CARBON CAPTURING AS A PART OF EFUELS PLANT OPTIMIZATION

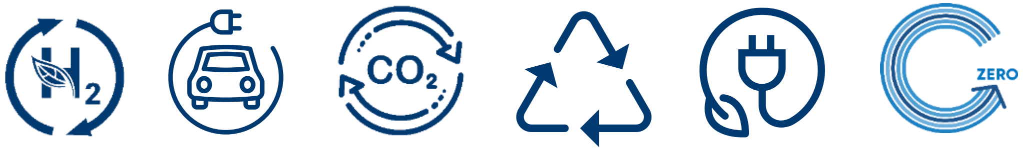
ANDRITZ P2X SOLUTIONS

MAY 2025, MIKKO ULVINEN

ANDRITZ

DECARBONIZATION:
WE ENABLE THE GREEN TRANSITION

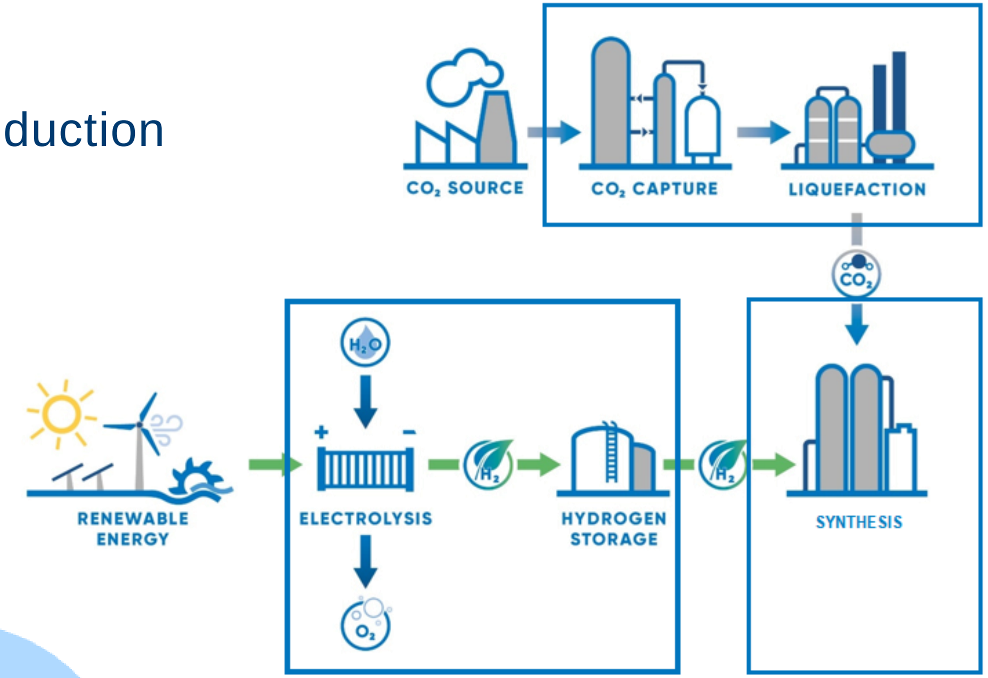
- Developing economically viable key technologies for the green transition
- Providing full lifecycle services from project development to operation and maintenance
- We offer solutions for:
  - carbon capture
  - production of green hydrogen
  - production of renewable fuels
  - battery production for e-mobility
  - textile recycling

