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Oliver Wyman

WORLD ECONOMIC FORUM

From Blueprint to Reality: A Stronger Business Case for Shared Energy Infrastructure

LEARNINGS FROM TRANSITIONING INDUSTRIAL CLUSTERS

WHITE PAPER

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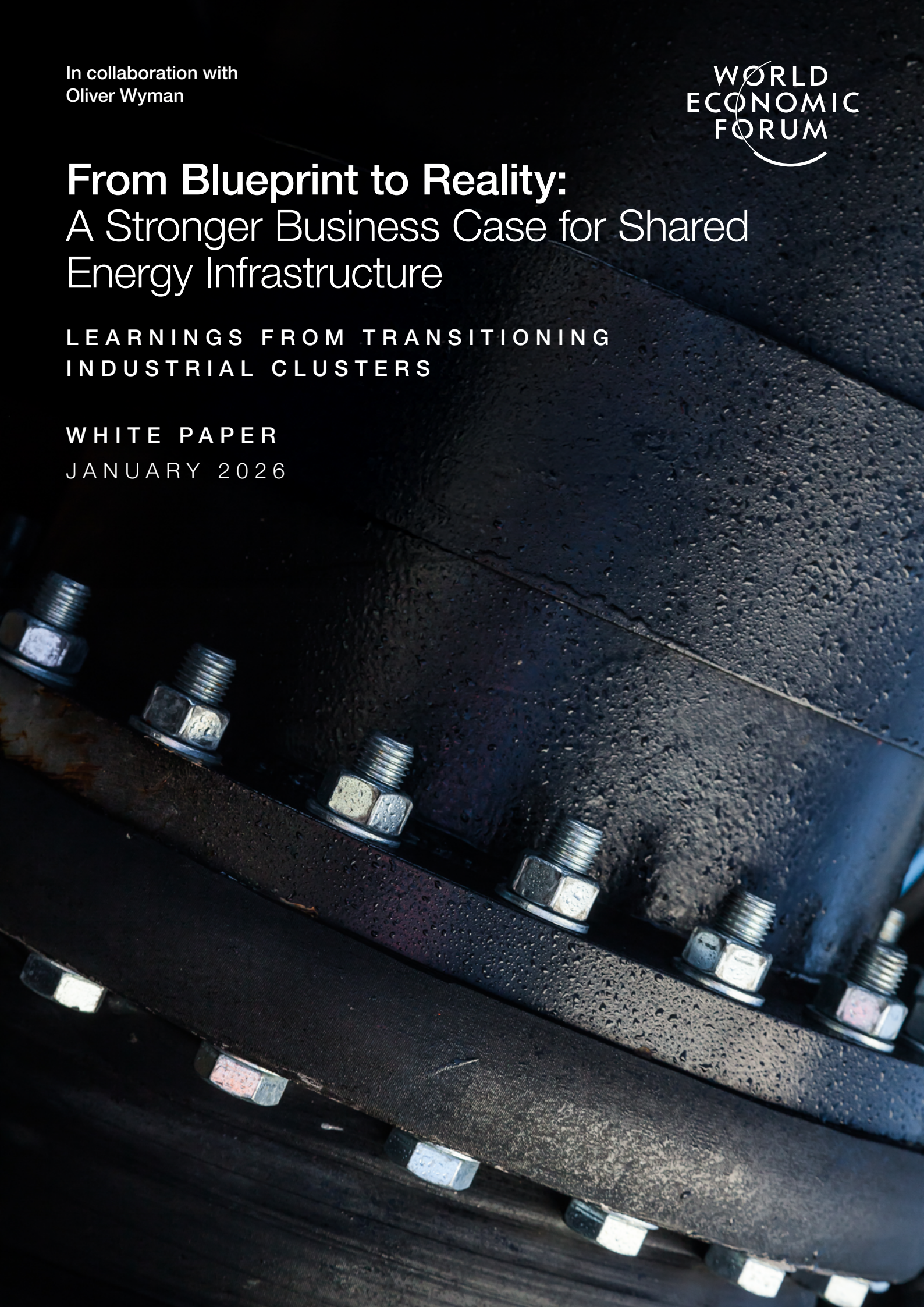

