INITIATE PROJECT

AMMONIA FROM STEEL GASES

NEXTCHEM

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01

INTRODUCTION

GENERAL INFORMATION

- ✓ Project title: "**Innovative industrial transformation of the steel and chemical industries of Europe**"
- ✓ Funding programme: EU HORIZON 2020 (H2020-LCCI-2020-EASME-singlestage / CE-SPIRE-01-2020)
- ✓ Duration: 54 months + 6 months of time extension (Start date: 1 November 2020 / End date: 30 October 2025)
- ✓ Keywords: Energy efficient industry, Decarbonisation, Automation and control systems
- ✓ Website: https://www.initiate-project.eu/
- ✓ LinkedIn page: https://www.linkedin.com/company/initiate-project/

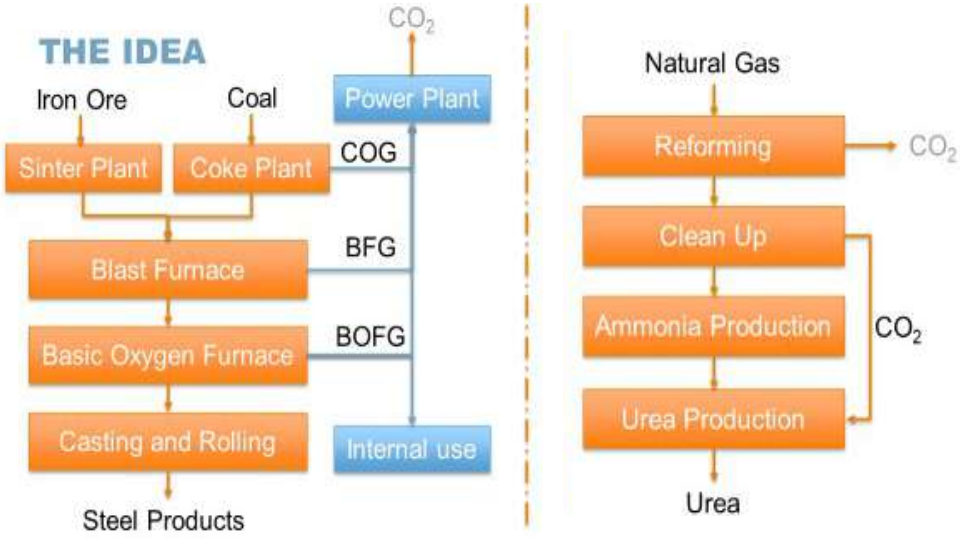
ABSTRACT

INITIATE proposes a novel symbiotic process to produce urea from steel residual gases. The project will demonstrate a reduction in primary energy intensity of 30%; carbon footprint of 95%; the raw material intensity of 40%; and waste production of 90%. Additional to this level of reduction, the concept represents a positive business case. INITIATE will demonstrate operating reliability and technology-based innovations in a real industrial setting at TRL7 by producing urea NH_3 from steel residual gases as part of three test campaigns spanning six weeks each. The reduction in primary energy intensity, carbon footprint, raw material intensity and waste production will be assessed and verified on a regional and European level by advanced dynamic modelling and Life Cycle Assessment commiserated with ISO 14404 guidelines.

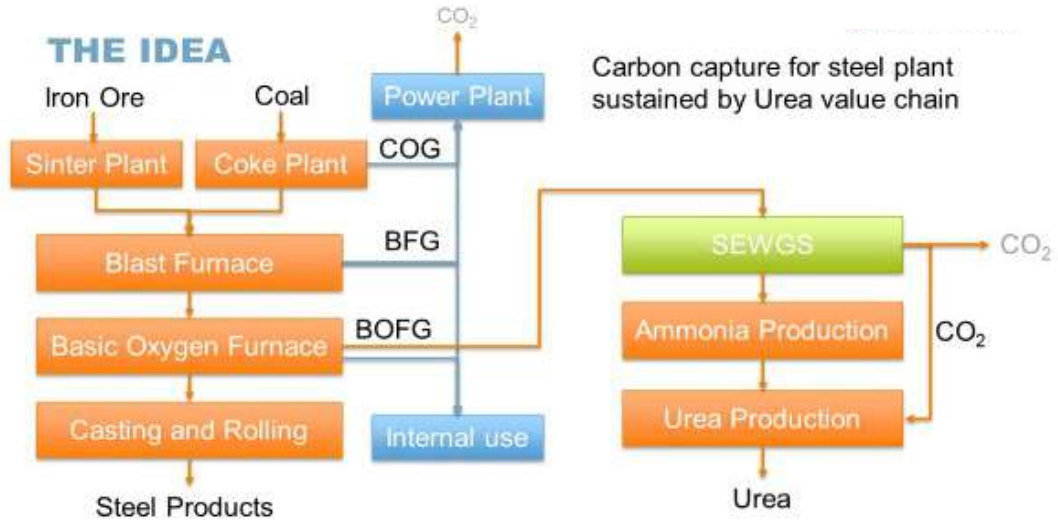
The project will develop a commercial implementation roadmap for immediate deployment of INITIATE after project conclusion and for ensuring roll-out of INITIATE and similar symbiotic systems. Designing a robust and bankable first-of-a-kind commercial plant to produce urea from residual steel gases will allow implementation after project conclusion. Long term roll-out will be enabled by defining collaborative strategy for stakeholders alignment to implement INITIATE and similar symbiotic systems. Finally, effective and inclusive communication and dissemination of project results are maximized by organizing summer schools and creation of Massive Open Online Course.

INITIATE will take advantage of a consortium spanning the full value chain, including major steel and urea industrial players (Arcelor Mittal, SSAB, Stamicarbon, NextChem), functional material suppliers (Johnson Matthey, Kisuma Chemicals), multi-disciplinary researchers (TNO, POLIMI, Radboud University) and experienced promoters of CCUS, circularity and symbiosis topics to public (CO_2 Value Europe).

