Towards Liquefaction of Sustainable Feedstock to Upgraded Intermediate Products

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Valmet
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- Leading supplier of process technologies, automation and services for the pulp, paper and energy industries

A strong financial profile and balanced business portfolio

2022 key figures of Valmet

Orders received
EUR 5,194 million

Net sales
EUR 5,074 million

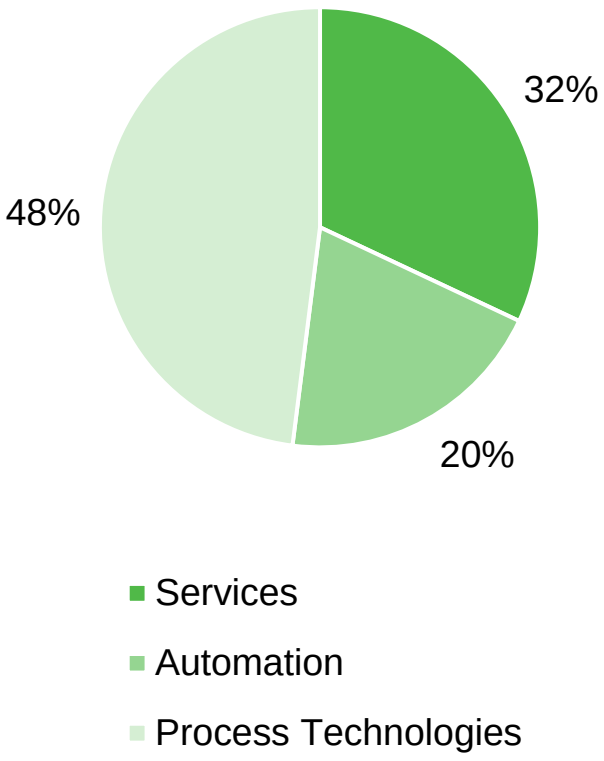
Comparable EBITA
EUR 533 million

Comparable EBITA margin
10.5%

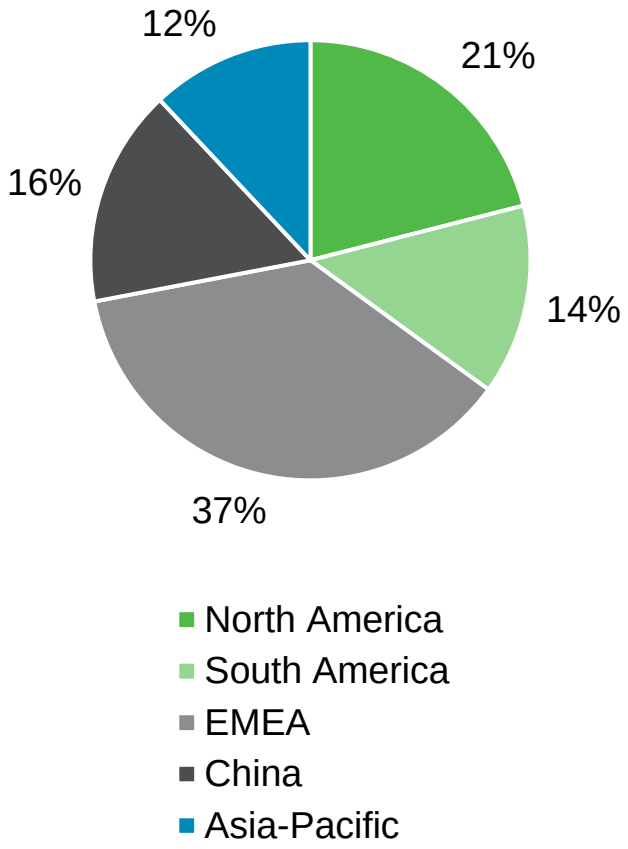
Order backlog
EUR 4,403 million

Employees
17,548

Net sales by segment



Net sales by area



Unique offering combining process technology, services and automation

Board and paper technologies

- Board, paper and tissue production lines
- Rebuilds
- Machine sections

Pulp technologies

- Complete pulp mills
- Pulp mill processes
  - Wood handling, Cooking and fiber line, Pulp drying and baling, Chemical recovery

