Pioneering Sustainable Aluminium: Aluminium Dunkerque's Decarbonization and Partnership Strategy

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Abstract

Aluminium Dunkerque (AD) benefits from the low carbon footprint of the French electricity grid and the continual improvement of its smelting technology, which places AD in the top quartile worldwide for carbon emissions (scope 1 & 2). Building on this enviable position, AD revealed in 2023 its decarbonization strategy, which aims to halve its emissions by 2030 and to reach carbon neutrality by 2050. To achieve this, Aluminium Dunkerque has formed partnerships with other entities to prepare and implement this ambitious plan.

As early as 2017, along with other industrial companies from the Dunkirk port hub, it helped found the "Industry, Carbone and Territory" committee (now DKarbonation), which was established to engage with local, regional, and national public authorities in a platform for exchange and innovation with a view to decarbonizing this industrial territory. This initiative has since been recognized as France's first Low-Carbon Industrial Zone.

Subsequently, with the support of long-standing partners, members of Aluminium France, AD has initiated the acceleration phase of its decarbonization roadmap, the design of a solution for pre-concentrating and capturing CO_2 in pot flue gases, specifically tailored to the aluminium smelting technology.

Finally, AD is also forging partnerships with international companies active in the transport and long-term storage of CO_2, with a view to preparing the scaling-up of this CCS solution and being able to share the costs associated with the transport and the storage of the captured carbon at various sites below the North Sea.

Aluminium Dunkerque is convinced that success in these innovative and capital-intensive fields can only be achieved by building ad hoc, solid, and ambitious partnerships.

Keywords: Aluminium Dunkerque, French aluminium, Partnership, Innovation, Decarbonation, CO_2 emissions, Carbon Capture and Storage (CCS).

1. Introduction

Aluminium Dunkerque (AD) is one of the largest producers of primary aluminium in Europe. The plant is located in the port of Dunkirk, France, and benefits from a strategic position due to its direct access to the sea and a well-developed energy infrastructure. AD stands as a prominent player in the global aluminium industry. It is renowned for its significant contributions to both industrial production and environmental sustainability. The aluminium sector, known for its high energy consumption and substantial carbon emissions, faces increasing pressure to innovate and, eventually, adopt greener practices.

In this context, AD's operations are influenced by the low-carbon footprint of the French electricity grid and advancements in smelting technology. French electricity grid is one of the

lowest carbon grids in Europe. The country derives a significant portion of its electricity from nuclear power, which reduces the carbon emissions associated with its electricity consumption. This favorable context has allowed AD to benefit from a relatively low carbon footprint compared to other global aluminium producers, placing the company in the top quartile worldwide for carbon emissions. The company has succeeded in cutting its emissions (scope 1 & 2) by 18 % since 2013 and greenhouse effect gas emissions are four times lower than the global sector average (scopes 1, 2 & 3) [1].

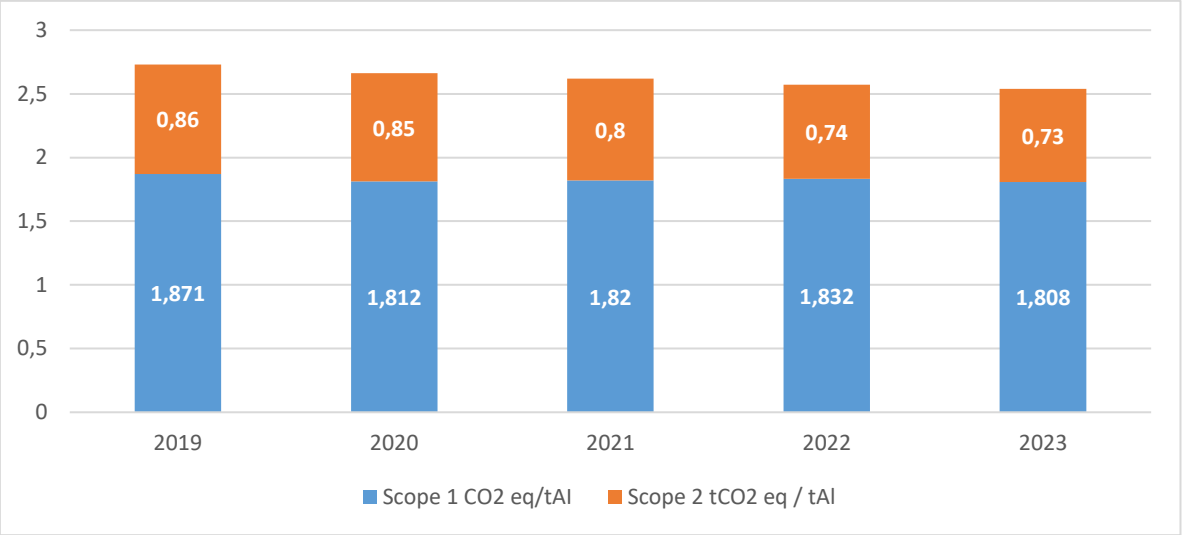

Figure 1. CO2 Scope 1 & 2.

