17th International Conference on Greenhouse Gas Control Technologies **GHGT-17**

20th -24th October 2024, Calgary Canada

"INITIATE: CO_2 capture, re-use and sequestration through industrial symbiosis of the steel and ammonia/urea industries"

Eric van Dijk[a]*, Marian Flores Granobles[b], Anastasios Perimenis[c], Liliana Lukashuk[d], Siebe van der Veer[e], Barbara Masciocchi[f], Giampaolo Manzolini[g], Rosalie van Zelm[h], David Bellqvist[i], Joey Dobrée[j], Magnus Lundqvist[k]

[a] *TNO, Petten, the Netherlands*
[b] *ArcelorMittal Belgium NV, Brussel, Belgium*
[c] *CVE, Brussel, Belgium*
[d] *Johnson Matthey, Billingham, UK*
[e] *Kisuma Chemicals, Veendam, the Netherlands*
[f] *NextChem Tech, Rome, Italy*
[g] *Politecnico de Milano, Milan, Italy*
[h] *Radboud University, Nijmegen, the Netherlands*
[i] *SSAB, Luleå, Sweden*
[j] *Stamicarbon BV, Sittard, the Netherlands*
[k] *SWERIM, Luleå, Sweden*

Abstract

The steel and fertilizer markets are predicted to grow in the decades to come, while they need to take actions to transform towards CO_2 neutrality. These two industrial sectors are responsible for 30% of all industrial CO_2 emission and >4% of annual global GDP (gross domestic product).

In the H2020 INITIATE project, these two industrial sectors are coupled using a symbiosis approach: the steel works arising gasses are used as feedstock for the production of NH_3 and urea. This directly contributes to the reduction of i) the CO_2 emissions, ii) the energy requirement and iii) the raw material use. It concept shows that carbon capture, re-use and storage are sustained on the value generated for generation of added value products such as NH_3 and urea. The project aims at a 30% decrease of primary energy use, a 40% decrease of raw material demand and up to 90% reduction in the direct CO_2 emissions, see Figure 1. The project also contributes toward preserving jobs in both sectors, while making Europe more independent and robust in view of increasing feedstock prices and trade uncertainties. Additional benefits are the provision of grid balancing services through flexibly using green H_2 and by proving CO_2 for circular use, accelerating the transition towards locally closed loop and integrated renewable energy systems.

* Corresponding author. *E-mail address:* eric.vandijk@tno.nl

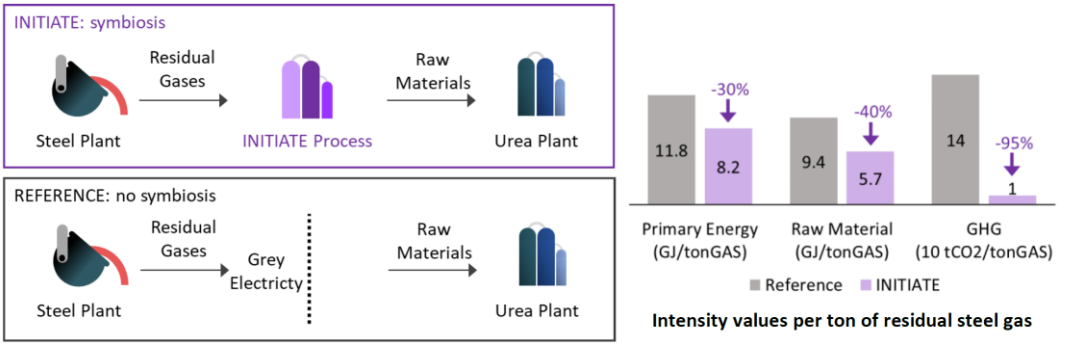

Figure 1: Schematic representation of the INITIATE symbiotic concept and the overall goals

INITIATE concept

To reach these goals, the INITIATE project takes all necessary steps to provide the basis for the roll-out of a 1st commercial size demonstrator at 50 kt/y urea in the basis of basic oxygen furnace gas (BOFG). The operational reliability of the technological innovations is demonstrated in a pilot plant at TRL-7. Additionally, the energy, economic and environmental advantages are assessed via the verification of the key-performance indicators of the concept and comparing them with a reference case w/o CO_2 removal and base cases that use amine based CO_2 removal technology. Next, a bankable design of the First-Of-A-Kind (FOAK) commercial plant is made to convert BOFG to AdBlue® and/or another NH_3 based product. Site identification and selection is performed, while the development of a long-term implementation plan ensures the successful implementation beyond the FOAK plant. The synergies on local and European scale are identified, considering industrial infrastructures and other symbiotic systems. As part of the implementation plan, stakeholder alignment is required and licensing strategies are developed to ensure successful future deployment.

