Sumitomo SHI FW Oxy-fuel Technologies

Powering a decarbonized world for everyone

25 November 2022

Heritage

Over 130 years of excellence in delivering complex energy solutions around the world.

PYROPOWER
AHLSTROM PYROFLOW

amec foster wheeler

Sumitomo SHI/FW

1891
Foster Wheeler founded

1995
Foster Wheeler acquires Pyropower

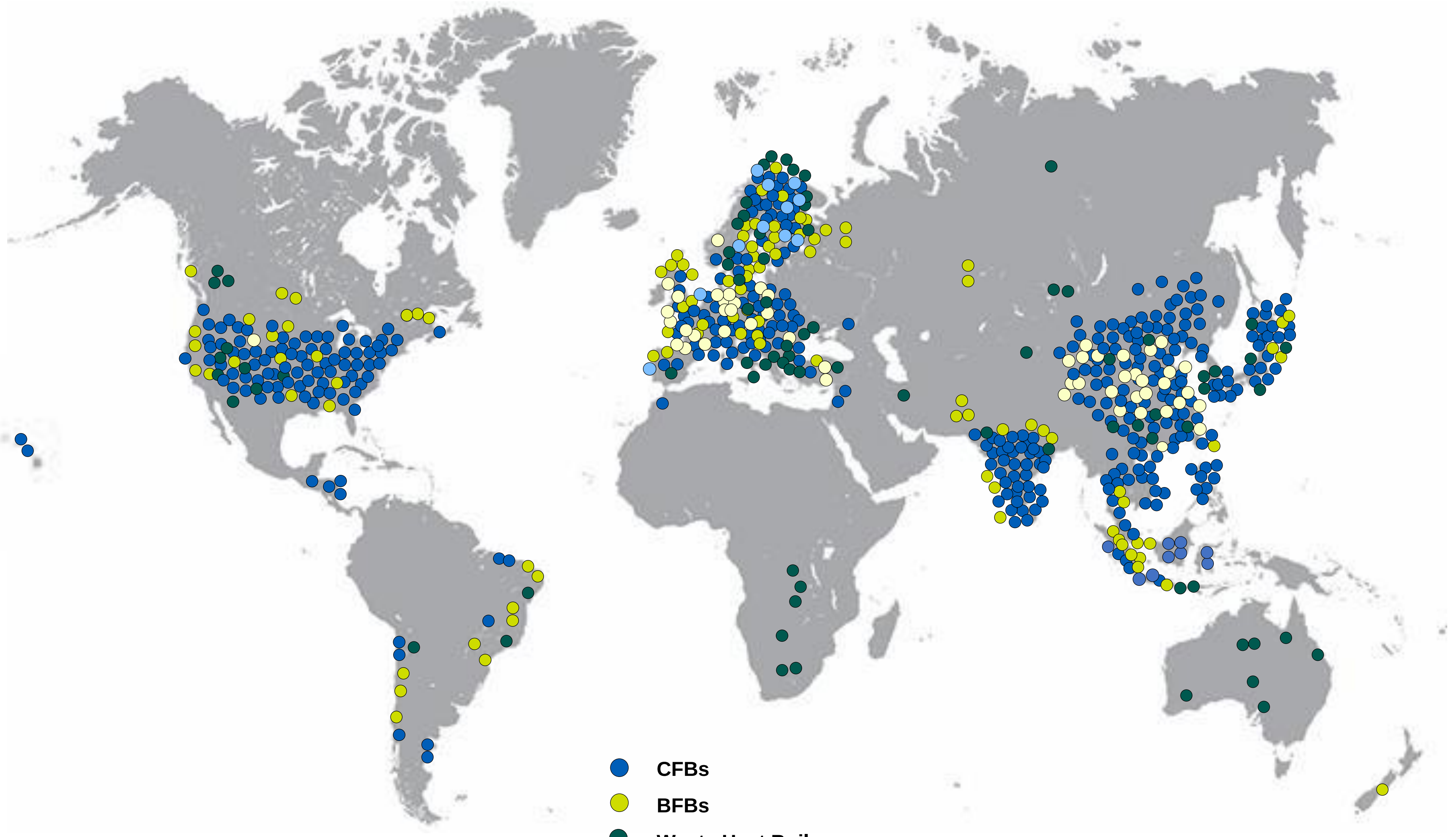
2014
Amec acquires Foster Wheeler

2017
SHI acquires Amec Foster Wheeler's fluidized bed boiler business

A global business with 1,800 highly skilled people

- Head office
- Engineering centers
- Sales offices
- Factories and after-sales service offices
- Research and development centers

Our Global References



- CFBs
- BFBs
- Waste Heat Boilers
- CFB Scrubbers
- Biomass Gasifiers

Over 800 units
Over 40GWe of power capacity

Decarbonization and climate change mitigation

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Helping our customers to reach decarbonization goals

Energy generation

Energy from biomass or waste for carbon neutral or carbon negative heat & power applications

Carbon capture

Carbon neutral traditional energy generation and integration with production of renewable fuels

Services

Life cycle solutions enabling high plant availability and efficiency

Waste to value

Solid waste into syngas, biofuels & chemicals, or plastics recycling

Energy storage

Long Duration - Enabling net zero grid systems to limit the climate change

Oxygen enriched CFB design and experience

Wide range of diversified energy products and services for Industrial Decarbonization

