INITIATE
A STEPWISE PROJECT

CO_2 Capture Process Integration

Final Modelling Step to Determine the Overall Plant KPIs

Nicola Zecca, Politecnico di Milano

26/09/2022

The INITIATE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958318

PUBLIC

Presentation outlines

1	**General plant design criteria**
2	Integration of CO_2 carbon capture technologies in the overall plant flowsheet: steps to be followed
3	An example: the INITIATE project

Plant design criteria

- Definition of the **basis of design** (BoD): assumptions, requirements and boundary conditions of the project

- **Compression** at **low temperatures**

- **Heat exchange** between sources at **similar temperatures**

- **Exploitation** of available **waste heat**
    1. minimizes the consumption of fossil fuels
    2. decreases the Primary Energy Consumption
    3. decreases the CO_2 emissions
    4. decreases the SPECCA
    5. increases the Carbon Avoidance of the system
    6. decreases the Cost of CO_2 Avoided

Presentation outlines

1	General plant design criteria
2	**Integration of CO_2 carbon capture technologies in the overall plant flowsheet: steps to be followed**
3	An example: the INITIATE project

Methodology

General steps to be followed

1. Definition of the condition to be met at the inlet of different equipment/sections of the plant (i.e. **temperature**, **pressure**, **streams composition**)

2. **First design** and **simulation** of the plant without heat integration

   ⟶ Preliminary heat and mass balances

3. **Heat integration**

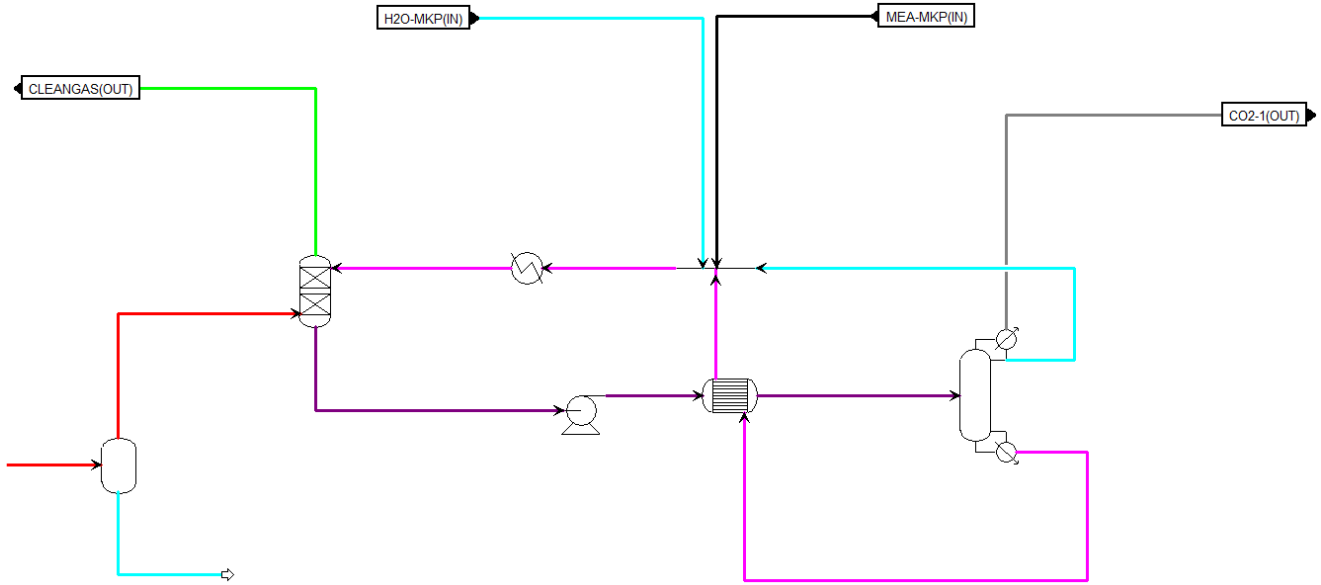
   1. **minimize** the **energy consumption** within the plant exploiting the available waste heat
   2. use, when possible, the **decarbonized** streams as **fuel** to produce additional steam
   3. if point 1 and 2 are not enough to fulfil the energy requirement, consider to supply heat with external sources (i.e. fossil fuels)

4. Calculation of the **KPIs**

Tools

- Integration of carbon capture technologies in the overall plant layout:
  - **different technologies ⟶ different energy requirements**

- Tools: **Aspen Plus**
  - Model of the whole system to **compute** the **energy requirement of a CO_2 capture process** and to understand the best way to fulfil it



Example: Aspen Plus model of MEA carbon capture section

Presentation outlines

1. General plant design criteria
2. Integration of CO_2 carbon capture technologies in the overall plant flowsheet: steps to be followed
3. **An example: the INITIATE project**

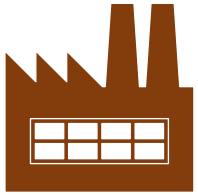
A real case: the INITIATE project

- Production of **urea** from **residual steel gases** instead from natural gas → **Industrial symbiosis**
- Carbon capture technology: **Sorption Enhanced Water Gas Shift**
- The residual steel gases, mainly composed by CO, CO_2, H_2, N_2 are treated in the WGS + SEWGS unit to produce an **H_2/N_2** stream suitable for **ammonia** production and a **CO_2 stream**, partly used for **urea** synthesis and partly sent to **storage**