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A global industrial transformation is underway. Energy consumption is rising, especially in emerging economies, while shifting geopolitics are, in many regions, pushing energy security and competitiveness up corporate and political agendas. The mix and supply of renewable energy are increasing, but this is still not enough to meet demand. Meanwhile, supply chains are being reconfigured and resources are becoming more constrained. As a consequence, the economies most likely to succeed are those that combine industrial efficiency, local value creation and innovation in cleaner production.

Hard-to-abate sectors such as aluminium, cement, steel, chemicals, aviation, shipping and trucking are the backbone of growth, jobs and trade – and will remain so in any future economy. To stay competitive, these industries need to transition in ways that cut emissions while enhancing long-term value. Yet investment in this industrial transformation remains inadequate – at just $30-50 billion annually[1] – and many low-carbon projects struggle to reach financial close or become operational, leaving a persistent gap between targets and results.

Closing this gap will take more than stand-alone projects; it requires systemic innovation in how industries, value chains, governments and financiers align and deliver together. This is where well-organized industrial clusters – the focus of the World Economic Forum's Transitioning Industrial Clusters (TIC) initiative – come in. By aggregating demand and supply, sharing infrastructure and coordinating investment in a defined geography, clusters make industrial transformation more bankable and commercially attractive while safeguarding and creating jobs.

Since its launch at COP26, the TIC initiative has grown into a global community of clusters with an estimated 877 million tonnes of CO_2e abatement potential, contributing $508 billion to global GDP and supporting 4.6 million jobs.[2] One of the first TIC signatory clusters, HyNet North West in the United Kingdom, has reached final investment decision for its CO_2 transport and storage system – a milestone that provides a reference point for financing shared energy infrastructure. Similar momentum is visible in port-anchored clusters such as Antwerp-Bruges and Rotterdam, and in low-carbon industrial hubs around the world.

This report aims to capture and share some of these emerging success stories. It distils lessons on how to organize clusters, structure risk-sharing and finance shared infrastructure in ways that align policy and private investment. The intention is to offer a practical resource for policy-makers, financiers and industry leaders seeking to turn targets into competitive advantage and deliver industrial transformation that is both economically robust and environmentally sustainable.

Executive summary

Industrial transformation in energy ecosystems is a powerful driver of competitiveness, innovation and job creation.

Unlocking the next stage of industrial transformation in energy ecosystems is critical for enhancing the competitiveness of domestic industries, protecting existing jobs and generating new employment opportunities in the growing clean technology sector. Realizing this potential will require innovative business models that mobilize capital at scale, direct resources efficiently and deliver projects that provide widespread commercial and societal value.

The industrial cluster model, where co-located companies across multiple sectors and public institutions collaborate around low-carbon projects and shared solutions, offers a powerful pathway for transformation. This report highlights models for leading industrial clusters – chosen because they showcase successful low-carbon projects that have already reached final investment decision (FID) or are close to doing so. It also draws on additional research into a broader set of international clusters that are using innovative approaches to financing.

It outlines how industrial clusters can advantageously position low-carbon projects through:

Market and policy set-up:

- Garnering institutional support, with governments increasingly providing targeted policies supporting transformation efforts within clusters.

Technical development:

- Sharing infrastructure such as pipelines or storage, lowering unit capital expenditure and maximizing asset utilization.
- Centralizing project coordination which reduces duplication, streamlines processes and improves investor confidence.

Market realization:

- Aggregating demand and supply so proximity of projects leads to reliable, bankable market volumes and optimized infrastructure use.
- Decreasing costs by enabling bulk procurement, construction efficiency and allowing "fast followers" to connect at lower risk, thus delivering economies of scale.

Learning and development:

- Promoting innovation and knowledge sharing, facilitating cross-organization research to accelerate the maturity of new technologies.