Calcium Looping (CaL) for tail-end industrial CCUS

1-2 MWth pilot in La Pereda

5000+ hours demonstrated

Oxy-fuel CFB for greenfield and retrofit to power plants with CCUS

30 MWth demo at CIUDEN

300 MWe ready design for 90+% CO_2 capture

Oxy-steam gasification for circular fuel and chemical plants

12 MWth NSE demo for biofuels

Commercial designs for single and indirect gasifiers

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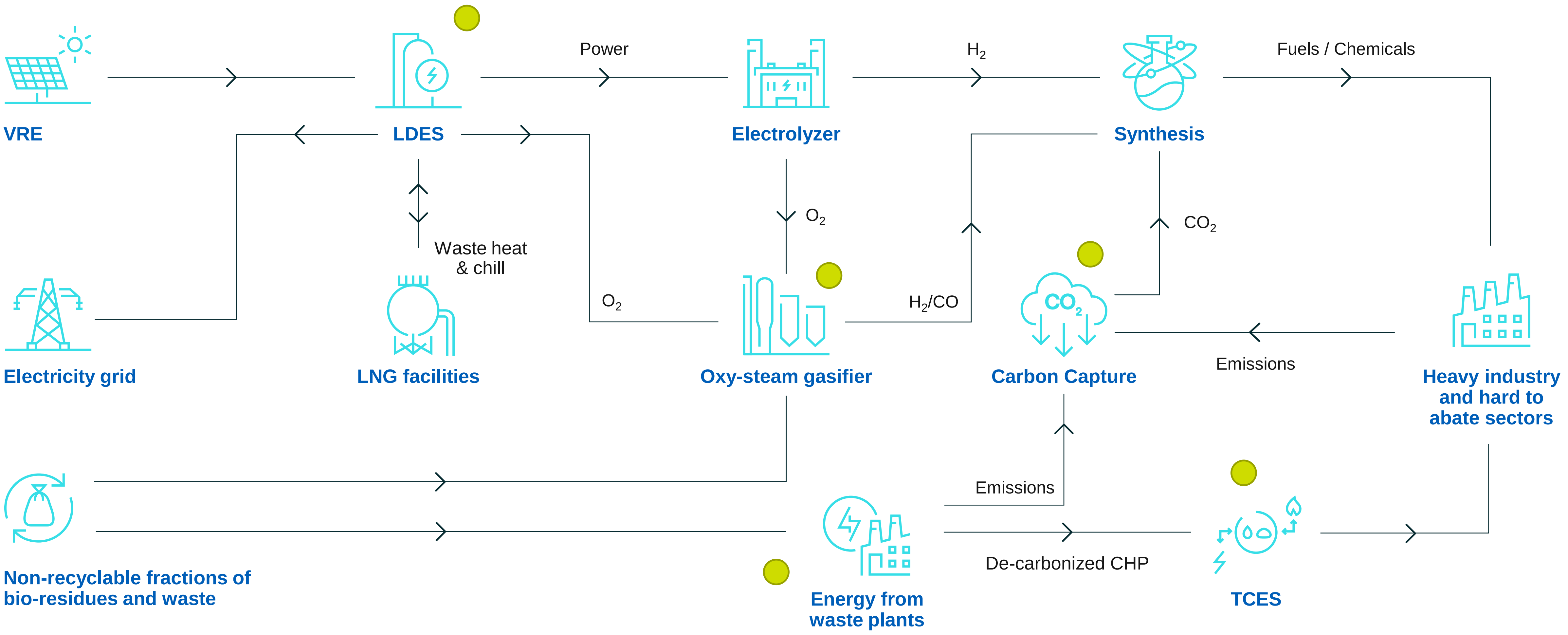
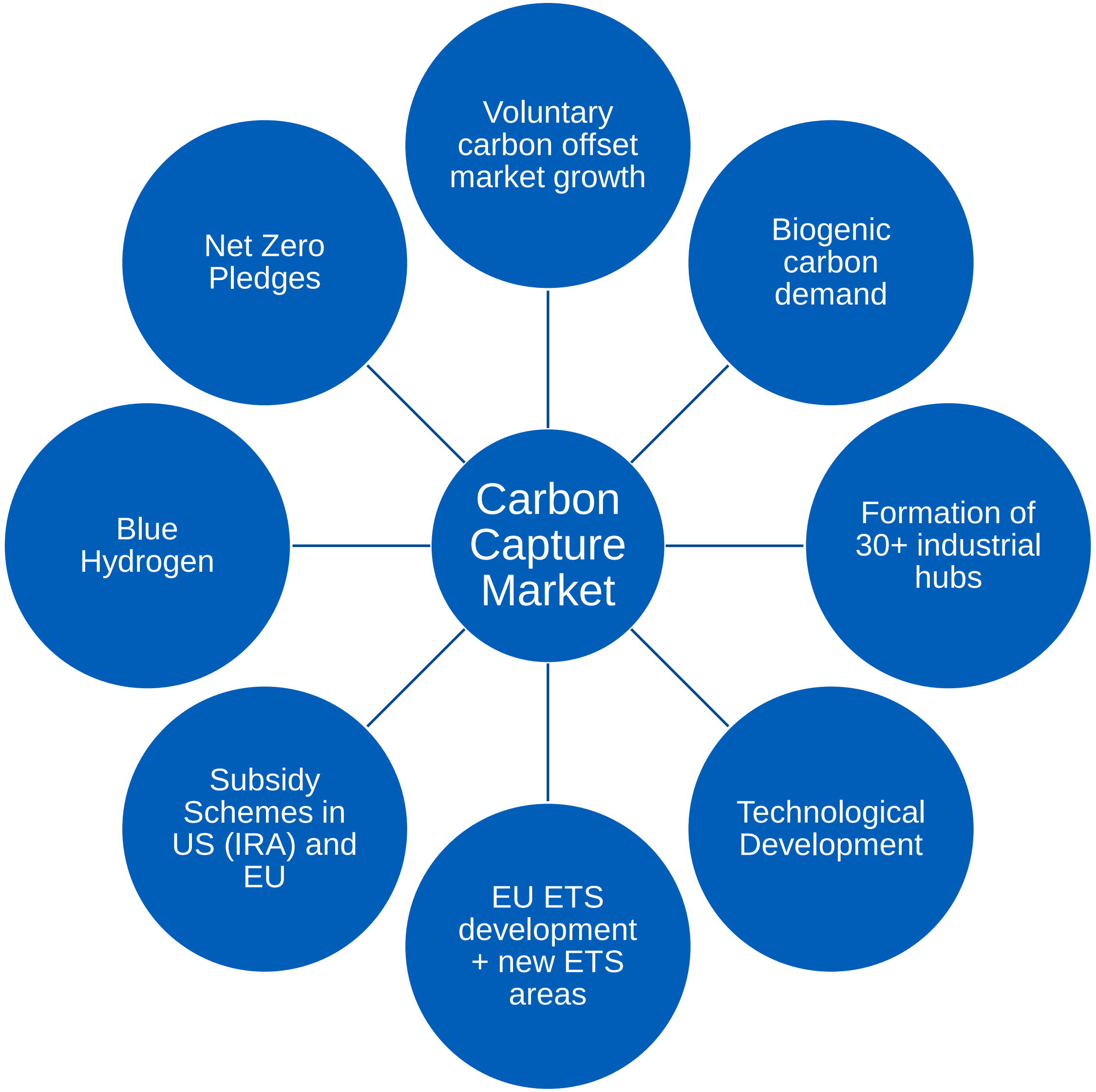
Net Zero Energy Ecosystem

