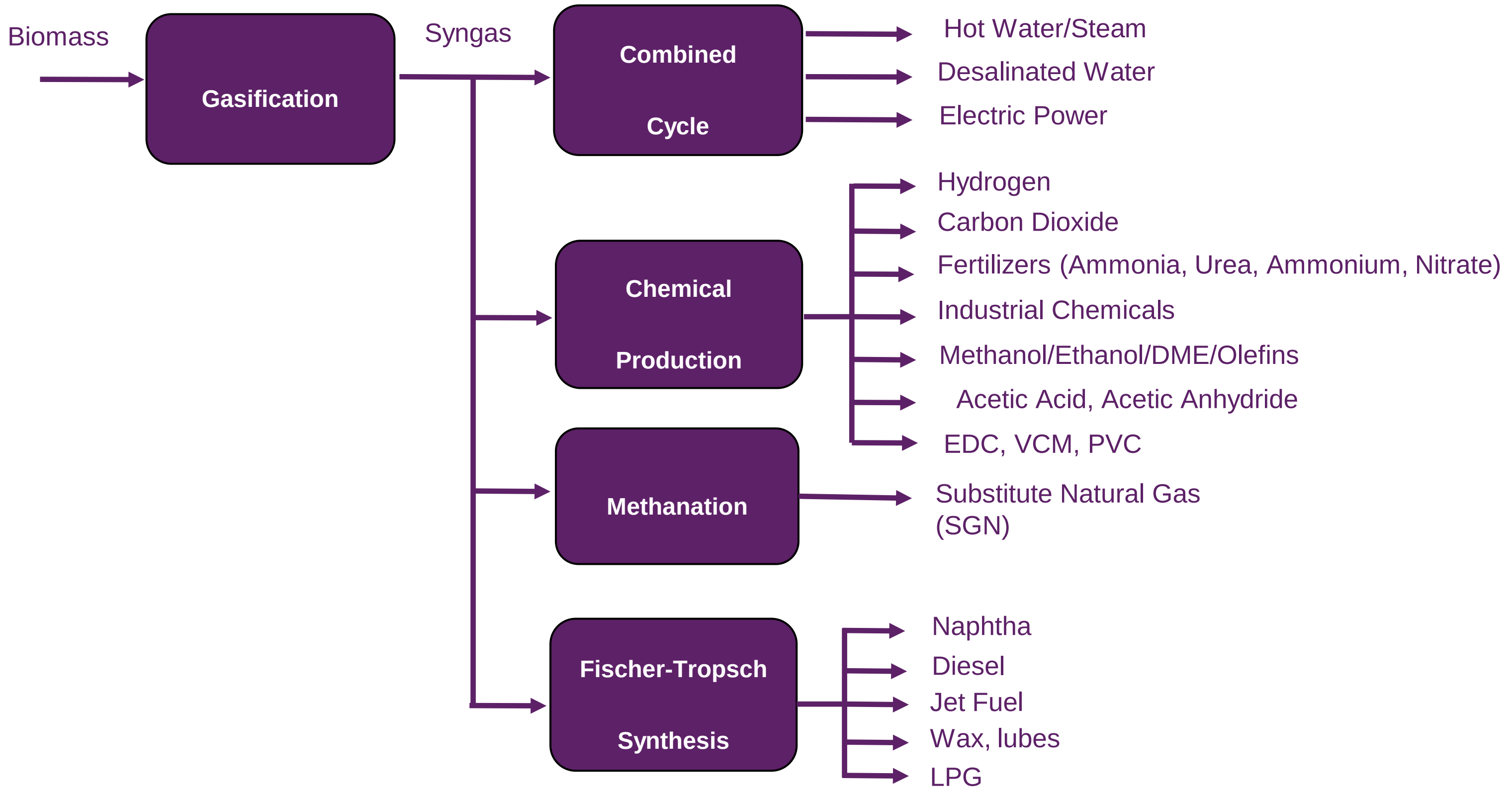


Amec Foster Wheeler
Four business units, operating across four key markets



Why biomass gasification? Why SNG?

