

## Pre-feasibility studies for carbon capture at the ArcelorMittal site in Dunkirk.

2034



AAP ZIBAC

### 1. General Context and Objectives

As part of the Dunkirk site's decarbonization strategy, ArcelorMittal commissioned two complementary pre-feasibility studies:

- A Technip study, with contributions from SHELL (advanced amine) and CMS (membranes), focused on analyzing CO<sub>2</sub> capture technologies and implementation architectures across the site's various residual emission sources;
- An Ekium study, with contributions from MHI (advanced amine) and Air Liquide (CRYOCAP cryogenic technology), focused on the techno-economic comparison of several capture configurations across seven major emission streams.

These studies, funded by ADEME, aim to identify the most relevant technical solutions by 2034, in alignment with:

- The future industrial configuration of the site (EAF + residual blast furnace),
- The requirements of the CO<sub>2</sub> transport and storage project led by Natran/Equinor (onshore pipeline, terminal compression, offshore export to the North Sea).

The studies are conducted at a pre-feasibility level (Class V), with the following objectives:

- To determine which technologies are industrially deployable and robust for Dunkirk,
- To compare individual capture versus centralized (shared) capture,
- To assess full-chain compatibility from capture → purification → compression → delivery to the CO<sub>2</sub> network,
- To prepare the selection of a preferred concept to be launched into pre-FEED.

### 2. CO<sub>2</sub> Sources and Scope of the Studied Cases

The studies identify seven emission streams covering the entire future steelmaking perimeter:

- **Blast Furnace route:** blast furnace gas (BFG), hot stove (cowper) flue gases, and Power Plant flue gases using BFG;
- **DRP route:** preheating furnace, CO<sub>2</sub> from the "selective CO<sub>2</sub>" process;
- **Downstream route:** hot rolling mill flue gases;
- **Associated projects:** CO<sub>2</sub> from the AMELI lime unit.

Based on these streams, Ekium/MHI/Air Liquide assessed representative capture configurations:

- Individual cases (stream-by-stream capture),
- Centralized cases (notably mixing streams B–D–F–G),
- Cases integrating streams modified after upstream capture,
- Oxy-combustion variants.

The technologies assessed:

- Advanced amine (Advanced KM CDR Process™ – MHI),
- Advanced amine SHELL CANSOLV,
- CRYOCAP cryogenic technology (Air Liquide),
- Alternatives analyzed by Technip: membranes (SVANTE CMS), adsorption, extended pre-treatment solutions.

### 3. Key Findings from the Technip Study

#### 3.1. Technological Feasibility

Technip concludes that:

- Amine-based systems represent the most mature and reliable technology for post-combustion capture on steelmaking flue gases, particularly those from the Power Plant.
- Membranes are considered less suitable at this stage for large volumes and require additional purification (cryogenic polishing).
- Adsorption is limited to specific niche applications.

#### 3.2. Full Treatment Chain

The study confirms the feasibility of a fully integrated chain:

- Advanced flue gas pre-treatment (DeSO<sub>x</sub>, DeNO<sub>x</sub>, filtration), essential for solvent stability.
- Final CO<sub>2</sub> purification (deoxygenation, H<sub>2</sub>S/NO<sub>x</sub>/SO<sub>x</sub> treatment, dehydration).
- Compression to the pressure level specified by the Natran CO<sub>2</sub> network.

#### 3.3. Architecture: Individual vs Centralized Capture

Technip highlights:

- An optimal capacity threshold for an amine unit beyond which full centralization provides no additional benefit,
- Limited centralization (e.g., grouping several streams around the Power Plant) as the best compromise,
- The need to avoid multiplying small units, which are costly and complex to operate.

### 4. Key Findings from the Ekium / MHI / Air Liquide Study

#### 4.1. Technical Performance of the Technologies

##### MHI Amine:

- Suitable for a wide range of gas compositions,
- High thermal demand, primarily steam-dependent,
- High capture rates, with the avoided CO<sub>2</sub> rate slightly impacted by energy consumption,
- Possibility to reduce thermal load through heat recovery (WHRU) on certain streams.

##### CRYOCAP Cryogenic:

- Particularly effective for CO<sub>2</sub>-rich flue gases,
- Mainly electricity-based consumption, highly sensitive to inlet CO<sub>2</sub> concentration,
- Full integration of Grade A purification,

- Very high capture and avoided CO<sub>2</sub> rates when powered by decarbonized electricity.

**Oxy-combustion:** Less attractive in the configurations studied.

#### 4.2. Costs and Competitiveness (Qualitative Analysis)

Both studies conclude that:

- Amine units are primarily driven by steam costs,
- CRYOCAP units are primarily driven by electricity costs,
- Heat recovery from steelmaking installations can improve amine competitiveness,
- Cost uncertainties remain significant at this stage.

### 5. Convergence Between Studies and Implications for Dunkirk

#### 5.1. Structuring Messages

The studies converge on the following key points:

- Post-combustion capture on Power Plant flue gases is technically feasible and represents the main short- to medium-term lever.
- Amine technologies and CRYOCAP are the two leading candidates for industrial deployment.
- Reasonable centralization of streams around the Power Plant constitutes the optimal implementation scheme.
- The quality of the produced CO<sub>2</sub> can meet the requirements of the Natran/Equinor transport and storage chain.
- Membrane and oxy-combustion alternatives are not priority options in this context.

### 6. Recommendations for the Next Steps

1. **Select a concept to be launched into pre-FEED**  
Maintain a dual technological pathway (amine / cryogenic), focused on a representative BFG or Power Plant case.
2. **Launch utilities and heat recovery studies**  
Essential to optimize energy costs and secure the steam balance (ENGIE with DK6).
3. **Further characterize flue gases**  
Variability, trace contaminants, and transient conditions are critical for properly sizing pre-treatment and purification systems.
4. **Conduct detailed brownfield integration studies**  
Footprint constraints, co-activity, safety, and network tie-ins.
5. **Accelerate coordination with Natran / Equinor**  
Alignment on CO<sub>2</sub> specifications, flow profiles, and availability constraints.

### 7. Conclusion

The Technip–SHELL and Ekium–MHI–Air Liquide pre-feasibility studies demonstrate that CO<sub>2</sub> capture at Dunkirk is technically credible, that two industrial technologies — advanced amine and CRYOCAP cryogenics — clearly stand out, and that an architecture centered around the Power Plant represents the most robust pathway.

These studies provide ADEME and ArcelorMittal with a solid foundation to launch the pre-FEED phase and structure the site's future CCS chain, in alignment with the planned North Sea transport and storage infrastructure.

## RÉSUMÉ

As part of its decarbonization strategy targeting 2034, ArcelorMittal Dunkirk conducted two pre-feasibility studies to identify optimal CO<sub>2</sub> capture solutions, aligned with the future North Sea transport and storage network.

The techno-economic analyses carried out by Technip (with SHELL and CMS) and Ekium (with MHI and Air Liquide) conclude that:

- Post-combustion capture on the Power Plant flue gases represents the priority lever.
- Two industrial technologies stand out:
  - Advanced amines, a mature and robust solution,
  - CRYOCAP cryogenic technology, particularly effective for CO<sub>2</sub>-rich flue gases.
- Partial centralization of streams around the Power Plant offers the best techno-economic compromise.
- The full chain — capture → purification → compression → transport — is compatible with the requirements of the future CO<sub>2</sub> network.

These studies establish a solid technical foundation for launching the pre-FEED phase and structuring the site's future CCS chain.

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