1.1 Strategic Challenge

AD has always been dedicated to improvement, initially focusing on energy and electricity, particularly through electrolysis. However, with the new decarbonization goals, there is now a pressing need to tackle additional challenges such as gas emissions.

This broader approach demonstrates a significant shift from AD's historical focus to a more comprehensive strategy. This strategy is illustrated by the Lowcal ambition, which aims to address direct emissions related to gases. In recent years, this commitment has expanded to embrace operational excellence and energy efficiency throughout the entire site, with ISO 50001 certification now applied across the facility.

While some of these issues can be tackled with existing expertise, others necessitate external partnerships. This approach ensures that improvement efforts are enhanced by integrating both internal skills and external collaborations.

In particularly disruptive areas, where new technologies are essential yet not part of our core business, the need for external partnerships becomes even more crucial. While these innovations are vital for maintaining competitiveness and relevance in a constantly evolving market, they are not at the center of our primary expertise. Consequently, collaborating with other stakeholders allows AD to complement and enhance its internal skill set, bridging the gap between our core competencies and these emerging technologies. By working with external experts, AD not only leverages its own strengths but also integrates new insights and capabilities, which are crucial for advancing cutting-edge initiatives. This strategic approach ensures that AD remains at the forefront of technological advancements while effectively navigating areas beyond our traditional focus.

In 2023, AD unveiled an ambitious decarbonization strategy aimed at halving its emissions by 2030 and achieving carbon neutrality by 2050 [2]. AD's decarbonization plan revolves around several key areas: ramping up the mobilization of resources, energy efficiency, innovative technologies such as carbon capture and storage, the implementation of new economic models, including recycling and the circular economy, and, overall, adopting more environmentally friendly industrial practices. Central to AD's strategy is the adoption of circular economy principles, particularly applied to aluminium production. In the circular economy framework, AD focuses on maximizing the lifecycle of aluminium products by promoting the reuse and recycling of aluminium materials. This approach not only conserves raw materials but also reduces the energy and emissions associated with primary aluminium production.

These efforts aim not only to reinforce AD's leadership position in sustainability but also to make a significant contribution to global climate goals. This strategy underscores a pivotal shift towards sustainability, demonstrates a willingness to take ownership of the issues at stake, and aligns with broader industry and regulatory goals. The challenge, however, lies not only in developing and implementing innovative technologies but also in establishing effective partnerships to support this transformative journey. The integration of local, regional, and international collaborations is critical to overcoming the new technical and financial challenges that lies ahead.

At its core, AD remains a vibrant hub for innovation and experimentation. This dynamic environment not only fosters continuous improvement but also supports collaboration essential for overcoming both current and future challenges.

1.2 Key Focus Areas

This paper aims to examine AD's comprehensive approach to decarbonization, focusing on the following objectives:

- To explore the company's strategy for reducing carbon emissions and achieving its long-term sustainability goals.
- To assess the role and effectiveness of various partnerships in supporting AD's decarbonization efforts.
- To evaluate the challenges and opportunities associated with implementing CCS technologies and scaling up carbon capture initiatives.

By addressing these objectives, the paper will provide a detailed understanding of how AD is pioneering sustainable practices within the aluminium industry and how its strategic partnerships play a crucial role in advancing these goals.

2. Background and Current Environmental Performance of Aluminium Dunkerque

Historically, continuous improvement has been a driving force at AD. From the outset, AD has been committed to enhancing energy efficiency. This unwavering dedication to operational excellence has been a cornerstone of AD's strategy, enabling it to achieve remarkable results in reducing energy consumption and improving overall efficiency.

This longstanding commitment to improvement has seamlessly transitioned into AD's approach to new challenges, particularly those related to decarbonization. As the industry faces unprecedented pressures to reduce carbon emissions, AD has applied the same ethos of continuous enhancement to its decarbonization efforts. By leveraging its historical expertise in energy management, AD is not only addressing current challenges but also positioning itself to lead in the transition towards a low-carbon future.

