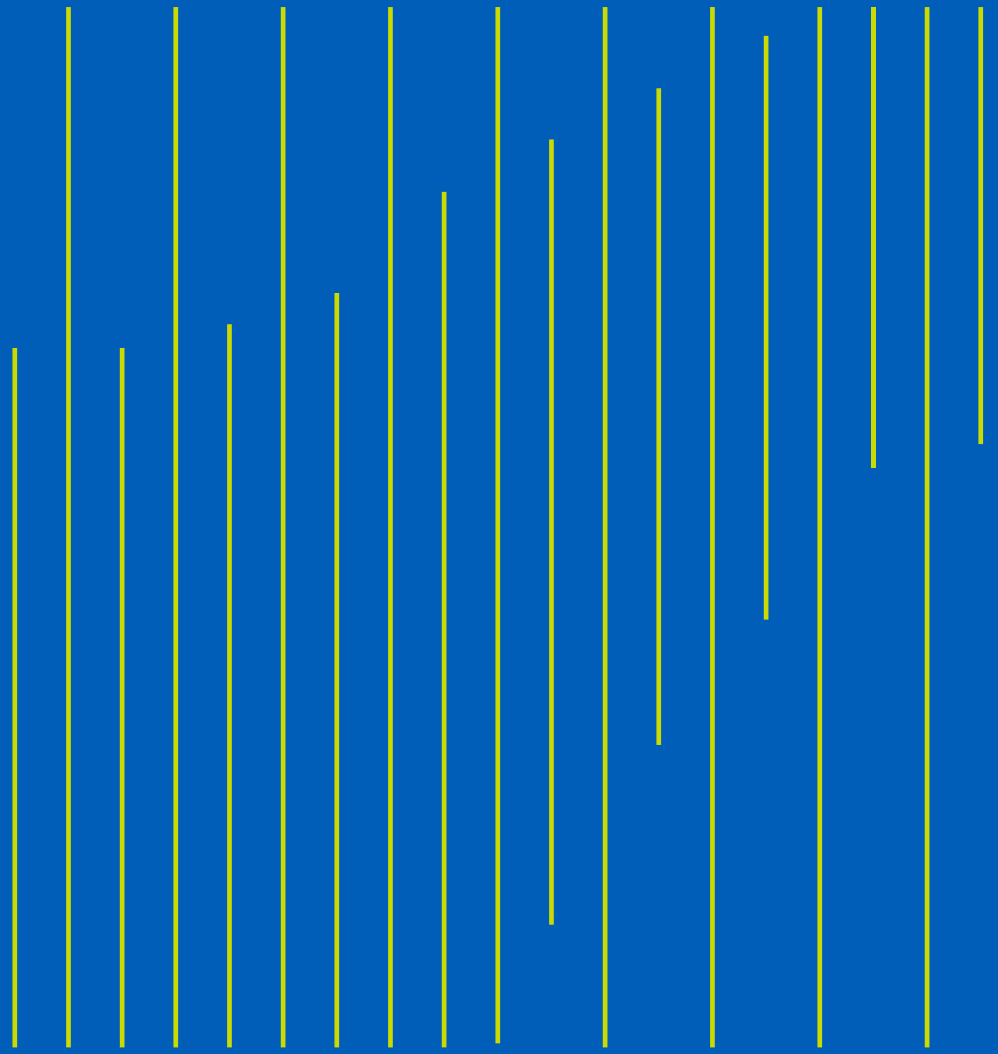
Sumitomo SHI FW (SFW)

Decarbonization - new products in SHIFW portfolio

Grzegorz Kocot, SBD

Sepetna 2023



SFW response to 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

Oxyfuel carbon neutral and negative CFB plants, Calcium looping for hard to abate industries and Hot potassium carbonate for biomass and WtE

Services

Life cycle solutions enabling high plant availability and efficiency

Waste to value

Gasification of solid waste into syngas, biofuels & chemicals, or plastics recycling

Energy storage

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

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Agenda

Carbon Capture

1. Oxy-Fuel
2. Calcium Looping (CaL)
3. Hot Potassium Carbonate (HPC)

Waste-to-Value (WtV)

Fluidized Bed Gasification

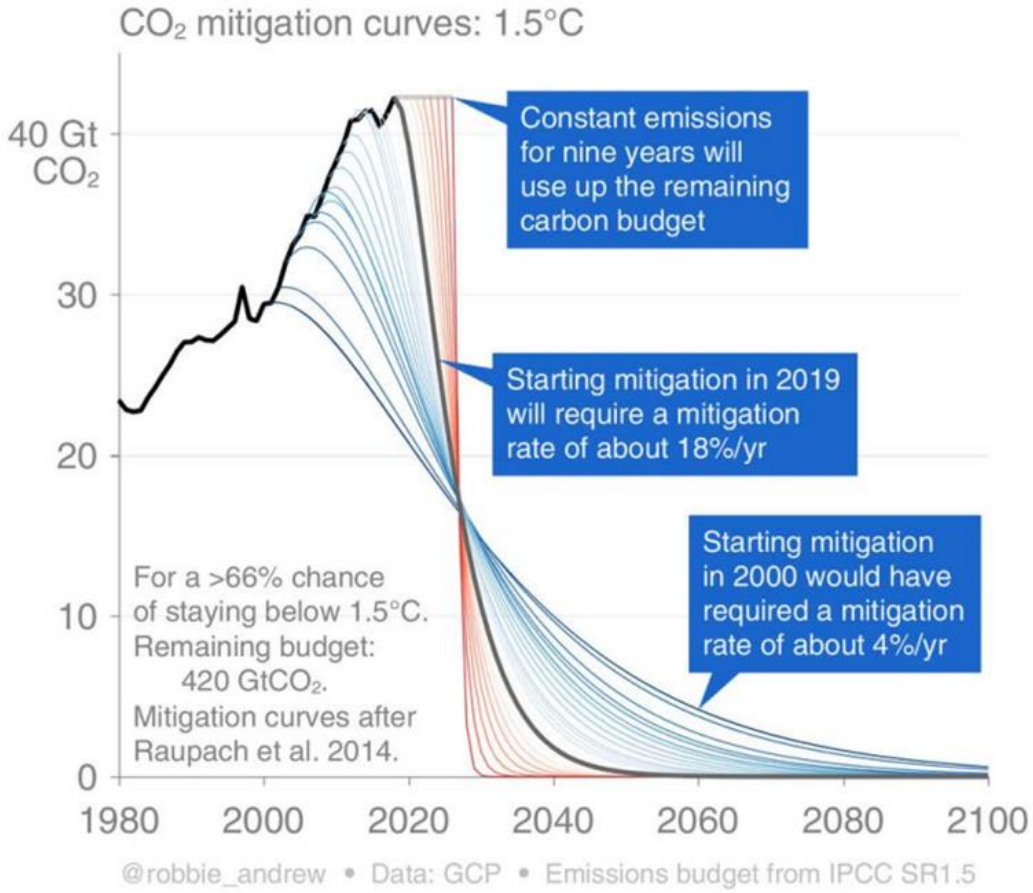
Carbon Capture is an essential climate mitigation tool to reach Net Zero

With 37 Gt of annual CO_2 still emitted today, anywhere between 4 -10 Gt of carbon removals is needed between now and 2050

IPCC classified Carbon Capture and Removal (CCR) technologies as essential to reach the Paris accord target of 1.5 °C global warming.

CCR solutions enable:

- Negative emission and circularity pathways
- Dispatchable and low carbon CHP production
- Production in scale of low carbon commodities
- Decarbonizing “hard to abate” sectors
- Reversing historical mistakes in the carbon cycle



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Carbon Capture is an essential to improve WtE plant’s economic

Carbon Capture and Removal (CCR) technologies as essential to improve WtE plant economics from 2026, when EU ETS will be introduced for fossil part of fired wastes.

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Carbon Capture – from the decarbonization of heavy industries to carbon negative emissions with BECCS (Bioenergy with Carbon Capture and Storage)

https://en.wikipedia.org/wiki/Bioenergy_with_carbon_capture_and_storage

Oxy-Fuel

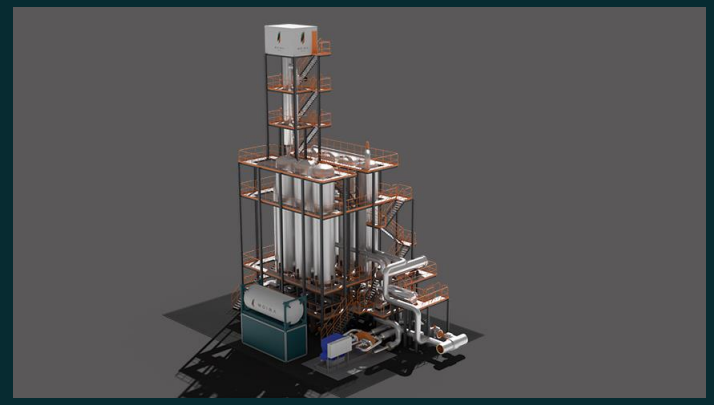
CO_2 capture integrated within the energy production plant to efficiently remove carbon emissions.

A typical sized Biomass CHP plant can decarbonize electricity and district heat for around 120 000 households.

Calcium Looping

Using calcium, a natural sorbent to capture CO_2 from industrial stacks.