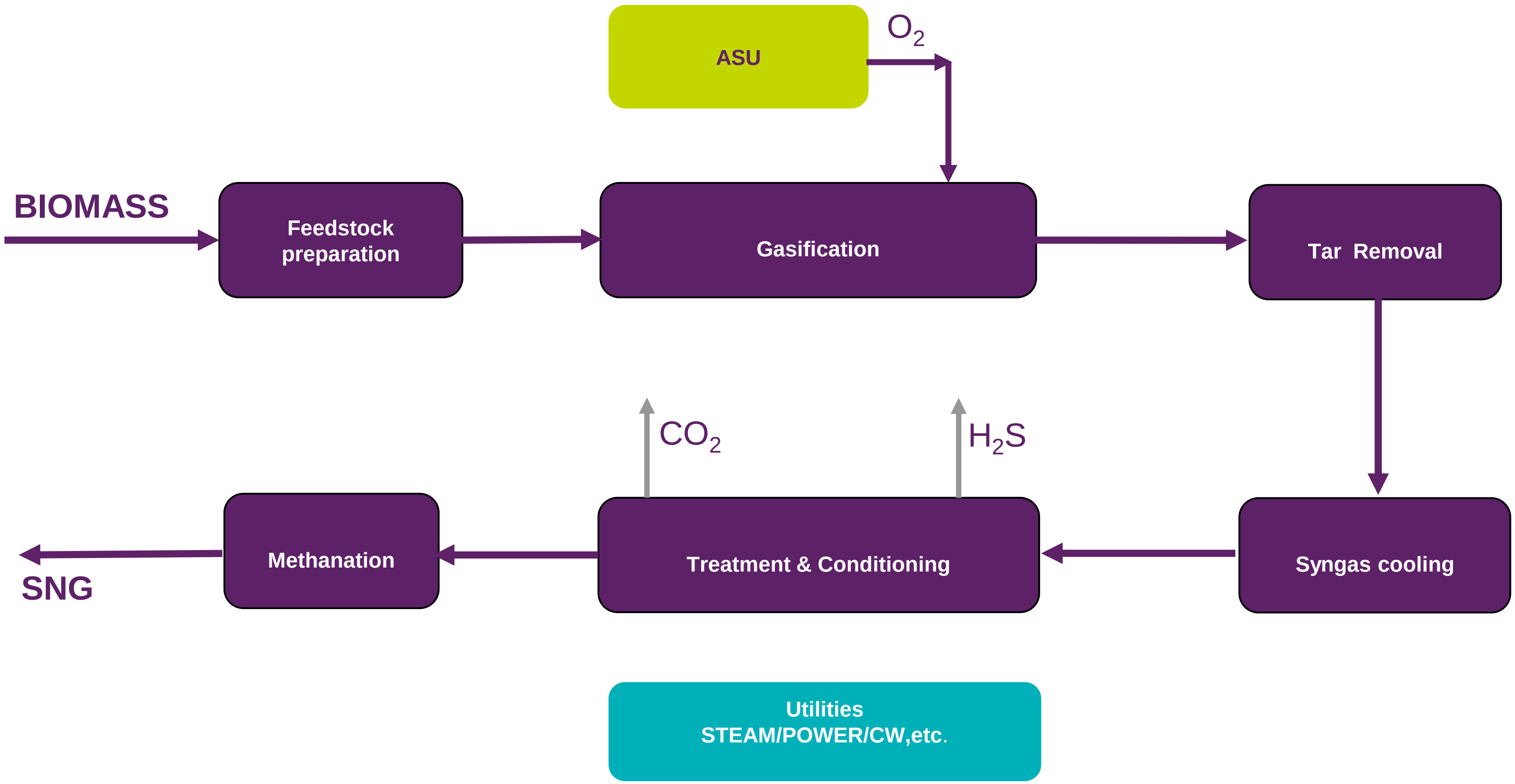
- Introduction: why biomass and SNG?



