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Innovate UK

This project has received funding from UK Research and Innovation - Innovate UK under Innovation Funding Service (ISF)

Tallinn, Estonia. 13/06/2024

Dissemination event on CO_2 capture, transport, use and storage technology (CCUS)

A. Carrara / A2A SpA
M. Foiadelli / Tecno Project Industriale S.r.l.

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1.1 _ A2A presentation

We deal with energy, water and the environment, through a circular use of natural resources.

Energy
We invest in the infinite energy generated by the sun, water and the wind.

Environment
We protect the environment by transforming waste and surplus material into new resources, reducing wastage.

Smart infrastructure
We distribute electricity and gas, drinking water and district heating. We light, connect and plan towns, cities and businesses using smart, digital infrastructures.

13,000 People

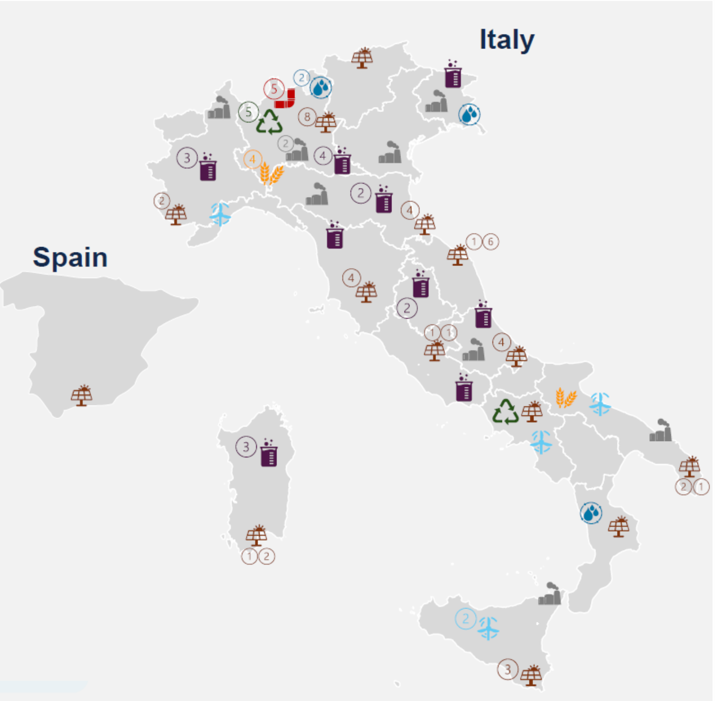
11,549 M€ Revenue

5.5 Mt Waste treated

5.7 GW Installed capacity from renewable sources (target 2035)

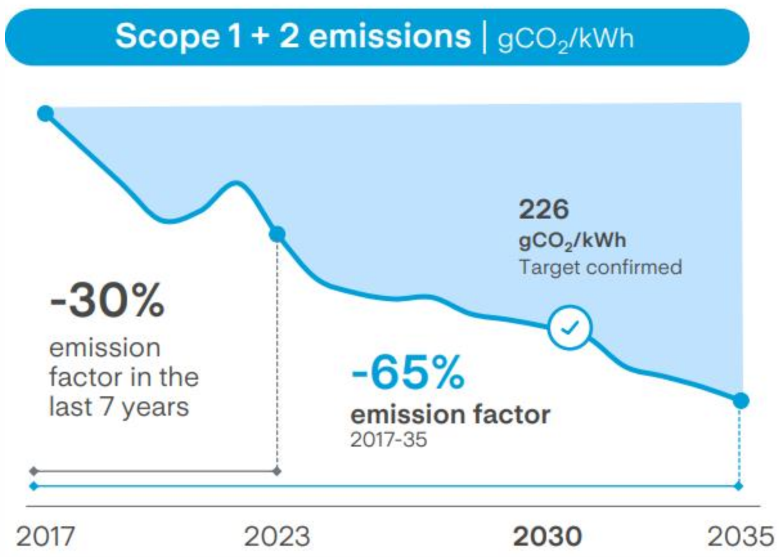
Total 141

- 5 Wind
- 6 Waste-to-Energy
- 89 Photovoltaic
- 4 Hydroelectric
- 5 District Heating
- 5 Biomass
- 9 Thermoelectric
- 18 Biogas



1.2 _ A2A decarbonisation vision

Commitment to decarbonisation through tangible and measurable actions

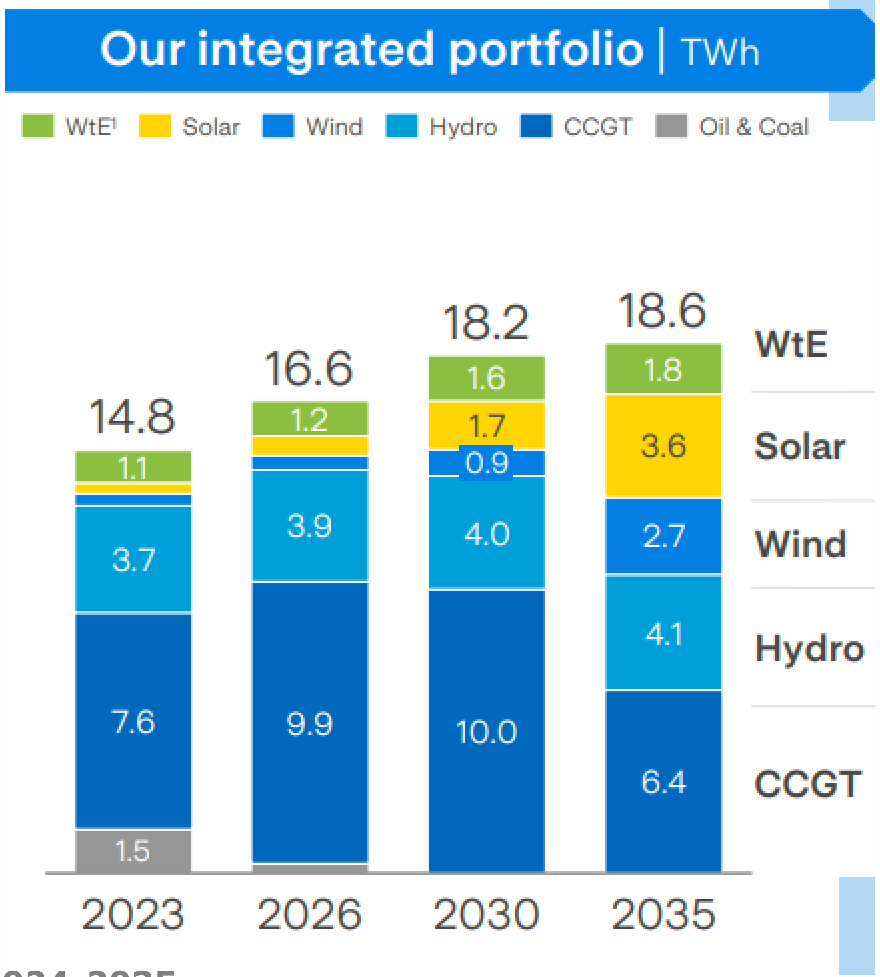


Goals achieved in 2021-23

- Stop to **coal** production plant
- Brescia **district heating** 85% renewable
- 1.8 TWh produced from **wind and solar**

Action Plan 2024-35

- **Net zero Scope 2 @2026**[1]
- **-60% Scope 3** upstream fuel[2]
- **Electrification** of company's **fleet**
- **1 plant** with **Carbon Capture** technology
- **Reduction** of **production from CCGT**



A2A Strategic Plan 2024-2035

1.3 _ What's a WtE?