Cement and metallurgical plants, considered “hard to abate” sectors account for over 15% of global emissions



Hot Potassium Carbonate

Modularized concept based on hot potassium carbonate (HPC) solvent with many industrial references

Decarbonize up to 530 EU based WTE plants to be included into emission trading by 2028

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SFW Carbon Capture solution portfolio

SFW's Fluidized bed solutions

Oxy Fuel

- BECCUS — Greenfield & Retrofit
- Fossil — Retrofit

Calcium Looping

- WtE
- Cement
- Iron&Steel
- Other industry

Retrofits

HPC

- WtE
- BECCUS
- Other Industry

Retrofits

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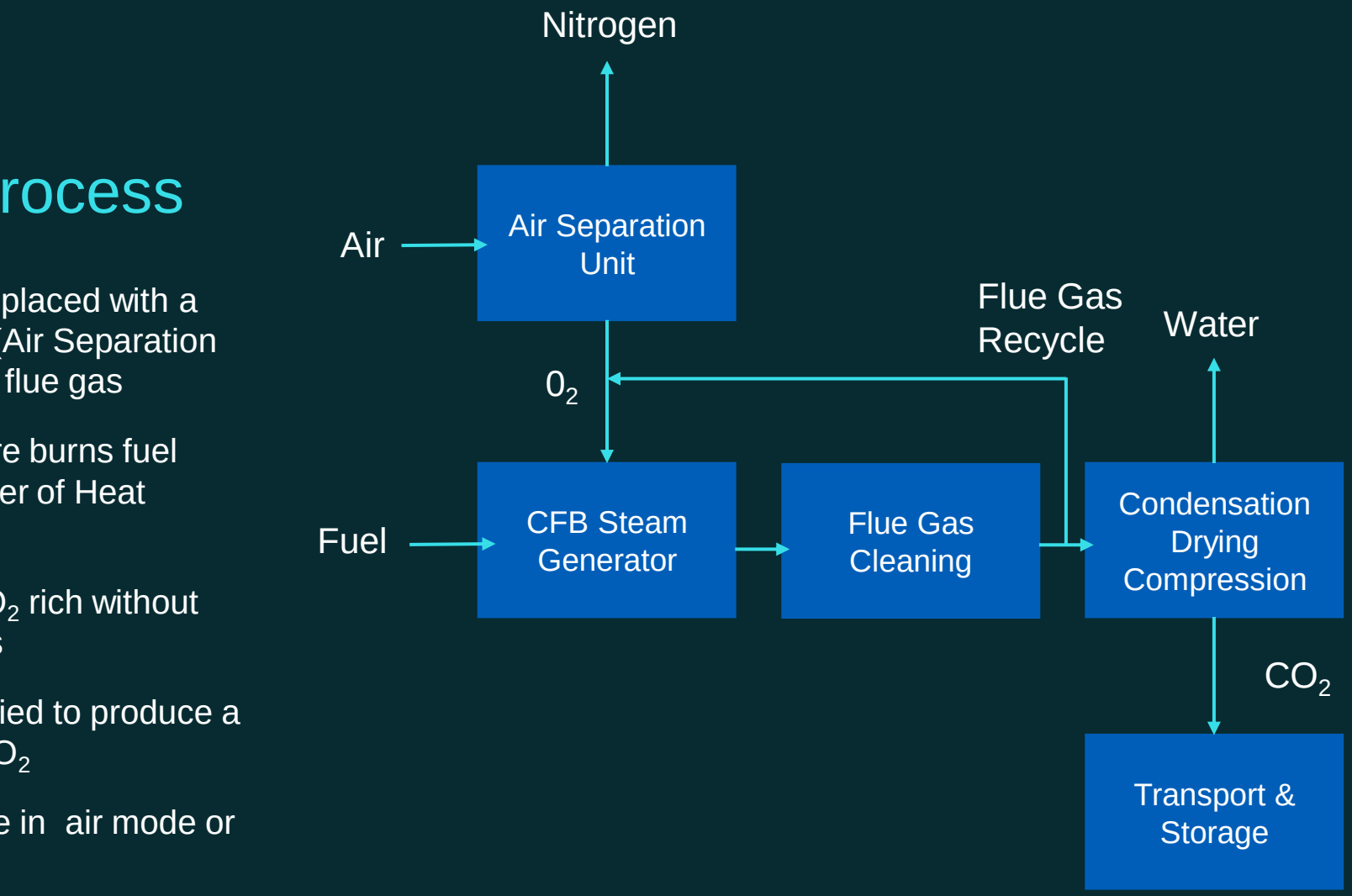
Oxyfuel Combustion Technology

How does it work?

Simple Continuous Process

- Combustion air to the boiler is replaced with a mixture of oxygen from an ASU (Air Separation Unit) Plant and recycled furnace flue gas
- Recycled flue gas/oxygen mixture burns fuel while allowing for uniform Transfer of Heat throughout the boiler
- Flue gas becomes inherently CO_2 rich without needing CO_2 separation process
- Plant stack gas can be simply dried to produce a highly concentrated stream of CO_2
- Plant can be designed to operate in air mode or Oxyfuel mode



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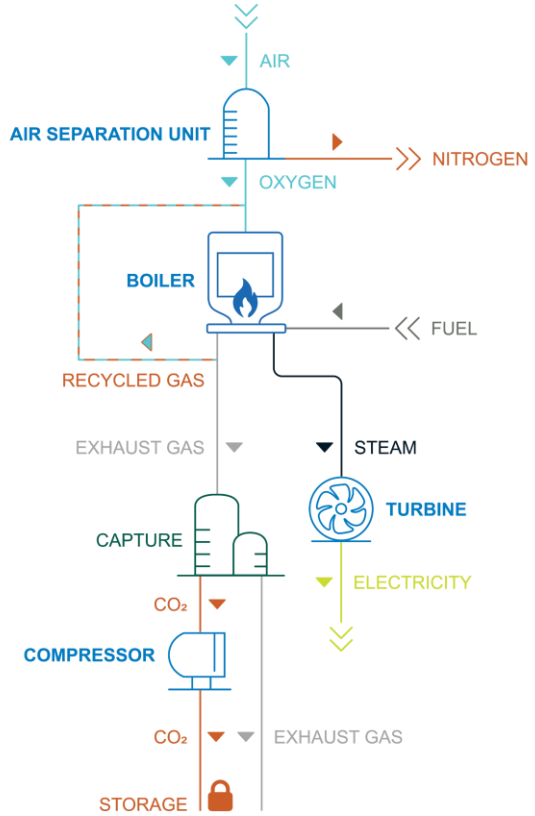
Carbon Capture (CC) technologies for industrial applications

Oxyfuel and Post-combustion capture are the two technology options

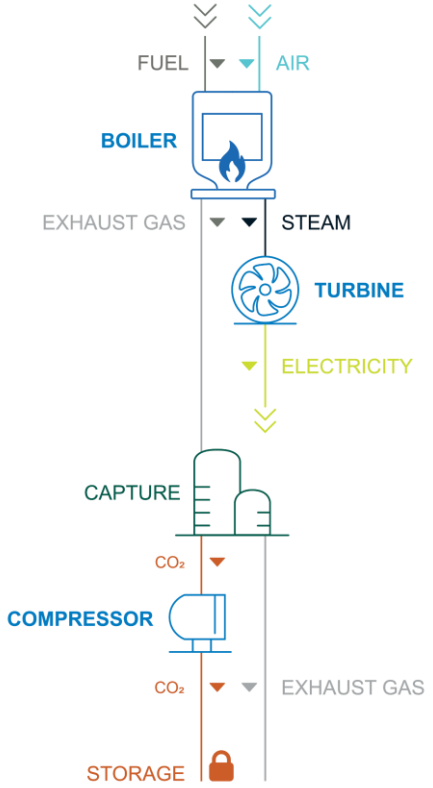
OXYFUEL

Replace air with O_2 + recirculated flue gas
→ CO_2 enriched in flue gas is easier to capture



POST-COMBUSTION

Combustion unchanged, all tail-end
→ CO_2 capture requires sorbents



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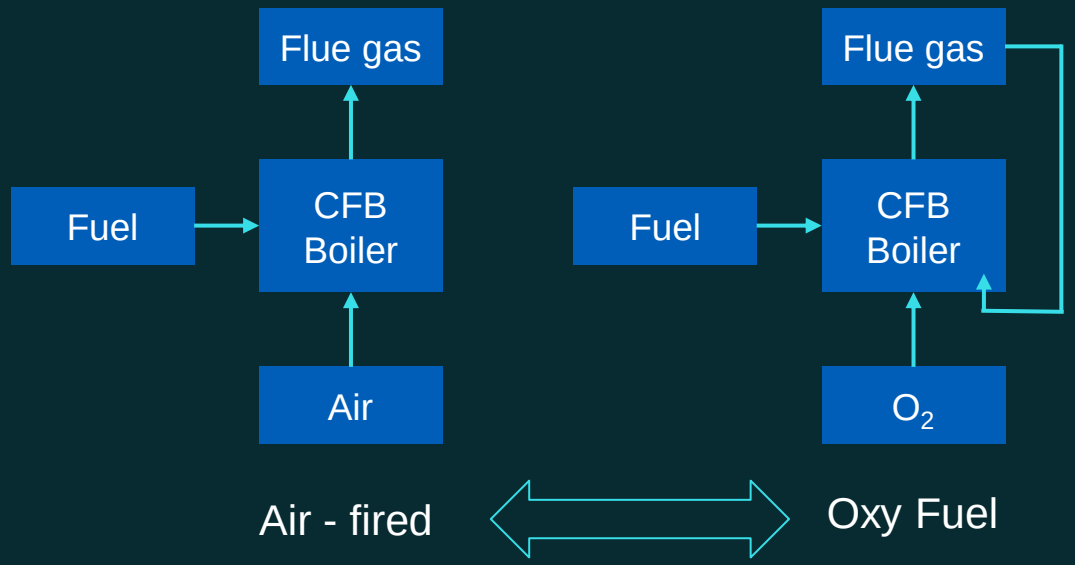
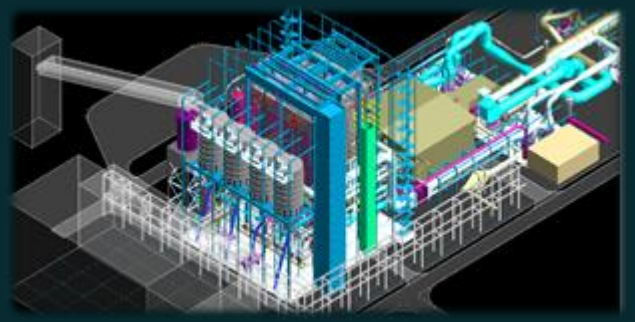
SFW's Oxyfuel for CFB Combustion (OXY)

Solution can be applied to coal fired units for carbon neutrality and sustainable bio/waste units for carbon negativity



300 MWe design ready



- Wide fuel range (up to full CFB range)
- O_2 production technology is mature and synergetic with electrolysis for H_2
- Low energy penalty – 1.5 to 1.7 GJ/tCO_2 for BECCS
- Retrofit option to reduce liability of existing industrial fleets
- New builds for optimized oxy performance with high O_2 concentration to reduce equipment sizing