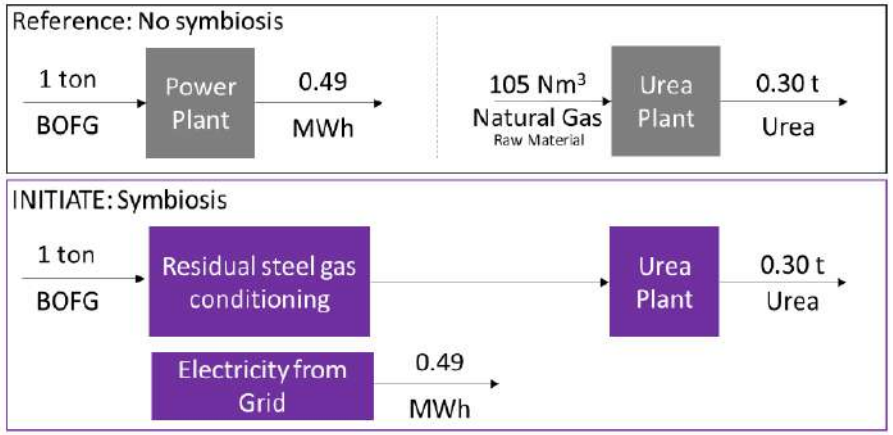
CONCEPTUAL SCHEME



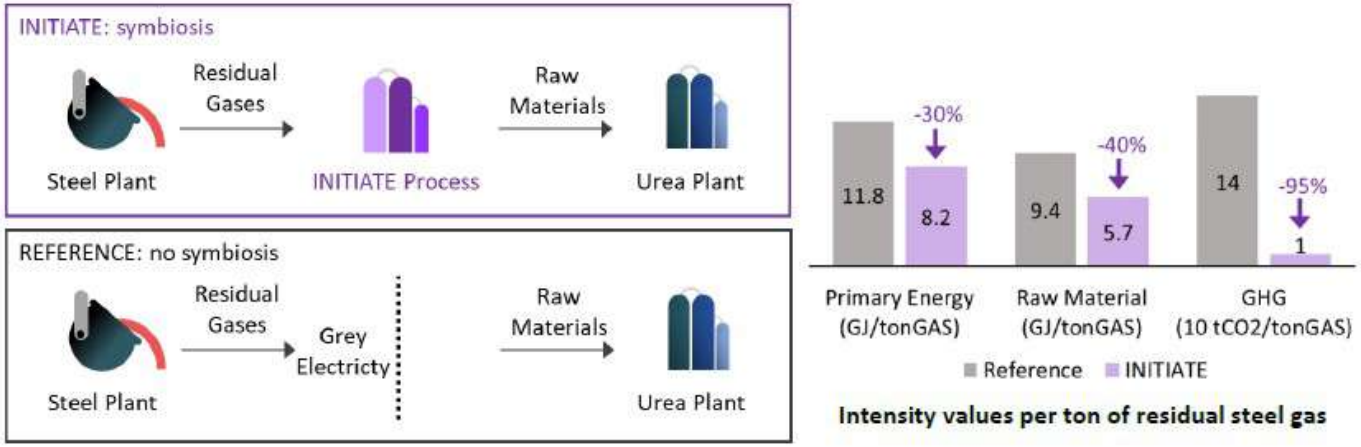
Conventional Iron & Steel making and Urea Production



INITIATE symbiotic production route

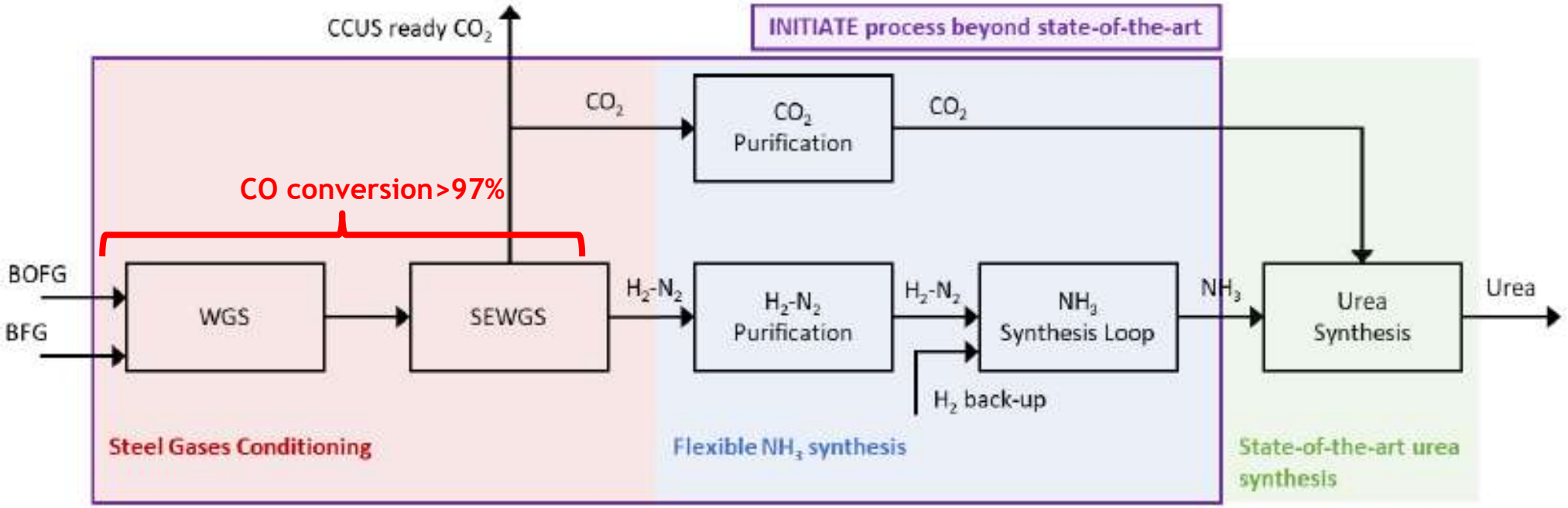


Reference and INITIATE system boundaries and main flows for 1 ton of BOFG (ref. unit)



On the left, the INITIATE symbiotic system and the respective reference system. On the right, estimated impacts