- SNG: a practical pathway to final users
  - Easy connection of production plants to existing NG networks

Plant overview

Main process blocks



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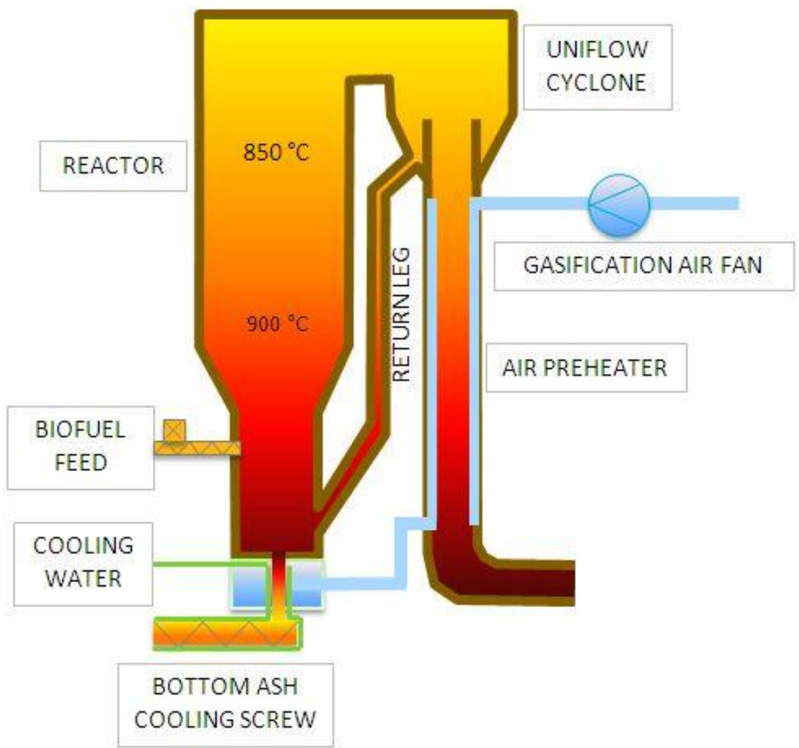
Technology review

- Gasification: Amec Foster Wheeler CFB Gasifier

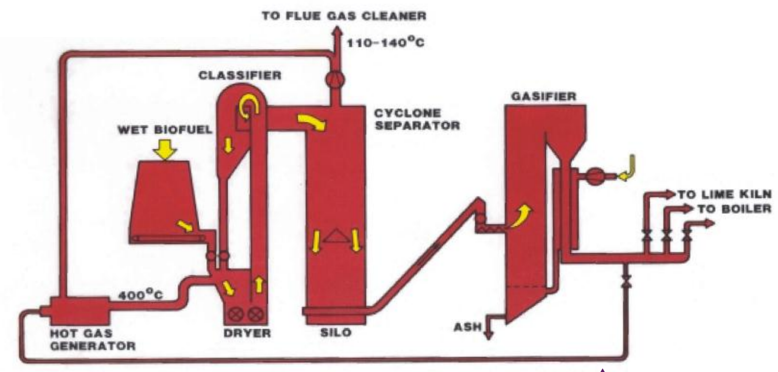


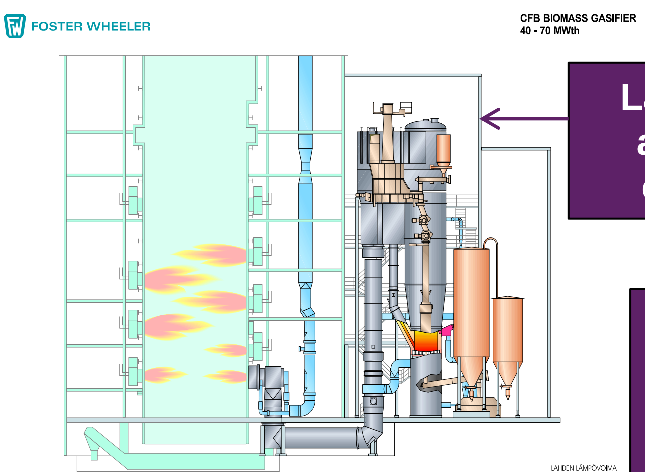
- 11 gasifiers built in 1981-2008
- Readiness to offer plants for over 150 MWth air-blown applications for various wood and waste based fuels
- Readiness to offer pressurized oxygen-steam blown gasifiers up to ~300 MW for biorefinery applications with wood based fuels
- Process conditions according to fuels and applications