2.1 Current Environmental Performance of AD

A focus on energy efficiency

Historically, AD has excelled in energy management within the aluminium industry, driven by the high energy demands of electrolytic aluminium production. A prime example is the AD 415 project, launched in 2015, which upgraded the entire production line to advanced electrolytic cell technology. This significant enhancement reduced energy consumption to below 13 075 kWh per tonne of aluminium, outperforming the European average of nearly 14 000 kWh per tonne.

The Electrolysis sector received significant attention during the first half of 2023, with 74 cells having to be restarted following the energy crisis of 2022. Given the energy crisis context, it became even more crucial to continuously monitor the energy performance of the cells, as they represent about 94 % of AD's electricity consumption, amounting to approximately 3.5 TWh in 2023. Operational excellence led to outstanding results in the second half of the year, surpassing previous site records and achieving global benchmark levels.

The year 2023 was also marked by excellent energy consumption results for the casthouse furnaces, despite a production decline due to the partial curtailment of the potline.

These results stemmed from various projects undertaken to manage and operate the seven casthouse furnaces. Several measurement campaigns were conducted to assess the combustion rates of the burners, which helped identify key factors influencing furnace operation and management. Additionally, a techno-economic study on the burners was carried out to explore the best available technologies that could meet future strategic needs. It is also noteworthy that all gas meters have been replaced. The new meters, currently being calibrated, will enhance our results, particularly with the development of a dedicated portal for real-time tracking of energy consumption.

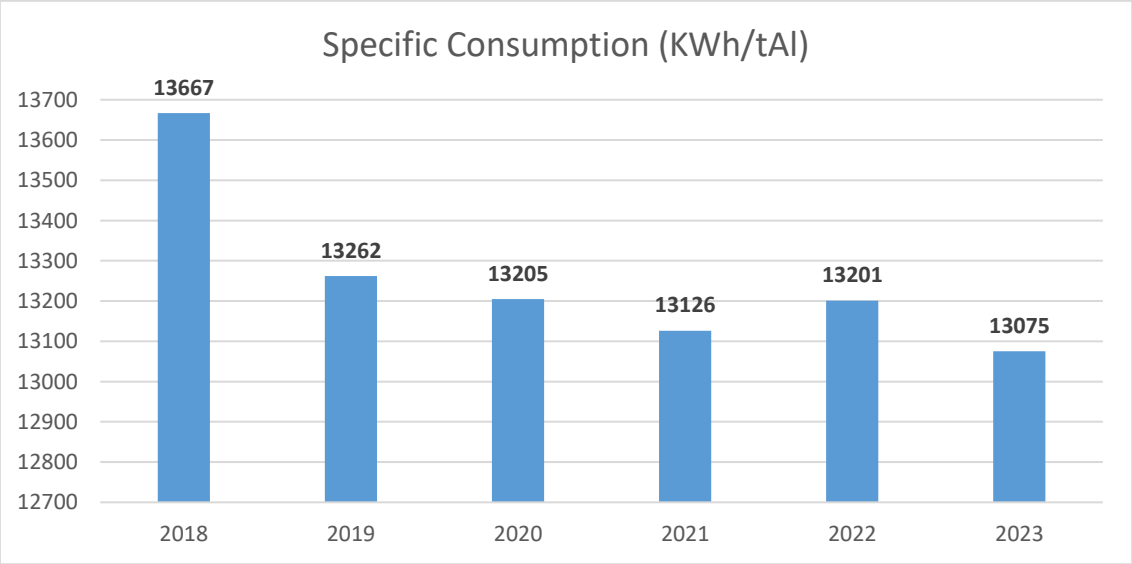

Figure 2. Evolution of the specific consumption of electrolytic cells [3].

Several projects supported this performance, including the optimization of electrical contacts between the anode beam and anode rods, the pot relining program, and the maintenance of anode rods and hexapods.

Technological development trials also began in 2023, focusing on optimizing anode stub holes and greasing pot connectors, which will continue into 2024.

The year 2023 was challenging, with a context of cell restarts. Numerous technical and economic studies were conducted across all operational sectors and support services with the goal of reducing energy consumption. Some of these will be implemented in 2024 and are expected to lead to reductions in gas consumption in the Carbon sector (Rodding Shop and Baking Furnace) as well as in Electrolysis (Potline auxiliaries). Additionally, an energy recovery project is anticipated to reduce electricity consumption in some utility infrastructures.