Energy technologies

- Heat and power generation
- Air emission control
- Biofuels production

Services

- Spare and process parts
- Workshop and roll services
- Fabrics
- Maintenance development and outsourcing
- Field services
- Process upgrades
- Industrial Internet solutions

Flow Control and Automation Systems

- Valves
- Valve automation
- Valve controls
- Distributed Control Systems (DCS)
- Quality Management Systems (QMS)
- Analyzers and measurements
- Industrial applications
- Services and Industrial Internet solutions

Leading technology supplier of biomass and multifuel boiler plants globally

Renewables to energy

Biomass to energy

Sorted waste to energy (RDF-refuse derived fuel

Multifuel to energy

Co-firing biomass, waste (RDF, SRF) and fossil fuels (coal, gas)

Industrial boilers

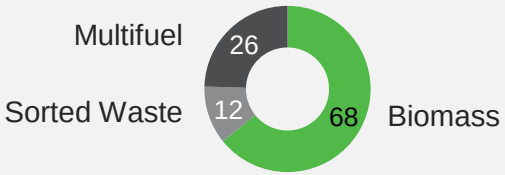
O&G / Process Gas Boiler plants

Heat recovery boiler plants

Air emission control

- Over 200 Bubbling Fluidized Bed boilers (BFB) since 1979
  Capacity 10-400 MW_{th}
- Over 100 Circulating Fluidized Bed boilers (CFB) since 1980 Capacity 50 -1000 MW_{th}
- Over 30 Modularized biomass power plants since 1999 Capacity 2-10 MW_e
- 8 Gasification plants for waste and biomass

Since 2007 ~100 new boiler plants
Total capacity ~ 12 000 MW_{th}



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Strategic direction towards more valuable products

Resources

Biomass
- Forest residues
- Agro residues

Industrial residual wastes
- Pulp & Paper
- Mechanical forest industries
- Process industries