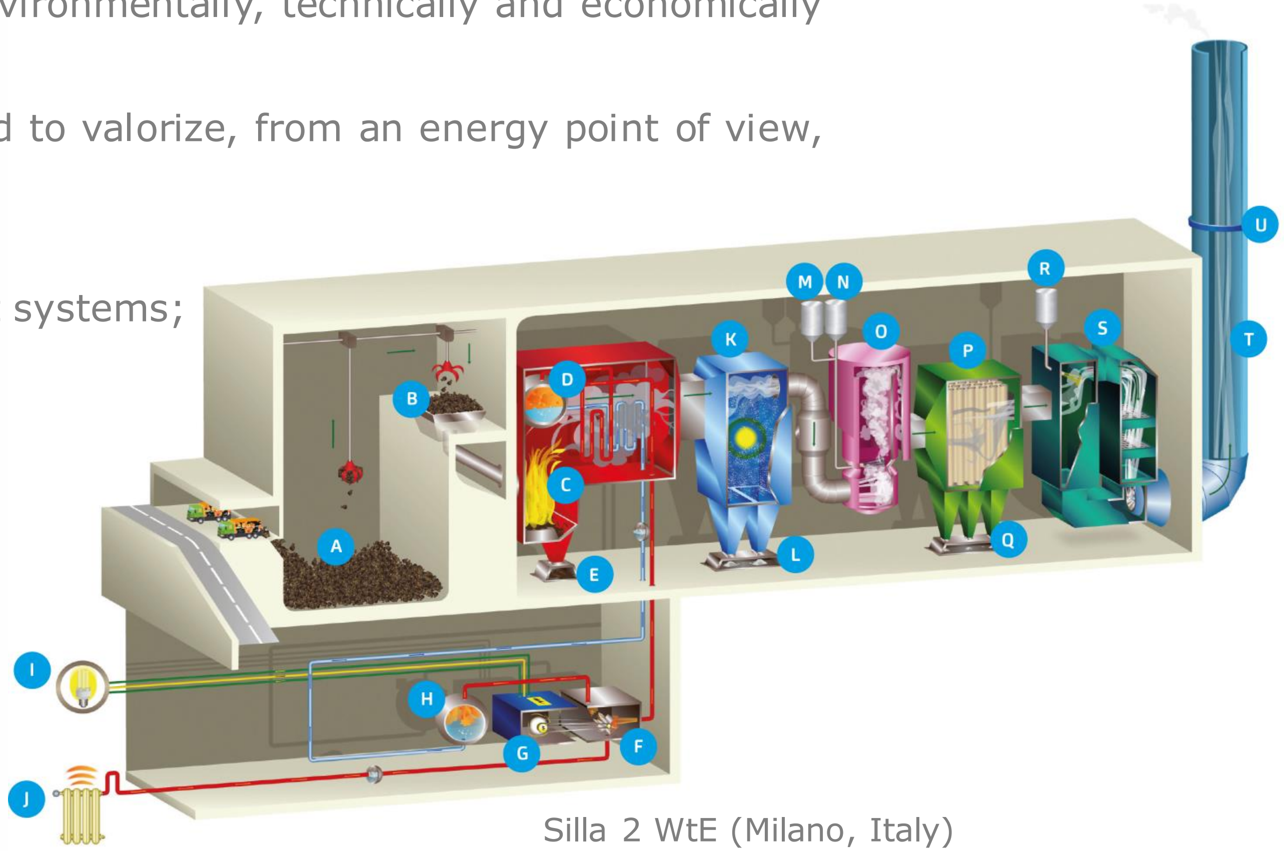
The waste-to-energy plant is an essential element in an environmentally, technically and economically sustainable waste management system.

WtE are necessary to minimize waste disposal in landfill and to valorize, from an energy point of view, non-recyclable waste.

Many different technical configurations of WtE are possible (different types of: combustion chamber; flue gas treatment systems; power cycle configuration).

Below is a typical configuration of A2A WtE.

- **A** Waste bunker
- **B** Waste hopper
- **C** Combustion chamber
- **D** Boiler
- **E** Bottom ash
- **F** Turbine
- **G** Generator
- **H** Condenser/ heat exchanger
- **I** Electric energy
- **J** Thermal energy (district heating)
- **K** ESP
- **L** Fly ash
- **M** Sodium bicarbonate
- **N** Activate carbon
- **O** Reactor
- **P** Fabric filter
- **Q** Dust
- **R** Ammonia
- **S** DeNO$_X$
- **T** Cimney
- **U** Emission control



Silla 2 WtE (Milano, Italy)

1.4 _ WtE flue gas characteristics – Silla 2 (Milano WtE – year 2022)

Parameter	Process (average)	Process (max)	Stack (average)	Stack – legal emission limits (daily average)
O_2 (%v)	7,95		10,45	
H_2O (%v)	14,58	26,64	13,97	
CO_2 (%v) (*)			10,08	
CO (mg/Nm³)	10,04	407,01	10,84	
HCl (mg/Nm³)	743,12	2658,94	2,37	5
NH_3 (mg/Nm³)	0,67	45,24	0,92	5
NOx (mg/Nm³)	349,89	538,67	37,77	60
SOx (mg/Nm³)	87,12	431,73	2,65	15
TOC (mg/Nm³)			4,64	5
Dust (mg/Nm³)			0,24	3

Process: boiler outlet flue gas, before treatment.

Stack: flue gas at the point of emission (chimney).

Three elements must be considered in the application of carbon capture in WtE:

- High oxygen concentrations (in the range of 8 to 13%v).
- Low CO_2 concentrations, around 9 – 10% (compared to the typical value for: TGCC of 4%v; coal-fired power plant 14%v).
- Presence, although in small concentration, of some pollutants that can be critical for some types of carbon capture technologies. For example, SOx for MCFC.

1 _ CARBON CAPTURE IN WTE SECTOR

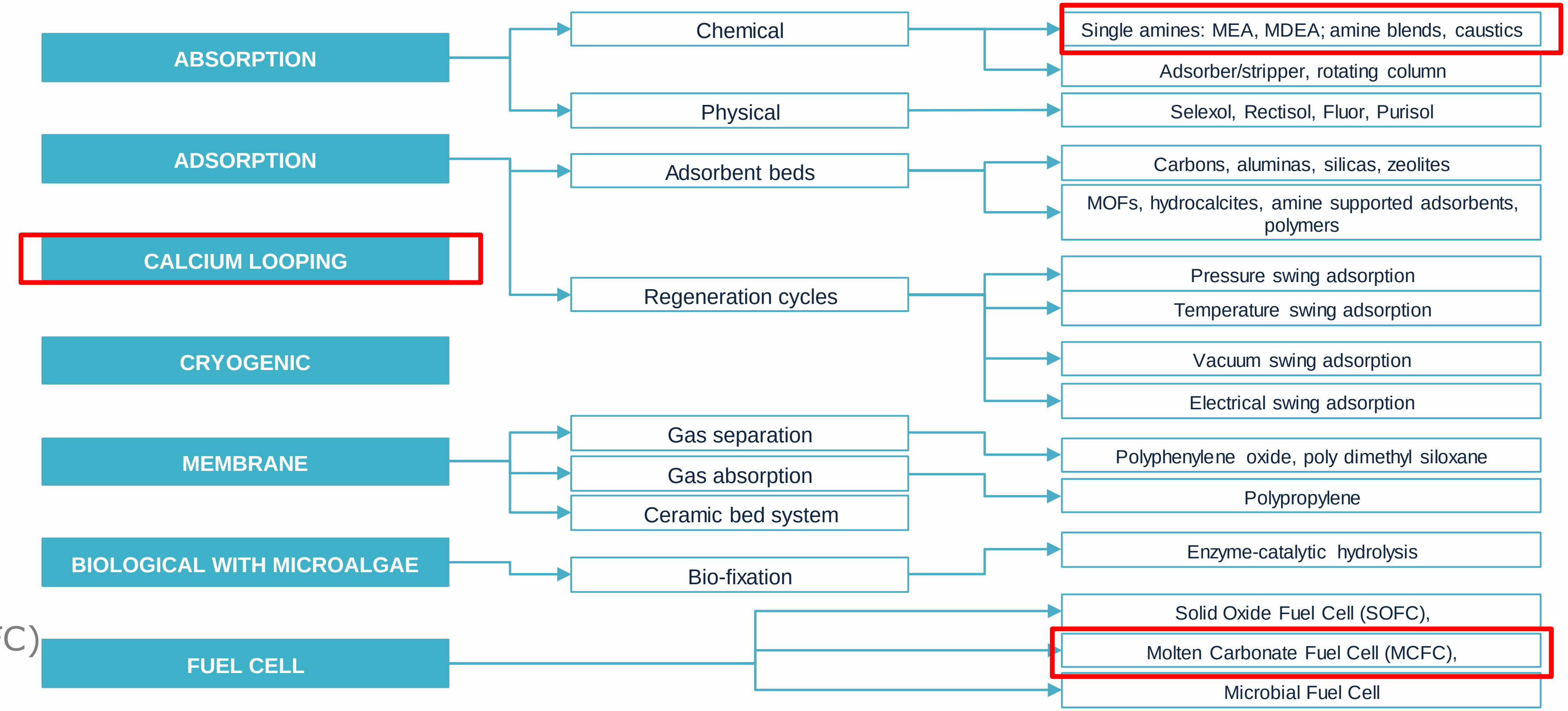
1.5 _ Carbon Capture technologies

Carbon capture technologies can be classified into **three main families**: pre-combustion, oxy-combustion and post-combustion.