Tackling new challenges

AD is an aluminium producer with one of the lowest carbon contents in its finished products globally and has been actively working on reducing its greenhouse gas emissions for several years, focusing particularly on energy efficiency projects and reducing PFC (perfluorocarbons) emissions. Between 2013 and 2023, the site reduced its Scope 1 emissions by 10 % and its Scope 1 and 2 emissions by 18 %, and above 7 % since 2019.

The site contributes to the decarbonization of the entire industry. AD is involved in the international decarbonization initiative "Aluminium for Climate," which was launched by the World Economic Forum and the Energy Transition Commission. The site also contributed to developing the ACT (Assessing low-Carbon Transition) evaluation model for corporate decarbonization strategies, created by the French Agency for Ecological Transition (ADEME) and the Carbon Disclosure Project (CDP) [4]. Aluminium Dunkerque received an excellent rating of 13B+ compared to a sector average of 10B+. The evaluation system provides three distinct scores based on performance (0 to 20), coherence (A to E), and the strategy's dynamic (+, =, or -). AD’s dedication to reducing its carbon footprint is further validated by its bronze medal award from the EcoVadis platform, which assesses Corporate Social Responsibility (CSR) performance based on 21 criteria across four themes: environment, social and human rights, ethics, and responsible purchasing. Additionally, AD renewed its ASI (Aluminium Stewardship Initiative) Performance Standard and Chain of Custody certifications in 2023, reinforcing its commitment to upholding the highest industry standards.

2.2 Decarbonization Goals: The LowCAl Roadmap

The demand for aluminium products and those incorporating aluminium continues to rise year after year. Aluminium is increasingly replacing other materials due to its unique properties, making it a key element in environmental sustainability. In response to this situation, AD is dedicated to preparing for the future by implementing a comprehensive decarbonization strategy. In line with COP21 objectives, AD is accelerating its energy and environmental transition by adopting a road map for 2050 called LowCAl, which stands for “Low Carbon Aluminium”, and “Local Aluminium”. Key goals are set to be achieved by 2025 and 2030.

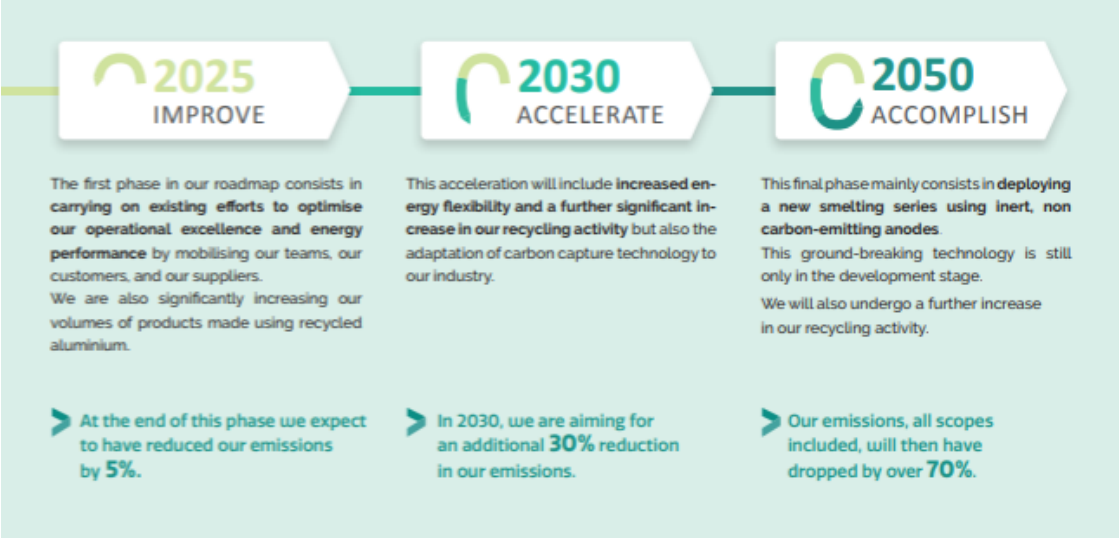

Figure 3. AD roadmap of CO_2 emissions reduction.

As part of this roadmap, AD is implementing several key initiatives aimed at reducing its carbon footprint and enhancing energy efficiency. These initiatives are integral to the milestones set to be achieved by 2025. They include addressing the net carbon consumption, the anode effect, leveraging AI in the baking furnace, reducing gas consumption, undertaking energy efficiency projects, and expanding recycling efforts.

Anode effects

One of the primary focuses of AD's decarbonization efforts is the mitigation of the anode effects. The anode effect occurs when there is an insufficient amount of alumina in the electrolytic cell, leading to the formation of perfluorocarbons (PFCs). By optimizing the alumina feeding process and improving the monitoring systems, AD aims to significantly reduce the frequency and duration of anode effects. This reduction is crucial as it directly lowers the emissions of PFCs, thereby decreasing the overall greenhouse gas emissions of the smelting process.