Municipal solid waste (MSW)
- Refuse-derived fuels

Commercial & Industrial wastes (C&I)
- Refuse-derived fuels

Plastics

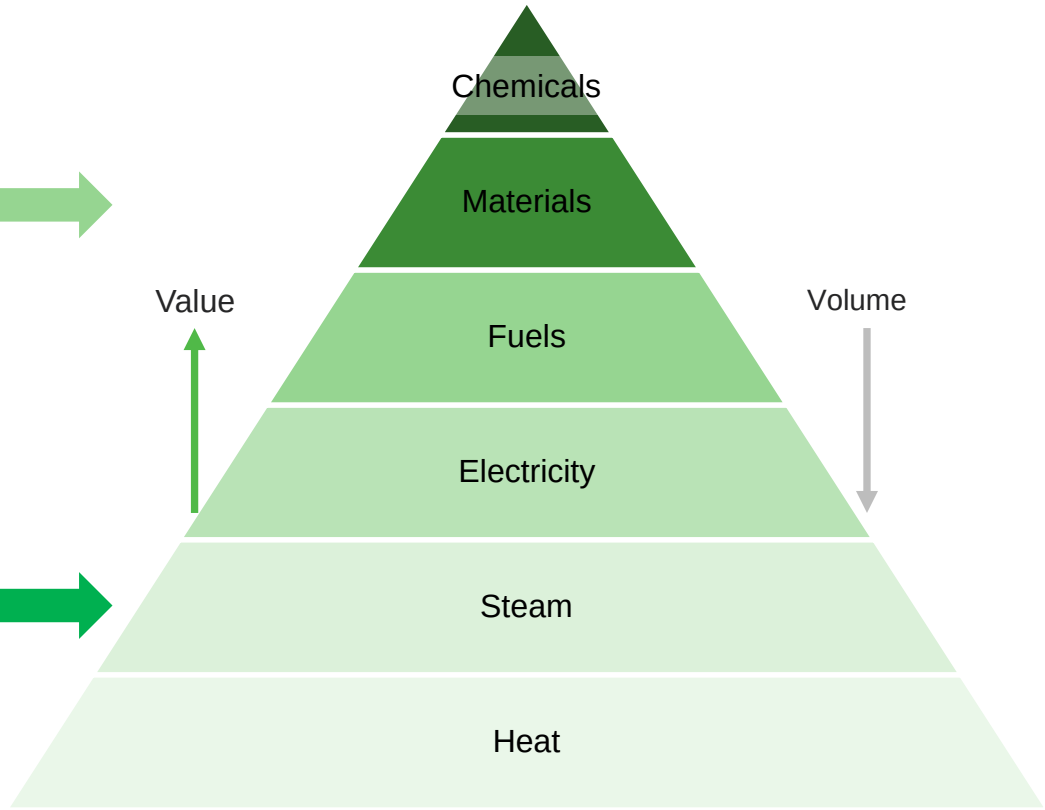
Thermochemical Conversion

Pyrolysis

Gasification

Combustion

Value



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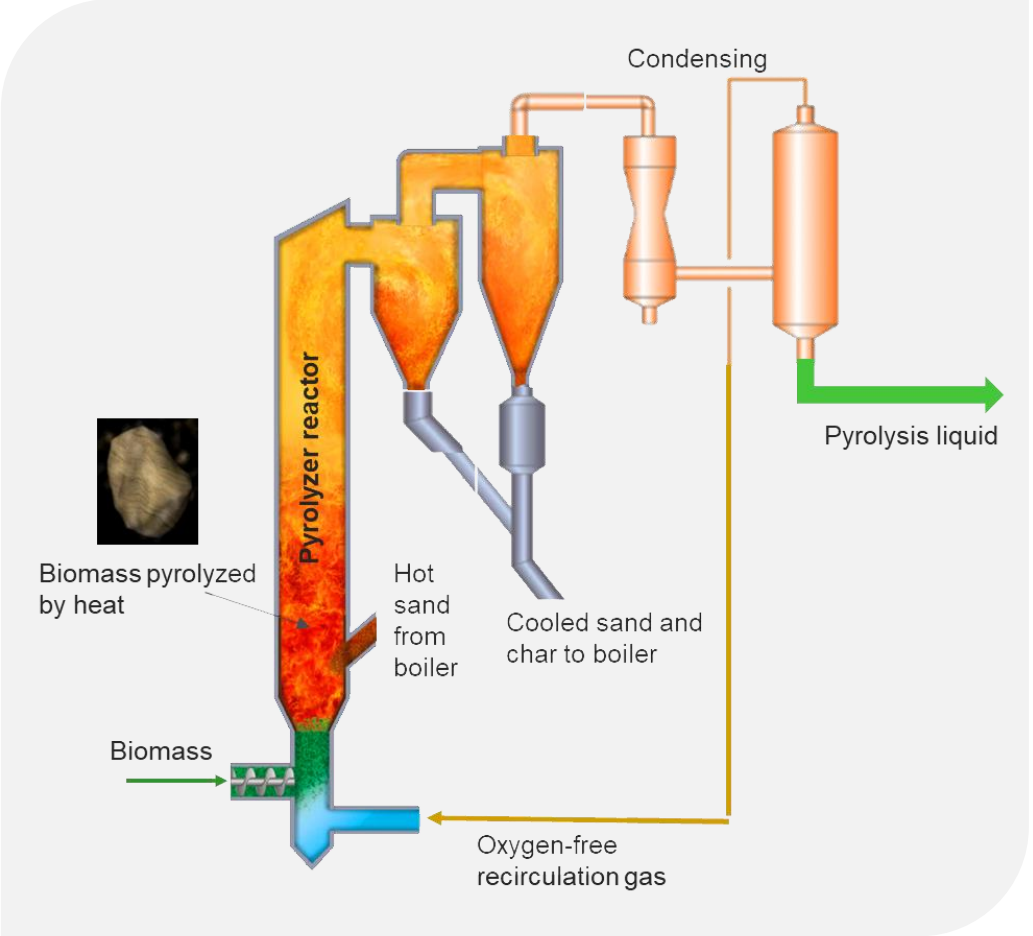
Pyrolysis