The same technology can have different **Technological Readiness Level** (TRL) Depending on the specific application.

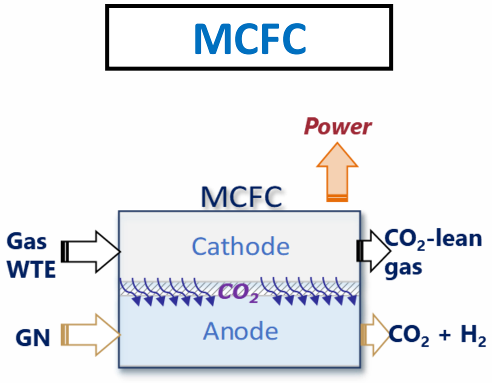
Three of these technologies are currently the most promising, for WtE applications:

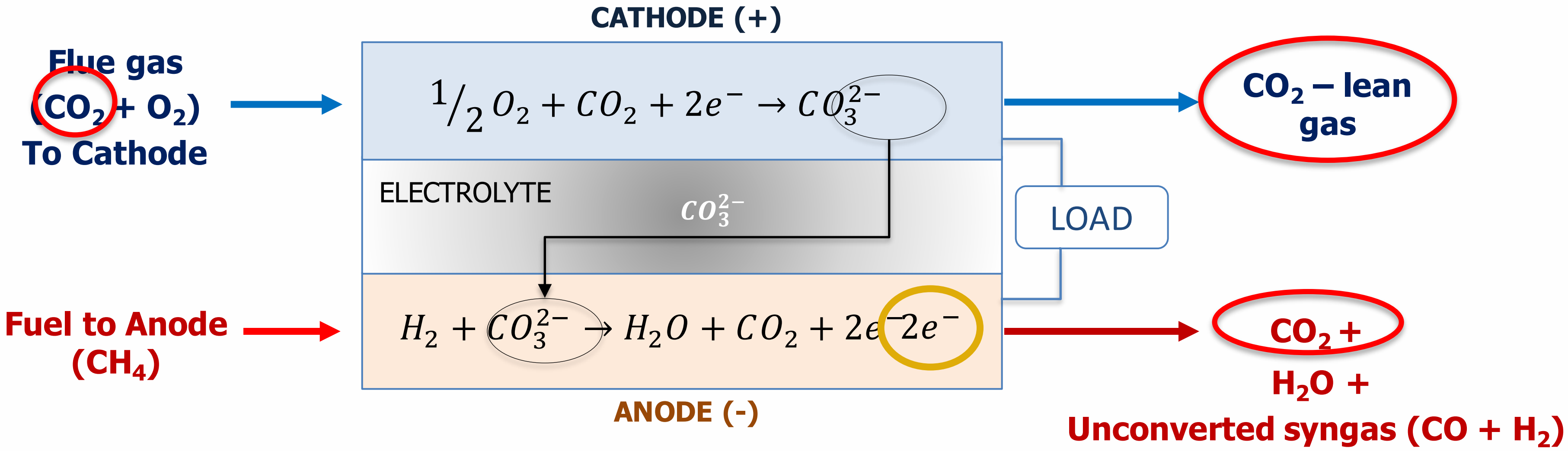
- Amines.
- Molten carbonate fuel cells (MCFC)
- Calcium Looping.



This slide was kindly provided by Maurizio Spinelli (researcher at Leap - https://www.leap.polimi.it/)

1.5 _ Carbon Capture technologies - MCFC





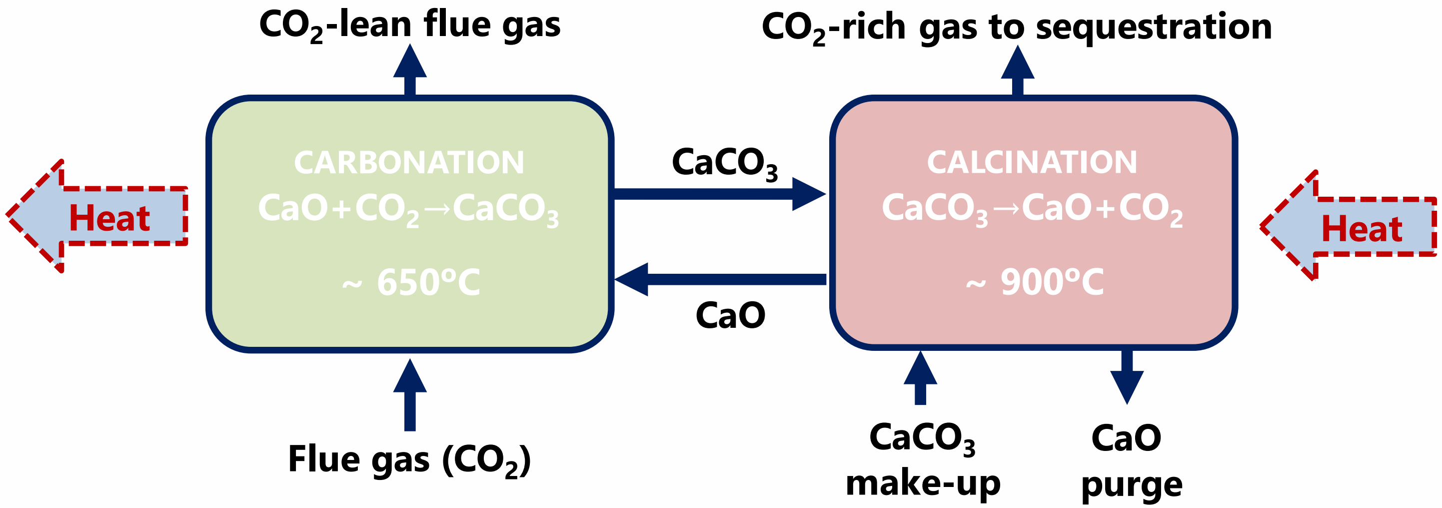
- MCFCs are fed by natural gas (NG) or other gaseous fuels converted into H_2 and electricity with high efficiency (up to~50%)
- They require a simple CO_2 purification unit (CPU) for (i) separating unconverted syngas and (ii) reaching CO_2 purity specifications
- CO_2 can potentially be captured to 90%, while enhancing electrical and thermal output of the host plant
- They have been lab tested for CO_2 capture from flue gas of coal- and NG-fired plants, but never on flue gas from WtE plants
- Low tolerance against side pollutants (e.g. SO_2, metals)
- They feature very high CAPEX and OPEX (limited durability of the active layers of MCFC stacks, that must be substituted every 5-7 years)

1.5 _ Carbon Capture technologies - Ammine

Ammine are a commercially available technology with a high CO_2 capture efficiency (over 90%) but currently characterized by high energy consumption per ton of CO_2 captured

More information on amine technologies will be provided in the next slides by TPI, an EPC contractor with great expertise in this technology.