Reduction of gas consumption

In its ongoing efforts to improve energy efficiency, AD has implemented several projects aimed at reducing gas consumption. These projects include upgrading the burners in the foundry furnaces, optimizing the combustion process, and improving insulation. The replacement of old gas meters with new, highly accurate ones has also been a critical step in monitoring and managing gas usage more effectively. By focusing on these areas, AD has successfully reduced its gas consumption, leading to lower emissions and operating costs.

Recycling initiatives

Recycling is a cornerstone of AD's decarbonization strategy. The construction of a new aluminium recycling furnace, Furnace #8, is a testament to this commitment. This innovating equipment, capable to produce up to 20 kt of additional ingots per year, will also be used to recycle up to 7 kt of external used aluminium. This production represents 19 % of French imports of primary aluminium ingots and 8 % of European imports.

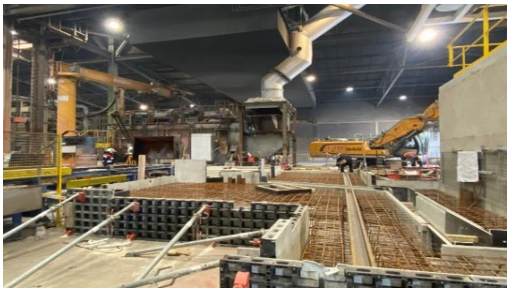

Figure 4. Furnace 8 under construction at the Aluminium Dunkirk site.

This new furnace is equipped with advanced burner technology designed to maximize energy efficiency and reduce emissions. The recycling process at AD not only reduces the need for primary aluminium production but also conserves natural resources and minimizes environmental impact. Aluminium is 100 % recyclable without any loss of quality, and the recycling process consumes only 5 % of the energy required for primary production. By expanding its recycling capabilities, AD supports the development of a low-carbon circular economy and contributes to the overall reduction of its carbon footprint.

3. A Strategy Unfolding at a Local, Regional and National Level

AD has long been at the forefront of the aluminium industry, thanks to its extensive internal expertise and dedication to technological advancement. This deep-seated knowledge base has been instrumental in driving significant progress across various facets of production and energy efficiency.

The strong internal capabilities at AD provide a solid foundation for exploring and developing innovative technologies. Building on this established internal knowledge, AD is now focusing on cutting-edge technologies that promise to further enhance its sustainability and operational performance.

AD's strategic location in Dunkerque, a key hub for decarbonization efforts, significantly enhances its ability to drive innovation. The region’s focus on advancing carbon reduction technologies and developing sustainable industrial practices creates a supportive environment for AD’s initiatives. By leveraging this strategic advantage, AD is uniquely positioned to capitalize on local and regional advancements in new technologies.

3.1 Technological Initiatives “Made in Dunkerque”

With a commitment to technological advancement and environmental stewardship, AD is uniquely positioned to drive significant progress in decarbonization and operational efficiency within the sector. It provides a fertile ground for innovation, beneficial to the entire industry. Indeed, the facility's dedication to innovation extends beyond its own operations. By serving as a testing ground for new technologies and processes, AD aims to contribute to the broader industry’s evolution. The outcomes of its initiatives have the potential to set new benchmarks for low-carbon aluminium production, offering valuable insights and practical solutions.

AI-Enhanced baking furnace

AD is at the forefront of utilizing artificial intelligence (AI) to enhance the efficiency of its anode baking furnace. This innovative approach includes collaborations with Fives and BCG to explore AI-driven solutions aimed at reducing gas consumption in the anode baking furnace. The

advanced AI technologies will enable precise control and optimization of furnace operations, leading to improved thermal efficiency, reduced gas consumption, and lower emissions.

This pioneering effort extends beyond the anode baking furnace and aims to address other areas of the aluminium production process, such as treatment of anode effects and gas consumption in casting furnaces. By shifting from empirical methods to data-driven approaches, AD plans to characterize and analyze gas consumption more effectively to identify potential reductions. The AI system will continuously monitor and adjust furnace parameters in real-time, ensuring optimal performance and energy use. Additionally, these models will help create interfaces for operators to make well-informed decisions.

Increasing frequency of pot tending

One of the key initiatives under this strategy involves increasing the frequency of pot tending operations to reduce net carbon consumption. Pot tending, a critical maintenance activity in aluminium smelting, involves monitoring and maintaining the pot's covering material to ensure its effectiveness. By enhancing the frequency of these operations, AD aims to reduce the carbon footprint associated with anode consumption.