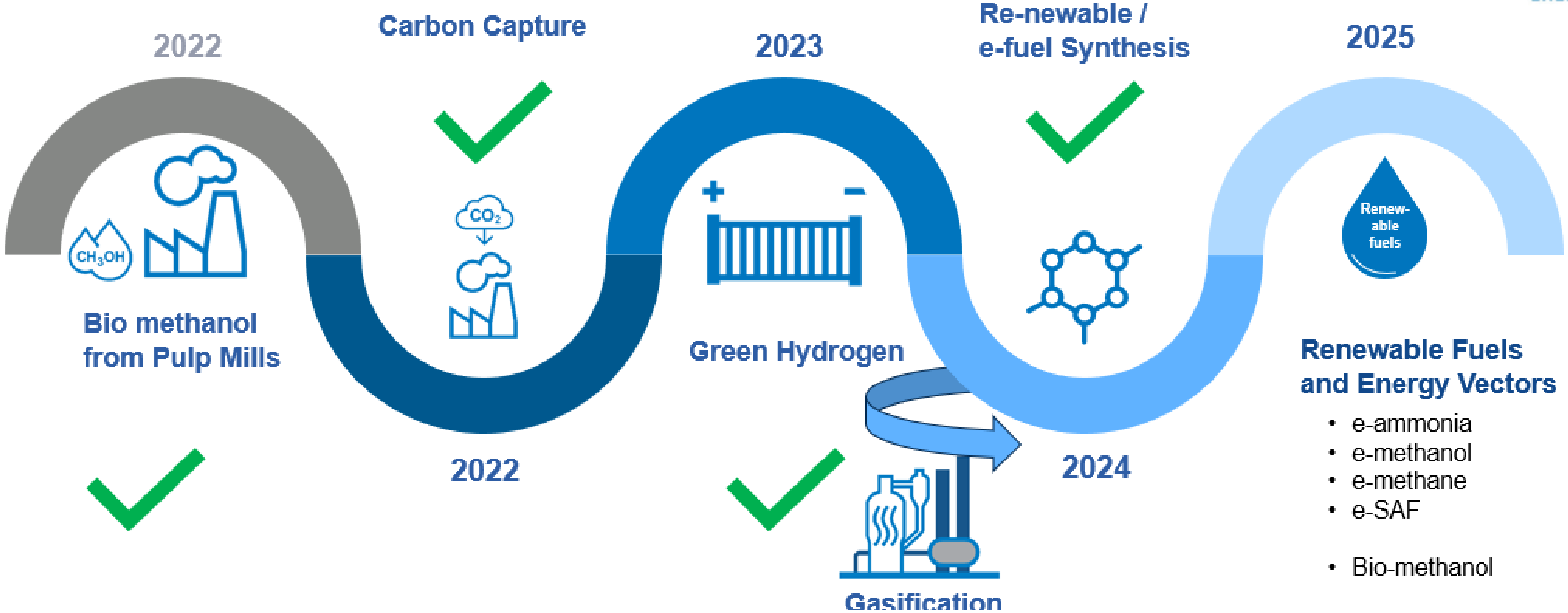


ANDRITZ CARBON CAPTURING

Most comprehensive portfolio on CC for utilization in eFuels production

- Proprietary CO_2 technology developed ever since early 2000's
- Capturing by Amines, HPC, and Membrane technologies
- Understanding for eFuels production needs for CO_2 for being supplier for complete eFuels plants





ANDRITZ CCS TECHNOLOGIES

Comparison of available technologies

	Amine Wash	Membrane	Hot Potassium Carbonate
Removal Efficiency	>95%	Up to 90%	>95%
Energy Consumption incl. ~0.5 GJ_{el}/t for Compr.	1.5 – 3.5 GJ/t CO_2*	1.7 – 2.0 GJ/t CO_2**	1.8 – 2.5 GJ/t CO_2***
CO_2 Purity	>99.5%	Up to 95%	>99.5%
TRL	TRL 8 – 9	TRL 5 – 6	TRL 8 – 9