Long History (originally developed end 70's/beginning 80's) → **Recent commercial applications** → **Developments always in progress**

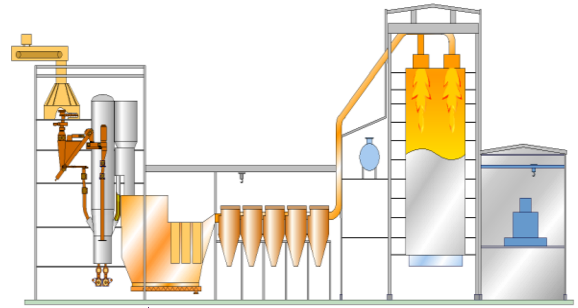
Technology review

- Gasification: History of Amec Foster Wheeler biomass gasification in brief



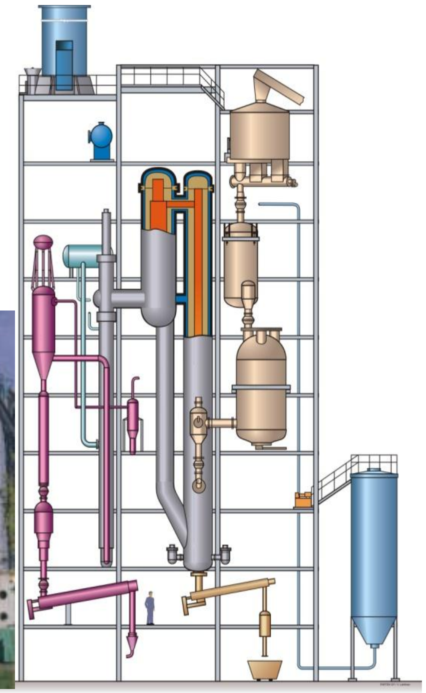


Lahti: raw gas applications commercial



Varkaus: Atmospheric clean gas applications Demonstrated

Varnamo: Pressurized air blown gasification Demonstrated



Technology review

- Gasification: Varkaus 12 MW_{th} O_2-H_2O Demo plant and 5 MWth slip stream
- Gasification temp: 870-890 °C
- Fluidization gas: O_2 40-50 %-m and H_2O
- Bed material: Mixture of limestone and sand, 70/30 (50/50)
- Fuel: Wood based biomass (wood chips, bark, forest residues, etc)

- Typical raw gas composition on wet basis:

CO	17 %
CO_2	22 %
H_2	21 %
C_xH_y *	7 %
H_2O	33 %

* Contains components from CH_4 to heavy tars.

Gas composition can vary to some extent and is affected by process conditions, fuel type and particle size, bed material, etc.

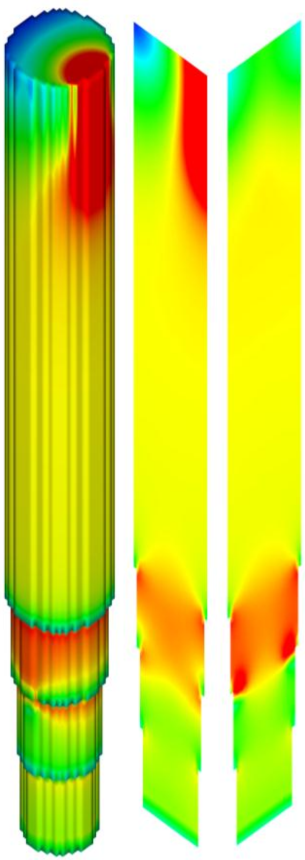
Technology review

- Gasification: Varkaus 12 MWth O_2-H_2O Demo plant and 5 MWth slip stream

Technology review

Gasification: Status of gasification technology development

- Test runs at Varkaus demonstration plant completed
  - Complete FT production chain demonstrated successfully
  - 12 MW_{th} O_2-H_2O gasifier (~9000 h)
  - 5 MW_{th} slip stream (~5500 h)
  - 0.1 MW_{th} gas ultra cleaning and FT synthesis
  - FT supplier was impressed with regard to the gas quality
- Low pressure (4 bar) design for a commercial size O_2-H_2O gasifier exists, higher pressures under development
- 3D gasification model developed with Lappeenranta University of Technology in use to improve process design
- Commercial size design calculations done (~300 MW)