Initially, pots were tended every 7.5 days. To explore the potential benefits of increased frequency, the company tested a more frequent tending schedule of every 5 days. The test involved selecting six pots, three as references with the original schedule and three as test pots with the increased frequency. This test spanned over three anode cycles (approximately three months), during which anode consumption and net carbon emissions were meticulously measured.

The test results revealed a significant reduction in net carbon consumption for pots with increased tending frequency. Specifically, the test pots demonstrated a 9.8 kg reduction in net carbon per tonne of aluminium produced compared to the reference pots. Despite these promising results, variations in data were observed, particularly with one test pot showing less favorable results. Further analysis indicated that differences in operational parameters, such as bath temperature and superheat, influenced the outcomes.

Increasing the frequency of pot tending does not require substantial investment but necessitates additional workforce to manage the increased operation duration. The potential net carbon gains, although substantial, may be moderated by operational constraints and quality considerations. A preliminary economic analysis suggests that the project could yield positive returns, with a payback period of approximately one year.

Anode coating for reduced oxidation

Another innovative approach involves applying a coating to the anodes to mitigate oxidation and reduce carbon emissions. This method aims to improve the longevity and efficiency of the anodes by preventing oxidation and CO_2-related reactions (carboxidation).

The coating product was tested over three anode cycles. The anodes were coated with a two-layer application of alumina-based product. The results indicated a notable improvement in net carbon consumption, with a reduction of 17 kg C per tonne of aluminium produced in coated pots compared to non-coated reference pots. Laboratory tests further confirmed that the coating significantly reduced oxidation and carboxidation.

Implementing this coating technology requires an estimated investment of 2 million euros for installation and an ongoing operational expenditure of 2.5 million ruros annually for the coating

material. While the initial results are promising, the technology requires further validation on a larger scale to ensure consistent performance and cost-effectiveness.

3.2 Local and Regional Partnerships

AD is deeply integrated into a pioneering region that is redefining the future of industrial decarbonization. The Dunkirk industrial area, known as "DKarbonation," is establishing itself as a leading example on the global stage for its ambitious carbon neutrality goals. With substantial support from local, regional, and national authorities, Dunkirk is leveraging its unique industrial and port ecosystem to become Europe's foremost demonstrator of the future low-carbon industry.

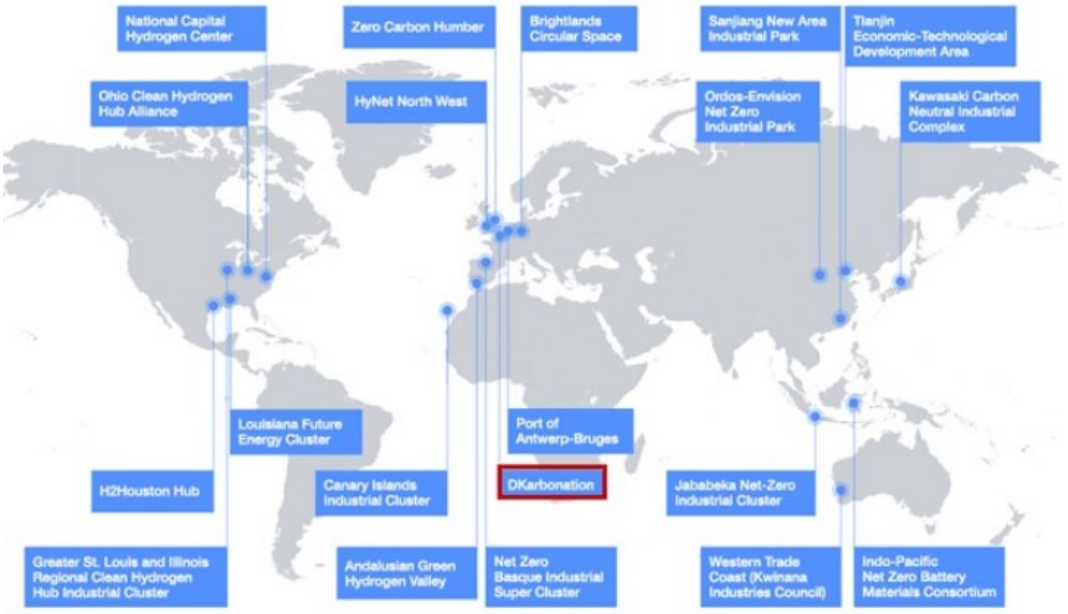

Figure 5. Dunkirk: one of the world's first industrial area with 'net zero emissions' ambitions [5].