*) Contribution of thermal and electrical energy depending on heat integration

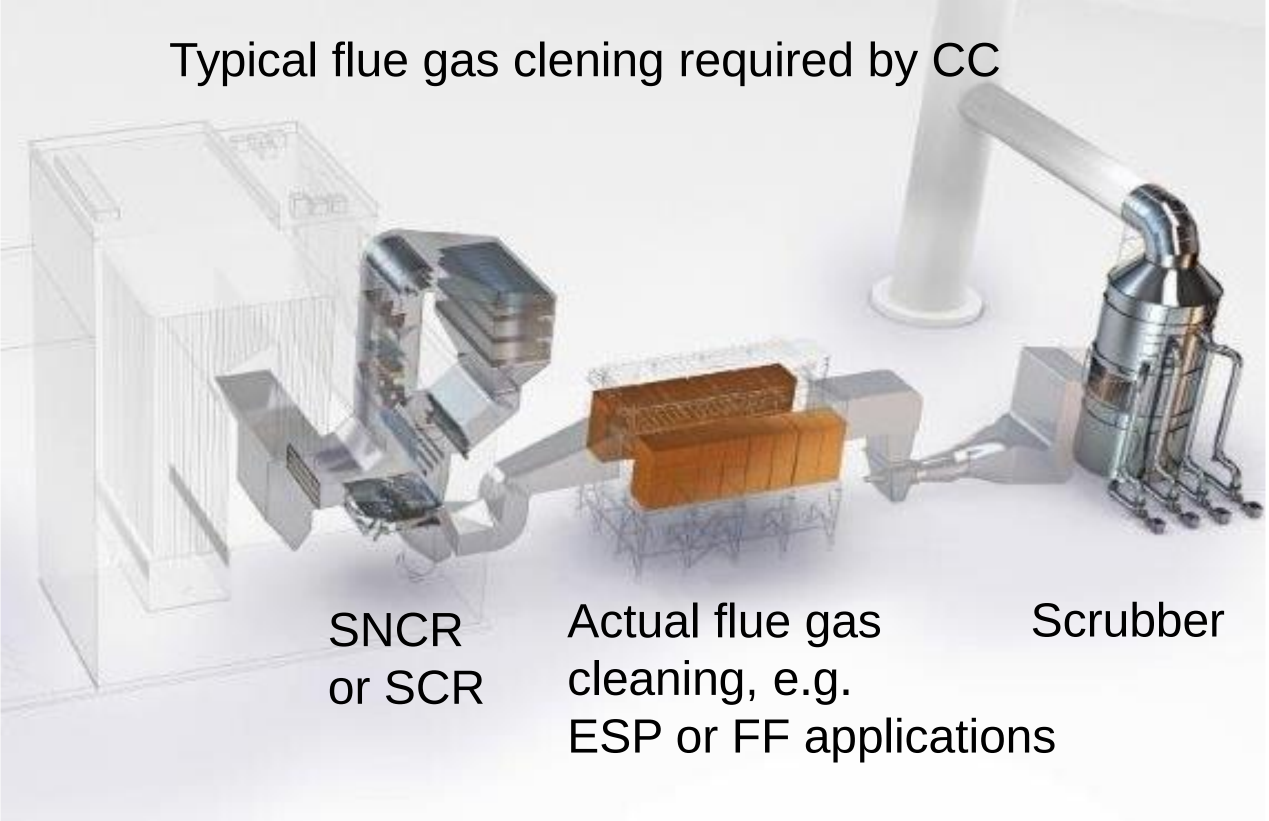
) Electrical energy only *) 70% Electrical energy

CC EFFICIENCY AND CO_2 PURITY

Not a problem to deliver clean CO_2 but it has to do with CAPEX and OPEX

- Capturing process sets reguirements for flue gas purity
  - Quite high purity requirement non dependent of selected capturing method
  - With low flue gas purity high capturing rate will be reached with high OPEX
  - This drives easily on high reguirements for flue gas cleaning system prior capturing