Technology review

- Tar removal: Syngas quality from biomass gasification

	Entrained Flow	Circulating Fluidized Bed
Methane content	< 0.5%	5-7%
Tar content	~ 0	10^4 mg/Nm^3 max

- Tar: organic compounds with boiling temperature higher than benzene (80°C)
- Heavy tar (boiling temperature > 350°C)

    Potential fouling of heat exchangers, filters, etc.

- Light tar (i.e. phenol, naphthalene)

    Condensate contamination

Technology review

Tar removal: Features of TAR removal processes

Process	Advantages	Disadvantages	Risk
Aqueous Scrubbing	▪ Good efficiency ▪ Smooth and trouble-free operation	▪ Tars pass from gas to liquid phase ▪ High Capex for WWT	▪ Light tars in the clean syngas
Thermal Cracking	• Complete removal • Chemical energy remains in syngas	▪ Soot formation ▪ High Capex ▪ Low thermal efficiency (product used to provide heat)	▪ None
Catalytic Cracking	• Potential complete removal • Chemical energy remains in syngas • Composition of product gas can be adjusted	▪ Soot formation ▪ Catalyst consumption and cost ▪ Catalyst disposal due to Ni	▪ Coke formation and catalyst deactivation ▪ Low references
Oil Scrubbing	• Stability and availability • Chemical energy remains in syngas (tars recycle) • High efficiency	▪ Scrubber/Stripper to remove NH_3, HCl, H_2S ▪ High level of filtration at high temperature	▪ Naphtalene in the clean syngas: test required

Technology review

- Syngas composition may be adjusted by partial shift to obtain the required H2/CO ratio (depending on Methanation technologies), for example:
  - $(H_2-CO_2)/(CO+CO_2)$ (vol. ratio): 3 **or**
  - H_2/CO (vol. ratio): 3 **or**
  - UNSHIFTED