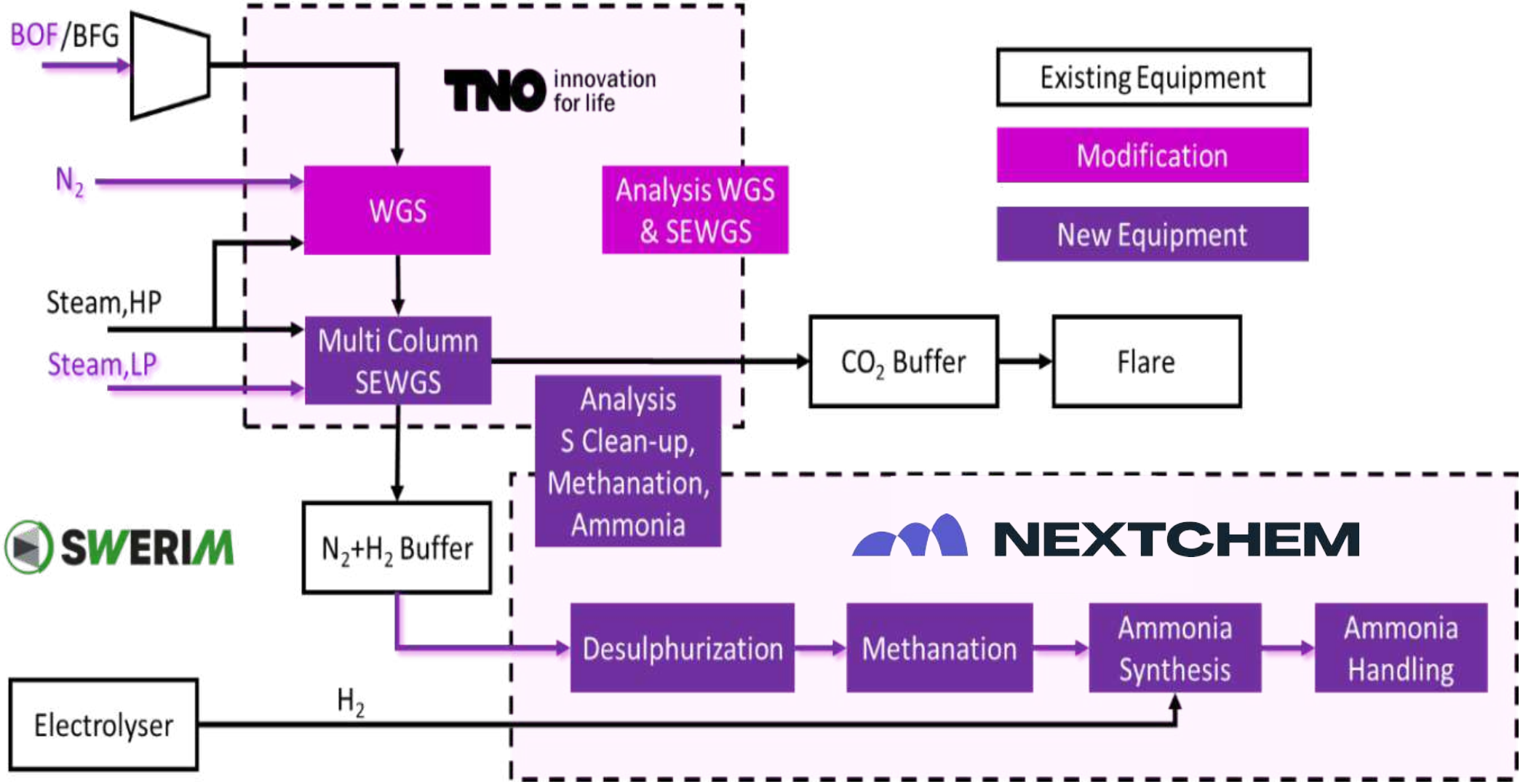
CONCEPTUAL SCHEME



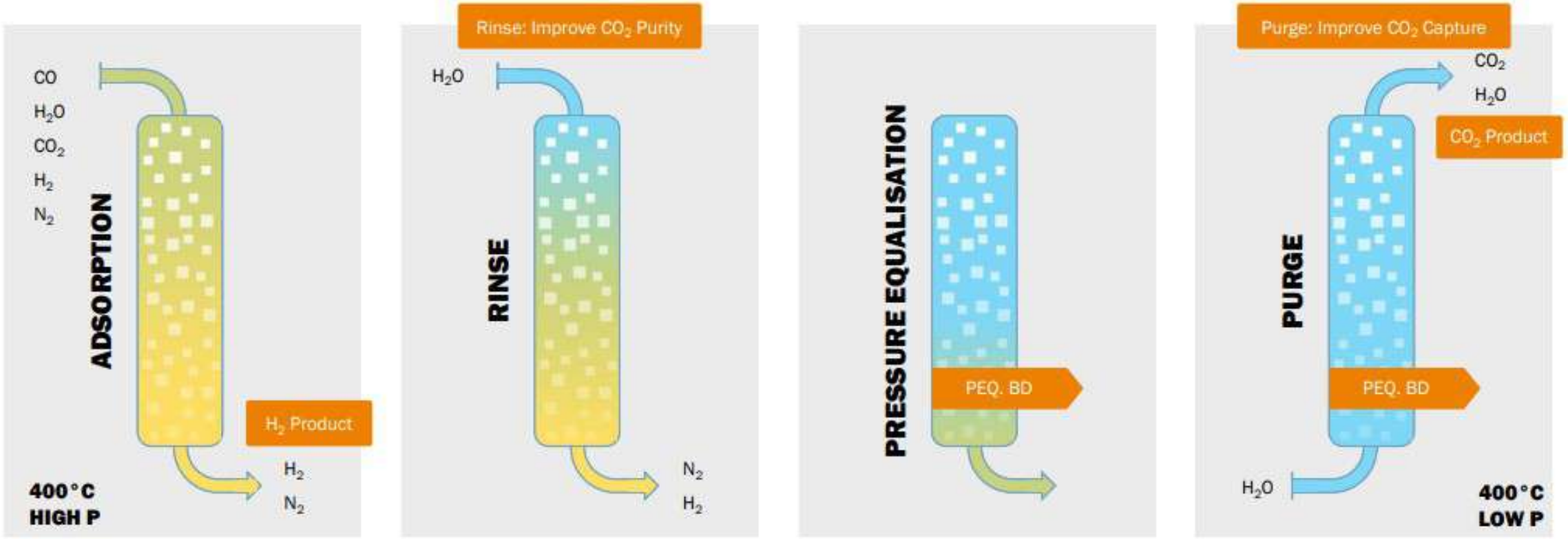
Block diagram of the INITIATE process technology for converting residual steel gases (BFG and BOFG) to urea

Legenda
- BOFG: Basic-Oxygen-Furnace-Gas
- BFG: Blast-Furnace-Gas
- WGS: Water Gas Shift
- SEWGS: Sorption Enhanced Water Gas Shift
- CCUS: Carbon Capture, Utilization and Storage

CONCEPTUAL SCHEME



CONCEPTUAL SCHEME



$CO + H_2O \rightarrow CO_2 + H_2$

$CO_2 + ads \rightarrow CO_2\text{-ads}$

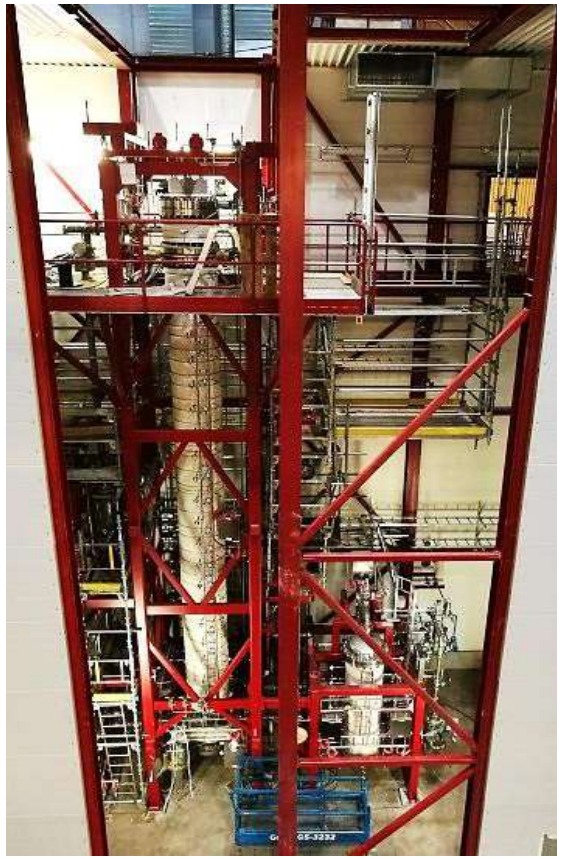
Functional material: K-promoted Mg/Al hydrotalcite | Active for both CO_2 capture and Water Gas Shift

In 2010, Kisuma partnered the TNO-owned technology platform focused on the steel industry, refineries and power industry to develop the Sorption Enhanced Water Gas Shift (SEWGS) technology.