- Pyrolysis is the thermal decomposition of feedstock in absence of oxygen
- Pyrolysis produces three product streams:
  - Pyrolysis liquid
  - Char
  - Non-condensable gas
- Most biomasses and plastics are suitable for pyrolysis
  - Woody biomass: woodchips, sawdust or forest residue
  - Styrene or mixed waste plastics
- Pyrolysis liquid can be used
  - To replace heavy fuel oil in heating applications
  - For co-processing in refinery
  - As a feedstock biochemical production



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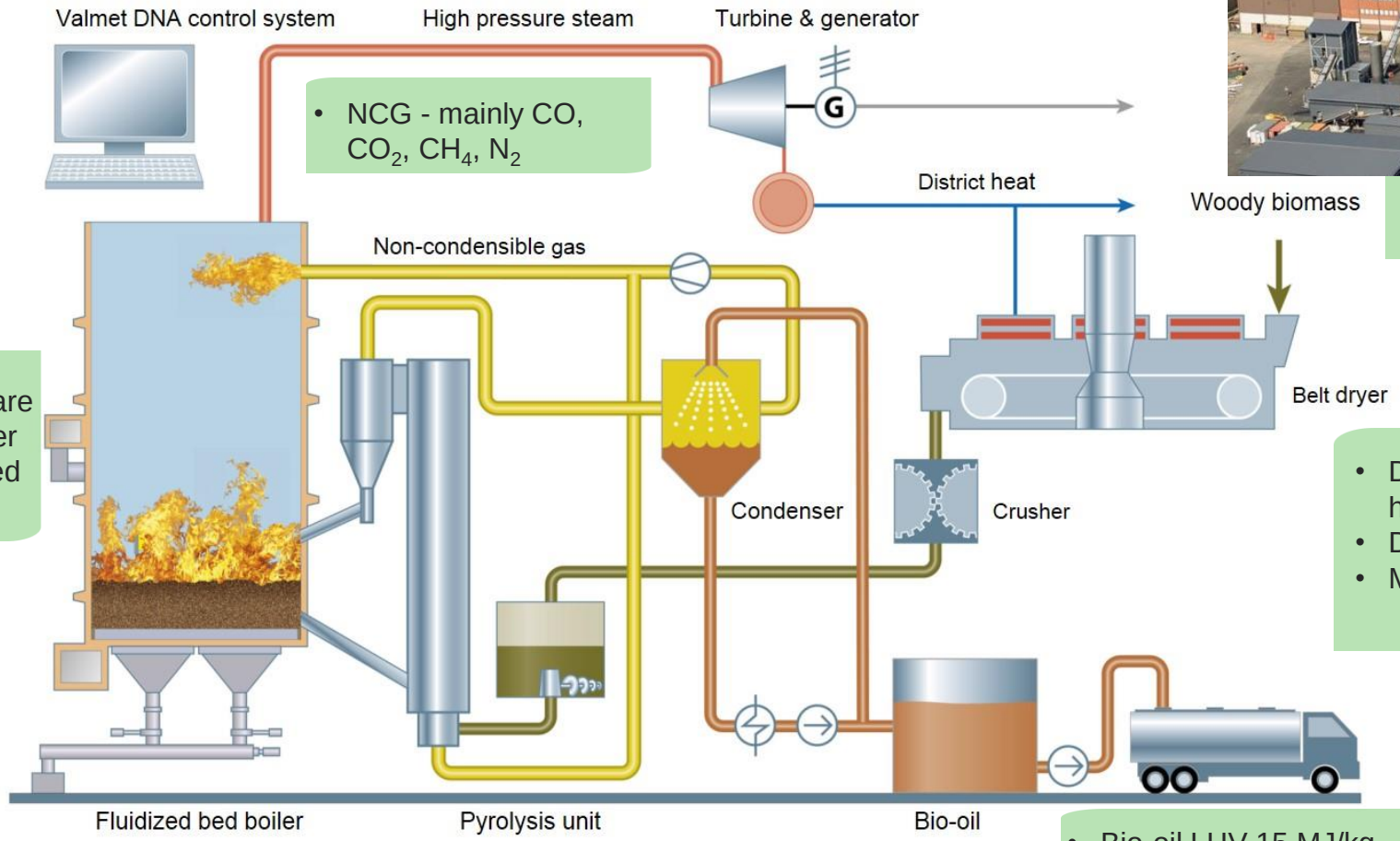
Valmet Fast Pyrolyzer