1.5 _ Carbon Capture technologies - Calcium Looping



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- The sorbent is regenerated by the reverse reaction (calcination, $CaCO_3$+heat -> CaO + CO_2) sustained by oxyfuel combustion
- A continuous sorbent make-up (and a corresponding purge) is required to keep high reactivity and low ash build-up
- The high quality CaO-rich purge can be valorized as raw material for the production of clinker, cement or binders

1.5 _ Carbon Capture technologies – Calcium Looping

From the point of view of A2A, owner and operator of waste-to-energy plants, the Calcium Looping technology presents several positive and critical aspects, which must be studied.

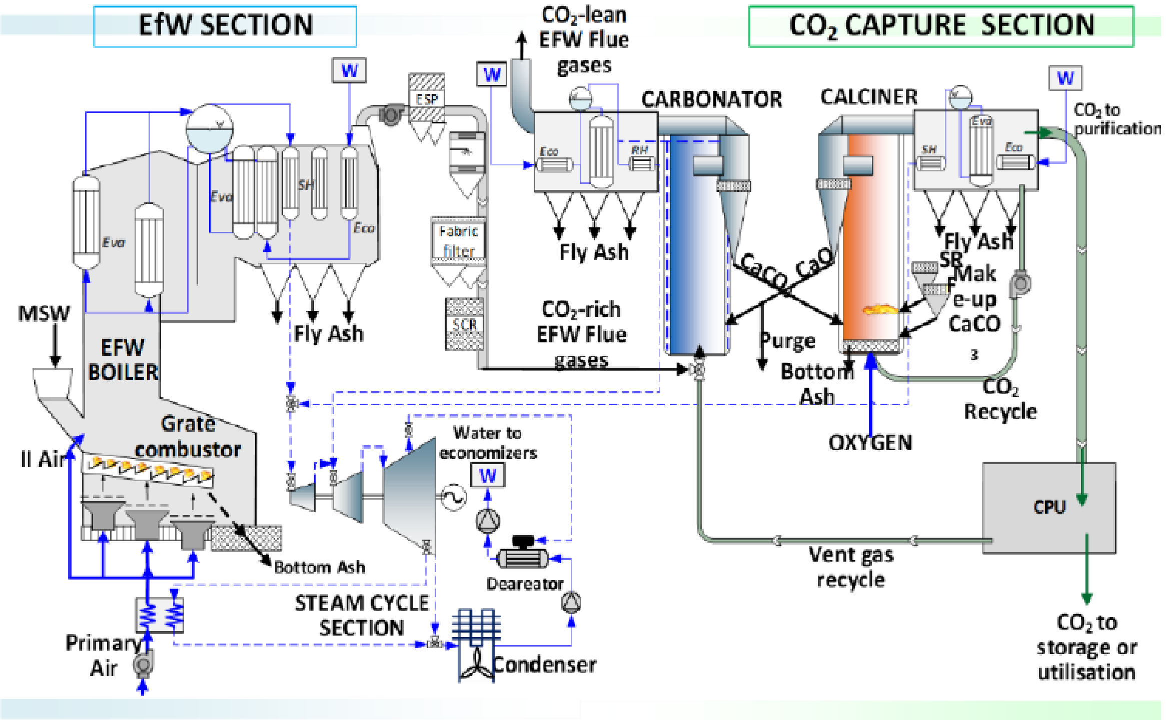
plant or construction of a completely new plant).

Positive elements:

- Possibility of integration with current waste-to-energy technologies.
- Use of recovered solid fuel (CSS) for the calcination process.
- High CO2 capture efficiency.

Critical aspects to investigate:

- Process complexity (power cycle integration, treatment of combustion gases entering the CPU, ..).
- Implementation cost (two possible options: revamping of an existing plant or construction of a completely new plant).



Conceptual configuration of an integrated EfW+CaL power plant (by Herccules grant request documentation)

2.1 _ W.P.3 tasks and partners

- Task 3.1: Engineering and erection of the dual fluidized bed CaL pilot with the CO_2 Purification Unit (CPU)
- Task 3.2: Preliminary characterization of Ca-based sorbents exposed to waste and sludge derived flue gases
- Task 3.3: Demonstration of the EfW-CaL system at TRL7-8
- Task 3.4: Process simulations and economic analysis of pilot and full-scale plants, calculation of KPIs and comparison with benchmark processes

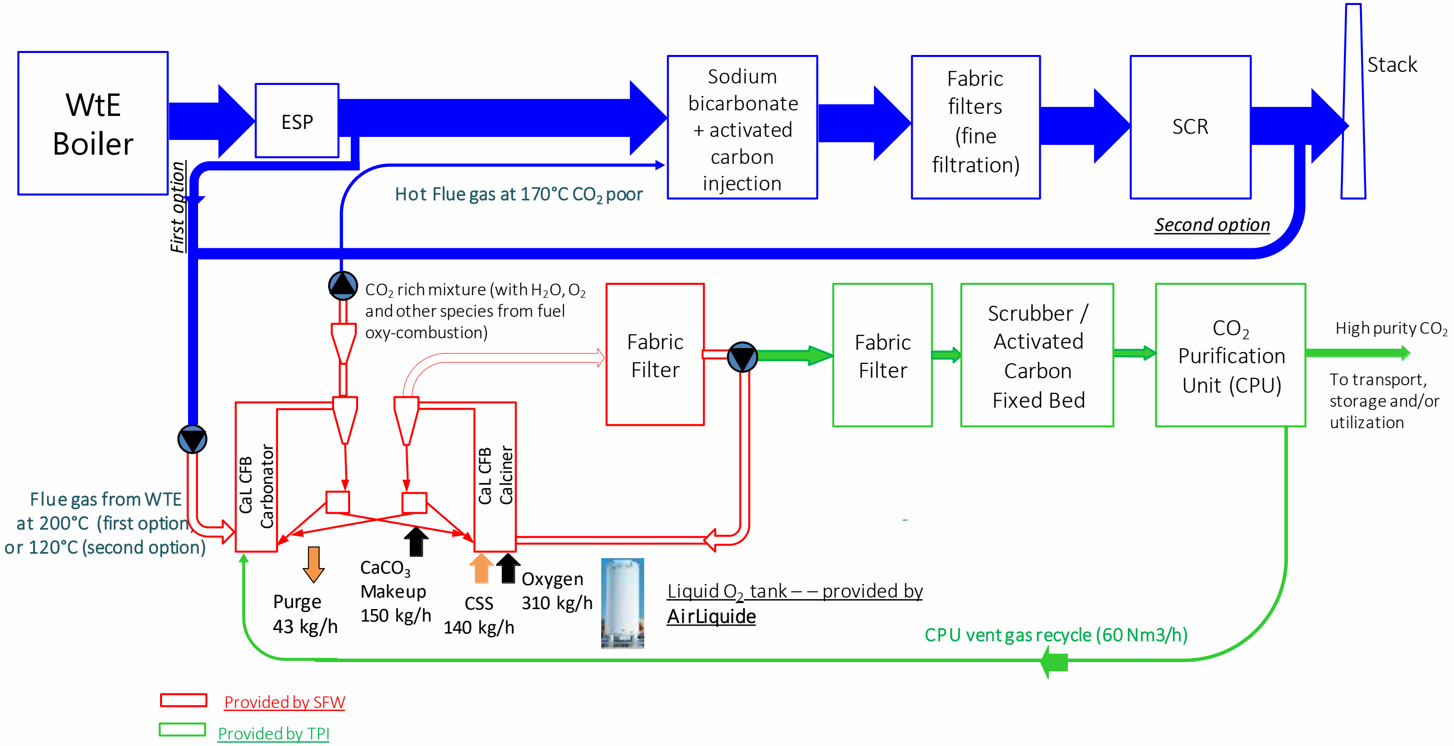
Number of international partner involved:

- Leap (LABORATORIO ENERGIA AMBIENTE PIACENZA) and Polimi (POLITECNICO DI MILANO), for scientific coordination
- CSIC (AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS), support at test matrix definition and Ca-based sorbent characterization
- LUT (LAPPEENRANNAN-LAHDEN TEKNILLINEN YLIOPISTO), performing CFD simulations of the oxyfuel calcination
- Sumitomo FW, technological provider leader in Calcium Looping technology (CaL unit engineering, construction and maintenance)
- Tecno Project Industriale, technological provider leader in CO2 Recovery Plants and biogas treatment process
- Air Liquide, technological provider responsible for liquid oxygen tank engineering, construction and maintenance and and the service for the collection and valorization of the captured CO_2
- A2A leader of WP3, owner and operator of the WtE plant in Milan, responsible for the connection of the pilot plant to the WtE in Milan and its operation.