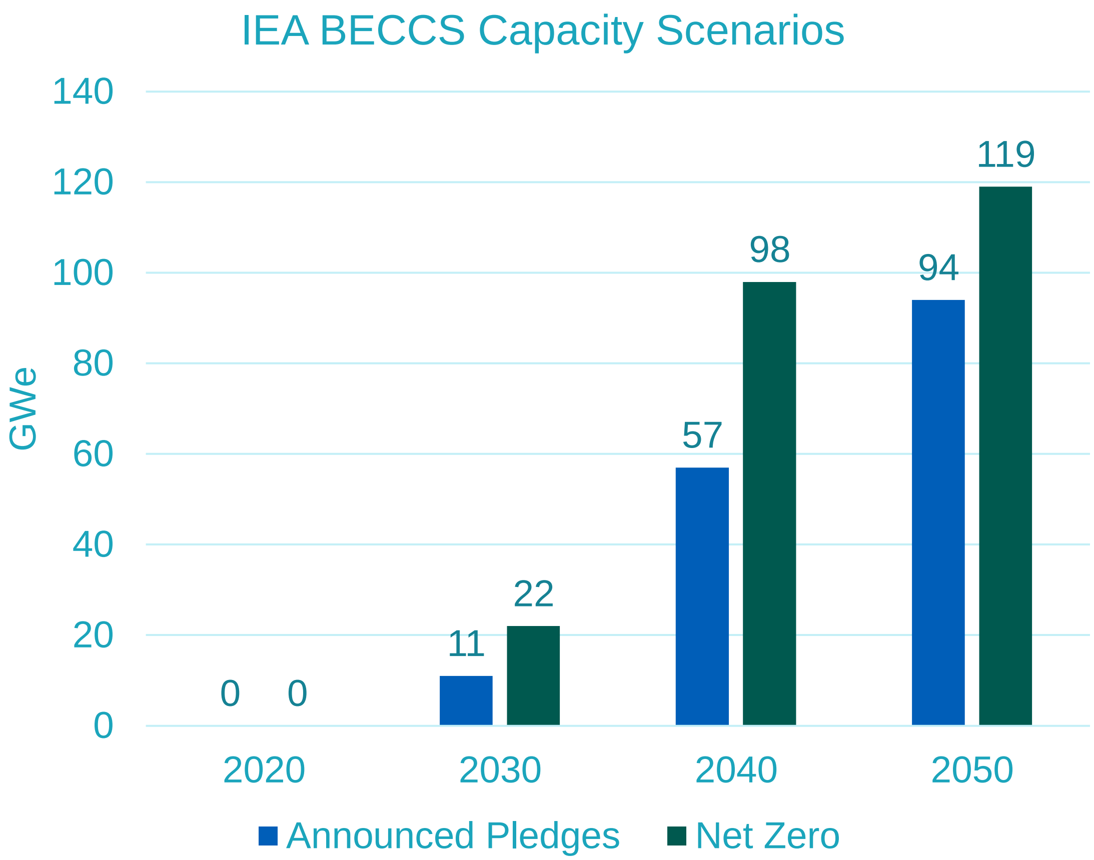


Oxy-Fuel Carbon Capture

Rapidly increased drivers globally supporting carbon capture

Biogenic CO2 required to substitute fossil carbon in chemicals and materials





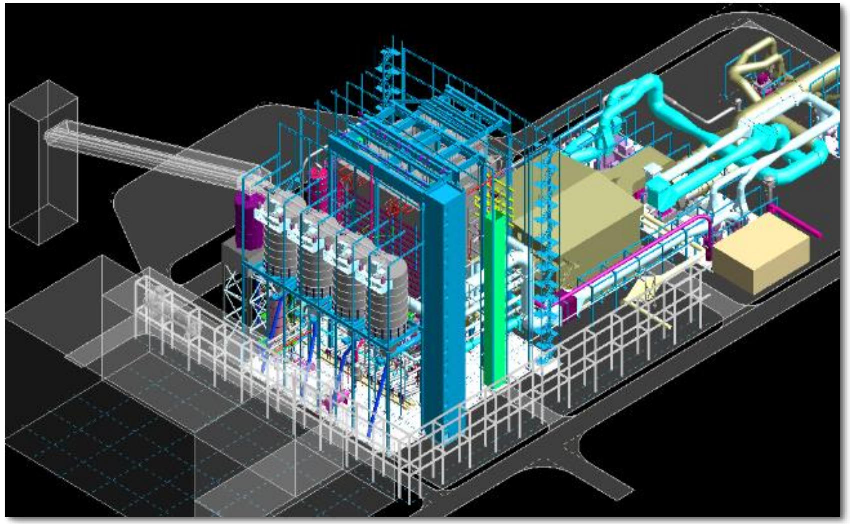
Source: IEA World Energy Outlook 2022

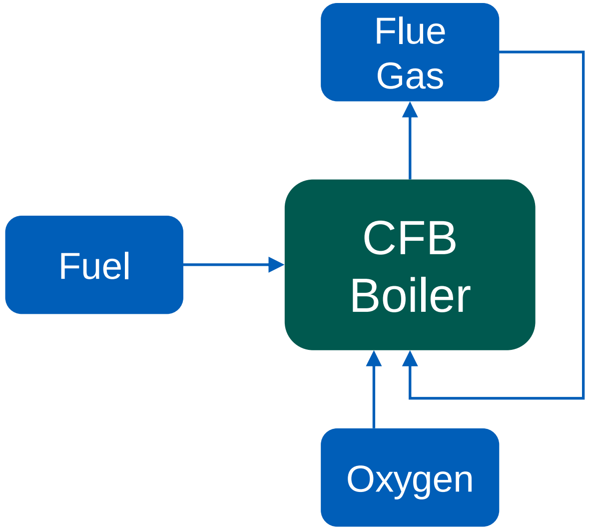
Oxy-fuel – Solutions from low carbon to carbon negative heat and power

CO_2 capture technology integrated within the combustion process

Demonstrated by SFW in 30 MWth Pilot (Ciuden, Spain), 300MWe commercial design ready

- Separation of CO2 during combustion. Ready for further processing to permanent storage or synthesis into biofuels and bio-chemicals
- Low energy penalty from 1.5 to 1.7GJ/tCO_2 for BECCS
- Avoidance of solvent waste to handle and dispose
- Operational flexibility – air/oxy modes
- Requires Air Separation Unit (ASU) upstream or alternatively synergy with electrolyzers or LAES's liquefaction
- May require CO2 Processing Unit (CPU) downstream to purify CO2 and increase concentration to the levels required for storage or utilization
- For oxy-fuel BECCS plant, every 1 MWth fuel input requires 1.5 -1.8 MWe electrolytic plant to match O2 demand