Technical description: fluidized bed boiler integrated fast pyrolysis

Fortum plant, 50 kt Bio-oil per annum



- NCG - mainly CO, CO_2, CH_4, N_2

- Residuals (char & NCG) are combusted in the FB boiler
- Excess energy is produced

woodchips, forest residue, sawdust

- Dryer uses process excess heat, district heat, LP-steam
- Drying to < 10 % H_2O
- Milling to < 5 mm size

- Reactor temperature 460 - 500 °C
- Continuous circulation of hot bed material

- Bio-oil LHV 15 MJ/kg
- Water content 25 %
- pH: 2-3

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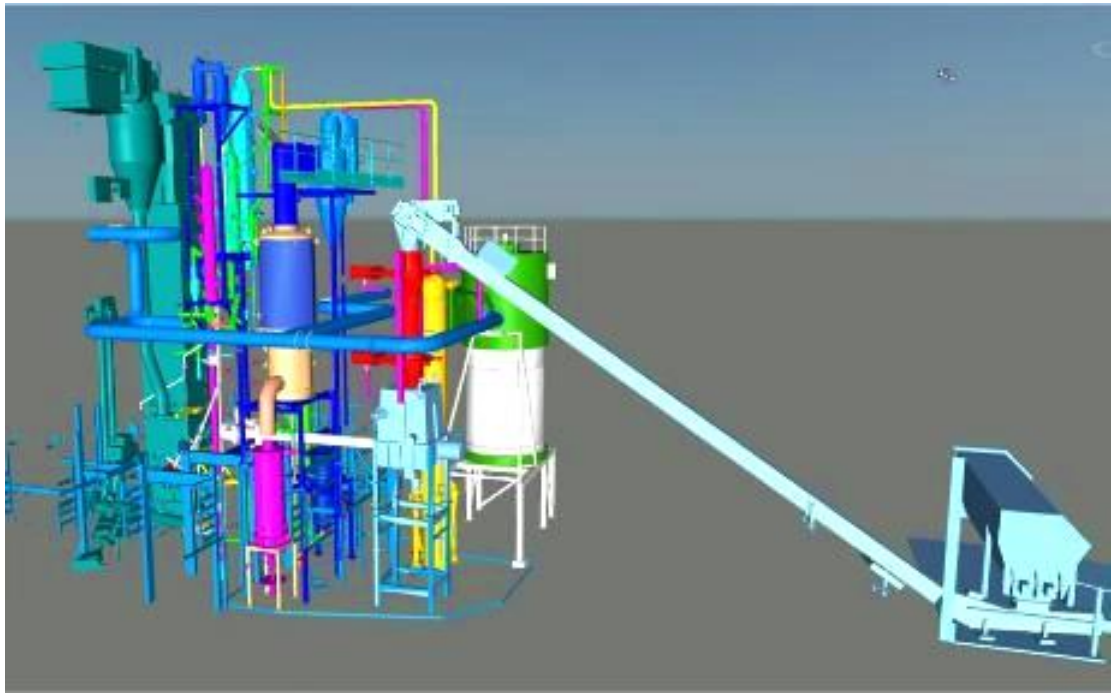
Valmet Pyrolyzer – development streams

Pyrolysis is Valmet's technology solution for:

- Biomass to chemicals
  - Pyrolysis liquid can be utilized as a raw material for renewable chemicals (for instance solvents)
- Biomass to traffic fuels
  - Catalytic pyrolysis of biomass can produce renewable feedstock to oil refinery (= biocrude)
- Chemical recycling of waste plastic
  - Pyrolysis can be applied also for plastics, targeting a feedstock for new plastics and chemicals