This initiative reflects Dunkirk's rich industrial and maritime heritage and its ongoing commitment to environmental stewardship. The Dunkirk region, with its long-standing tradition in maritime and industrial activities, boasts Europe's largest energy platform, including nuclear power, LNG terminal, combined-cycle power plants, green hydrogen production facilities, offshore wind farms, and solar energy installations. The area's significant industrial presence, which includes a major port handling 53 million tonnes of traffic annually, also made it the top emitter of CO_2 in France as of 2019. However, the region is transitioning from being a major CO_2 emitter to becoming a leader in decarbonization solutions.

This transformation is driven by a coordinated effort involving local stakeholders such as the Dunkirk Urban Community, the Hauts-de-France Chamber of Commerce and Industry, the regional REV3 initiative, French Ecological Transition Agency (ADEME), and the Grand Port Maritime de Dunkerque. Together, these entities are advancing Dunkirk's vision of integrating economic activity with high quality of life while utilizing the region's extensive industrial-port ecosystem.

The Dunkirk industrial area has been selected as one of the pilot sites for the World Economic Forum's global initiative to advance industrial clusters toward net-zero emissions [6]. This

recognition highlights Dunkirk's role as a vanguard in implementing innovative decarbonization solutions and underscores its significant contributions to the European and global climate agenda.

AD plays a pivotal role in this transformation. As a leader in the regional industrial sector, the company is actively engaged in local and regional partnerships that drive decarbonization. Since 2020, AD has been at the helm of Pôlenergie, a key local organization that supports regional decarbonization initiatives and fosters collaboration among industrial and public sector stakeholders.

The Dunkirk region's commitment to innovation and sustainability is evident in its numerous projects and partnerships. From early industrial ecology efforts like the creation of France's first industrial symbiosis network to recent advancements in low-carbon cement production and hydrogen energy, Dunkirk is a testing ground for cutting-edge technologies and practices. The region's integration into national programs like "Territoires d'Industrie," "Territoire d'Innovation," and "Contrat de Transition Écologique" further illustrates its leadership in shaping a sustainable industrial future [7].

With ambitious goals of reducing CO_2 emissions by 30 % by 2030 and achieving carbon neutrality by 2050, Dunkirk is committed to being a major player in the transition to a low-carbon economy. The region's extensive investments in infrastructure and innovation are crucial in reaching these targets and establishing Dunkirk as a global hub for sustainable industrial practices. By driving forward initiatives in carbon capture, renewable energy, and circular economy practices, Dunkerque, with AD at its core, is poised to make a significant impact in the fight against climate change and set a benchmark for other industrial regions worldwide.

4. Fostering Strong Partnerships to Get Ahead of Tomorrow

To meet the ambitious decarbonization goals set for the decades ahead, it is crucial for AD to engage in strategic partnerships. Historically, AD has leveraged its robust internal expertise to drive energy efficiency and operational excellence. However, the scale of the decarbonization challenge necessitate a collaborative approach.

By partnering with other specialized companies, AD can accelerate the development and adoption of essential technologies for reducing its carbon footprint. These partnerships enable the integration of cutting-edge solutions, such as carbon capture to achieve the necessary breakthroughs.

While AD's internal capabilities have been pivotal in its historical successes, addressing the new decarbonization challenges calls for new pools of expertise. Collaborating with industry leaders and innovation experts enhances AD's ability to overcome technical and operational hurdles. These joint efforts are vital for achieving the 2050 climate goal.

4.1 Technological Innovations for CCS: the C4Capture Project

Overview of the ongoing capture project

For AD, embracing global collaborations and integrating local, regional, and international efforts are essential to addressing the new technical and financial challenges of CCS. Together with Trimet, Rio Tinto Aluminium, and Fives, Aluminium Dunkerque is working on a specialized solution aimed at halving the site's CO_2 emissions by 2030. This ambitious target reflects the company's dedication to achieving substantial emission reductions in the short term while awaiting the development and deployment of other promising technologies that may not be ready by the 2030 deadline.

No industrial scale pilot for CO_2 capture has yet been implemented in this industrial sector. Indeed, the very low concentration of CO_2 in effluents (~1 %) means that performance is poor with the most mature processes known to date, developed for industrial sectors whose effluents are more concentrated in CO_2 (15 to 80 %).