CONCEPTUAL SCHEME

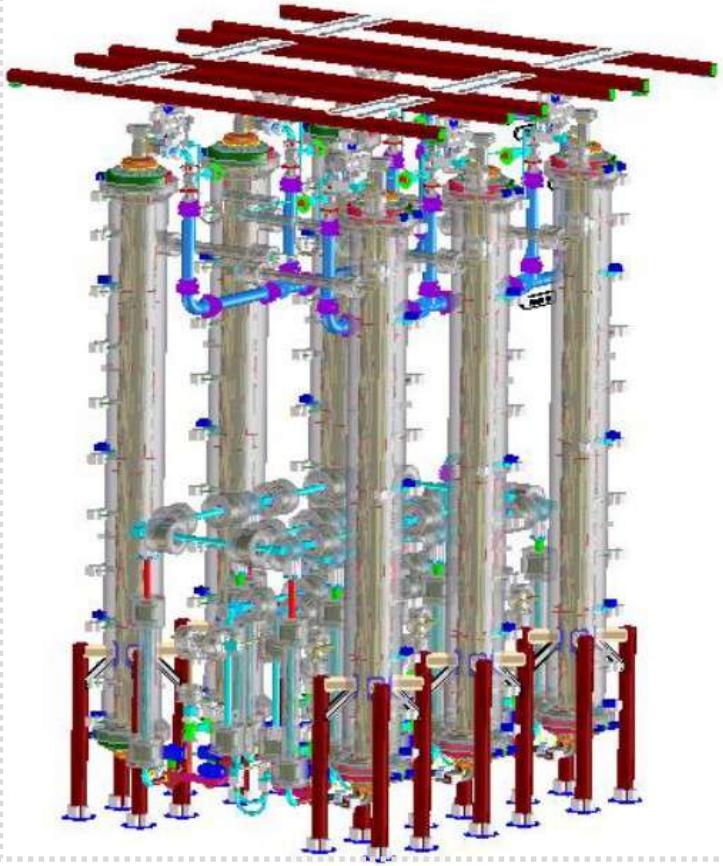
SEWGS installation:
- 10-m tall
- 40-cm diameter
- 3,000 kilos of Kisuma's sorbent material
- 14 tpd of CO2 as cyclic capacity

SEWGS – Single Column
STEPWISE PROJECT



TRL6

SEWGS – Multiple Columns
INITIATE PROJECT



TRL7

FUTURE PLANS

- TRL8 in 2026-2027
- scaling up to full commercialisation during 2028.

VISION AND ROUTE

VISION:

✓ Create a bankable case for the **First-Of-A-Kind (FOAK) plant** at the scale of **150 t_{Urea}/d** (~50 kt_{Urea}/y) to be realized within a timeframe of 5 years.

ROUTE:

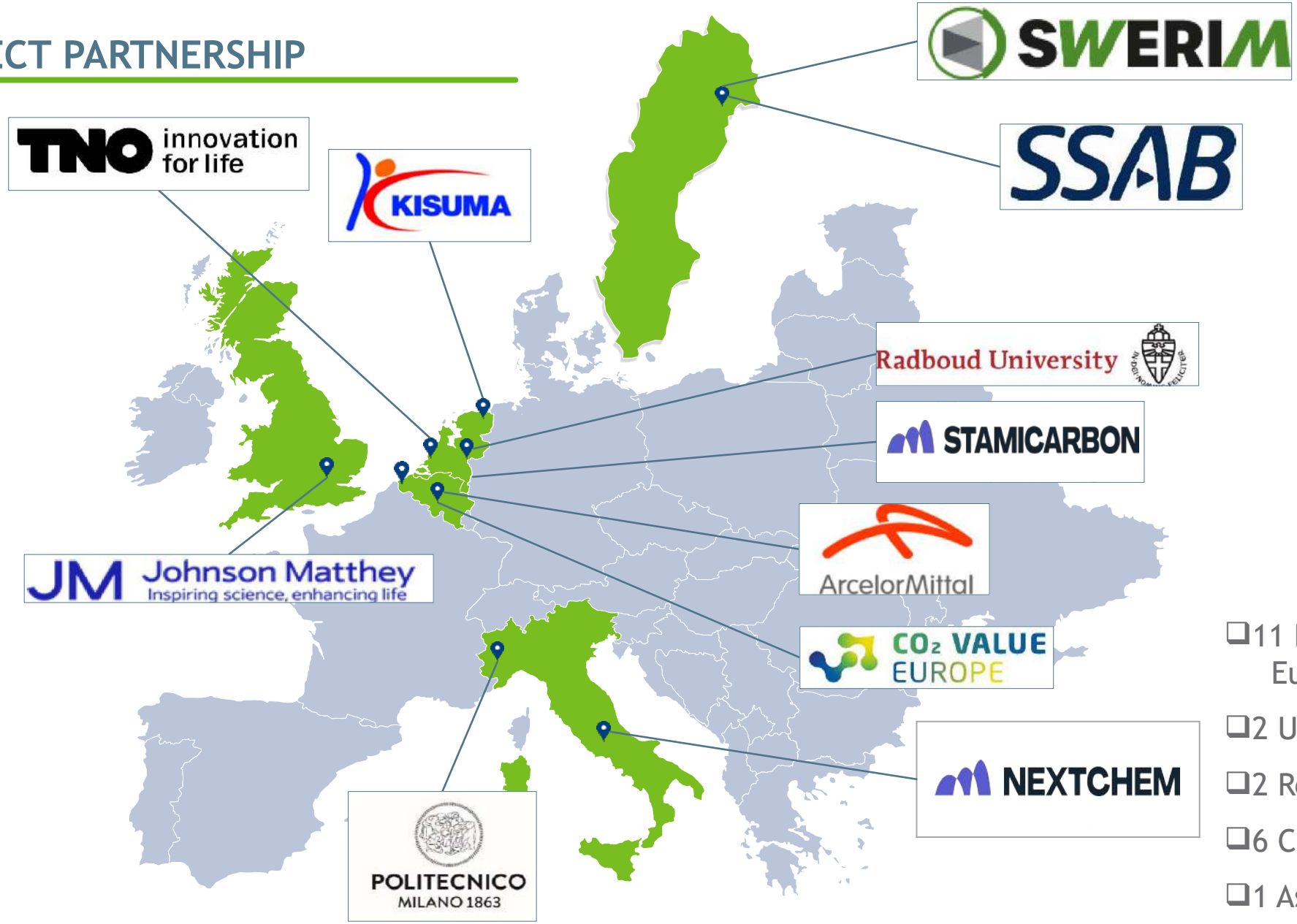
✓ The INITIATE project takes all the steps required to develop the FOAK plant:

- Bankability requires demonstration of continuous production of Ammonia from residual steel gases at scale
  - Multiple demonstrators will be constructed and connected at a final scale of **2.88 t(NH_3)/d (equivalent to 5 t(Urea)/d).**
  - The flexible conditioning of both time variable BOFG and less energy BFG will be demonstrated for the first time at such a scale with a multi-column sorption intensified reactor **(carbon-capture-ratio-CCR > 96%, carbon purity-CP > 97.7%).**
  - The first sub-stochiometric **(up to 2.2 H_2/N_2 mol)** NH_3 synthesis loop at high pressure **(>250 bar)** will be demonstrated.
  - **Fluctuating BOFG composition** and ambition to switch between residual steel gases as needed, require process modelling upgrading to simulate such transient operations and to dynamically optimize process controllers including advance artificial intelligence (AI) based controllers.
- Site identification
- Business plan development
- IP&R, ownership, collaboration.