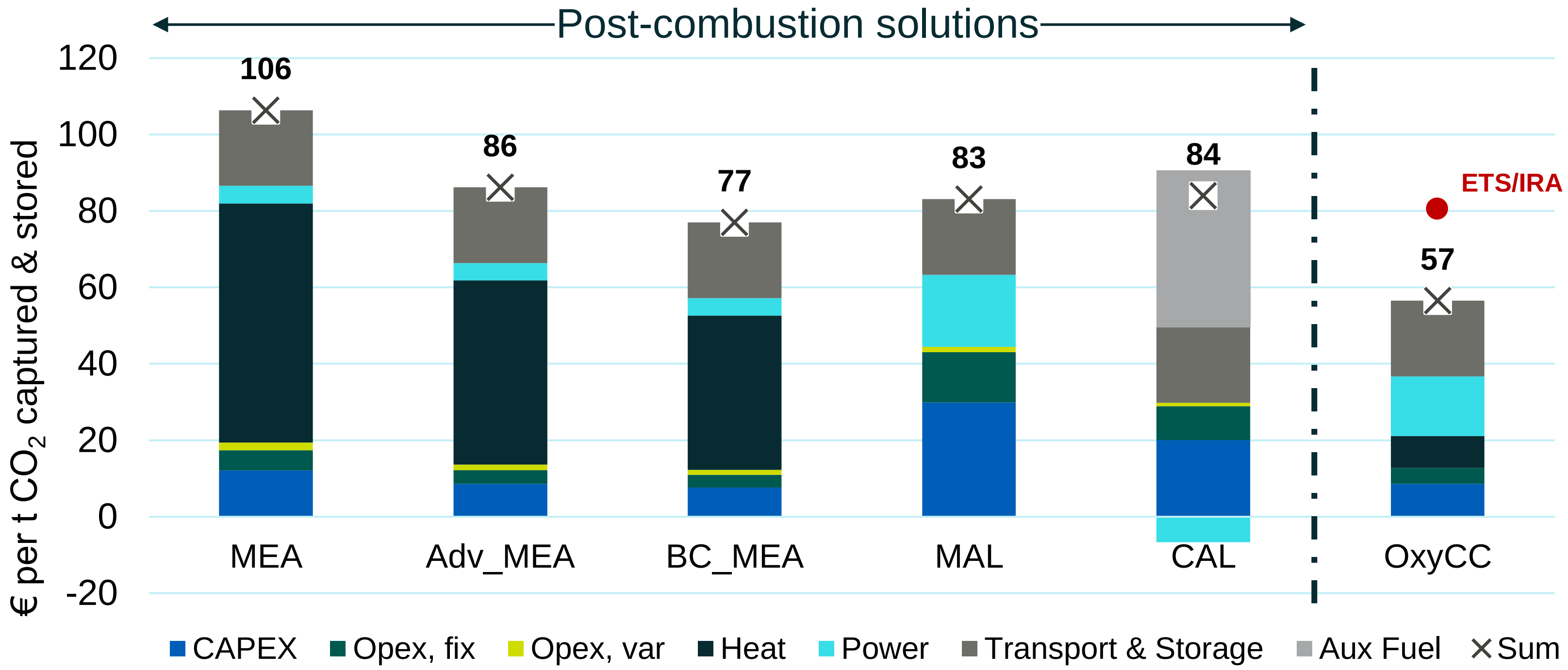




Bioenergy Carbon Capture and Storage (BECCS) plants

Case study: Feasibility evaluation for retrofitting Bio-CHP plant in the Nordics to capture 0.7 Mt of CO_2 per year

Greenfield and retrofit oxy-fuel solutions are cost-competitive and have lower primary energy penalty compared to other CCUS solutions



MEA	Reference Mono-Ethanol Amine (MEA) technology.
AdvMEA	Reported MEA CAPEX & OPEX improvement in commercial CCS.
BCMEA	Best case: public CAPEX & OPEX improvement from different vendors.
MAL	Membrane assisted liquefaction