A real case: the INITIATE project

SEWGS technology

- What is necessary to take into account when the SEWGS carbon capture process is integrated in the plant layout?
  1. SEWGS inlet **temperature**
  2. SEWGS working **pressure**
  3. SEWGS **steam demand**
  4. WGS reactor(s) inlet **temperature**
  5. WGS reactor(s) working **pressure**
  6. WGS reactor(s) steam **demand**



BF/BOF steel mill

Steel products

BFG/BOFG
~ 1 atm

CO_2 to storage

CO_2 pipeline

CO_2 pressure for storage: 110 bar
Constraints on CO_2 purity and on contaminants

Urea

Compressor outlet pressure: $P_{in,WGS}+\Delta P_{HX}$

CO_2

NH_3

Urea synthesis

Compressor

CO_2 compression

Steam production:
Consider the possibility to use part of H_2/N_2 stream as fuel

CO_2 free flue gas

WGS inlet temperature: 300-320 °C
WGS inlet pressure: $P_{in,SEWGS}+\Delta P_{WGS}+\Delta P_{HX}$
Steam consumption:
↑steam → ↑performances

Water Gas Shift

CO_2

Ammonia syntheisis

Compressor outlet pressure: >250 bar
Depends on ammonia loop design pressure

Steam

H_2/N_2

H_2/N_2

SEWGS

SEWGS inlet temperature: 400°C
SEWGS inlet pressure: 8-32 bar
x_{CO} at SEWGS inlet: ~5%
Steam consumption:
↑steam → ↑performances

Methanator inlet temperature: 250°C
Constraints on ΔT along the reactor

Steam production:
exploiting the available waste heat

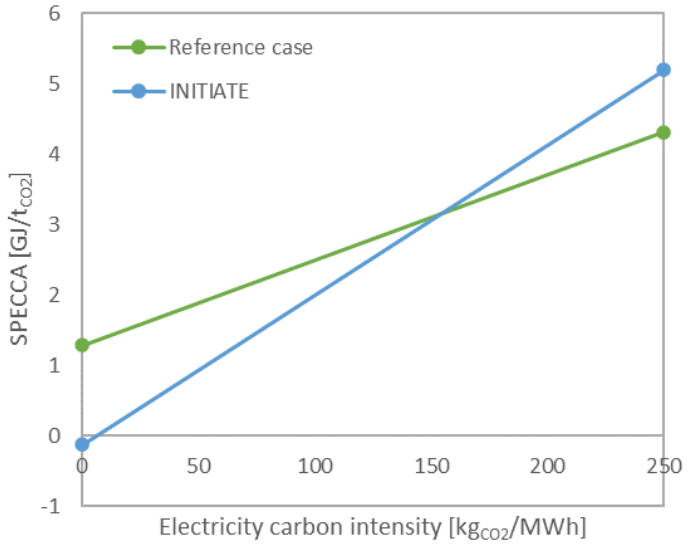
Compressor

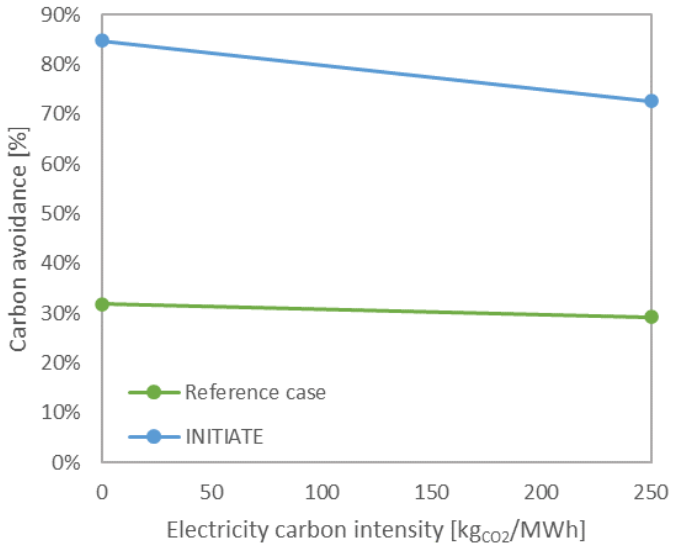
Methanator

Key Performace Indicators

		Base case	Reference case	INITIATE
Coal	[t/d]	6240	6240	6240
Natural gas	[t/d]	602	760	558
Electricity	[MW]	3	86	383
Steel	[t/d]	9249	9249	9249
Urea	[t/d]	1500	1500	1500
CO_2 emissions	[t/d]	18785	13301	5153
Total PEC	[GJ]	2.32E+05	2.40E+05	2.30E+05
Carbon avoidance	[%]		31.88	84.77
SPECCA	[GJ/t_{CO2}]		1.28	-0.13

Renewable energy scenario





Final remarks

- **Basis of Design** is **fundamental** and simplifies the following steps
- **Aspen Plus** main tool for plant simulation and for heat and mass balances
- Calculation of **KPIs**
- INITIATE project
  1. **Industrial symbiosis**
  2. **CA = 85%** in a renewable energy scenario
  3. **SPECCA < 0 GJ/t_{CO2}** in a renewable energy scenario


INITIATE
A STEPWISE PROJECT

INITIATE
A STEPWISE PROJECT

Nicola Zecca
nicola.zecca@polimi.it

The INITIATE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958318