2.2 _ CaL pilot plant scheme

MAIN DATA

- Flue gas in input at the carbonator: 1,500 Nm³/h
- Cumulated hours of testing: > 4,000 hours
- Two kind of test:
  - at least 20 short tests;
  - 2 long duration tests (8 weeks each).
- SRF consumption: <200 kg/h
- Carbon dioxide captured: 2,500 t (cumulative value)



2.3 _ CaL pilot plant installation site

WtE Plant Milan – main data:

529.000 t/year
WASTE BURNED
covers the need for Milan city and part of the hinterland

352 GWh/year
ELECTRIC PRODUCTION
covers the need for 130.000 households

481 GWh/year
THERMAL PRODUCTION
covers the need for 40.000 households

WtE Plant Milan – CaL Pilot Plant Installation Site

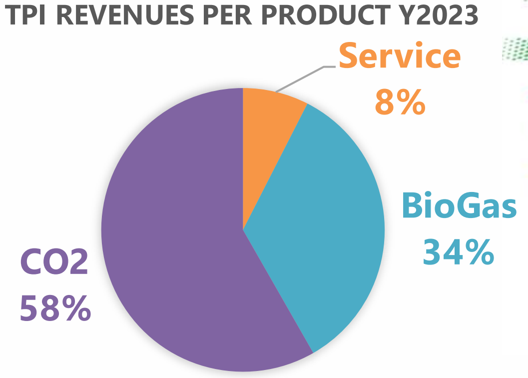
3 _ TPI company

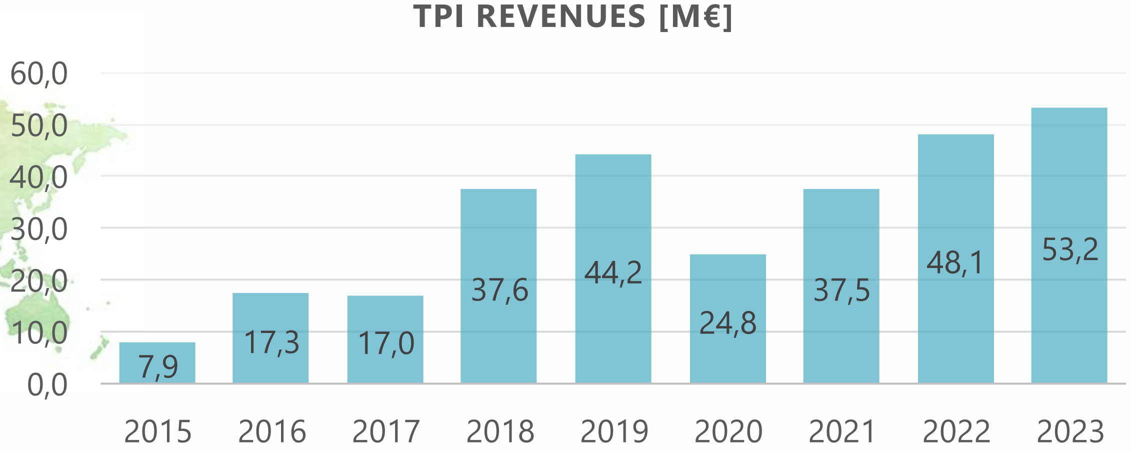
Design, production and installation of **CO_2 Carbon Capture and CO_2 Recovery and Liquefaction Plants** for all its applications according ISBT and EIGA quality guidelines

Design, production and installation of **Biogas Upgrading Plants**

With the support of SIAD, TPI offers optimized solutions for **Biomethane liquefaction**

Full range of **integrated service solutions**, digital services and aftersales. Remote supervision and direct access to After Sales Support - 24/7





3 _ TPI company

* list not exhaustive (TPI supplies covered by NDA)

3 _ TPI company

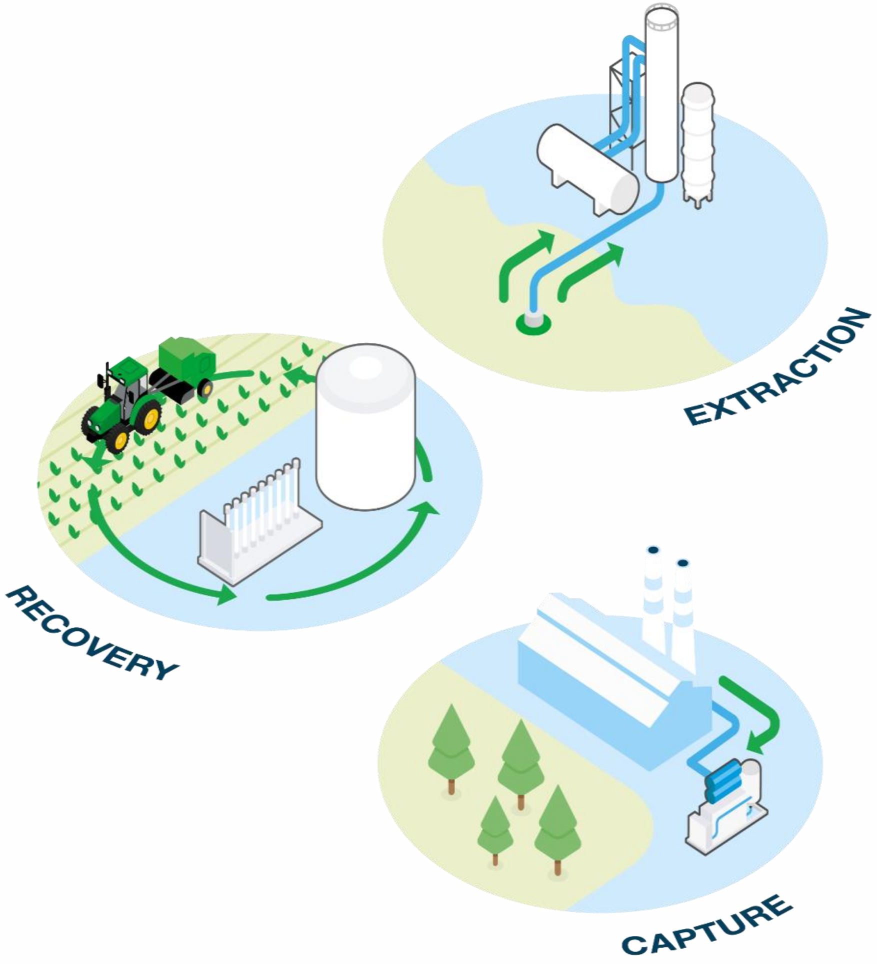
TPI's expertise in CO_2 recovery encompasses Carbon Capture systems and liquefaction process.
Depending on CO_2 concentration of the flue gas sources:

- Rich → CO_2 > 95% → Only liquefaction needed
- Medium → CO_2 > 40%
- Poor → > 10 %