  - With proper flue gas purity 95 % capturing rate can be reached with justified increment in OPEX

- Typically CO_2 purity requirement has been set by off-taker and eFuels synthesis
  - Still quite unknown what are all the actual limitations on CO_2 by different types of eFuels
  - Quite oftenly CO_2 purity is deemed by eFuels plant catalyst supplier
  - Typically CO_2 purity is achieved with flue gas cleaning prior capturing and cleaning of LCO_2



CC IS ALSO OPEX MANAGMENT

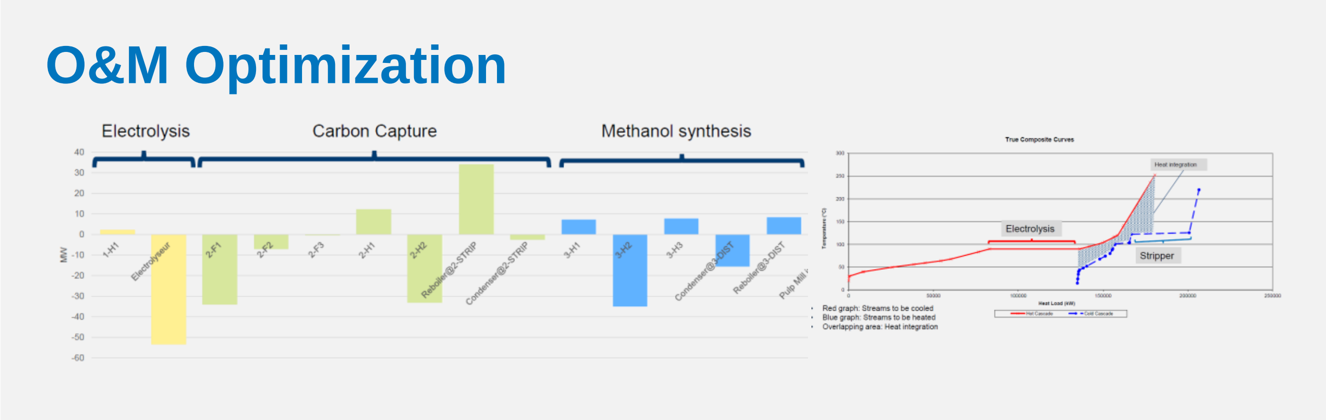
Main drivers for OPEX in CC processes, considering about 200 tTpa of CC