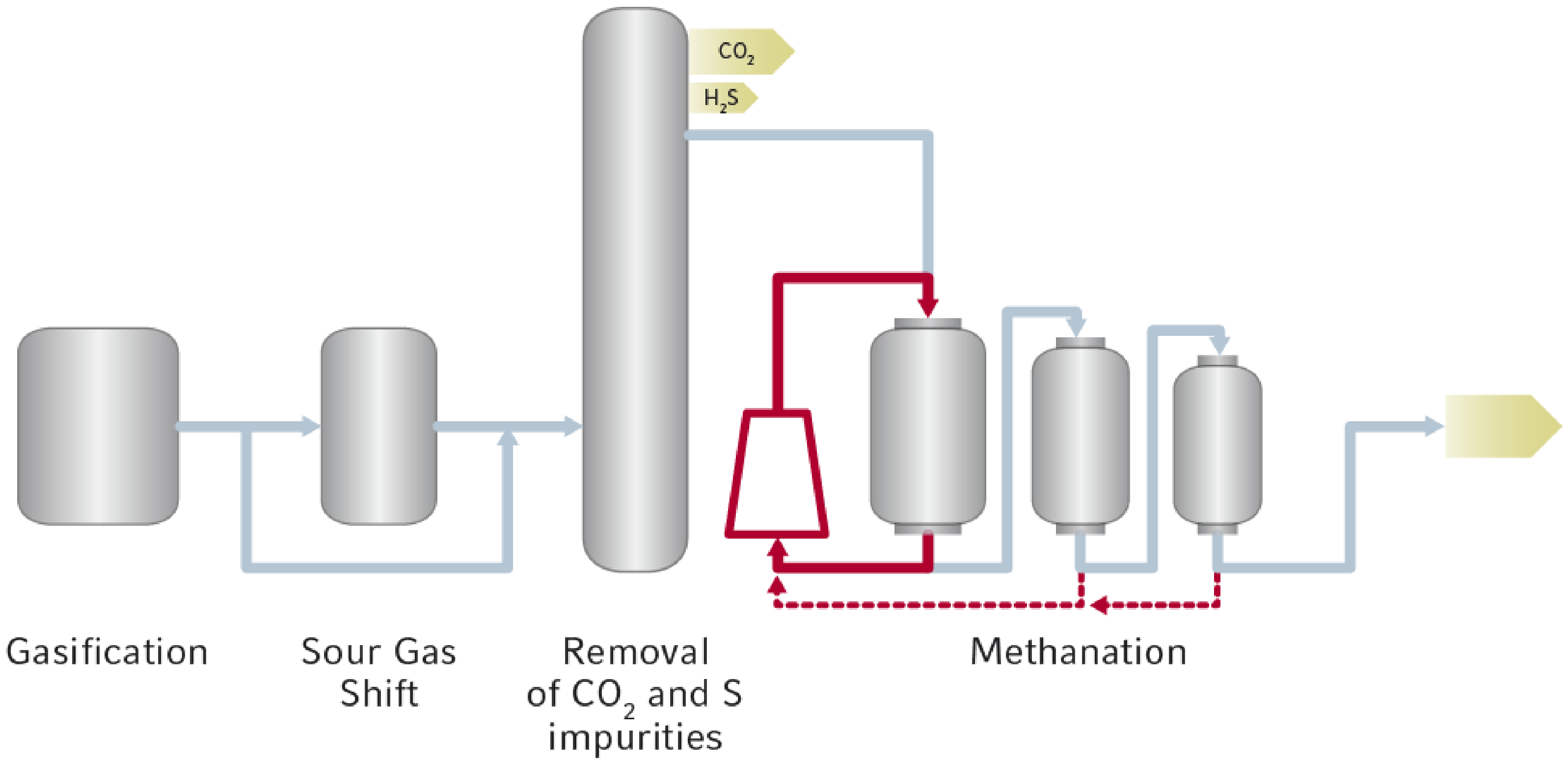
- Cooling of the shifted gas to enter the absorber of the Acid Gas Removal Unit. Physical/Chemical washing to remove sulphur (and CO_2), followed by guard reactor : SNG (methanation) catalysts require a very low (a few ppb) sulphur content

- Reference parameters for unit design:
  - Sulphur content (before guard bed) 1-2 ppm vol max
  - B,T,X,N 5 ppmv max.
  - H_2, CO, CH_4 recovery to be maximized