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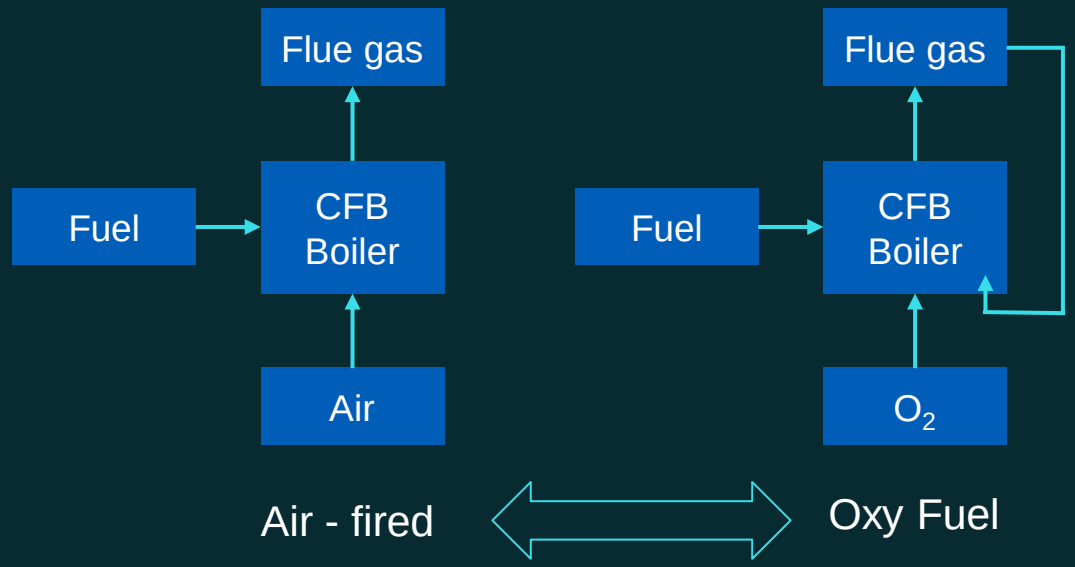
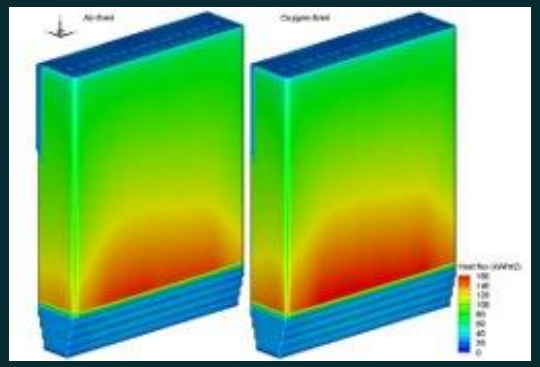
SFW's Fluid bed Oxyfuel solutions and its advantages

Fluidized beds allow replicating air-fired performance in oxy-mode while taking advantage of the latter





- Similar furnace heat transfer and solid distribution profile
- Unburned carbon and emissions are similar
- Operational flexibility (air/oxy mode)
- Oxyfuel allows higher fuel capacity in similar sized air-fired combustion units
- Commercially proven components and demonstrated with SFW technology

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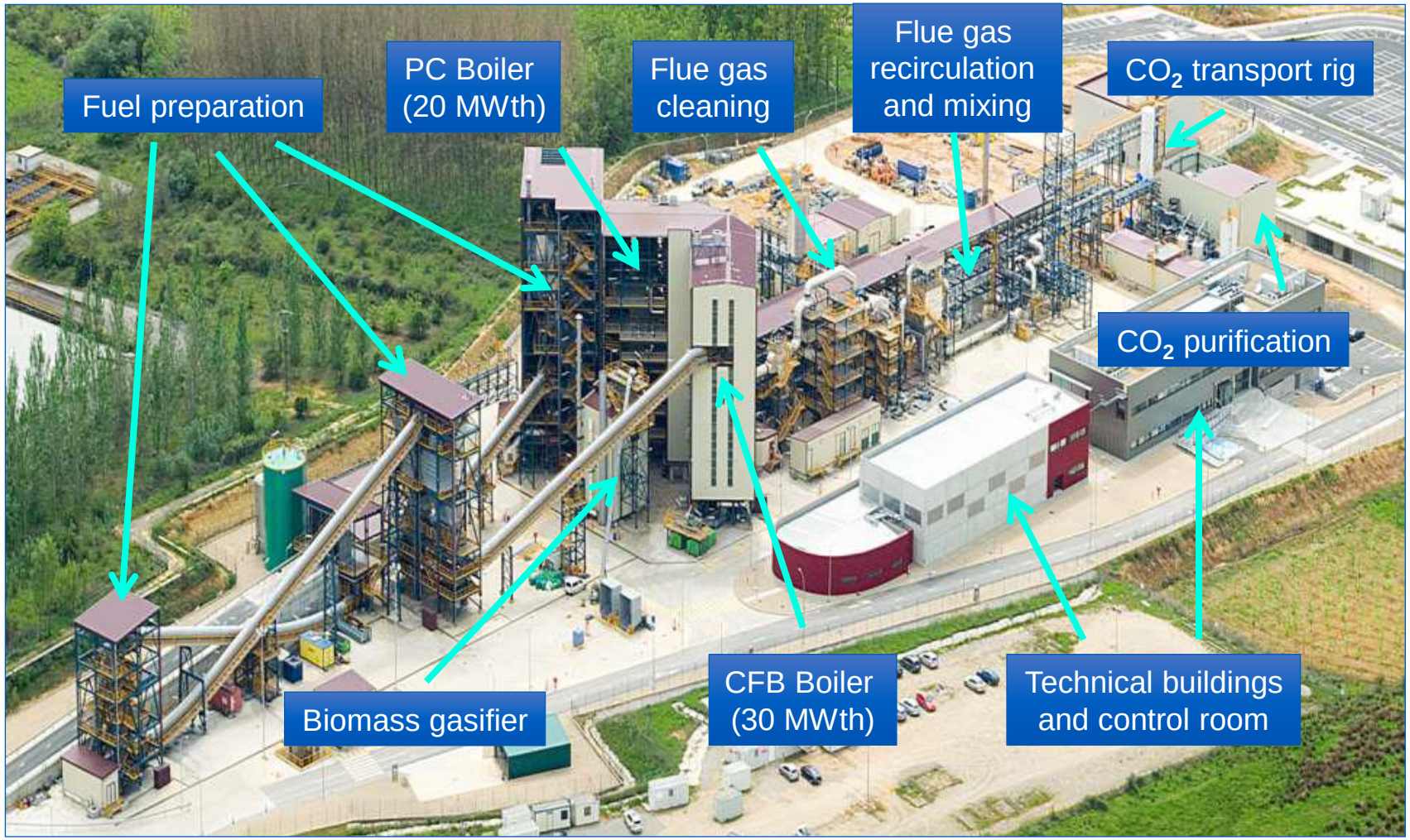
The CIUDEN Oxyfuel Carbon Capture Technological Development Plant (TDP)

A 30 MWth Oxyfuel plant in Ponferrada, Spain

A CCS demo plant with Endesa and CIUDEN during 2009-2017

Design for a full-scale 300 MWe plant was developed as a part of the project



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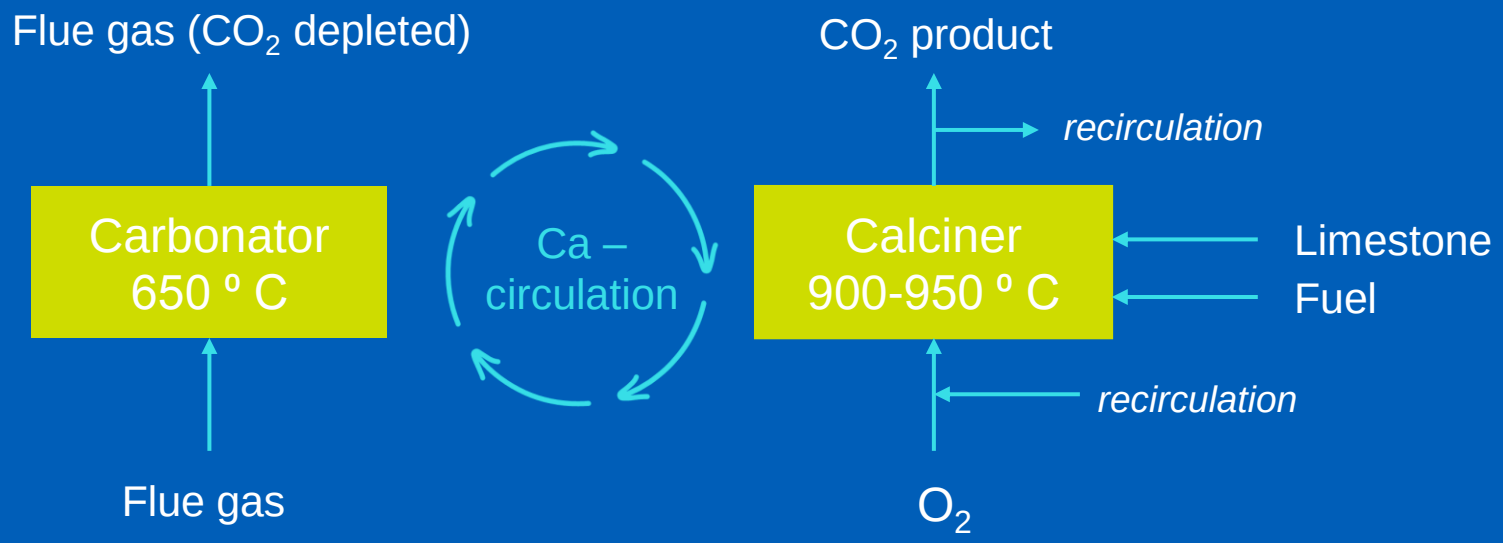
Calcium Looping (CaL) for post-combustion capture solutions

Oxyfuel based CFB technology utilizing Ca-solid sorbent to capture and release high purity CO_2

How does it work?