The C4Capture project was born of the desire to unite a group of players with varied but complementary skills around this issue, in order to develop and test on an industrial site a CO_2 pre-concentration, capture and treatment technology that would be totally compatible with the CO_2 emission characteristics in a primary aluminium smelter.

The C4Capture project has tendered for the DEMIBac call, part of the France 2030 strategy. This call for projects was launched after the COVID crisis and aims at helping industrial decarbonization projects in the hard-to-abate sector reach a technology readiness level compatible with industrial application.

France 2030 is an ambitious investment plan launched by the French government with a budget of €54 billion over five years. The strategy focuses on supporting innovation and accelerating the ecological and digital transition of the French economy. The plan also emphasizes strengthening France's industrial base and fostering technological sovereignty.

After submission of the file, the consortium has gone through detailed engineering and is now conducting the necessary pilots in order to carry out the tests in 2025.

All in all, the C4Capture project has a strong economic, social and environmental impact, creating numerous direct and indirect jobs and will help guarantee the long-term national, European and global sovereignty of the aluminium industry, while meeting the climate challenges facing our planet.

4.2 Transport and Storage Infrastructure

The transport and storage of CO_2 are pivotal in advancing industrial decarbonization, particularly in regions like Dunkirk, where significant initiatives are underway. For AD, these elements are essential for meeting its decarbonization goals and supporting climate targets. The development of CO_2 transport and storage infrastructure is crucial for enabling industries to reduce their emissions while continuing their operations.

AD is a natural player in the field of CO_2 capture due to its strategic location within the Dunkirk Industrial Port Zone, a region that is pivotal for decarbonization efforts. The Dunkirk area is responsible for about 20 % of France's industrial emissions, making it an essential focus for reducing carbon output. The local institutional leaders, including the Dunkirk Urban Community and the Dunkirk Grand Port Maritime, have committed to a decarbonization roadmap and an ecological transition plan aimed at achieving carbon neutrality by 2050.

The development of a CO_2 ecosystem—including capture, transport, storage, and utilization—is a central component of this strategy. Dunkirk is already advancing initial CO_2 capture projects and securing European funding for these initiatives. Moreover, significant geological CO_2 storage projects in the North Sea (Netherlands, United Kingdom, Norway) are accessible through Dunkirk's port infrastructure, complementing local efforts.

Among all the stakeholders that need to be mobilized and the partnerships that will be formed, we must not forget one of the most important and vital actors for the success of all efforts towards achieving decarbonization: the French State. The government has demonstrated its confidence in the Dunkirk industrial base by selecting it as one of the first low-carbon industrial zones following

the ADEME ZIBAC call for projects [8]. This endorsement underscores the region's critical role in advancing decarbonization. This backing is crucial for accelerating the deployment of CO_2 technologies and infrastructure.

In this context, AD's strategic positioning enhances its role in the development and implementation of CO_2 capture solutions. Working in tandem with GRTgaz and other regional stakeholders, AD will contribute to a CO_2 transport network connecting industrial CO_2 sources to storage and utilization sites. By leveraging its advantageous location and expertise, AD is well-positioned to drive advancements in CO_2 capture and contribute significantly to the sector's decarbonization goals.

5. Conclusion

Aluminium Dunkerque has long been a champion of continuous improvement, initially honing its focus on energy management and electrolytic processes. As the landscape of industrial decarbonization evolves, AD's commitment has expanded to encompass broader challenges, including the reduction of greenhouse gases emissions.

AD's strategy reflects a deepened commitment to operational excellence and sustainability. The implementation of ISO 50001 certification across the entire facility underscores the company's dedication to improving energy management and efficiency site wide. These internal advancements demonstrate AD's ability to adapt and enhance its practices in line with emerging decarbonization goals.

However, addressing the complexities of gas emissions and other disruptive areas of decarbonization requires a common effort from all the stakeholders. By collaborating with industry experts and leveraging external innovations, and with the essential support of governments and legislators, AD can supplement its internal strengths and drive forward cutting-edge initiatives.

The role of the aluminium industry is critical in this context. As a key player in the global industrial sector, the aluminium industry must lead by example in adopting innovative technologies and practices to drive substantial emissions reductions. The sector's unique position, given its significant energy consumption and carbon footprint, means that its contributions to decarbonization can have a profound impact on broader environmental goals.

In conclusion, Aluminium Dunkerque's evolution from a focus on energy efficiency to a comprehensive decarbonization strategy illustrates a proactive response to the pressing challenges of today's industrial landscape. By combining its internal expertise with strategic external partnerships, AD is well-positioned to take an important part in the charge in industrial decarbonization, driving progress towards a more sustainable future.

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