Technology review

Methanation: Available Technologies

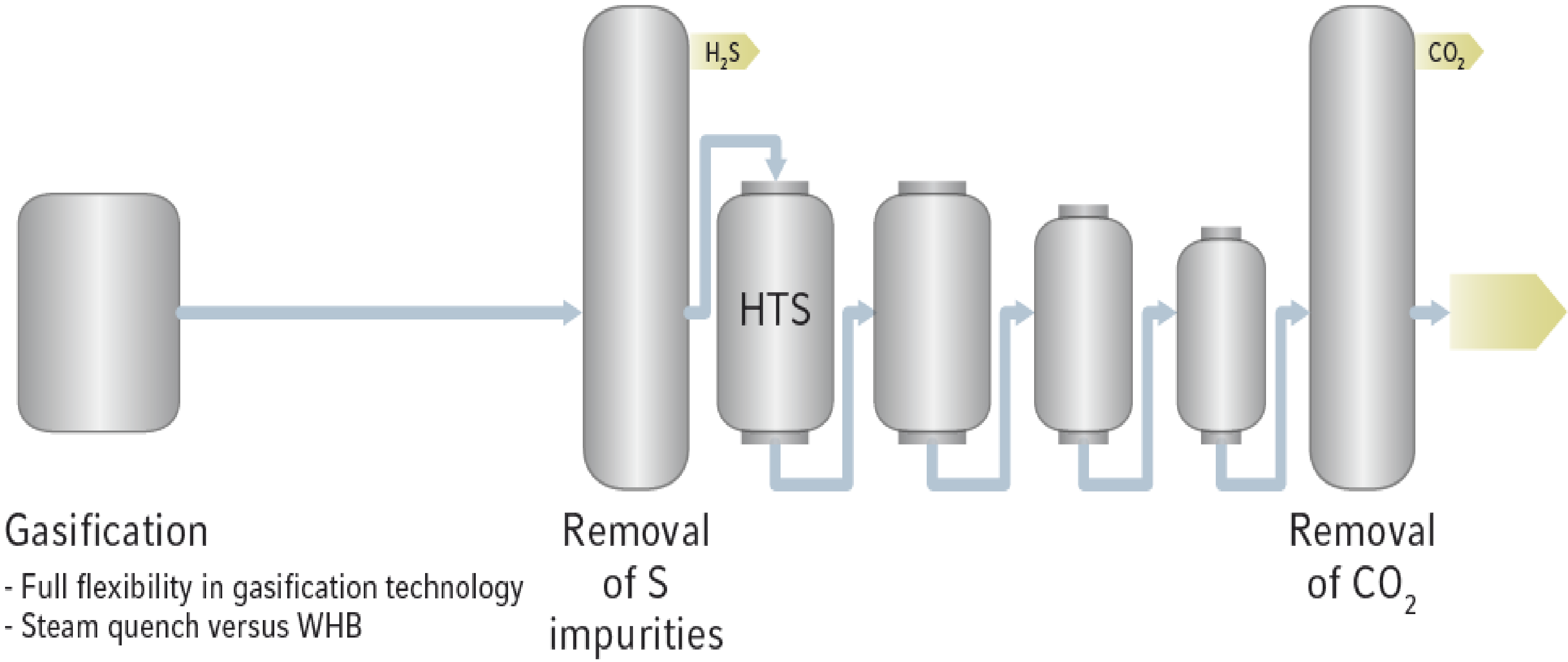
The recycle of CH_4 product to syngas is the standard process.
Dilute the CO concentration with CH_4



Technology review

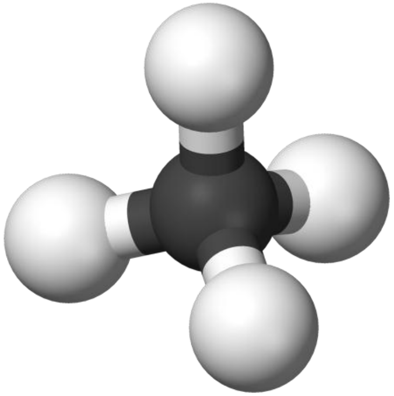
Methanation: VESTA Technology

The Amec Foster Wheeler VESTA SNG process uses CO_2 and water to control the heat of reaction

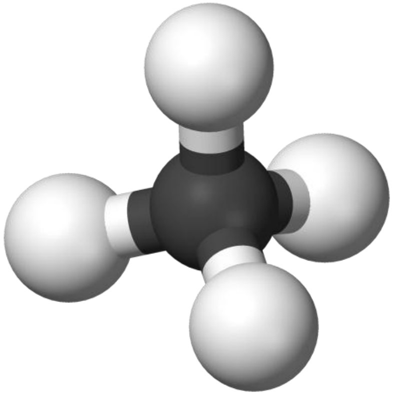


Technology review

Methanation: VESTA Technology Highlights



- No recycle of CH_4 product to the syngas
- Dilute with CO_2
- Dilute with Water



- **Dilution with CO_2 and Water**
  - No Recycle Stream
- **Temperature cannot exceed 550°C**
  - No uncontrolled reaction possible
- **Flexibility of syngas composition**
  - No need for sour gas shift