- Multi-product technology
- High purity CO_2 from capture system
- Excess heat at high temperatures
- Purge sold as SCM* in cement and other lime consumers.
- CO_2 capture > 90% and low energy penalty 4-7%

- Retrofittable to any large-scale CO_2-emitting source
- Robust towards challenging flue gases in industry
- O_2 utilization is synergetic with green H_2
- Heat supply via low-rank fuels, e.g., waste-derived Commercially proven components
- Demonstrated with SFW tech. for 1 000s hours

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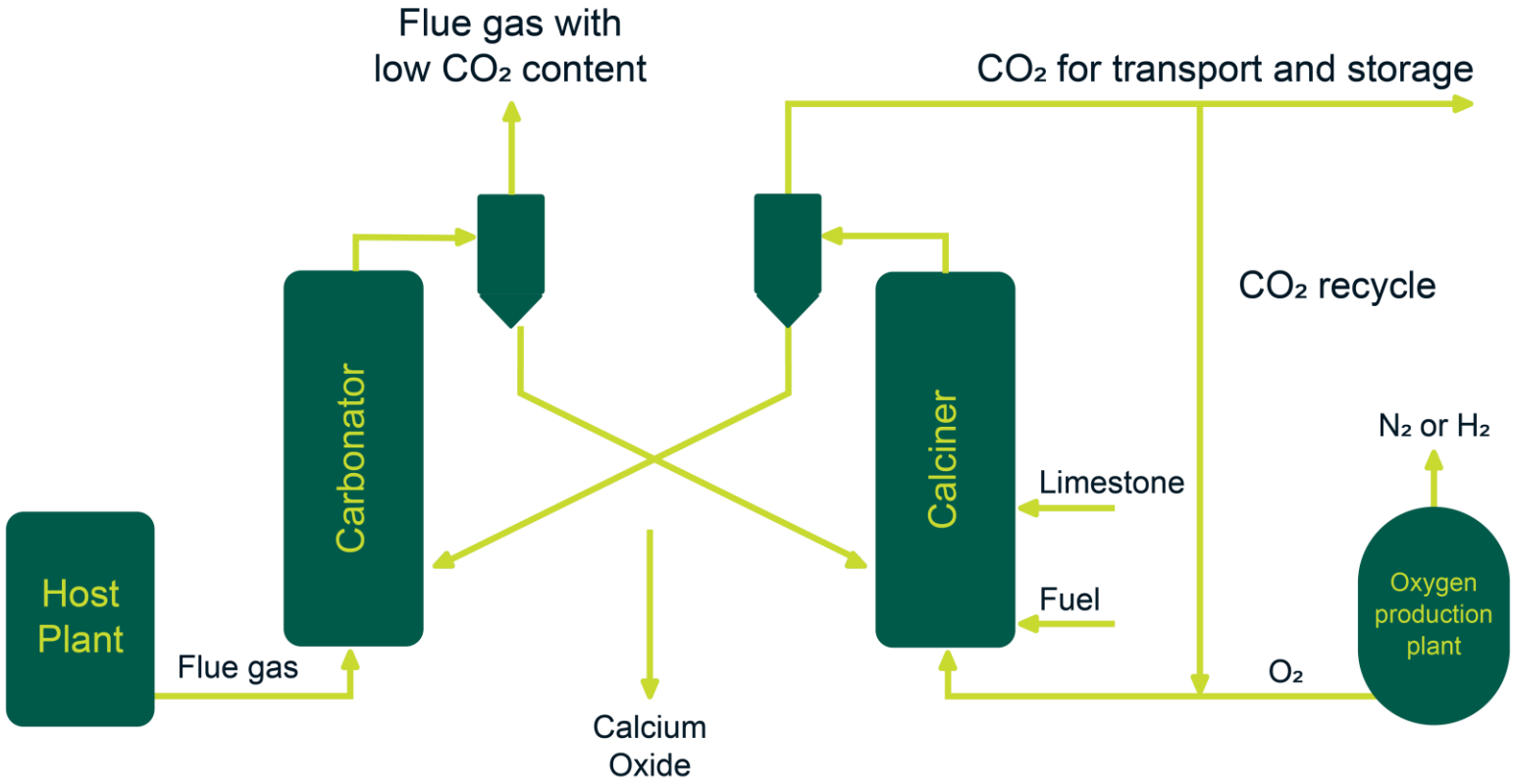
Calcium looping – Multiproduct technology for carbon capture

Oxyfuel based CFB technology utilizing Ca-solid sorbent to capture and release high purity CO_2

CaO absorbs CO_2 and forms $CaCO_3$

$CaCO_3$ is heated to release CO_2 and regenerate CaO



Potential revenue streams

- Waste gate fees
- Power
- District heat
- CDR credits
- Nitrogen
- Calcined lime
- Electrolyzer synergy

Reversible carbonation: $CaO + CO_2 = CaCO_3$

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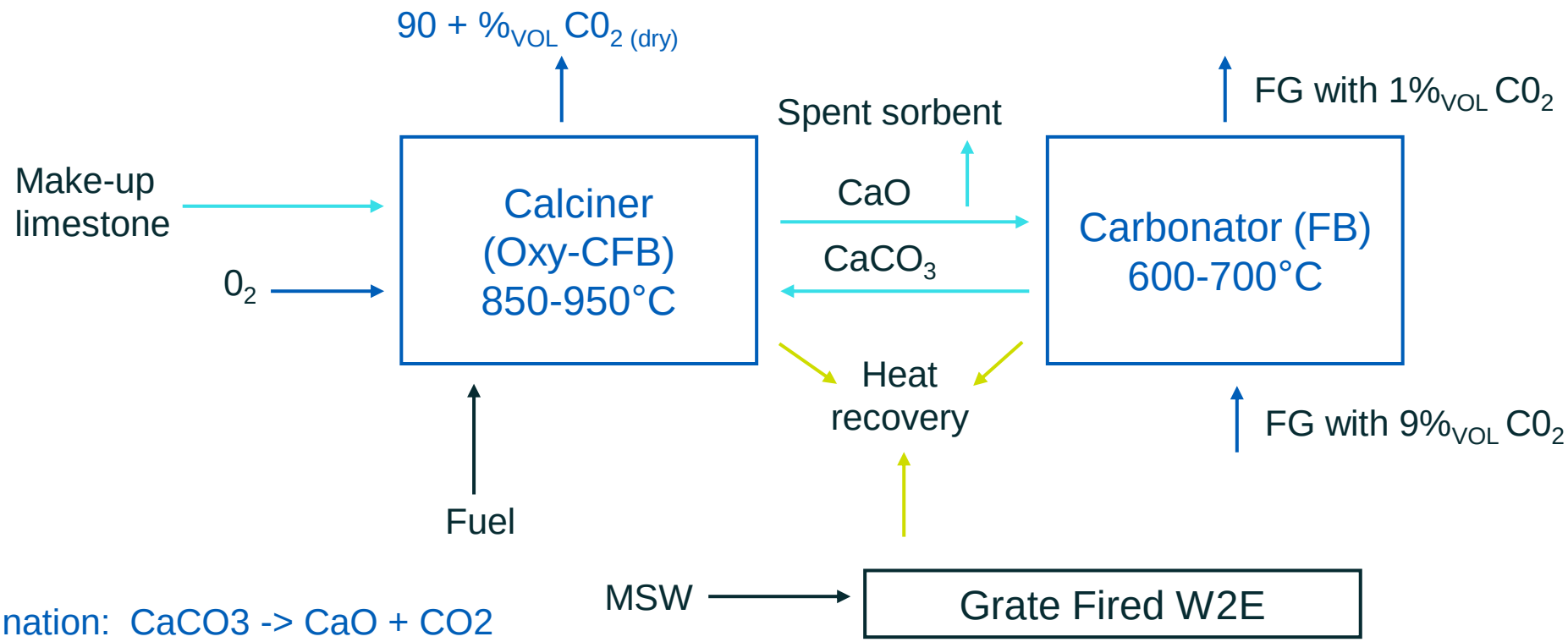
Technology Overview and Value Proposition

CaL Value Proposition: Waste-to-Energy Sector

- Decarbonizing WtE sectors allows for negative CO_2 Emissions (BECCS)
- CFBs (CaL calciner) suitable to digest low-rank fuels such as SRF
- Carbonator excess heat is suitable decarbonized heat source for external superheating
- WtE flue gas contaminants are eventually removed via CaL carbonator