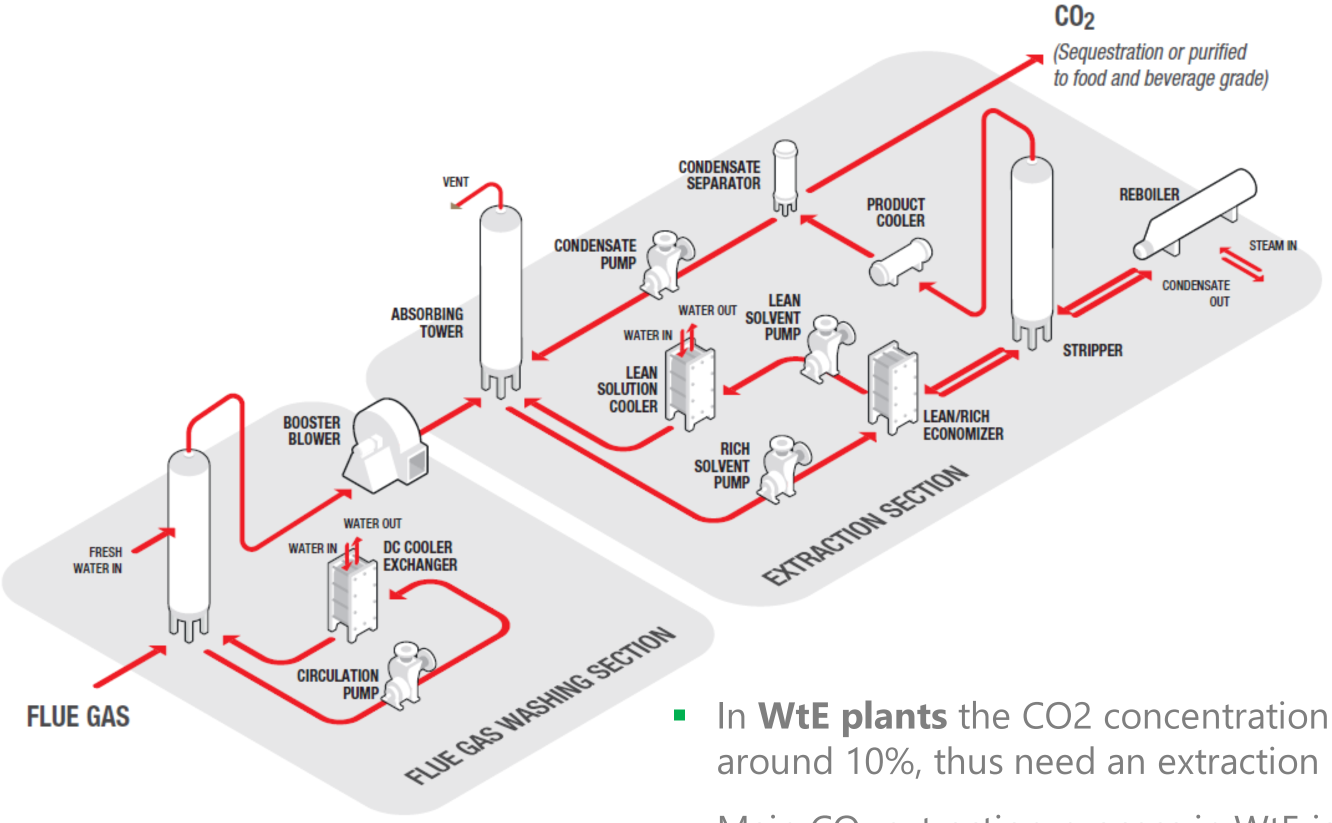
(Medium and Poor) → Need extraction process

General sources of CO_2 are:

- **Natural**
  - Deep wells
  - Natural Gas
- **Waste streams from chemical process**
  - Ammonia (NH_3) synthesis
  - Ethylene Oxide
  - Bioethanol
  - Steam Reforming
  - Flue gas from combustion processes
- **Biological processes**
  - Fermentation (bioethanol production)
  - Biogas

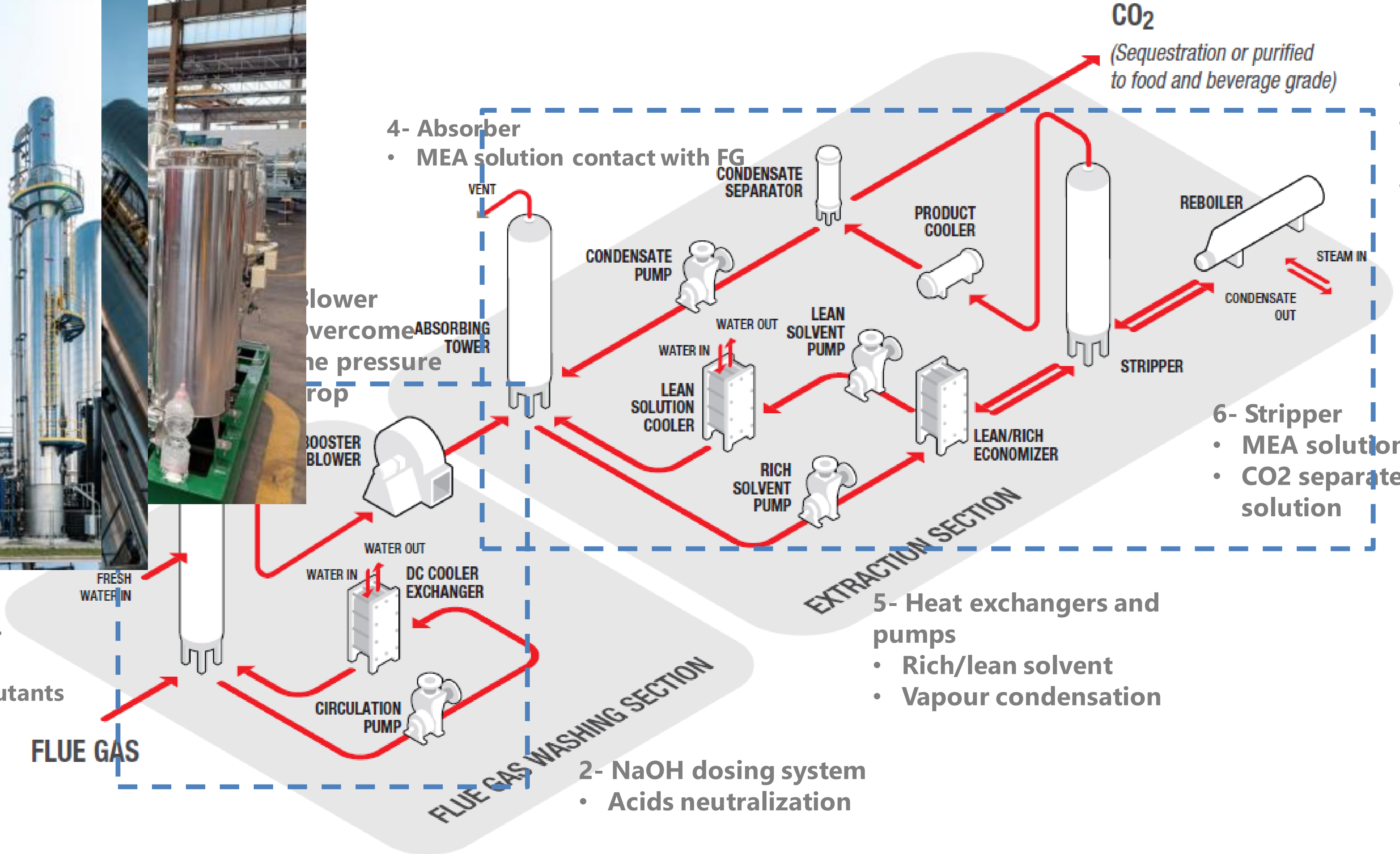


3 _ CO2 capture plant in Duiven WtE



- In **WtE plants** the CO2 concentration in the flue gases is around 10%, thus need an extraction section
- Main CO_2 extraction process in WtE is with **amine solution**
- Further purification and liquefaction steps are needed to reach **food quality CO_2**
- One of the biggest application of the TPI CO2 capture technologies in WtE plant is in AVR, **Duiven**, the Netherlands

3 _ CO2 capture plant in Duiven WtE



4- Absorber
- MEA solution contact with FG

lower
vercome
he pressure
rop

7- Reboiler
- Heat source equipment
- Saturated steam (150 °C @3,5 – 4 barg)