- Amine process 1,5 ... 3,0 GJ/T of CO_2 & max. ~4 bar_g steam for reboiler
  - Steam consumption is affected by amines concentration (dependent on purity of flue gases and available steam pressures and connection to e.g. DH process)
  - Amine consumption 0,3 ... 0,6 kg/pure amine for CO_2 T
- HPC 2,0 ... 2,5 GJ/T of CO_2 & max. ~2 bar_g steam for desorption
  - Certain temperature windows are must per certain chemicals but utilization of elecricity is the key consumable in the process
  - Steam is only about 20 ... 25 % of the full energy consumption
  - Chemicals mixture and consumption is dependant on flue gases purity
- Membranes 1,7 ... 2,5 GJ/T of CO_2
  - Electrical only
  - Requirements for temperatures prior capturing
  - Membrane replacemement 0,8 ... 1,5 m€/a depending on incoming flue gas purity

GH$_2$ OPTIMIZATION VS. CO$_2$ OPTIMIZATION

Essentials for running the eFuels plant

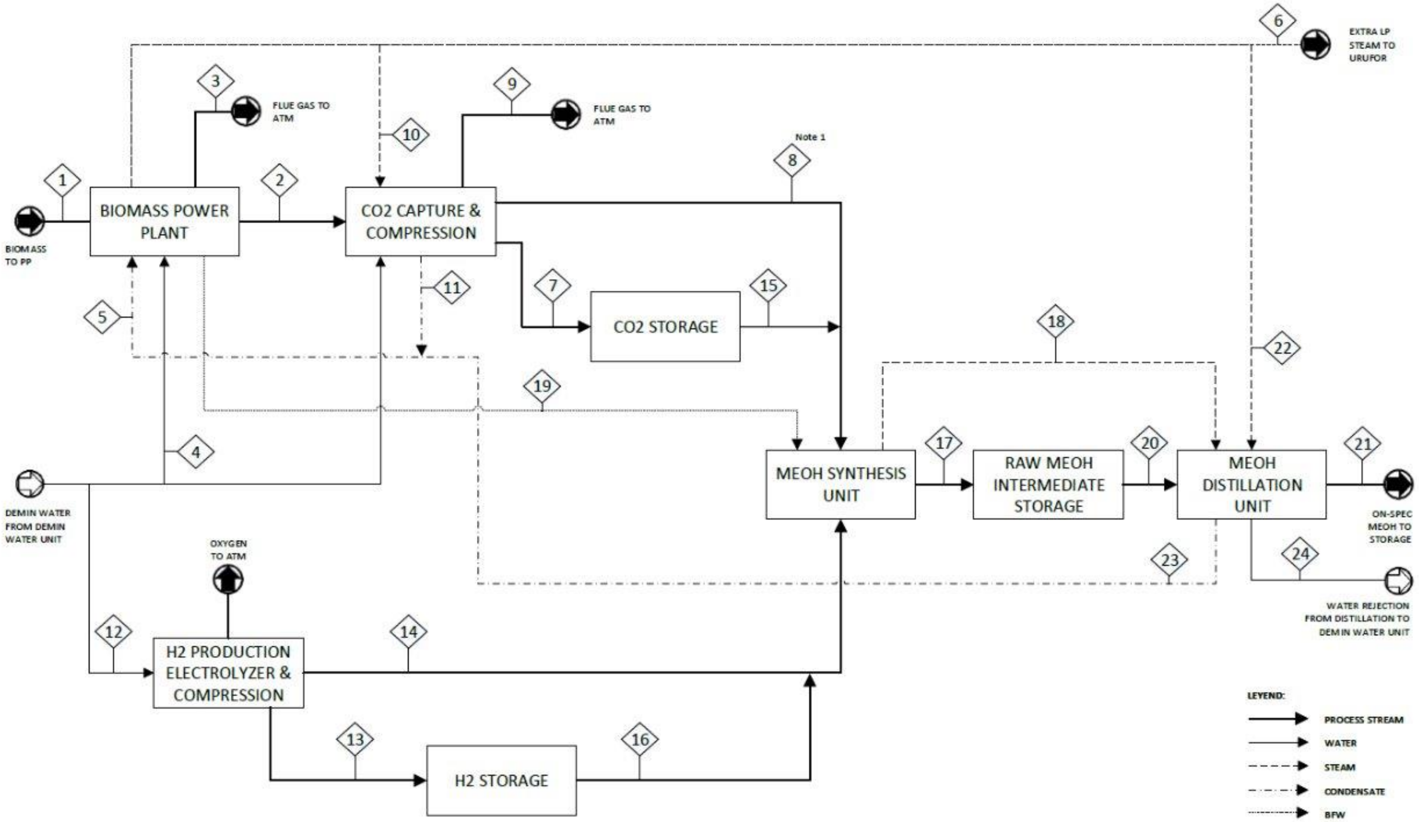
- Typical case is that there is ”constant” flow of CO_2 in flue gases to be treated
- Typical case is that CO_2 intermediate storaging is more economic than H_2 storaging
  - To enable dynamics in gH_2 production intermediate buffering is needed
  - The operation strategy of gH_2 plant the will define buffering
  - E.g. 25 Tph CC will require volume of about 3500 m^3 to store 5 days production
    → huge tank farm
- Compression and liquefaction is deemed by CO_2 storaging and evaporation of liquefied CO_2 can by used as optimization parameter for CC process
- In case CO_2 w/o pipeline connection will also generate returning CO_2 to the CC system from the terminal system