Calcination: CaCO3 -> CaO + CO2
Carbonation: CA(OH)2+ CO2 -> CaCO3 + H2O

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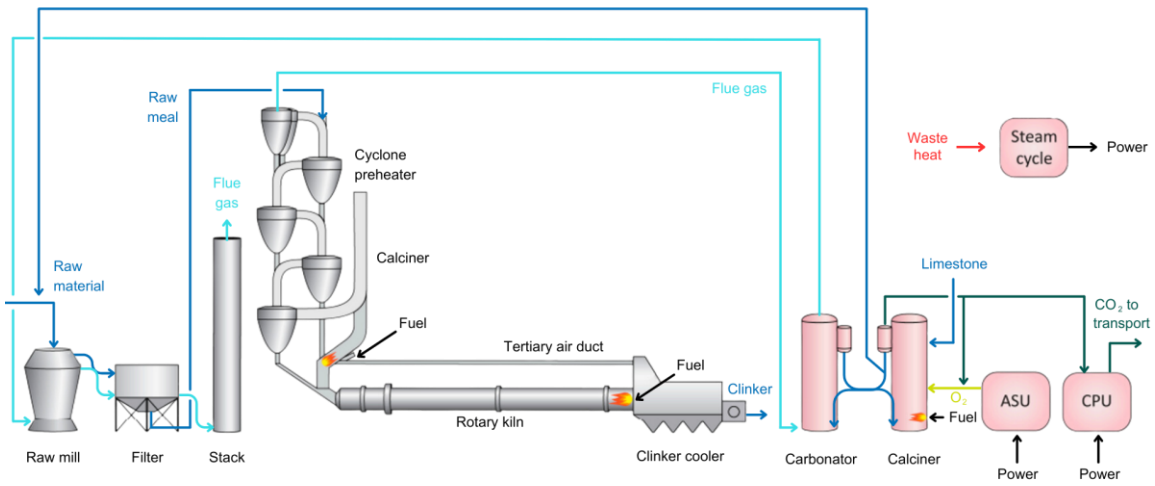
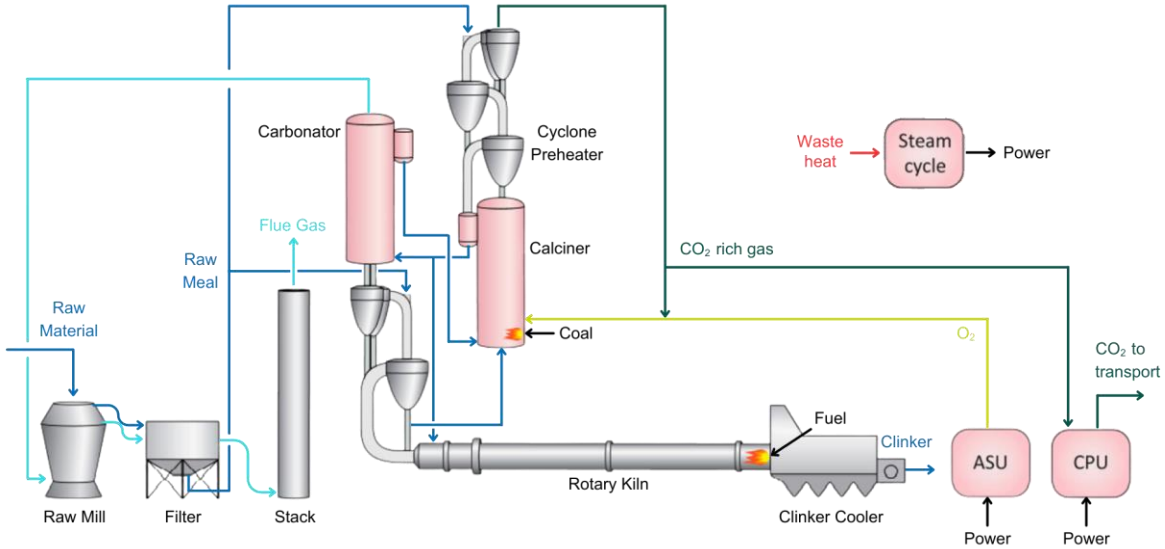
Technology Overview and Value Proposition

CaL Value Proposition: Cement Industry

- Solids handling and Ca-based systems are familiar for cement plant operators
- Limestone is available on site





- Spent sorbent to be used as feedstock for clinker production
- Supply of electricity via CaL excess heat utilization to decarbonize plant scope 2 & 3 emissions

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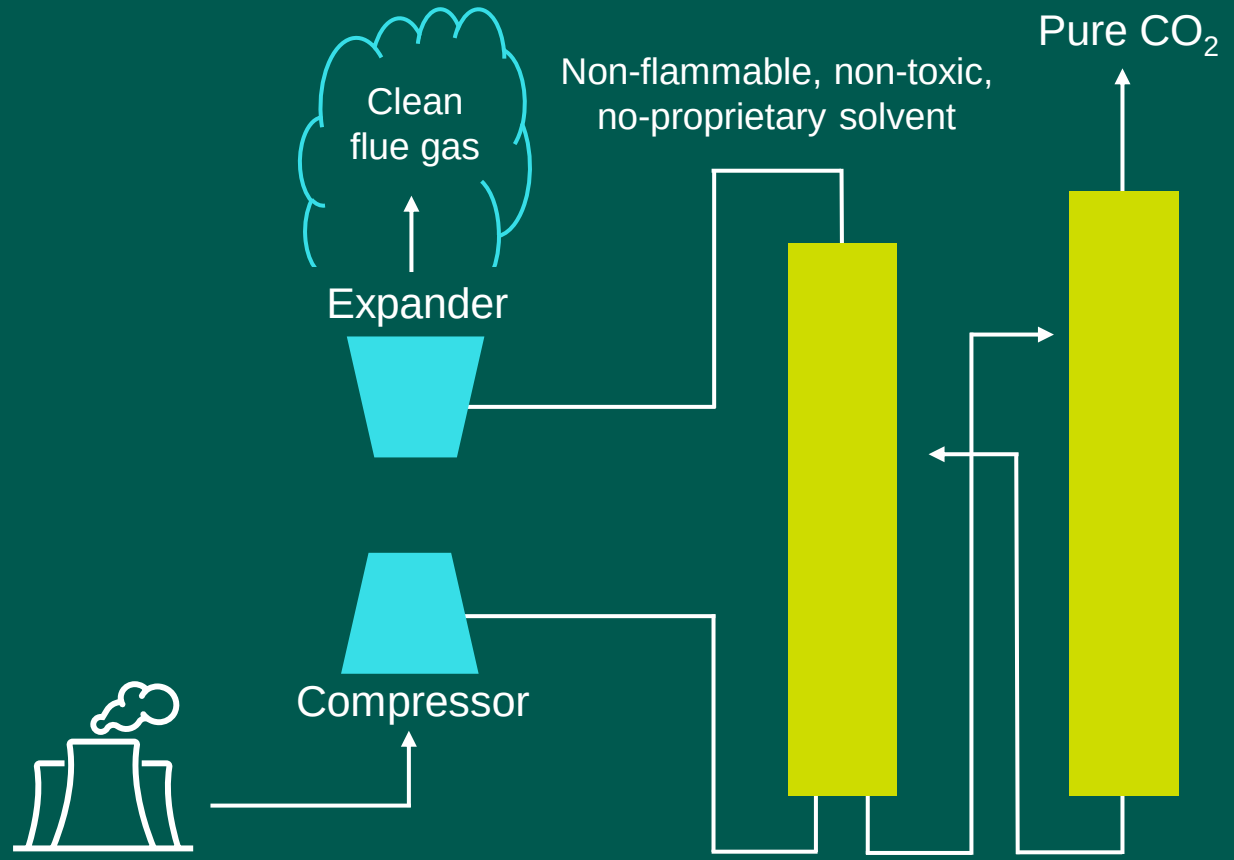
HPC Process (CAPSOL Technologies + SHIFW)

How it works?

Technology based on efficient heat recovery for low energy penalty and increased district heat production:

- Uses aqueous solvent of 25 wt.% K_2CO_3
- Uses pressure swing and waste heat for regeneration
- Recovery compression energy in expander
- Capture rate over 90%
- Produces high purity CO_2 > 99%
- Can be powered by electricity only, steam only, or combination
- Electricity consumption 0,7 - 1,5 GJ / ton of CO_2
- Low-temperature heat can be used in district heating



$$K_2CO_3 + CO_2 + H_2O \leftrightarrow 2KHCO_3$$

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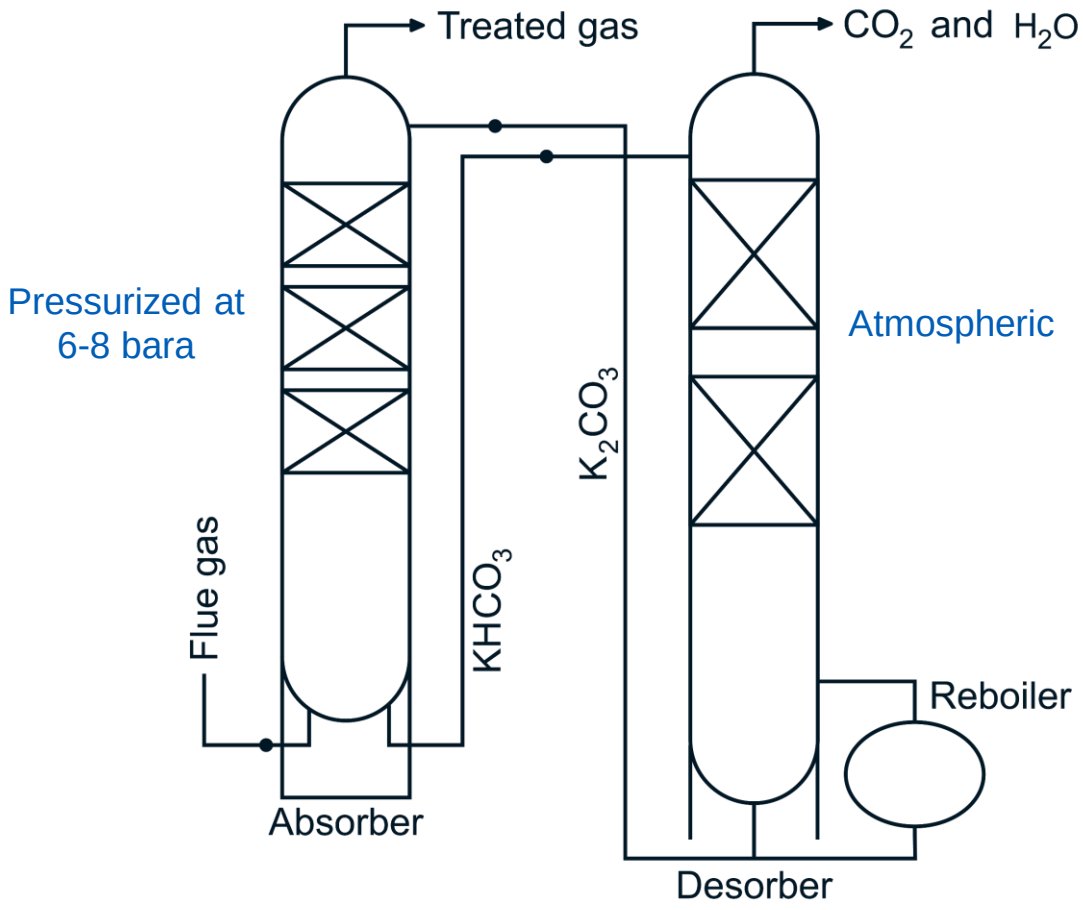
Added Value Carbon Capture – HPC solution