CAL	Calcium looping capture
FBCCS	FlexiBurn® with ASU and CPU blocks. OXY mode only.

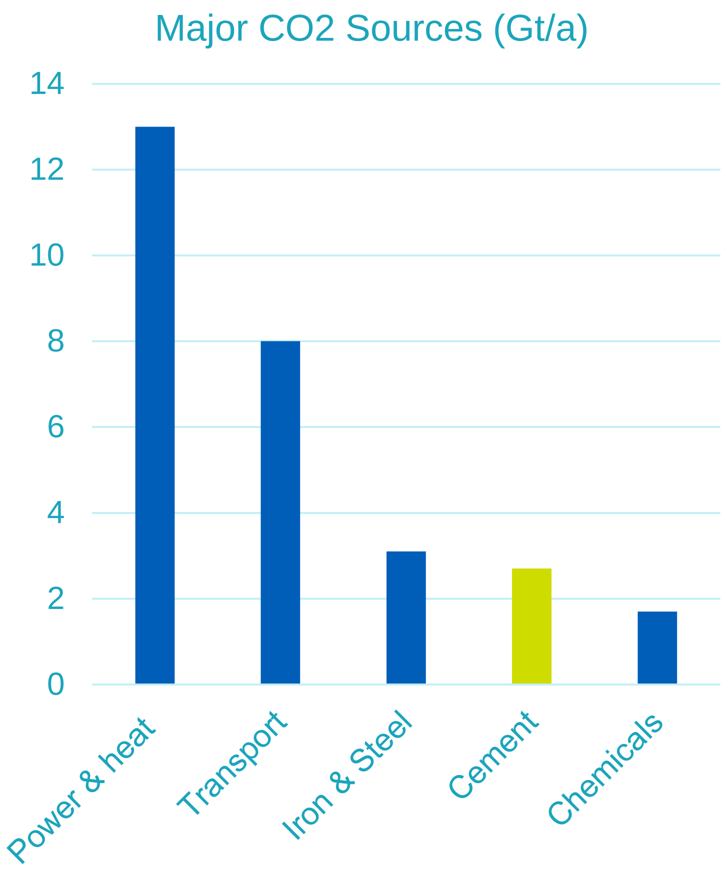
The cost numbers are representative of a pre-study for specific case. A feasibility evaluation is required on a project-to-project basis to take advantage of industrial synergies.

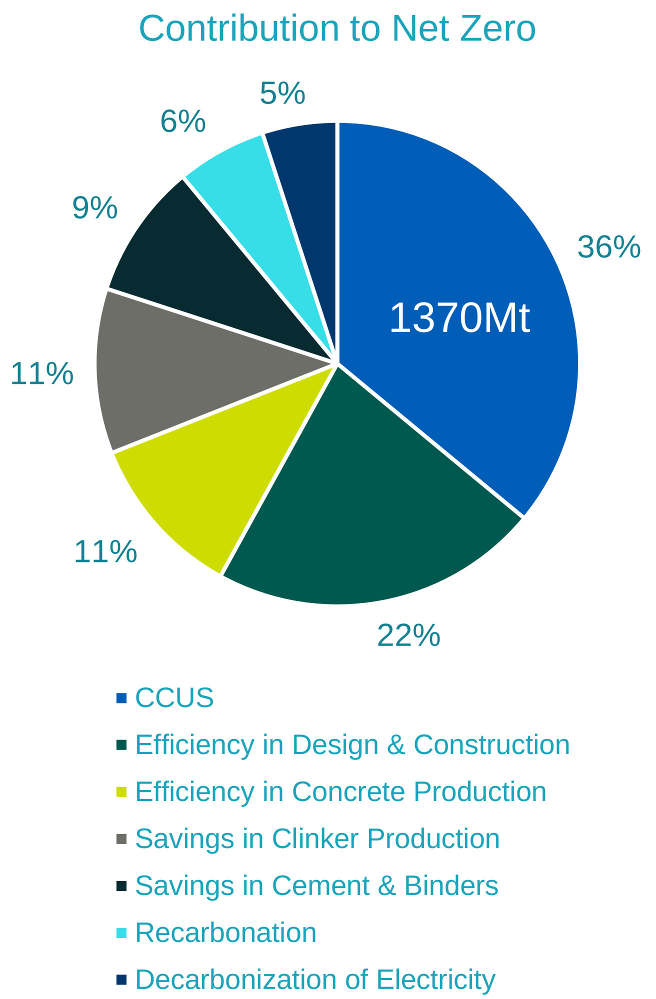
Calsium Looping Carbon Capture

GCCA members committed to 2050 net zero target in 2020 – Concrete Future

Main contribution towards cement decarbonization from CCUS to offset 3.8Gt of annual emissions by 2050