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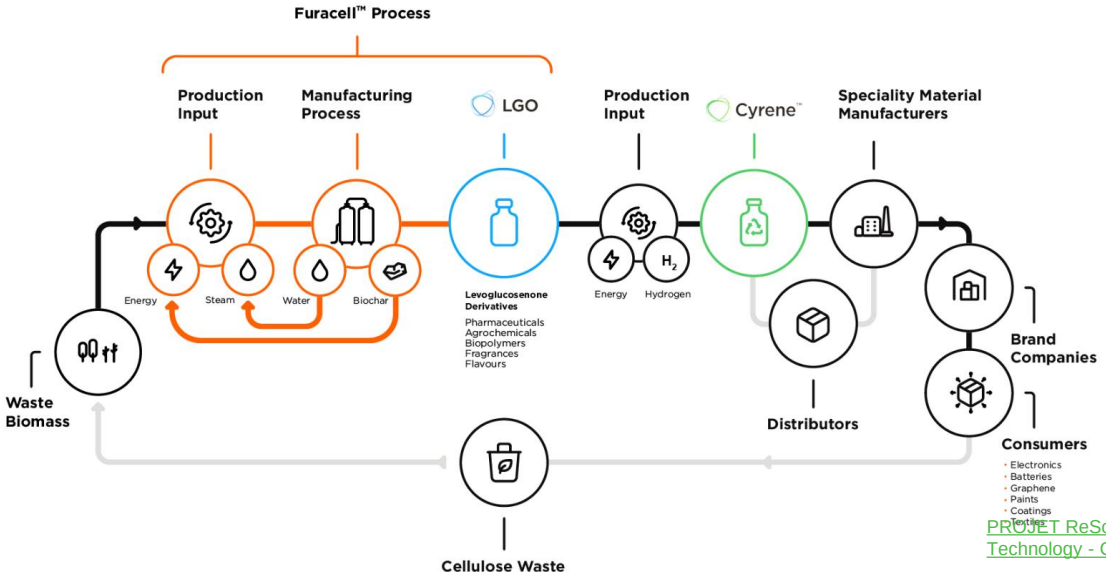
Biomass to Chemicals

- Circa Group produces biochemicals through pyrolysis
  - Different platform chemicals in the product liquid
  - For instance, Circa converts LGO to Cyrene, environmentally friendly solvent
    - Cyrene could be a replacement for NMP or DMF solvents

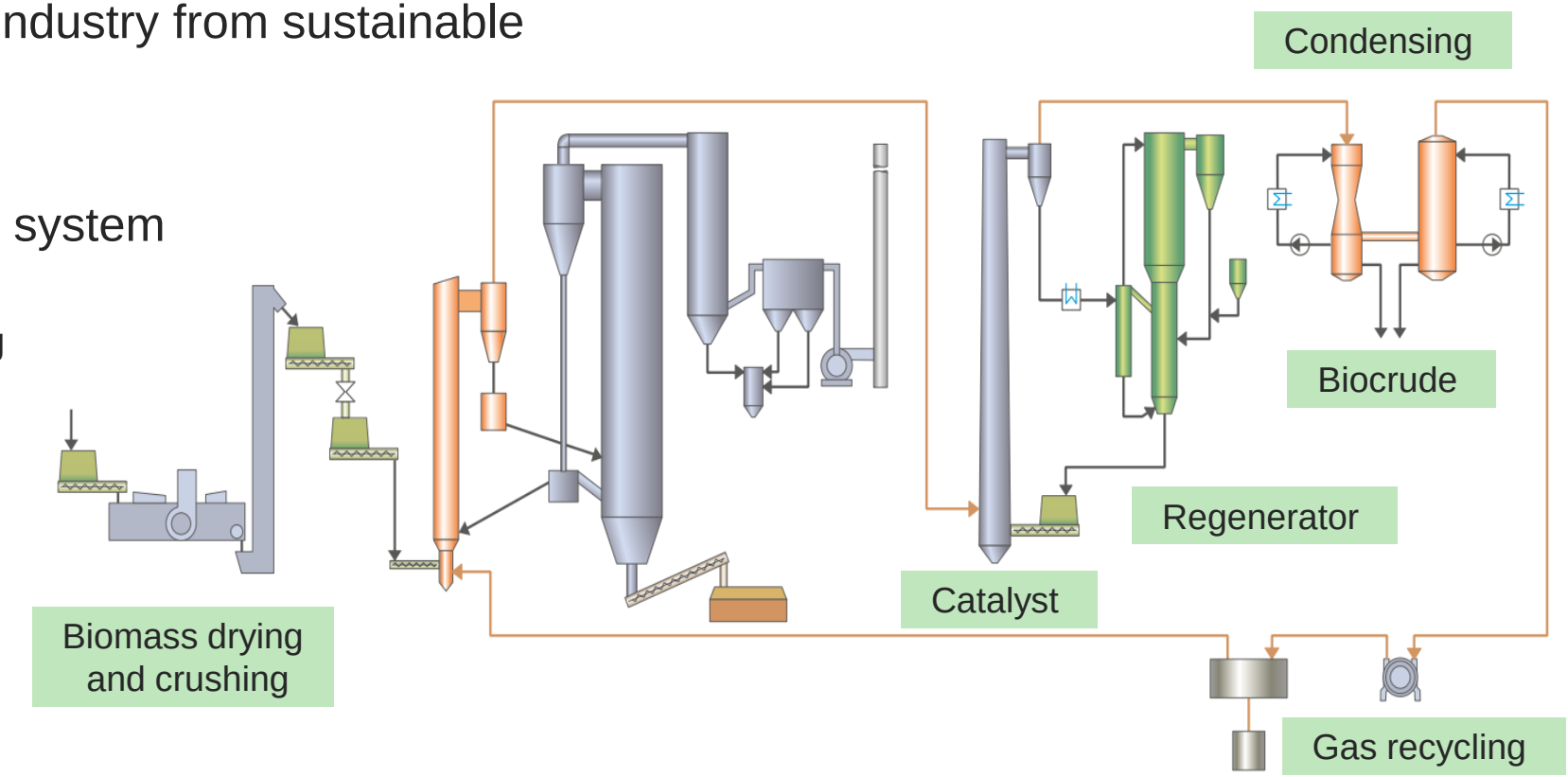
- Valmet delivers the key equipment of the pyrolyzer to ReSolute project in Carling, France