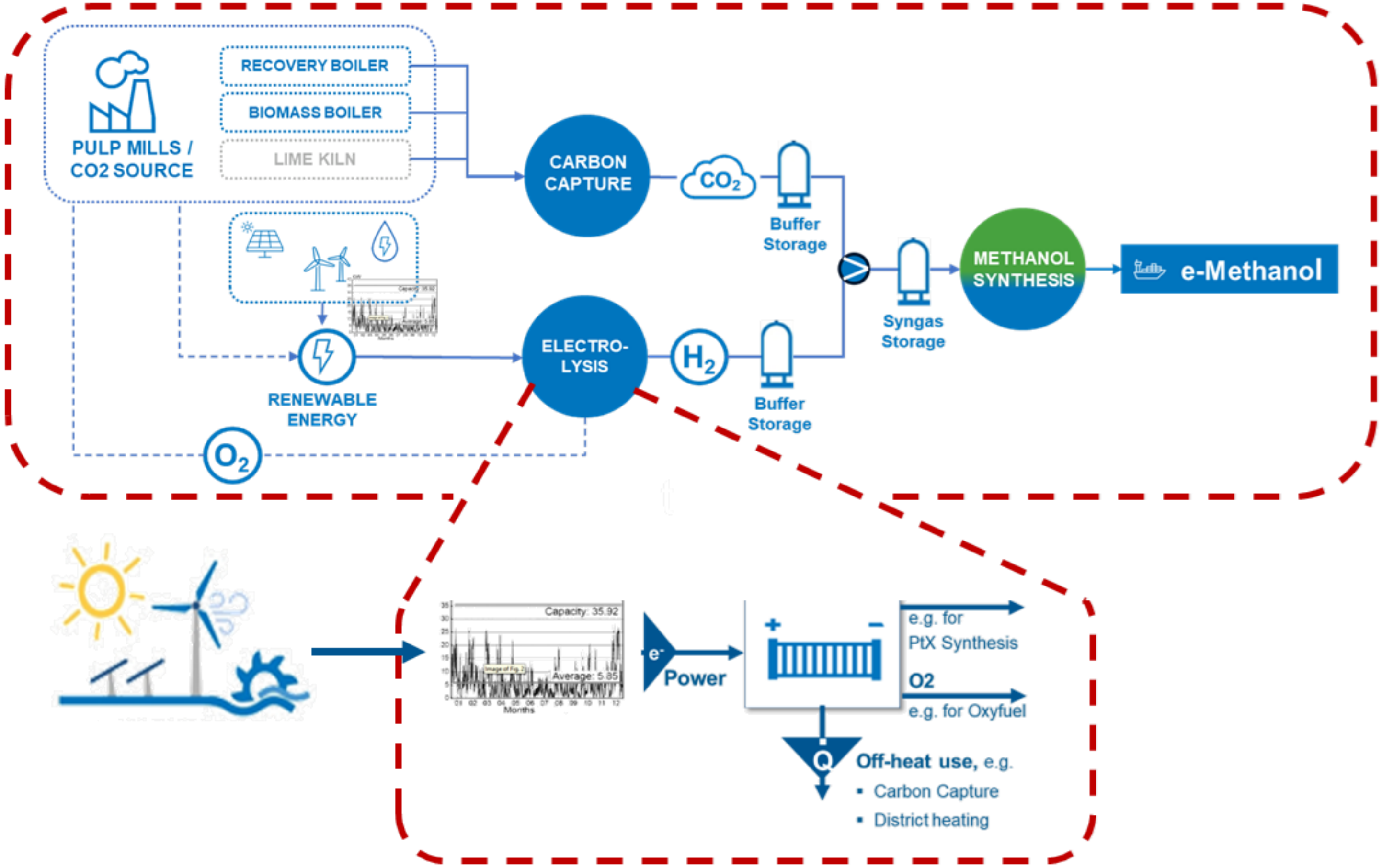
HIGH OXY COMBUSTION EFFECT ON CC

Utilization of the O_2 from the hydrolyzers

- O_2 supply from the electrolysers is not typically enought for full oxygen combustion in a furnace
  - Also boiler type and combustion processes might be a limiting factor
- Addition in O_2 in the combustion air will increase amount of CO_2 concentration in the stack
- Higher CO_2 concentration has positive effect on bot CAPEX and OPEX cost of CC



LEADING THE WAY IN INTEGRATION ENGINEERING



Reduce CapEx and OpEx through smart integration:

Optimized Feedstock Cost

- LCOP optimizer for Green Energy Farm & PPA portfolio
- LCOP optimizer Integrated Electrolyzer design and power profile optimization
- Pulp Mill Integration Concept

Plant Design Optimization

- Cost - optimized H2 production profile and buffer storage
- Cost - optimized synthesis plant and product buffer

Value Engineering & Smart Integration

- Equipment right-sizing
- Side stream valorization / cross industry linkage (e.g. district heating)
- Heat & utilities integration

Advanced Digitalization & Automation

- AI / IoT Optimization
- Process Automation

EXAMPLES FOR CARBON CAPTURING PROCESSES

Considerations in perspective to eFuel plant synthesis requirements

- Case calsinating owen with HPC (based on fossile fuel in combustion)
  - high requirements for purifying flue gases prior the CC w/o extensive increase in OPEX
  - flue gas purity can be reached quite easily to match requirements for Norther Lights or catalyst supplier specs
- WtE combustion with Amines (partially biogenic)
  - typically fairly well treated flue gases but fuel mixture changes may affect CC conditions and in hence OPEX
  - fuel may cause presence of e.g. heavy metals and other molecules in captured CO_2 that are exeeding catalyst supplier specifications (removing is increasing CAPEX)
- Bio BFB with Amines (100 % biogenic)
  - Age of the power plant is affecting hugely flue gas purity in the stack, the newer the better
  - Optimal for high oxy combustion to increase CO_2 concentration in the stack and improving CC CAPEX/OPEX
- Pulp, recovery boiler with Amines (100 % biogenic)
  - Filtering of flue gases is typically quite low and limits for SO_x and NO_x are moderate
  - Affect of impurites to the CC process and OPEX will be tested near future
  - Good availability of big amounts of biogenic CO_2