Technology review

Methanation: VESTA Pilot Plant

Amec Foster Wheeler has signed a cooperation agreement with Clariant International AG ("Clariant") and Wison Engineering Ltd ("Wison Engineering") to build a pilot plant to demonstrate the Amec Foster Wheeler VESTA Substitute Natural Gas (SNG) technology

The pilot plant:

- Designed for a production capacity of 100 Nm^3/h of SNG and includes all reactors and control system in order to completely demonstrate a real plant in addition to the verification of the chemical reactions
- Erected in Nanjing, China
- Started up in July 2014; 100% of SNG production, at Chinese natural gas grid specification, reached, and the plant as well as the catalyst performance perfectly in line with expectations

Technology review

Methanation: VESTA Pilot Plant

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Case study

- Case study: Biomass to SNG
  - **Main Input Data**

    Feedstock: Woody materials

    Outlet thermal power (SNG): 200 MWth

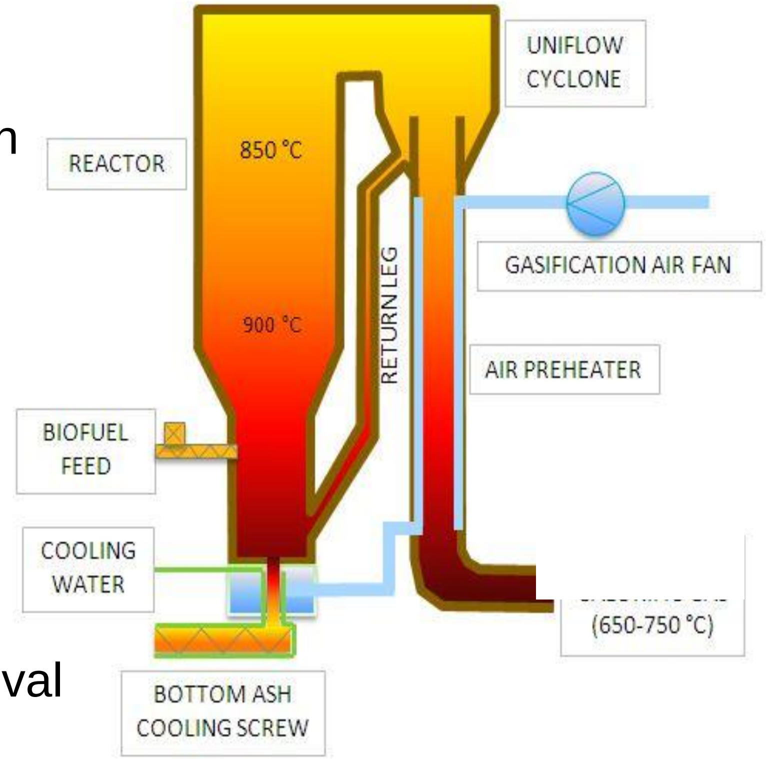
    (or 21,000 Nm^3/h)
  - **Plant Configuration**

    Amec Foster Wheeler CFB Gasifier pressurized and oxygen blown

    Catalytic tar reforming

    Physical solvent washing for H_2S removal

    VESTA SNG Technology



Case study

Case study: Biomass to SNG

ITEM	VALUE	UNIT
Feedstock type	Woody material	
Feedstock flowrate	130	t/h AR
Inlet thermal power	315-330	MW_{th}
Outlet SNG flowrate	21,000	Nm^3/h
Outlet Thermal power	200	MW_{th}
Biomass to SNG efficiency (Ther. Power bases, including biomass for power production)	60-63…..67	%
Total Investment Cost (TIC)	340-370	M€
Specific Total Investment Cost (TIC / Ther. power out)	1,700-1,850	€/kW_{th} SNG

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Conclusions

- SNG production via biomass gasification is technically feasible; main technologies are available and sufficiently mature for commercial application

- Recently Amec Foster Wheeler assessments showed that a biomass-to-SNG plant has the potential to be economically attractive

- Amec Foster Wheeler is strongly committed in this field, being technology leader for the biomass gasification process through its proprietary CFB-based gasification technology and, at the same time as owner, together with Clariant, of a patented and novel SNG production process (VESTA) amec foster wheeler

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