4.4Gt of cement produced globally in 2021 of which 57% in China, this leads to 2.7Gt CO2 emissions (~7%)





Source: GCCA Concrete Future (2022)

Calcium Looping (CaL)

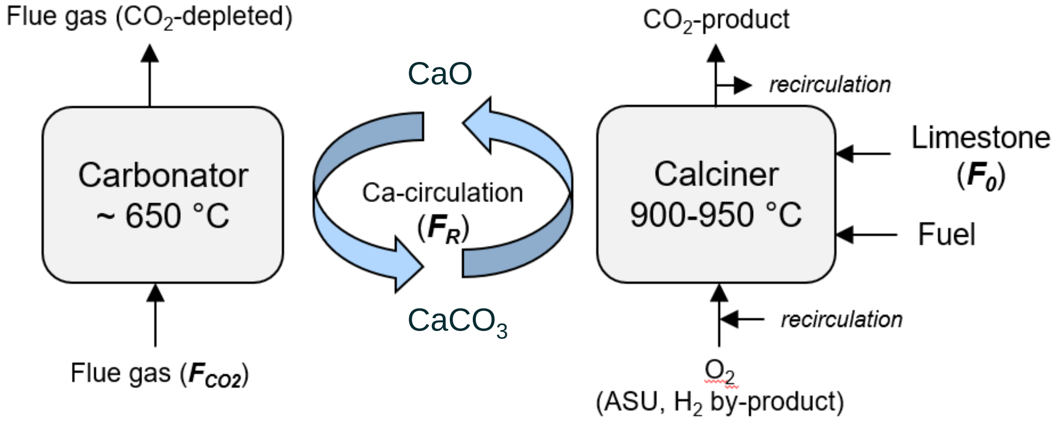
Post-combustion CO_2 capture technology using solid natural sorbent

Solutions to separate CO2 from flue gases

- CHP & W2E decarbonization
- Industrial decarbonization in sectors including cement, lime and steel

Demonstrated by SFW in 1 MWth with coal and clean biomass

- Can be stand alone in new deliveries (CLC) or retrofit to existing boilers (CaL)
- Requires Air Separation Unit (ASU) upstream, or alternatively synergy with electrolyzers and LAES’s liquefaction
- Steam cycle to produce electricity from carbonator excess heat
- May require CO2 Processing Unit (CPU) downstream to purify CO2 and increase concentration to the levels required for storage or utilization
- Purge CaO stream can be utilized as supplementary cementitious material (SCM)



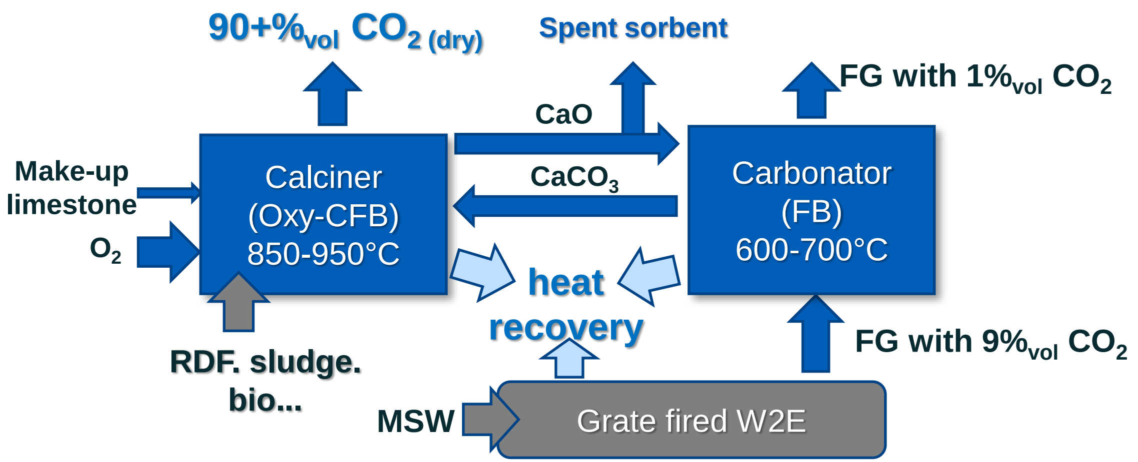
Reversible carbonation: CaO + CO2 = CaCO3