6- Stripper
- MEA solution heating
- CO2 separated from MEA solution

1- FG washing tower
- FG cooling
- Condensable pollutants abatement

5- Heat exchangers and pumps
- Rich/lean solvent
- Vapour condensation

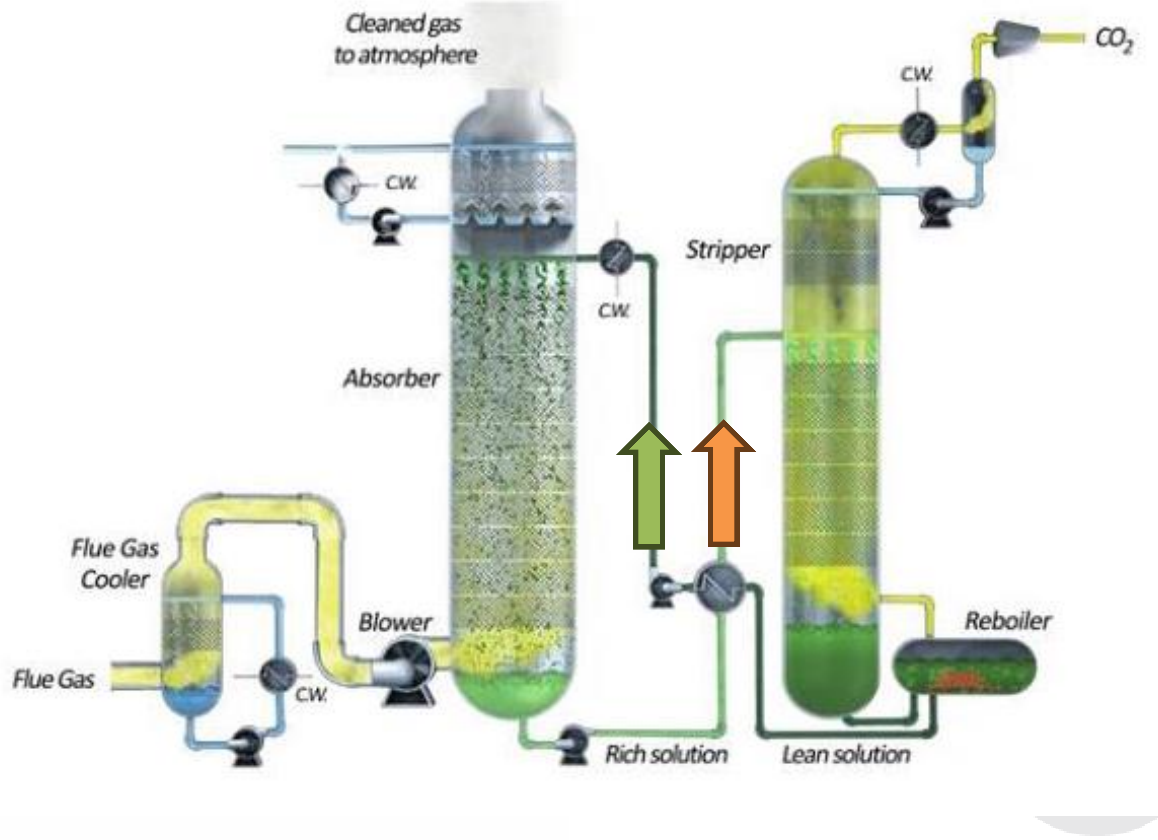
2- NaOH dosing system
- Acids neutralization

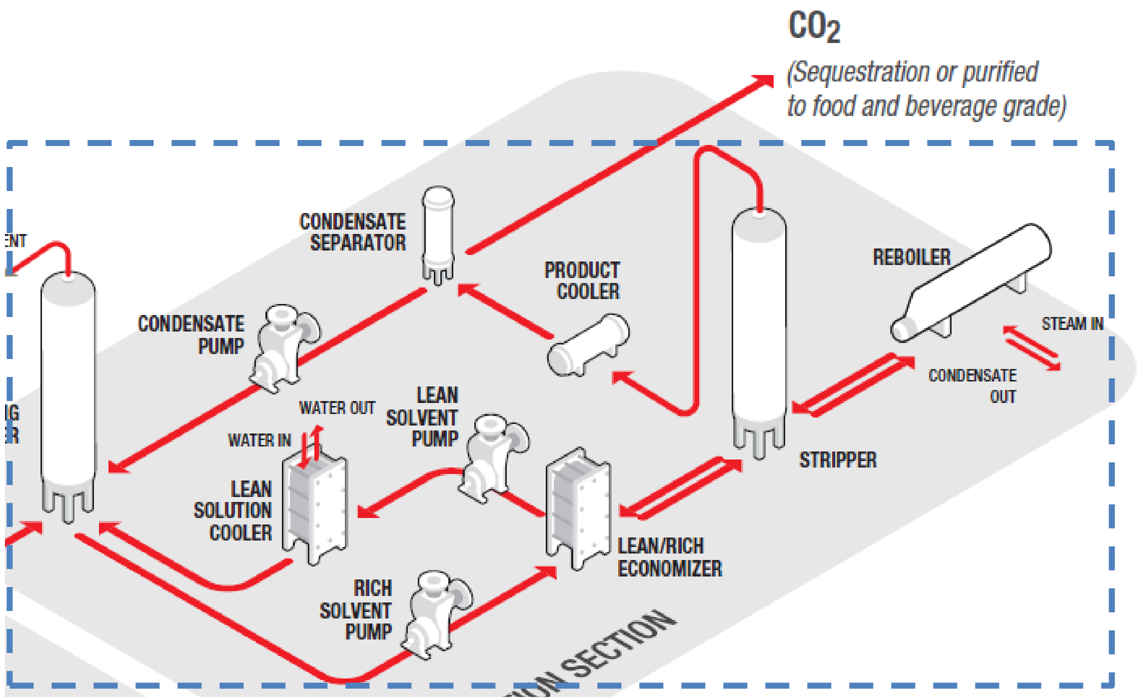
3 _ CO2 capture plant in Duiven WtE

Source: R. Anantharaman–Lookingbeyondsolventsfor CO2capturein WtEplants–a R&D perspective–Prewinmeeting 16-17/06/2022, Oslo

LEAN Solution

RICH Solution





- **Absorber tower:** amine solution meet CO2 and bound forming RICH solution
- RICH solution is pumped in stripping tower and heated in reboiler.
- **Stripping tower:** the release vapor of solvent, water and CO2 in condenser separator.
- CO2 is directed to recovery & liquefaction while the LEAN solution is pumped back in absorber tower

3 _ CO2 capture plant in Duiven WtE

RESULTS FROM EXTRACTION SECTION

- From a CO_2 concentration at the inlet of the CO_2 capture plant of **around 10%**
- After the extraction section, a CO_2 gas stream with **95% purity** is ready for recovery and liquefaction unit