Technology based on efficient heat recovery for low energy penalty and increased district heat production



$$K_2CO_3 + CO_2 + H_2O \leftrightarrow 2HCO_3^{-1} + 2K^+$$

- Uses aqueous solvent of 25 wt.% K_2CO_3
- Uses mainly pressure swing for regeneration
- Recovery compression energy in expander
- Capture rate over 90%
- Produces high purity CO_2
- Energy consumption < 1.7 GJ / ton of CO_2
- Low-temperature heat can be used in district heating

capsol technologies

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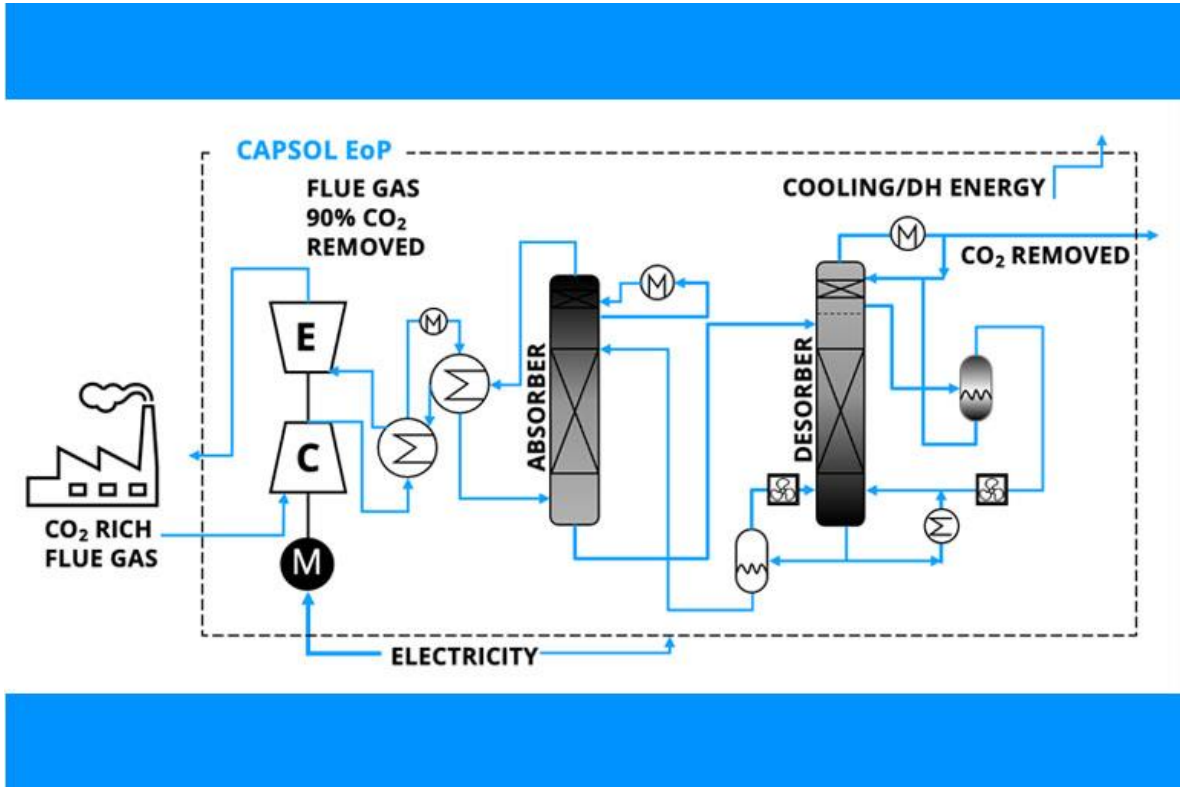
HPC Technology and Process

CAPSOL TECHNOLOGIES proprietary heat recovery enables alternative energy penalty sourcing adaptable to project business case



– Reference technology selected for Stockholm Exergi BECCS project to become operational end of 2026

– Technology piloting campaigning and product development at Waste-to-energy plant in Öresundskraft

capsol technologies

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Solvent and Chemistry

Well documented solvent with HSE and cost benefits

- Widely and freely available
- Used in food, detergent, glass and fertilizer industries
- Well-documented and proven as solvent
- Non-toxic, non-flammable, non-volatile and non-carcinogenic
- No foaming, corrosion tendency, and degradation
- HPC is low-cost and has low make-up
- No risk to environment or health
- Compatible with chemical additives to improve project-specific performance metrics.

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SFW's Carbon Capture development activities

Strategic objective to develop and deliver 100s $ktCO_2/a$ commercial capture facilities to our customers by 2026

OXYfuel CFB power plants

CIUDEN's 30 MW_{th} demonstration plant

- Carbon neutral and negative CHP plants
- 300 MWe commercial design & continued piloting of bio & waste fuels
- Feasability studies and project development to retro fit industrial CFBs
- Commercial development for SFW delivery of greenfield biomass and waste.
- Low energy penalty – 1.5 to 1.7 GJ/tCO2 for BECCS/U
- No additional chemical solvents needed

Calcium Looping for hard to abate

LaPareda 1.7 MW_{th} testing facility

- Multi product solution for heavy industry
- High purity CO2 for utilization or storage
- Low carbon CHP and calcined lime
- Solution addresses scope 1, 2 and 3 emissions
- Technology piloting and scale-up in CaLby2030 and HERCCULES demo projects for Steel, Cement and WtE plants.
- CO2 capture efficiency > 90%
- Integrated with green hydrogen plants.

HPC PCC for Bio & WtE

Modular & compact design for 20 - 200 $ktCO_2/a$

- Efficient flue gas cleaning solution for CHP applications
- Proven, widely available, safe, low-cost and non-carcinogenic Hot Potasium Carbonate (HPC) sorbent
- Partnership with Woima & CO2CAPSOL for solution development towards an integrator role
- Strategy is to expand to integration with CO_2 utilization applications

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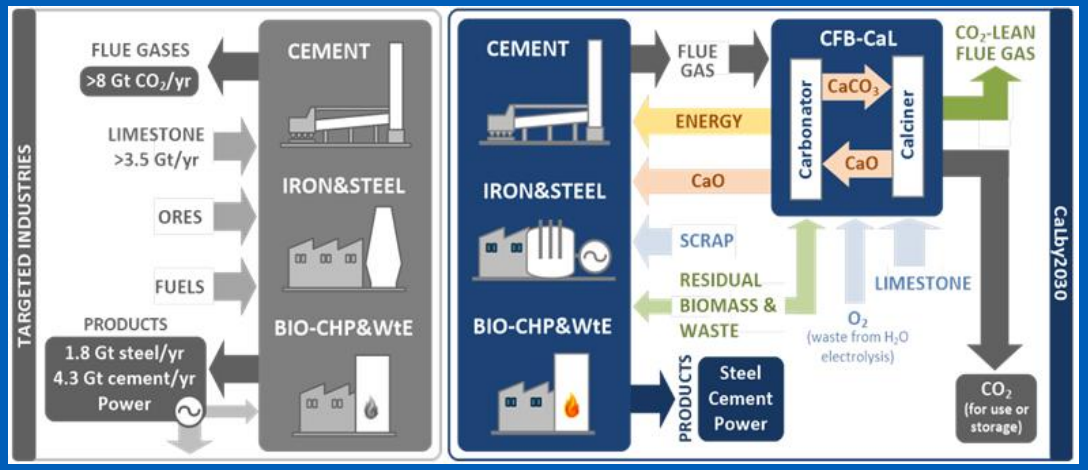
Calcium Looping: Demonstration projects for Cement, Steel and WtE industries

Reference projects: CaLby2030 & HERCCULES



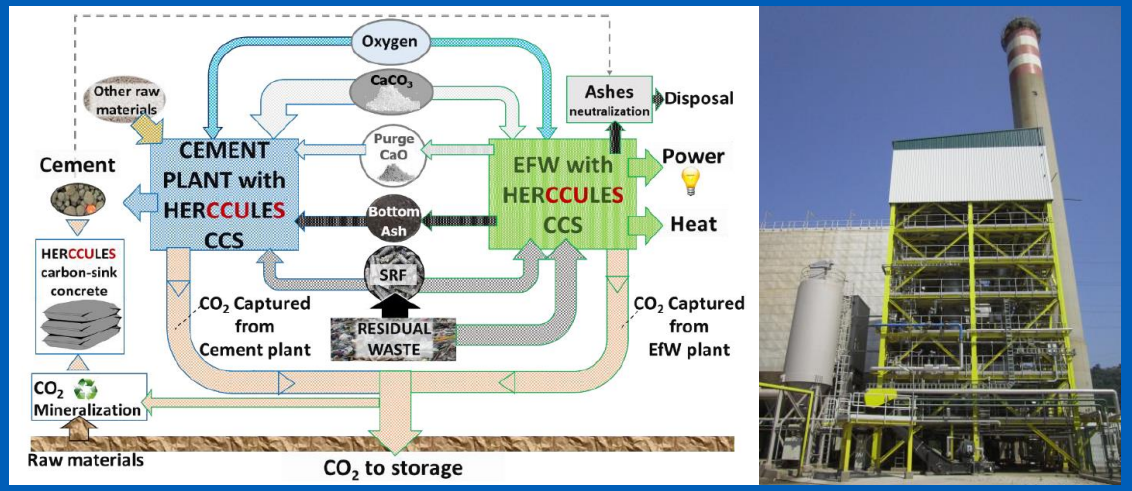
CaLby2030

Duration: Oct. 2022 to April 2026

Showcase CaL technology performance at different industry-relevant conditions

SFW to deliver:

- Design and engineering of 3 x 1-2 MW_{th} pilots (2 retrofit + 1 new)
- Scale-up and conceptual engineering for commercial projects at
  - Opterra's Karsdorf integrated cement plant in Germany
  - Alleima's Sandviken steelworks plant in Sweden
  - Hunosa's LaPareda power plant in Spain
  - IREN's waste to energy plants in Italy



HERCCULES

Duration: Jan. 2023 to Dec. 2027

Showcase full CCUS value chain towards CO_2 injection in the Italian Ravenna storage site and mineralization for built environment applications

SFW to deliver:

- New demo at a2a's Milan Silla 2 Waste-to-energy plant
- Scaleup and conceptual engineering for a2a commercial projects