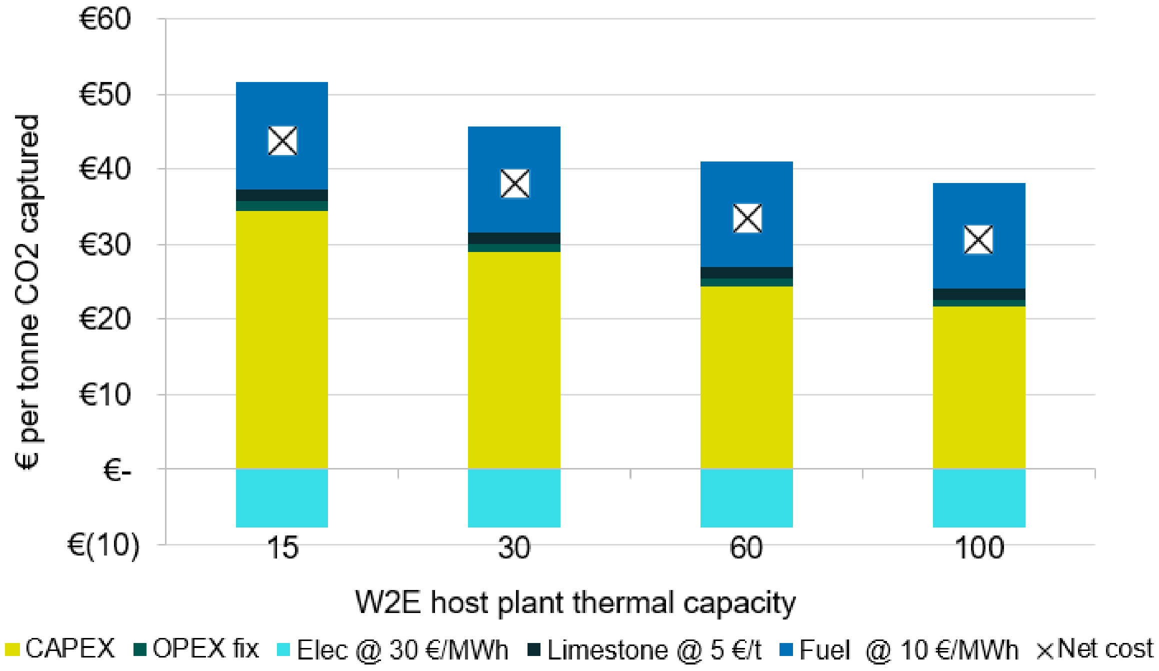
CaO absorbs CO2 and forms CaCO3

CaCO3 is heated to release CO2 and regenerate CaO

Tail-end calcium looping for waste-to-energy

WTE inclusion to EU ETS planned in 2026, 530 WTE plants emitting >100Mt CO2 of which 50% fossil





- Higher plant throughput → increased waste gate-fees while enabling carbon neutrality/negativity (based on bio-fraction of feed)
- Multi-product technology → additional CHP (at higher steam quality) and low carbon lime (spent sorbent) revenues
- Alternative for capacity increase or modernization
- Low cost, non-hazardous and abundant sorbent

The cost numbers are representative of a pre-study for specific case. A feasibility evaluation is required on a project-to-project basis to take advantage of industrial synergies.