02

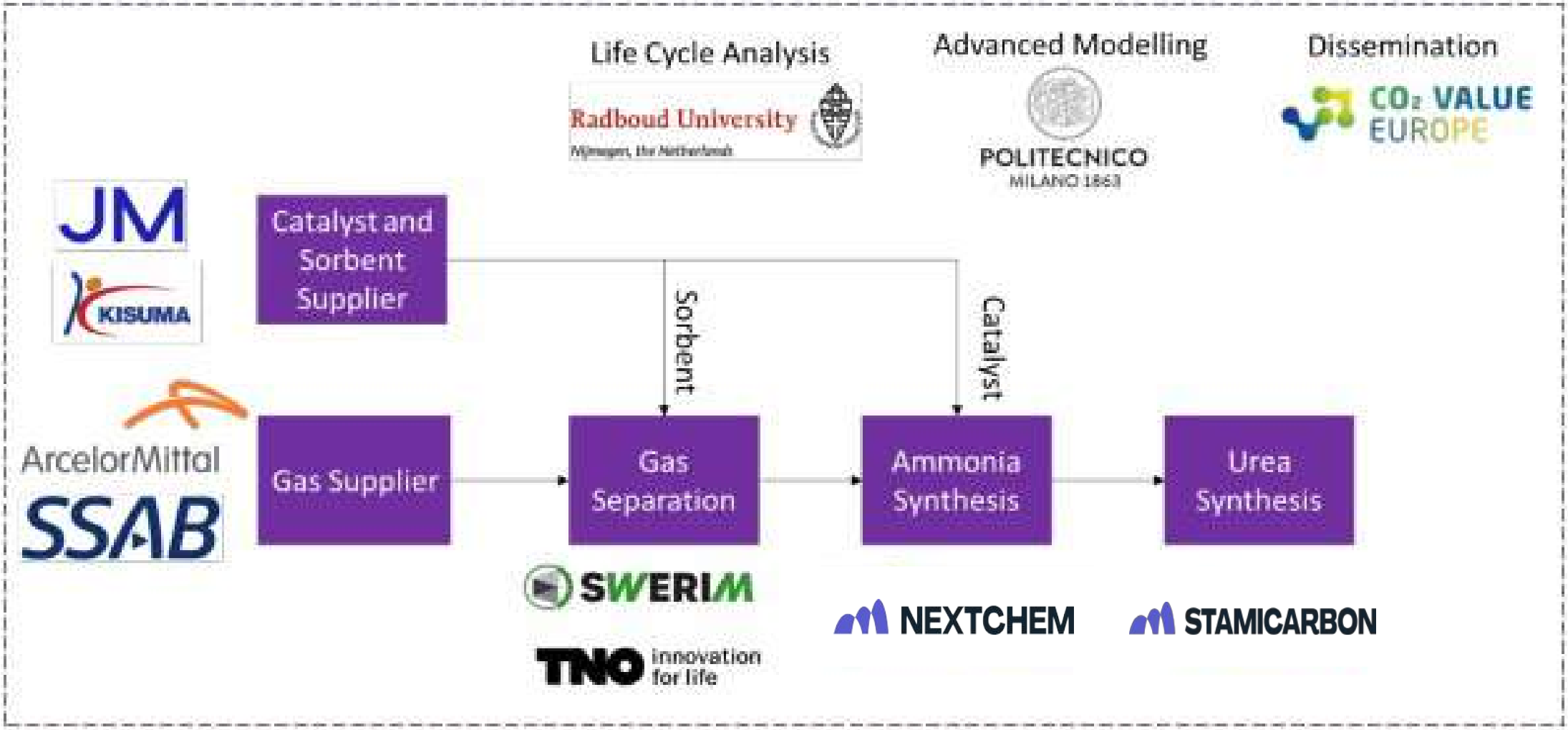
PARTNERSHIP

PROJECT PARTNERSHIP



- ❑11 Partners from 5 different European countries
- ❑2 Universities
- ❑2 Research Institutes
- ❑6 Companies
- ❑1 Association

POSITION IN THE VALUE CHAIN



EXTERNAL ADVISORY BOARD

OCI Nitrogen: nitrogen fertilizer and melamine producer; fully integrated production site in Geleen, the Netherlands.

Fertiberia produces a wide range of products from fertilizers for agriculture to industrial chemicals (>520 different products). Market leader in the Iberian Peninsula (30% share in Spain, 60% in Portugal). 5.5 million tons of production of intermediate and final products in 14 sites. 1.4 million tons of CO_2 emissions.

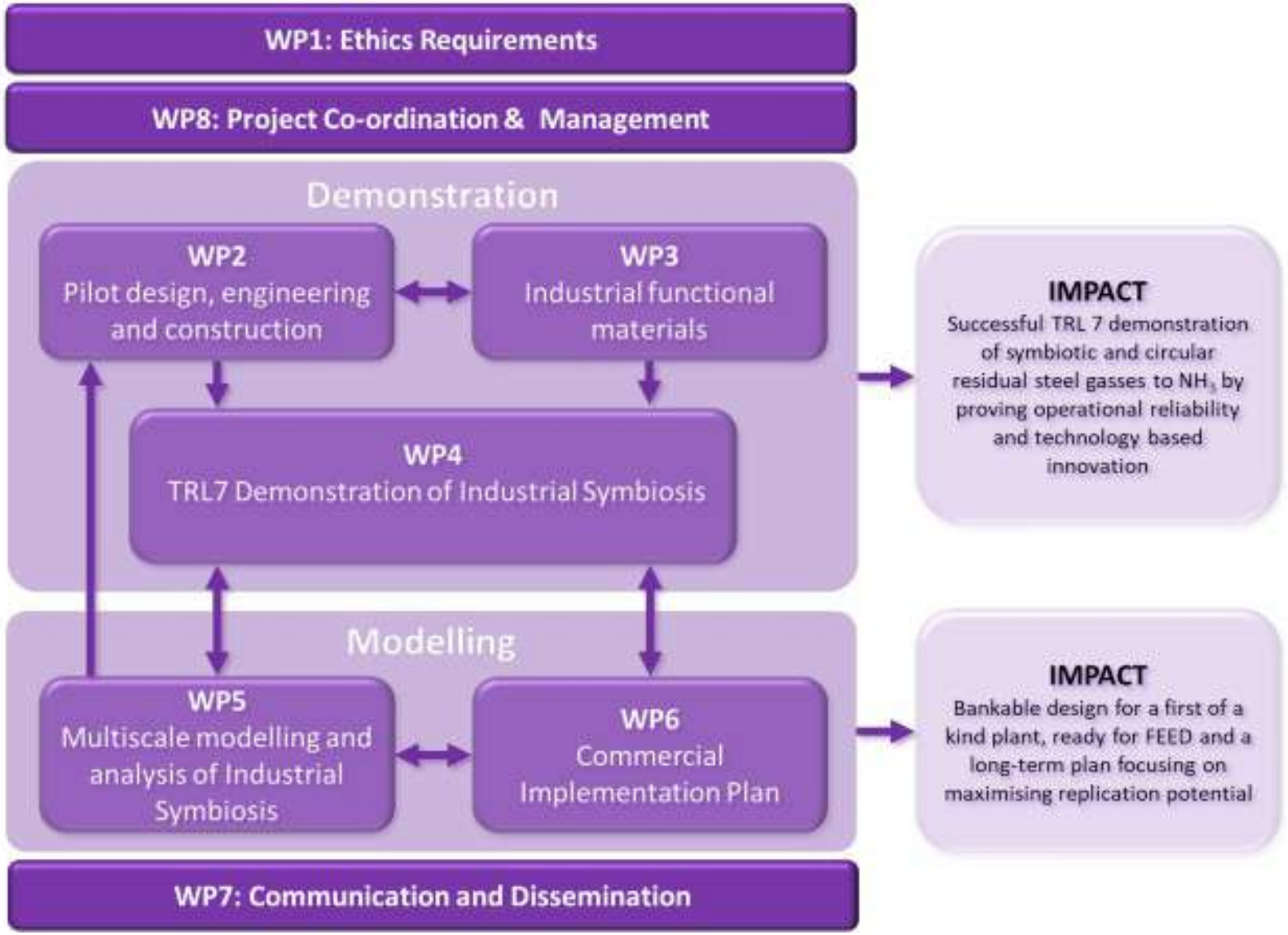
The **World Steel Association** is a non-profit organisation with headquarters in Brussels, represents steel producers, national and regional steel industry associations, and steel research institutes. Members represent around 85% of global steel production.