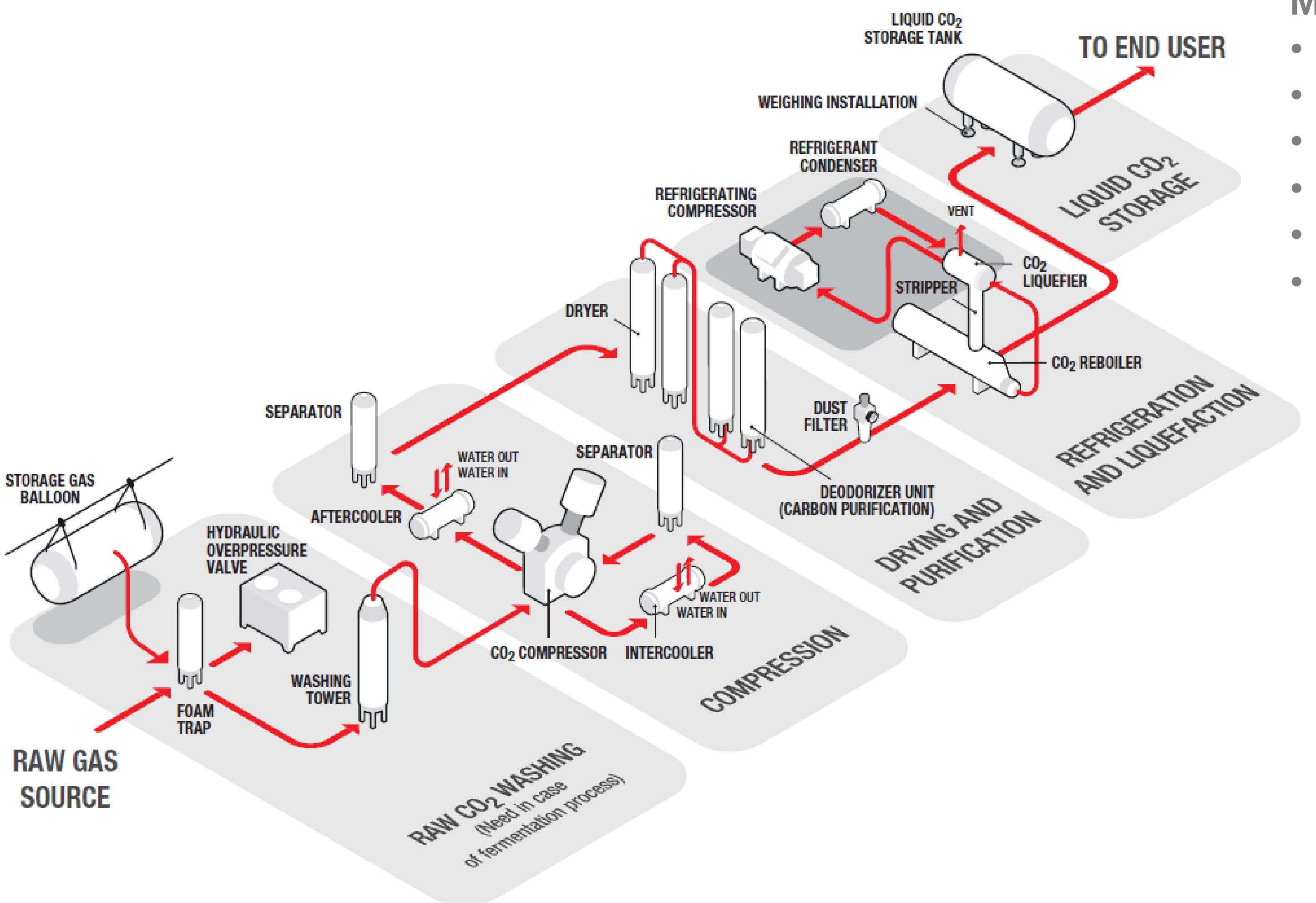
UTILITIES

- **MEA consumption**: the «dirtier» the gas, the higher the consumption. It can be considered 2.5 – 3.0 kg MEA per ton LCO_2 extracted

- **Steam consumption**: it can be considered 1.8 – 2.0 kg steam/kg LCO_2 extracted

- **EE consumption**:
  - Extraction system: 220 - 250 kW/ton of LCO_2 produced
  - Next EE consumption → CO_2 recovery system: around 180 kW/ton of LCO_2 produced

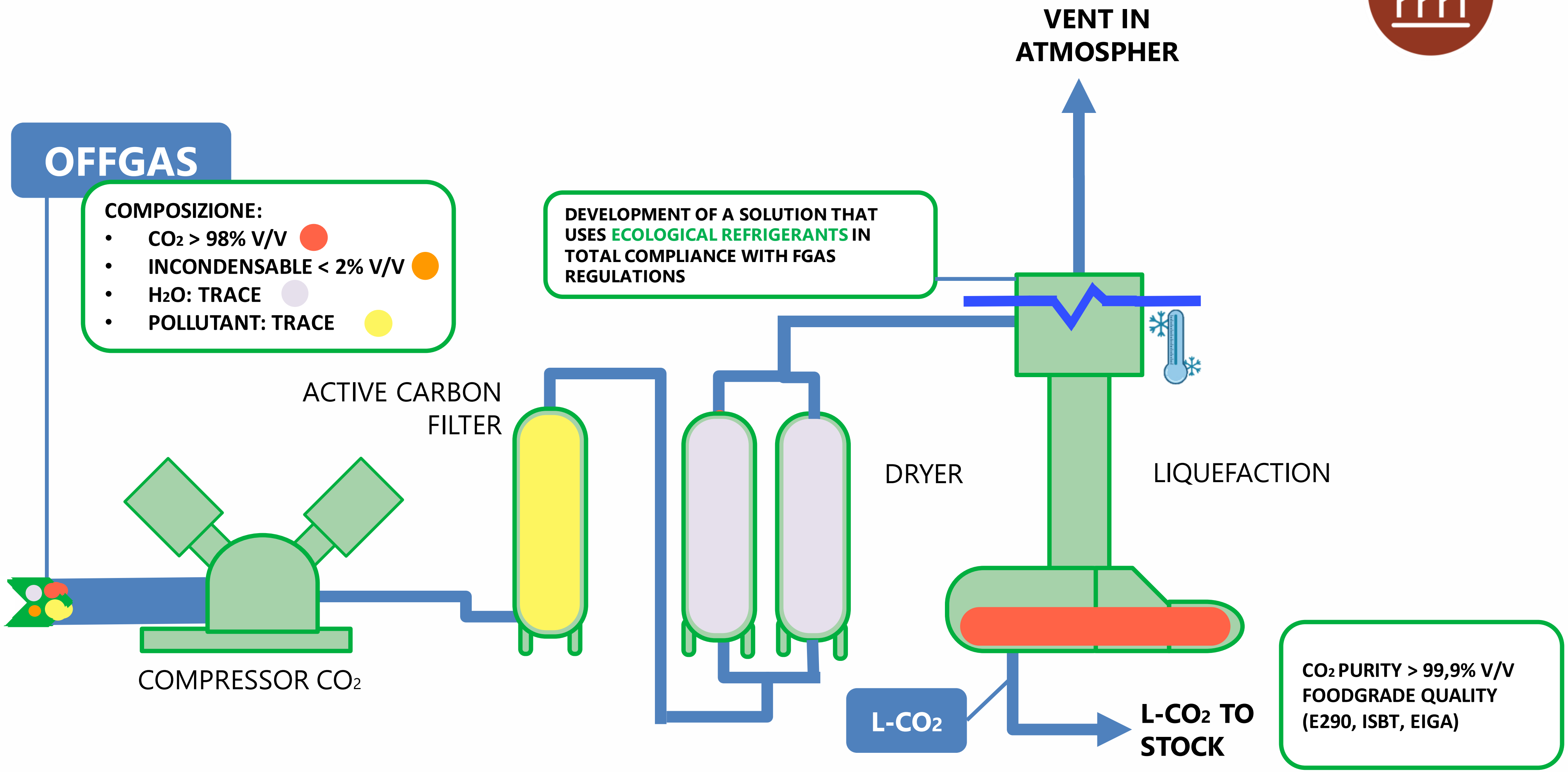
1 _ CO2 recovery and liquefaction section



Main equipments:

- Raw CO2 washing system (optional)
- CO2 compressor
- Dryers and purifiers
- CO2 liquefaction unit
- Refrigerant system
- Liquid CO2 storage

1 _ CO2 RECOVERY AND LIQUEFACTION PLANTS



3_ LCO2 storage tanks

- Final product has **CO_2 purity > 99,9%v/v**
- **CO_2 is storaged in cryogenic tanks:**
  - pressure at 11 / 18 barg
  - temperature between -35 / -20 ° C
- Lastly, transfer pumps are used to fill roadtanks

Image taken from AVR website - https://www.avr.nl/en/

3_ Some pictures from The Netherlands

3D model from Press release – 29-05-2018 – AVR website - https://www.avr.nl/en/

Image taken from AVR website - https://www.avr.nl/en/

3_ Some pictures from The Netherlands

Images taken from AVR website - https://www.avr.nl/en/

CCUS ZEN

HERCCULES

full CCUS chain demonstration

GRAZIE PER L'ATTENZIONE

THANKS FOR YOUR ATTENTION