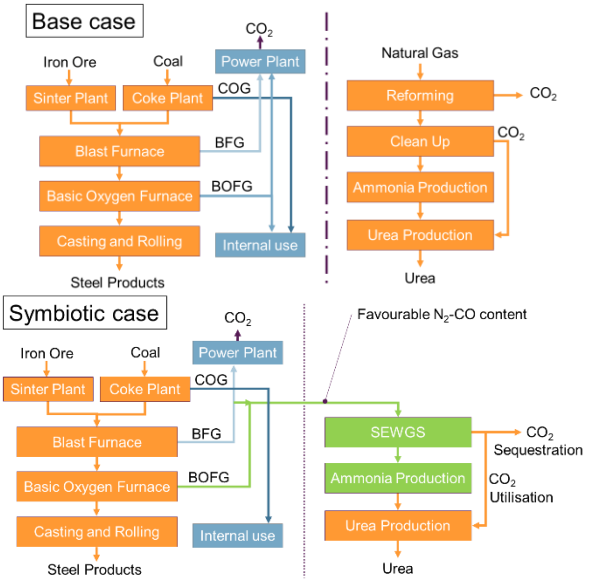

Figure 2: INITIATE concept explained

INITIATE status

The paper discusses the achievements of the project, being in month 48 of 60 at the time of the conference. The 2 key technologies together with their functional materials are discussed: i) the sorption enhanced water-gas shift (SEWGS) process and ii) the sub-stoichiometric NH_3 conversion loop. Functional materials have been validated and selected, accounting for the BOFG dynamics and contaminant types and levels. This analysis allows transferability of the concept to other locations having another BOFG composition. The industrial production of the functional materials started, while recycle options for spent materials are under development.

Pilot plant validation at TRL-7 is the efficient conversion of BOFG from the SSAB plant in Sweden into ammonia at 1.4 t_{NH3}/d scale. Detailed engineering of the pilot plant is ready and procurement and construction started. A redesign is successfully completed, dealing with the increased costs induced by the recent inflation. The reduction in scope and fund redistribution are captured in a project amendment. Pilot operation is foreseen to start late 2024.

Figure 3: pilot under construction

To effectively deal with the inherent BOFG composition dynamics, advanced control strategies are under development. Both physical as well as fast computation machine learning dynamic models are under construction. They allow assessment of the INITIATE plant behaviour for specific BOFG dynamics associated with other sites. The system assessment focusses on the small scale implementation, using BOFG for NH_3/urea production at 224 t_{NH3}/d, and large scale, using BFG+BOFG for 1500 t_{NH3}/d. A CO_2 avoidance potential of up to 80% compared to the non-symbiotic base case was reached. For the reference case using amine based CO_2 capture technology, this value peaks at 30% CO_2 avoidance. A negative Specific Energy Consumption for CO_2 Avoided (SPECCA) for both the small (BOFG to NH_3/urea) and large scale (BOFG+BFG to NH_3/urea) was established in case of low CO_2 intensity electricity mix, i.e. <140 and 25 kg/MWh respectively. A negative SPECCA means a lower primary energy use than the base case. This illustrates the potential of the INITIATE concept. The on-going life cycle analysis indicates that amine and degradation products emissions of the base case CO_2 capture technology are inherently avoided in the INITIATE concept as it uses a solid regenerable adsorbent. Moreover, the production, use and disposal of the sorbent is less environmentally impactful compared to the solvent case.

For the realization of the FOAK commercial plant, the identification and evaluation of the most promising site location has been performed and discussions with the involved parties are on-going. A long term implementation plan has been drafted and is currently under review. For a shortlist of product-market combinations the shared ambitions, physical flows and corresponding volumes, value network, effect of policies, and delta business cases were evaluated. The biggest cost and value drivers and uncertainties for these cases were established. These insights were translated into a roadmap covering three time horizons: ultimate potential, the key pathways and the first markets to start. The implementation analysis highlights that the challenges are foremost related to non-technical aspects such as uncertainties on CO_2 pricing via the ETS and CBAM mechanisms, policy developments on e.g. Recycled Carbon Fuels and CO_2 transport and sequestration regulations and requirements.

Abbreviations:

BFG	blast furnace gas
BOFG	basic oxygen furnace gas
CBAM	carbon border adjustment mechanism
ETS	emission trade system
FOAK	first of a kind
GDP	gross domestic product
SPECCA	specific energy consumption for CO_2 avoided
TRL	technology readiness level

Keywords: Steel industry ; Ammonia ; urea ; Carbon capture ; CO_2 utilisation ; CO_2 storage ; SEWGS ; industrial symbiosis

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