The **European Steel Technology Platform** brings together all the major stakeholders in the European steel industry, including major steel manufacturers; universities and research institutions active in steel research; major users of steel such as car manufacturers; and public bodies like the European Commission and national governments.

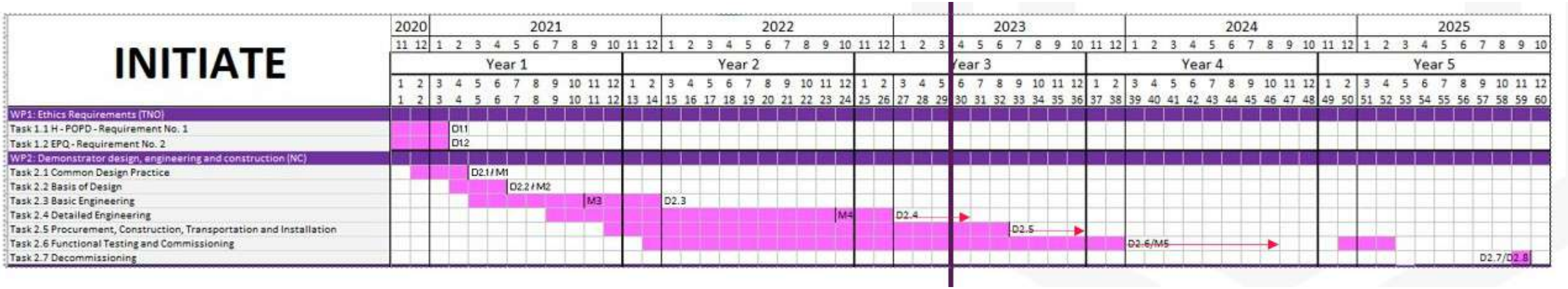
03

SCHEDULING

PERT CHART


WP1: Ethics Requirements
WP8: Project Co-ordination & Management
Demonstration
WP2
Pilot design, engineering and construction
WP3
Industrial functional materials
WP4
TRL7 Demonstration of Industrial Symbiosis
Modelling
WP5
Multiscale modelling and analysis of Industrial Symbiosis
WP6
Commercial Implementation Plan
WP7: Communication and Dissemination
IMPACT
Successful TRL 7 demonstration of symbiotic and circular residual steel gasses to NH_3 by proving operational reliability and technology based innovation
IMPACT
Bankable design for a first of a kind plant, ready for FEED and a long-term plan focusing on maximising replication potential

GANTT CHART



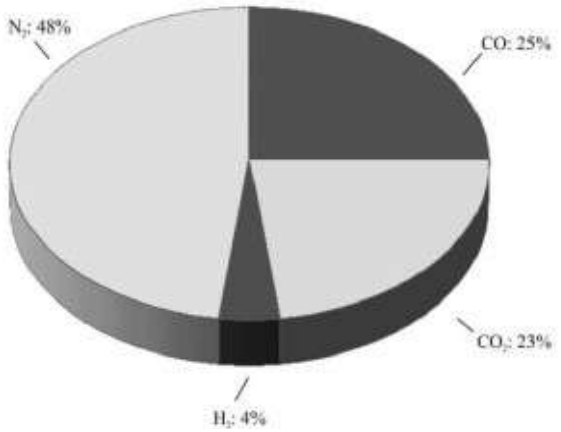
- First BOF campaign scheduled on 2024 CW39-CW44 (23/09 – 3/11)
- Second BOF campaign: 2025 CW18-CW23 (28/4 – 08/06)

04

BFG / BOFG

BFG/BOFG/COG COMPOSITION

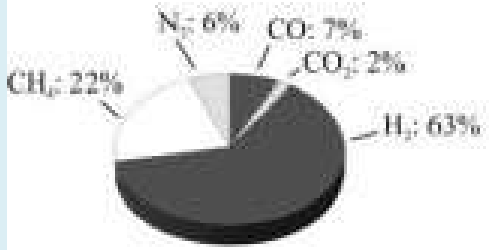
BLAST FURNACE GAS (BFG)



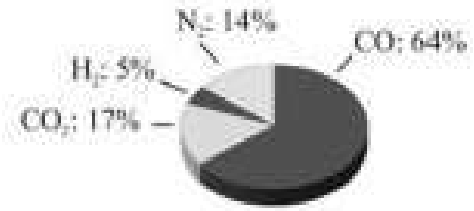
- Tipically collected and used for heat and power generation before being vented into atm

COKE OVEN GAS (COG)

- High gross calorific value.
- Tipically collected and used for oven heating, or for heat recovery o electricity generation, or used in BF to reduce coal consumption.
- Many examples of COG use in the chemical synthesis of methanol.



BASIC OXYGEN FURNACE GAS (BOFG)



- High variations in temperature, CO and N_2 composition due to the nature of batch operation.
- Due to the intermittent production and variable composition at many sites it is flared.

BFG/BOFG/COG COMPOSITION

Gas Type	CO	CO_2	H_2	N_2	CH_4	H_2:N_2	Energy	Mode	Cleaning
	mol%					-	MJ/Nm^3	-	-
BOFG	65	16	3	16	0	4.3	8.6	Dynamic	No
BFG	23	23	4	50	0	0.5	3.4	Steady	No
COG	5	2	62	7	24	9.6	15.7	Steady	Yes

Residual steel gases properties.