PROJET ReSolute CIRCA CEH SAINT-AVOLD – YouTube
Technology - Circa Group AS (circa-group.com)

Biomass to traffic fuels – pyrolysis with catalytic upgrading

- Target: to produce renewable feedstock (biocrude) to refineries and petrochemical industry from sustainable biomass sources
- Technology:
  dual reactor Valmet Pyrolyzer system
  - First stage: Fast pyrolysis
  - Second stage: Catalytic upgrading with catalyst regeneration



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Development of Valmet Pyrolyzer with catalytic upgrading

Scale-up of catalytic pyrolysis of biomass from laboratory to industry

Evaluation, development & comparison:

Catalytic pyrolysis technologies

In-situ and ex-situ catalyst

Pilot I tests: selected upgrading technology & catalyst

Phase II: Scaling up to industrial pilot

10's x pilot I

Scaling up to industrial demo plant

200x pilot I

Commercial upgrading technology available

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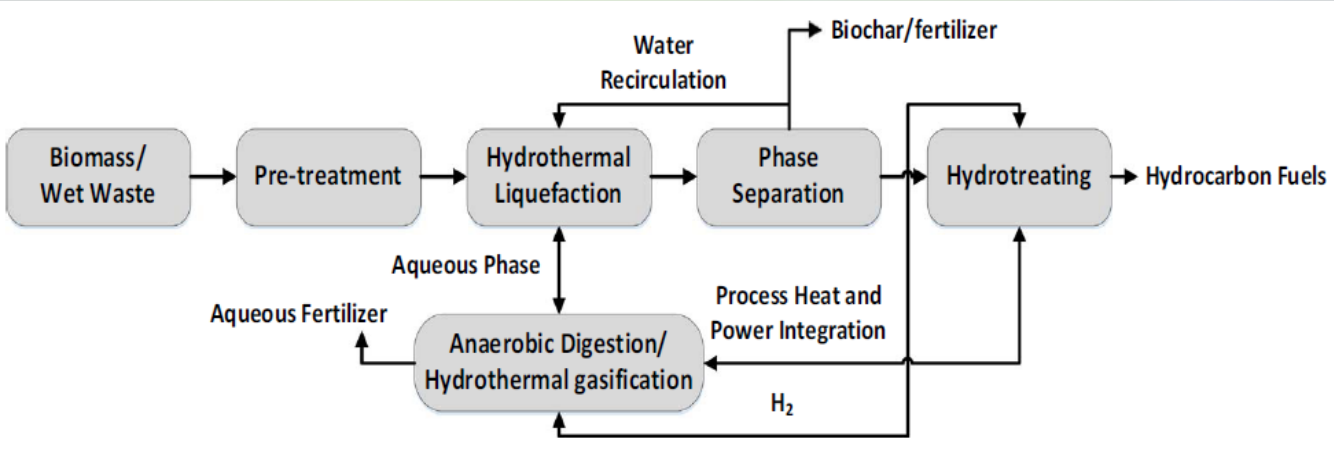
Chemical Recycling with Plastic Pyrolysis