CARBON CAPTURE SOLUTIONS

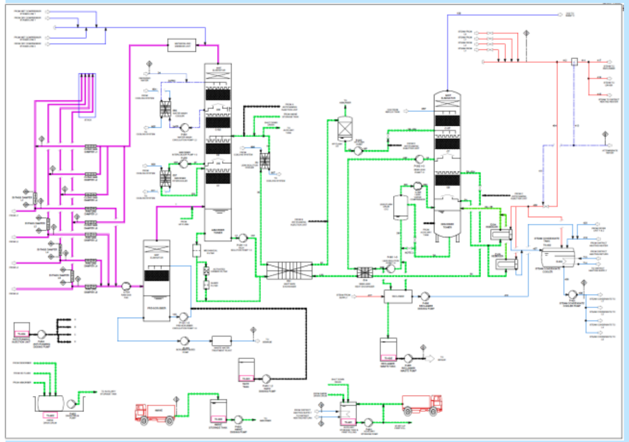
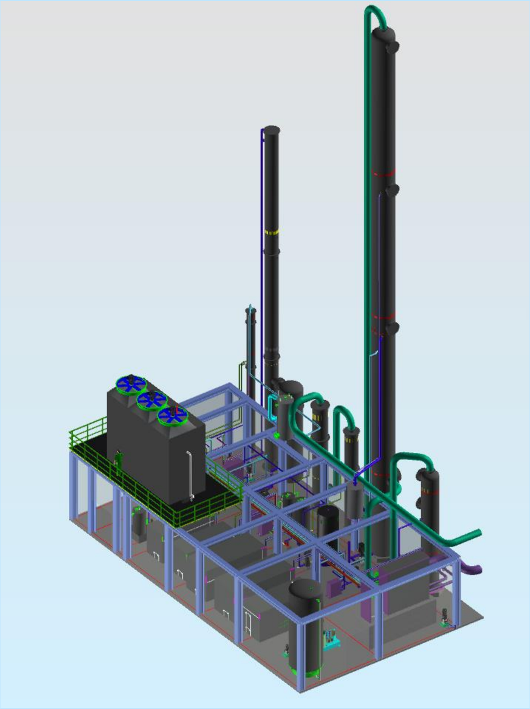
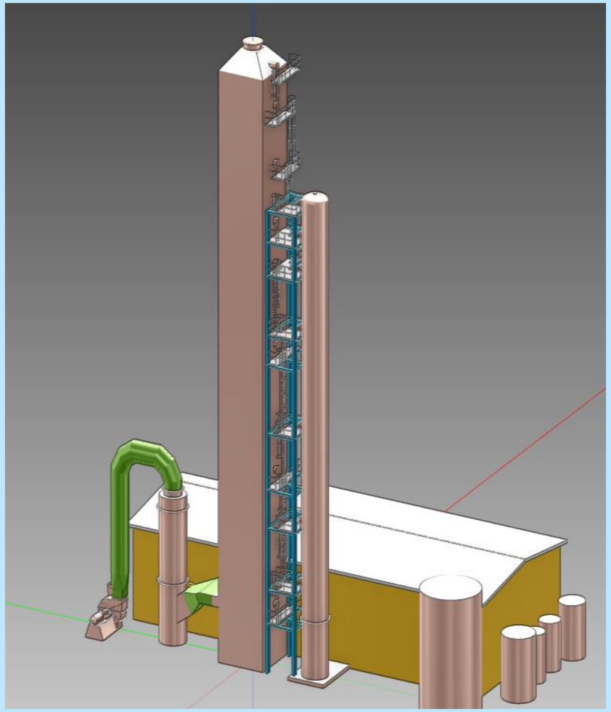
CLEAN AIR TECHNOLOGIES

2025

ANDRITZ

ANDRITZ CARBON CAPTURE – SCOPE

From FEED to EPC delivery / application of chemical absorption based on amines or HPC

Feasibility / FEED studies	Pilot plants	Compact plants < 200,000 tpa	Large-size plants > 200,000 tpa
			

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LET´S GO: ANDRITZ-LED BIOCIRCLETOZERO R&D PROGRAM IS SELECTED AS BUSINESS FINLAND LOCOMOTIVE PROGRAM IN 2025

Our commitment

“At ANDRITZ, we are committed to helping the forest products industry drive the green transition while ensuring its long-term competitiveness.”
Kari Tuominen, President & CEO, ANDRITZ Oy

Funding

- Business Finland has granted ANDRITZ 10 million euros in funding for the BioCircleToZero program.
- An additional 20 million euros will be provided by Business Finland to partners contributing to the program.

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FOR GROWTH
THAT MATTERS.

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