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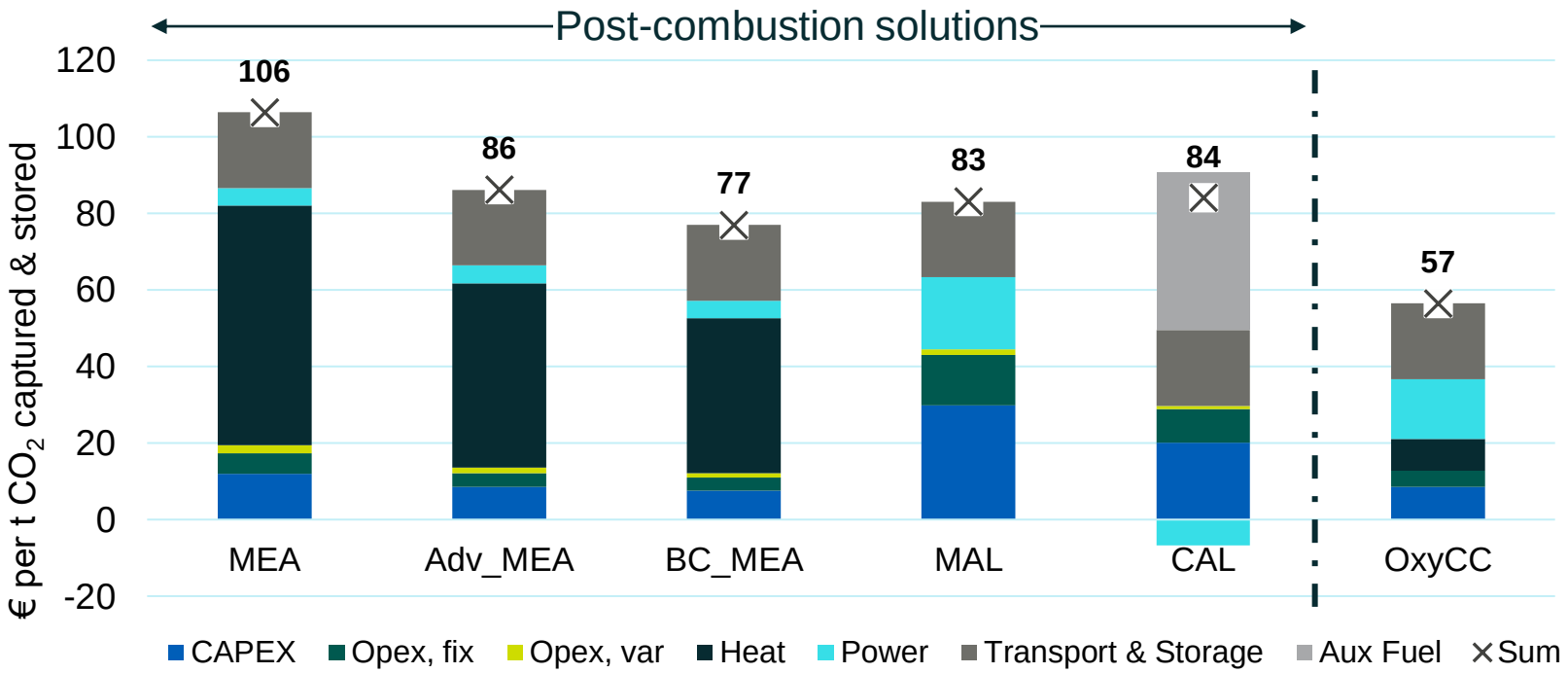
Bioenergy Carbon Capture and Storage (BECCS) plants

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 solutions of SFW's air-fired CFBs remain cost-competitive and have lower primary energy penalty compared to other realized CCUS solutions



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

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SFW response to decarbonization and climate change mitigation

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Energy storage

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

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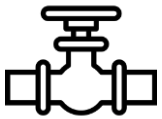
Waste to Value markets relate to demand for sustainable fuels and chemicals

Sustainable Aviation Fuels

- International aviation association (IATA) has net zero target for 2050, majority achieved via SAF
- ReFuelEU 70% SAF mandate by 2050

Methanol

- IRENA: 150Mt bio-methanol by 2050 vs. almost zero today
- New platform chemical for production of non-fossil olefins and aromatics with circular CO_2 lifecycle



Methane

- ReFuelEU target to increase biomethane from 3bcm to 35bcm
- Offset imported fossil natural gas with renewable gas from local resources

Hydrogen

- RePowerEU target: 10Mt domestic + 10Mt imported green hydrogen by 2030.
- Major support via tax credits in USA for production of low carbon hydrogen

Plastics

- Plastics production at 368Mt and estimated to grow to 1000Mt in 2050. Chemical recycling in key role to offset fossil feedstock use.

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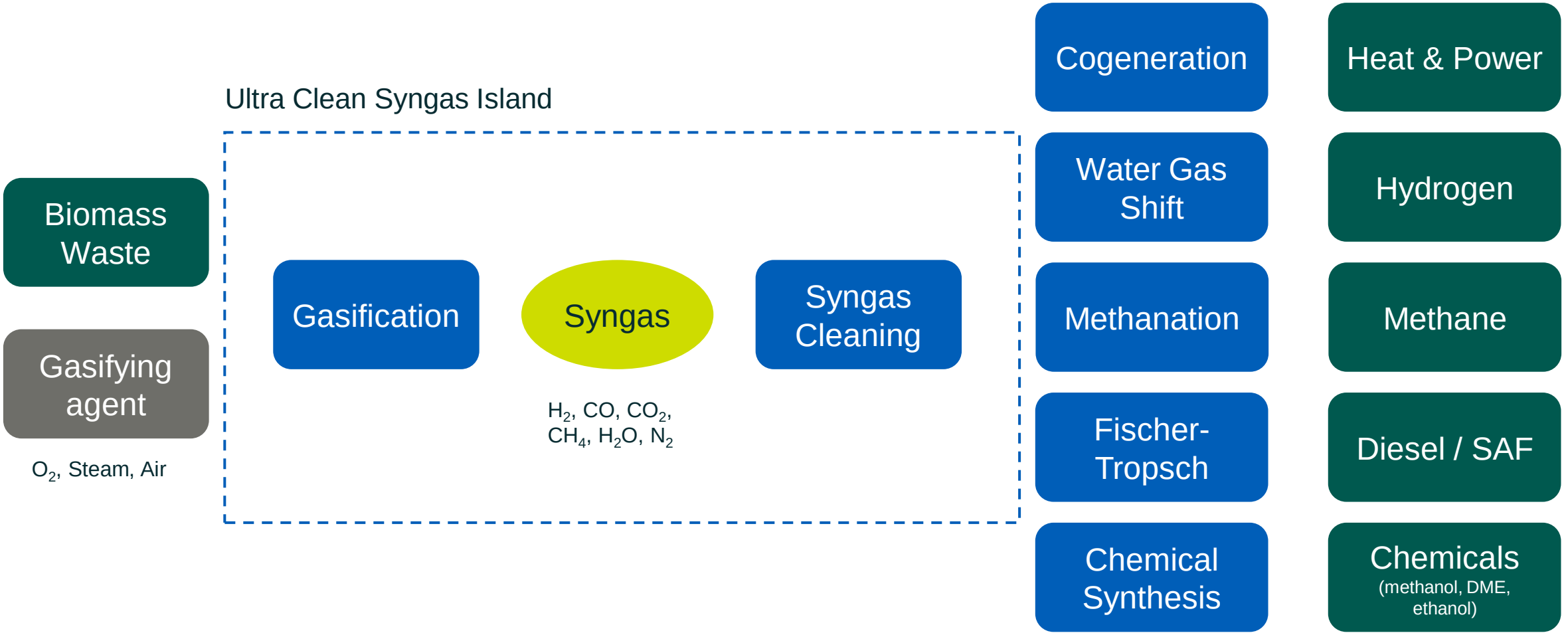
Oxy-steam Gasification - Solutions for green biofuels and bio-chemicals

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



- Cost competitive with SMR with carbon price or electrolytic, firm supply
- Synergies with electrolytic oxygen, versatile feedstocks
- Option for carbon negative with CCS

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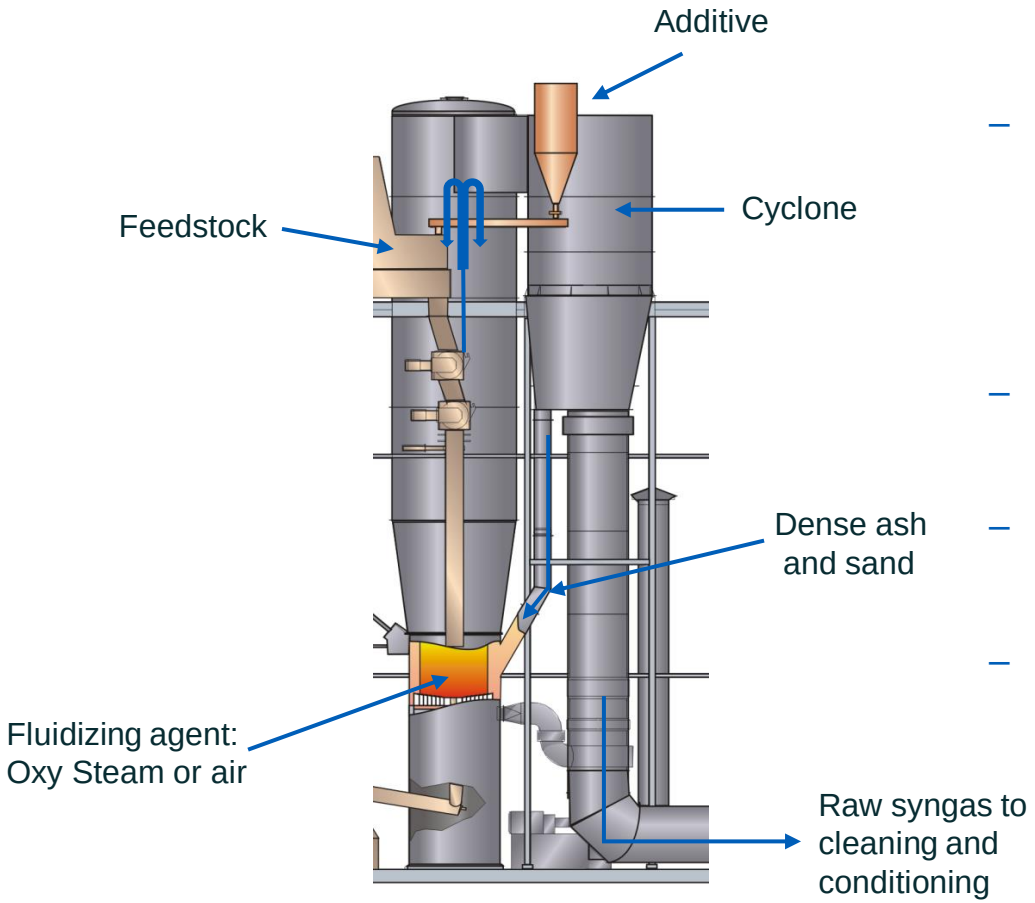
How it works?