Legenda
- BOFG: Basic-Oxygen-Furnace-Gas
- BFG: Blast-Furnace-Gas
- COG: Coke-Oven-Gas

- Approximately 70% of the current steel production is obtained through the combined Blast-Furnace (BF) and Basic-Oxygen-Furnace (BOFG) route.
- More than 90% of the CO_2 emissions are the results of the three residual gases: BOFG, BFG, COG.
- Currently about 50% of these gases are used for electricity generation, while 50% is used for internal energy generation.
- BOFG is the most suitable stream from NH_3 synthesis.
- However, its size is limited and composition highly variable.
- Gas holder aids continuous flow of BOFG but does little to prevent composition fluctuations.
- Furthermore, BOFG is produced intermittently and there could be periods during which BOF operation is over.
- BFG supply is needed and H_2 back-up to correct the H_2/N_2 ratio ≥ 2.2.

BOFG DYNAMICS

EU-based steel plant

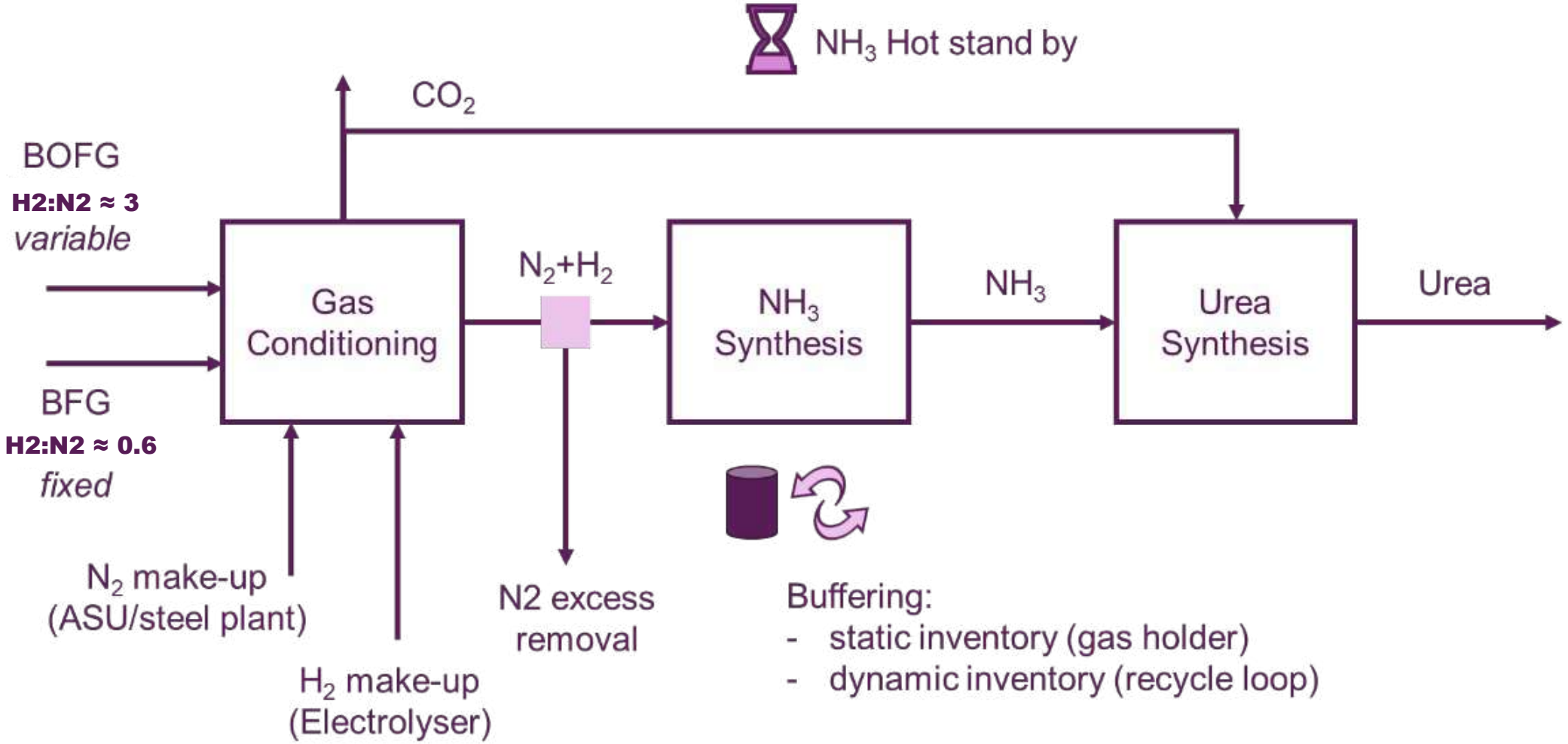
BOFG DYNAMICS

- ✓ Several **strategies** to deal with the **BOFG dynamics** have been identified and are under evaluation.

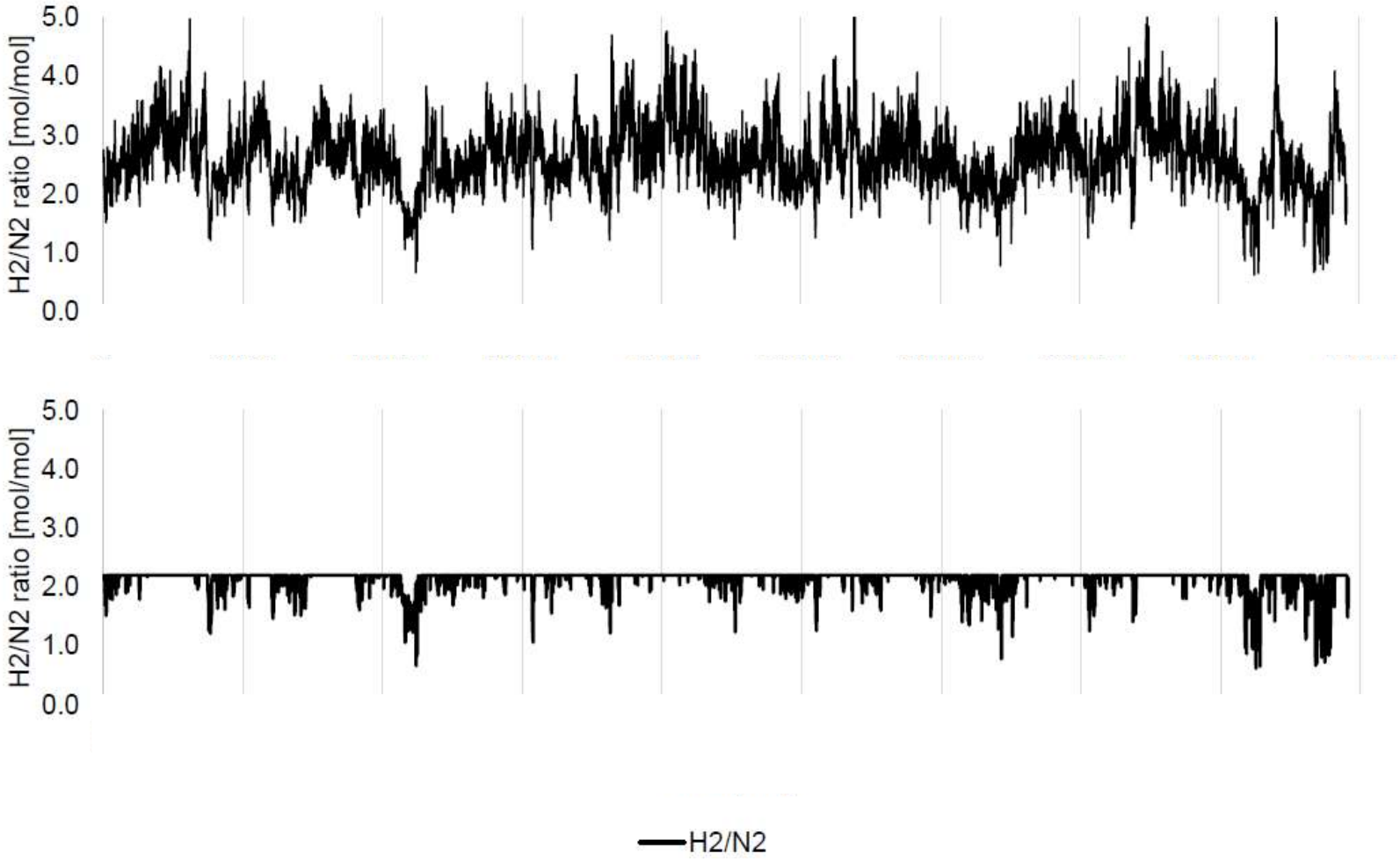
- ✓ **Identified approaches for CO excess**
  - N_2 make-up (ASU / Steel plant)
  - Use of BFG as it is rich in N_2