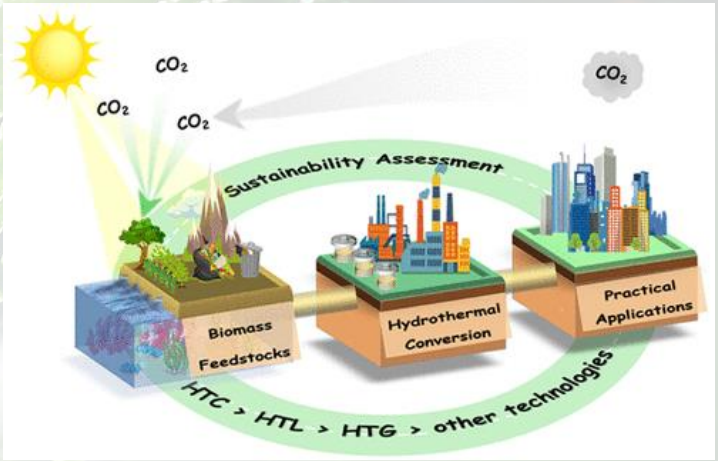
- Plastic recycling
  - Mechanical
  - Chemical
    - Pyrolysis is identified as a key promising technology
- Research currently in a small piloting scale to verify scale-up potential. Investigations on
  - Suitable feedstock
  - Feeding method
  - Removal of impurities and volatiles
  - Reactor type
  - Handling the side products
  - Post treatments: Fractionation and catalytic upgrading
  - Interesting final products

Pyrolysis and Catalytic Conversion of Plastics - YouTube

HTL is a promising pathway for wet wastes

- HTL is one of the most promising new technologies to convert **wet** feedstocks to renewable fuels
- Wet feedstocks
  - Agro waste
  - Algae
  - Municipal solid waste
  - Bio waste/Food waste
  - Sludges
  - Black liquor
- The oil as the final product
  - Has high heat value
  - Has low oxygen
  - Can be separated from the aqueous phase
  - Is stable
  - Needs post-treatment (refining)





Hydrothermal Treatment of Biomass Feedstocks for Sustainable Production of Chemicals, Fuels, and Materials: Progress and Perspectives | Chemical Reviews (acs.org)

Comparison of HTL and Pyrolysis

	Fast pyrolysis	Catalytic Pyrolysis	Hydrothermal liquefaction
Oil's oxygen content %	35-45%	10-35%	10-20%
Complexity	Low	Medium/High	High
Suitable feedstock	Dry biomass, plastic	Dry biomass, plastic	wet feedstock, biosludge, black liquor, algae, biomass and plastic
Challenges	Upgrading to fuel	Low oil yield	High-temperature pumps and handling the aqueous phase

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Summary

- Valmet has **experience** in the **fast pyrolysis** of woody biomass in the **pilot-, demo-** and **commercial-scales**

- Valmet is **actively developing** pyrolysis **technology for biochemical** and **biofuel** applications
  - The process can be **adjusted to customer's** applications
    - Examples: Joensuu plant and ReSolute plant

  - In-house **development of catalytic pyrolysis** to produce feedstock of **traffic biofuels**
    - Examples: Overall process needs to **reach maximum potential** in **commercial** operations, including **side-stream utilization**

- Development steps in the **chemical recycling** of waste **plastic** are progressing

- **Both** HTL and pyrolysis technologies have **pros and cons**, and Valmet closely follows up the advances in HTL technology


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