Gasifying medium selection

- Oxygen-Steam for converting feedstock into $H_2/CO/CH_4$ rich syngas for synthesis
- Air for converting feedstock into combustible syngas for heat and power, lime and cement kilns.



CFB Gasifier

- Circulating Fluidized bed process ensures very good mixing and long residence time, giving uniform temperature 850–900°C
- Drying and pyrolysis occurs near feedstock feeding point
- Combustion occurs in lower part of reactor
- Gasification occurs in entire reactor

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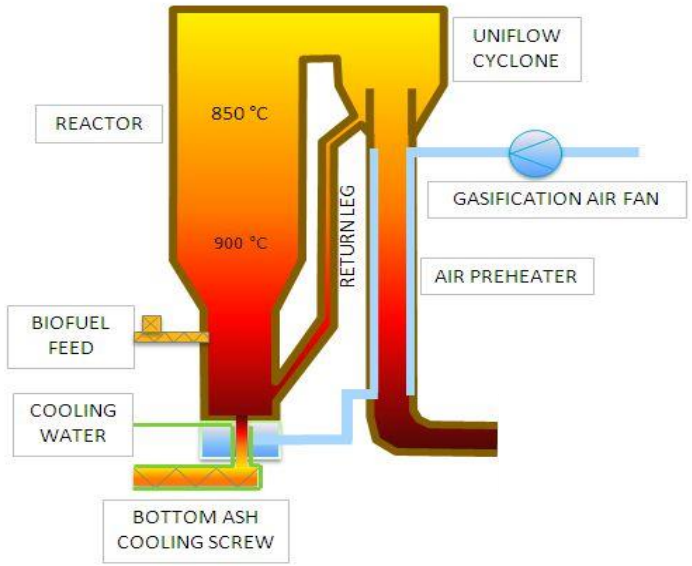
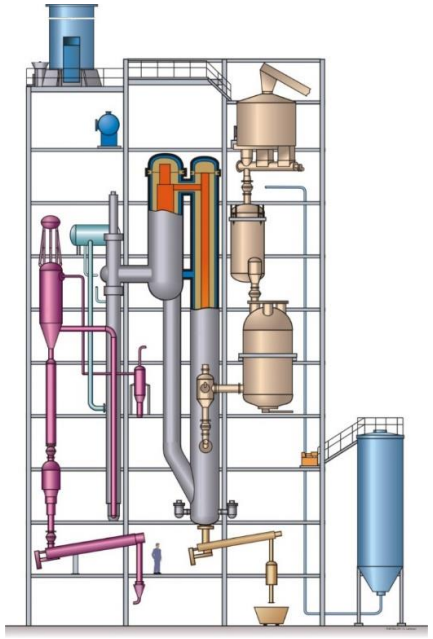
Gasification Technologies - Atmospheric and Pressurized Gasifiers

Atmospheric Air-Blown Gasifier



Pressurized Air-Blown Gasifier



Technology	Primary Feedstock	End-Product	SFW Own Technology	Targeted Full Scope	Size Currently Demonstrated	Target Market Max Size	Next Demo Size
Atmospheric air-blown Gasifier	Biomass, Waste and Plastics	Product Gas / Electricity / Heat	Gasifier + Filter + Burner + Boiler	Gasifier (+ Burner + Boiler)	60 MWf	100 MWf	Commercial Product
Pressurized air-blown Gasifier	Biomass	Product Gas / Electricity / Heat	Gasifier + Cooler + Filter	Gasifier + Cooler + Filter	18 MWf	300 MWf	80 – 120 MWf

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SFW's long history with Fluidized Bed Gasification

Over 40 years of experience with design and delivery biomass and waste gasifiers

Our Fluidized Bed Gasifier References					
Start-up date	**Customer**	**Country**	**Steam MWth**	**Primary Fuel**	**Application**
2009	NSE Biofuels OY Ltd	Finland	12	Biomass	Biomass to Renewable Diesel
2002	Electrabel	Belgium	50	Biomass	Biomas Co – Firing in PC
2000	Corenso United Ltd	Finland	50	Plastic Waste, RDF	Recycling and Energy Recovery
1997	Lahti Energia	Finland	50	Biomass, RDF	Biomass Co-Firing in PC
1993	Sydkraft	Sweden	18	Biomass	Biomass IGCC
1985*	Portucel	Portugal	15	Biomass, Bark	Biomass Derived Lime Klin
1984	ASSI Karlborg	Sweden	27	Biomass, Bark	Biomass Derived Lime Klin
1984	Norrsundet Bruks Ab	Sweden	25	Biomass, Bark	Biomass Derived Lime Klin
1983	Oy W. Schauman AB	Finland	35	Biomass, Bark	Biomass Derived Lime Klin
1981	Hans Alhstrom Laboratory	Finland	3	Mic.	Test Facility

*A. Ahlstrom Corp. Technology

Additional operating experience

- Lahti long term tests on gas cooling and filtration in 2003-2004
- Karhula atmospheric pilot gasification test runs with O_2 enriched air in 2005
- Corenso REF gasification tests / demonstration in commercial scale in 2011-2012
- Corenso O_2 enriched air gasification in commercial scale 2013 ->

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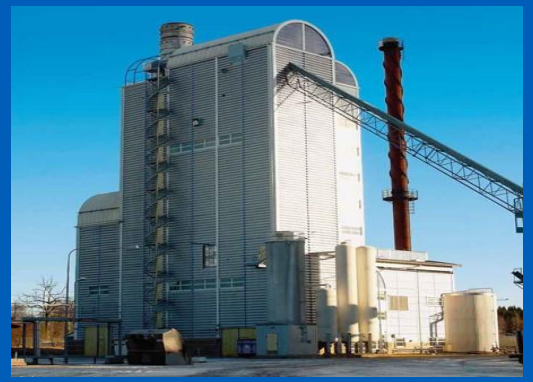
SFW's long history with Fluidized Bed Gasification

Gasification references

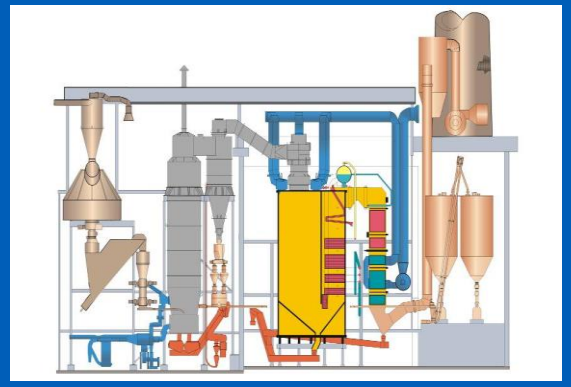


Sydkraft Värnamo IGCC demonstration project

- Pressurized circulating fluidized bed gasification integrated with combined cycle (IGCC)
- Built by Sydkraft AB and jointly developed by Sydkraft and SFW as Bioflow IGCC technology
- Operating experience 8500 gasification hours and 3600 IGCC operating hours
- Different wood fuels, straw and RDF were tested

NSE Biofuels (Stora Enso Oyj & Neste Oil Corporation) Varkaus

- 12 MWth Plant to demonstrate gasification for conversion biomass into biodiesel
- SFW delivered the CFB biomass gasification and syngas cleaning systems on EPC basis
- Oxy-steam CFB gasification testing for 9000 hours
- Successfully demonstrated technical viability of producing liquid biofuels



Corenso Varkaus

- Air-blown 50 MWth Bubbling fluid-bed (BFB) gasifier for recycling aluminium from juice packaging board waste
- Commercial operation in 2000
- BFB gasifier was converted to CFB gasifier in 2011
- O_2 enriched air gasification modification was made in 2013

Lahti Gasifier

- Air-blown 30-70 MWth Circulating fluid-bed (CFB) gasifier for mixture of biomass and recycled waste fuels
- Commercial operation 1998
- Annual fuel flow around 100kt of waste wood and MSW

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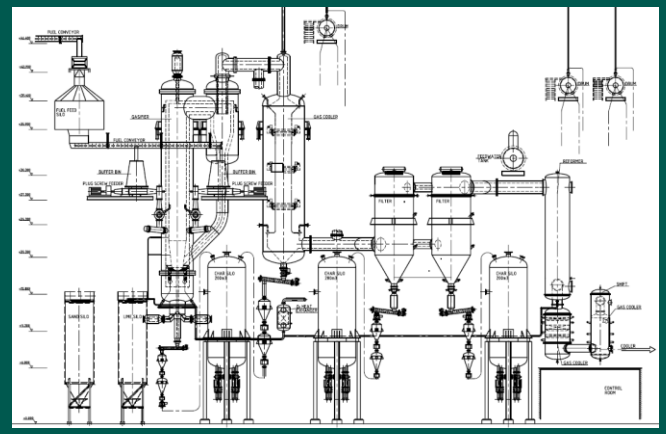
Gasification for carbon-neutral hydrogen, liquid fuels and chemicals

Production of decarbonized transportation fuels

Reference project: NSE Biofuels

- Start-up year: 2009
- Capacity: 12 MWth
- Fuel: Biomass, Forestry Residues

Design for 300 MWth



Key Features:

- 12 MWth Plant to demonstrate gasification for conversion biomass into biodiesel
- SFW delivered the CFB biomass gasification and syngas cleaning systems on EPC basis
- Oxy-steam CFB gasification testing for 9000 hours
- Successfully demonstrated technical viability of producing liquid biofuels

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Thank you

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