- ✓ **Identified approaches for N_2 excess**
  - Feed gas switch to BFG
  - N_2 excess removal (e.g. via membrane)
  - H_2 make-up (Electrolyzer or H_2 buffer)
  - Static (buffer tank)
  - Dynamic buffering (recycle loop)
  - Hot standby of NH_3 production unit, switching to power production

BOFG DYNAMICS



BOFG DYNAMICS

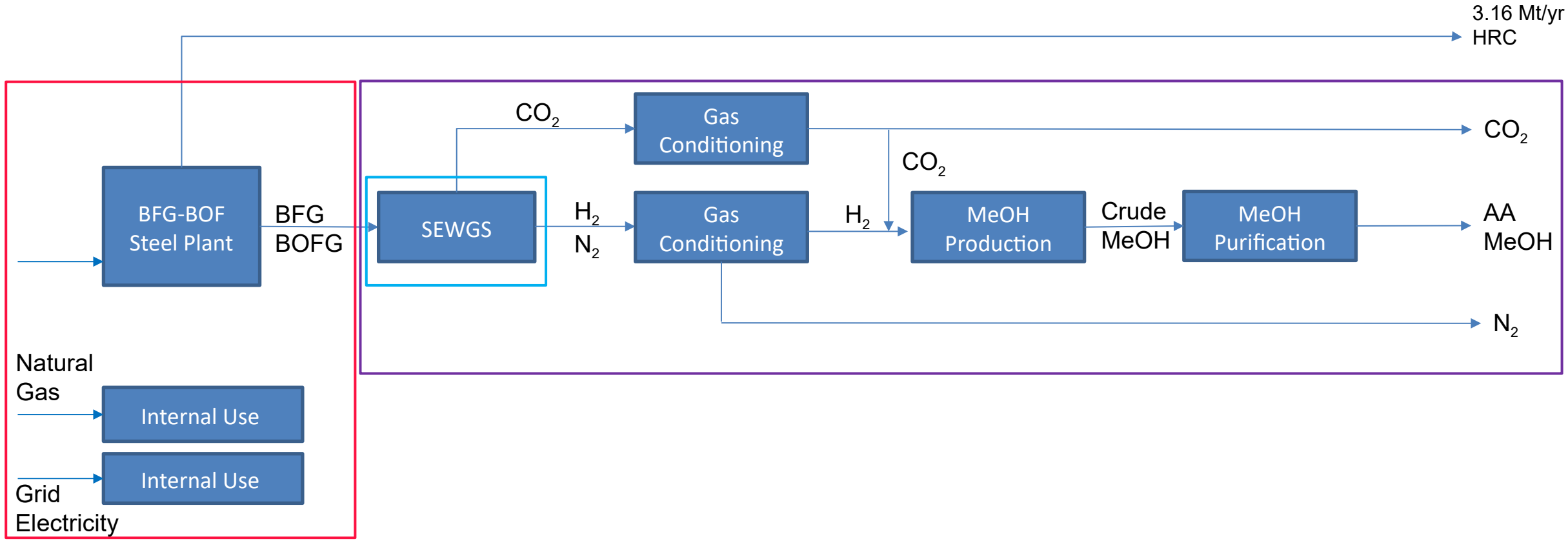


Nitrogen make-up control philosophy

05

BROADER INDUSTRIAL SYMBIOSIS ANALYSYS

METHANOL FROM BFG/BOF



METHANOL FROM BFG/BOF

- Production of 1740 TPD of Methanol GRADE AA, utilizing all the BOFG and BFG produced from reference steel plant (770 kNm^3/h)

- Analyzed two main Key Performance Indicators (KPI's):
  - **Primary Energy Consumption**
  - **GHG Emission Intensity**

- To evaluate this two KPIs we compared the symbiotic process with the reference industrial process

- Primary Energy Consumption:
  - Reference system PEC: 27,58 $GJ/ton_{HRC\text{-}BF}$
  - Symbiotic system PEC: 36,45 $GJ/ton_{HRC\text{-}BF}$
  - Energy penalty: **8,87 $GJ/ton_{HRC\text{-}BF}$ (32,16% relative energy penalty)**

- GHG Emission Intensity:
  - Reference system emissions: 2,13 $ton_{CO2}/ton_{HRC\text{-}BF}$
  - Symbiotic system emissions: 1,08 $ton_{CO2}/ton_{HRC\text{-}BF}$
  - Carbon avoidance: **-1,05 $ton_{CO2}/ton_{HRC\text{-}BF}$ (49,30% Carbon avoidance)**

06

COMMERCIAL IMPLEMENTATION PLANT

INITIATE COMMERCIAL IMPLEMENTATION PLANT

- ✓ A *feasibility study* will be developed within April 2025 (including pre-FEED) for the FOAK plant based on the INITIATE technology path:

  Urea solution (150 mtpd) as end product, to be used as input for liquid UAN (solution of urea and ammonium nitrate in water) fertilizers or AdBlue®, with decarbonized ammonia as alternative, while considering the long-term implementation plan.

  Potential location: Avilés (Spain), where a Fertiberia Nitric Acid /Ammonium Nitrate plant is located next to the Arcelor Mittal plant.

- ✓ Primary focus on available core plants of Arcelor Mittal (partner of the project) in combination with the premium urea markets for fertilizer or deratitives like AdBlue®.

Project objectives:

1. UREA levelized cost reduction ≥ 15%
2. Economic feasibility with IRR ≥ 15%

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