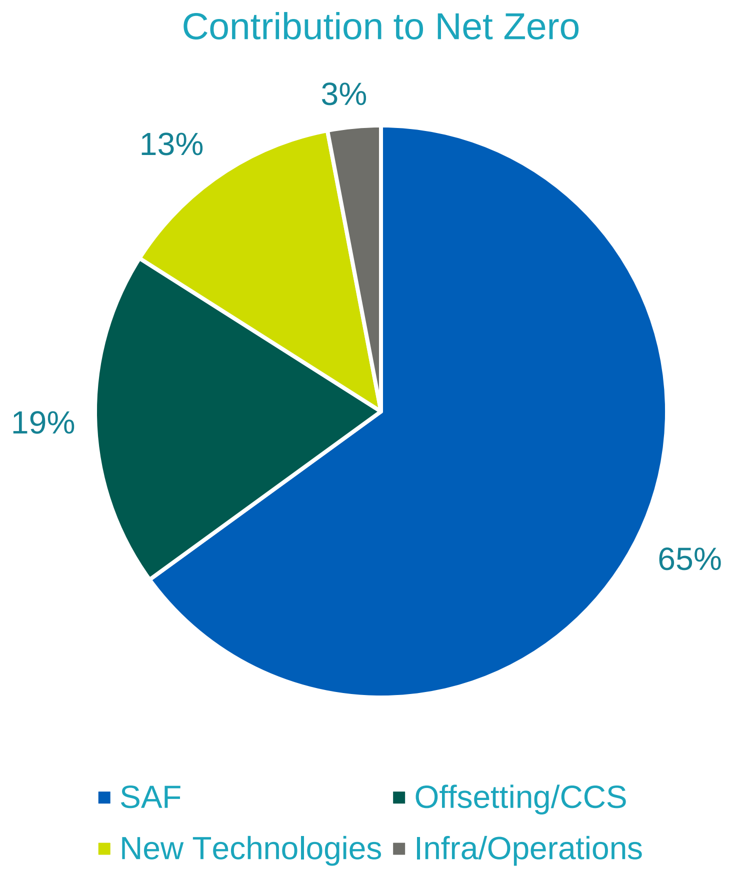
Oxy Steam Gasification

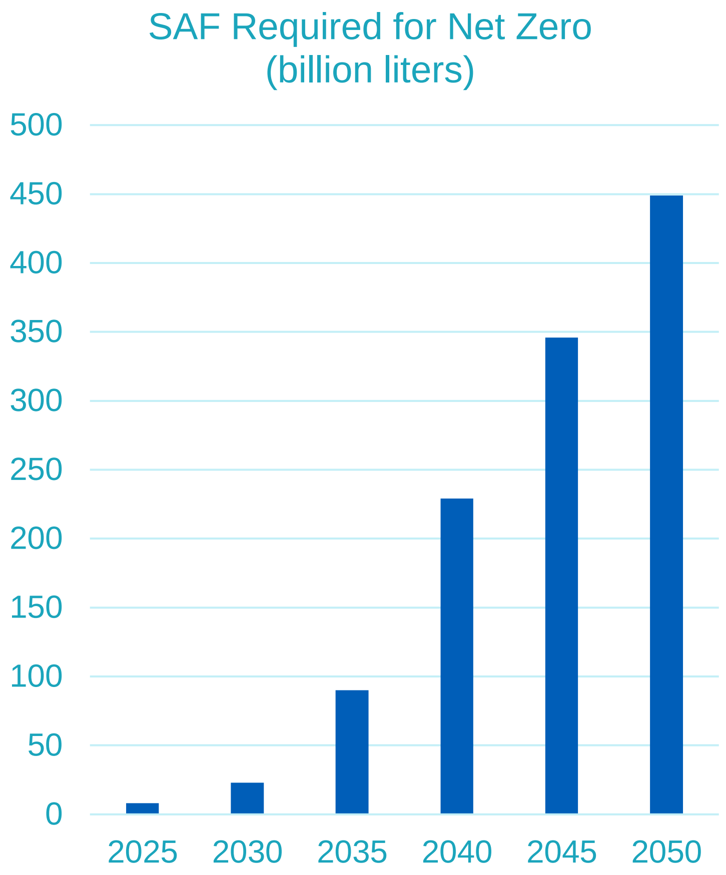
IATA member airlines committed to 2050 net zero target in late 2021

Majority of target to be achieved via use of Sustainable Aviation Fuels (SAF)

SAF pathways:

- Fats & Oils
- Solid Biomass
- Power-to-Liquid





Source: IATA Fly Net Zero (2021)

Oxy-steam Gasification - Solutions for green H2, biofuels and bio-chemicals

Technology that convert feedstocks into valuable products (Bio/waste to X)

Relevant SFW gasification technologies and commercial readiness

- **Oxy-steam gasifiers**
  - Production of ultra-clean bio/waste gases for further synthesis into Green H2, SNG, liquid biofuels, and bio-chemicals
  - Demonstrated in 12 MWth steam pilot, commercial readiness up to 150 MWth as single line
- **Indirect Gasifier**
  - Alternative option to avoid the need for oxygen
  - Conceptual studies done up to 100MWfuel

Bio/waste feedstock

↓

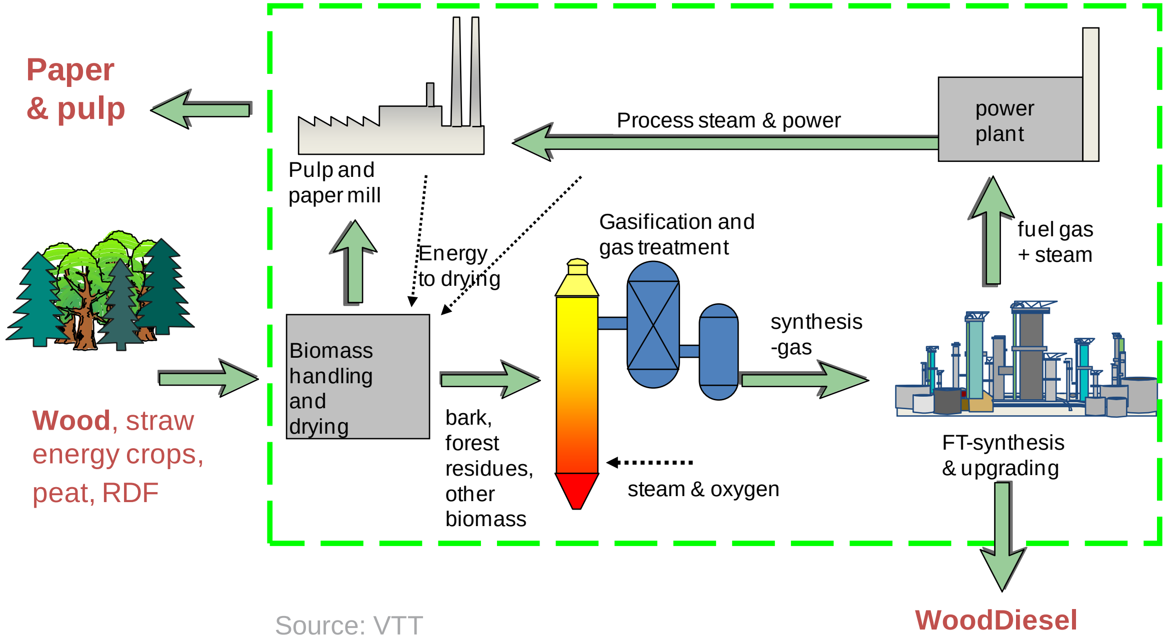
Gasifier → Cleaning → Synthesis

↓

Hydrogen
Ammonia
Methanol
Ethanol
Bio-chemicals
e.g. plastics

Bio-gasification enables pathway to carbon negative Gas-to-X

- Levelized cost of bio-H2 competitive against SMR with carbon price or CCS as well as electrolysis based H2
- Gasification economics can be further improved with O_2 synergy
- Feedstock for gasification is more versatile than feedstock for other biofuel technologies, e.g. cellulosic ethanol or HVO
- With CCS bio-H2 production can be carbon negative
- Bio-H2 lifecycle emissions have potential to be negative if upstream industry turns into biofuels



Source: VTT

Thank you

For more information, please visit:

www.shi-fw.com