Building on these lessons, the report identifies four drivers of success for financing shared energy infrastructure:

For industry:

1. **Establish a cluster administrator:** Centralize coordination of permitting, project origination, financial management and stakeholder engagement under a trusted cluster administrator, ensuring efficient project delivery and governance.
2. **Pool resources and future-proof infrastructure investment:** Leverage joint procurement and co-investment in shared assets (e.g. pipelines, storage, grid connections) to optimize upfront costs and future-proof projects for changing markets and regulations.
3. **Continue establishing strong offtake agreements:** To guarantee commercial viability at the operational stage, structure durable contracts between suppliers and offtakers (e.g. take-or-pay agreements) to enhance revenue certainty, operational viability and lender confidence.

For government:

4. **Use public capital to deploy phase-appropriate financial instruments:** Local and national governments could consider sequencing tools such as guarantees and revenue stabilization mechanisms across different stages. In cluster settings, these instruments may be able to de-risk shared infrastructure and a coordinated pipeline of projects, potentially making public support more efficient and scalable.

Achieving industrial transition at scale will require innovative risk-sharing approaches and public-private partnerships. Industrial clusters offer a commercially competitive pathway to deliver this transformation and support a resilient, sustainable global economy.

1 Introduction: clusters as engines of industrial transformation

As countries and companies accelerate efforts to deliver on decarbonization targets, they are seeking new ways to create value and stay competitive, while reducing emissions.

1.1 The state of play for industrial transformation

Global demand for energy continues to rise, with consumption growing by roughly 2% in 2024, driven largely by countries outside the Organisation for Economic Co-operation and Development (OECD).[3] At the same time, the race to decarbonize is reshaping global competition. As of mid-2025, 140 countries, representing over 90% of global GDP, have announced or are considering net-zero targets, and a growing share of major companies are moving to decarbonize their operations.[4]

Yet the world remains far off track. In November 2025, the United Nations Environment Programme (UNEP) reported that even if all current Nationally Determined Contributions (NDCs) are fully implemented, projected warming over this century is still 2.3-2.5°C and up to 2.8°C under current policies – only a marginal improvement from last year.[5] This underscores a widening gap between rising ambition and real-world emissions reductions and makes clear that current efforts are not yet sufficient to keep climate goals within safe reach.

Momentum is nonetheless building: 61 countries updated their NDCs in 2025, intensifying the search for scalable solutions that combine competitiveness with low emissions.[6] Increasingly, the focus is on robust business models that strengthen industrial resilience, particularly as energy security is challenged by shifting geopolitical dynamics.

Industrial sectors such as aluminium, cement, steel, chemicals, aviation, shipping and trucking are at the heart of this transition. They account for roughly 40% of global greenhouse gas emissions and are fundamental to economic output and jobs.[7] Decarbonizing these hard-to-abate sectors is complex and will require unprecedented innovation, investment and collaboration.

Key barriers to heavy industry's transition remain:

- **Technology and market readiness:** Many clean technologies are still maturing, and scalable solutions are not always available.
- **High capital costs:** Significant upfront investment is required for industrial retrofits and new infrastructure, which can deter stakeholders, particularly in uncertain markets.
- **Supply chain constraints:** Underdeveloped end-to-end value chains for emerging technologies and materials limit their ability to scale up.
- **Policy and permitting:** Lengthy approvals and inconsistent regulatory support can stall projects, creating uncertainty for investors.

Addressing these barriers is an economic and competitiveness imperative. Investment will ultimately follow returns, so scaling-up low-carbon industrial projects depends on providing credible profitability and risk-adjusted performance. With an estimated $30 trillion in additional investment needed by 2050 to decarbonize hard-to-abate sectors, progress will depend on strong market pull, stable policy and risk reduction that materially improves project economics. Well-organized industrial clusters have a key role to play in making the transition investable and internationally competitive.[8]

1.2 Making the case for low-carbon industrial clusters

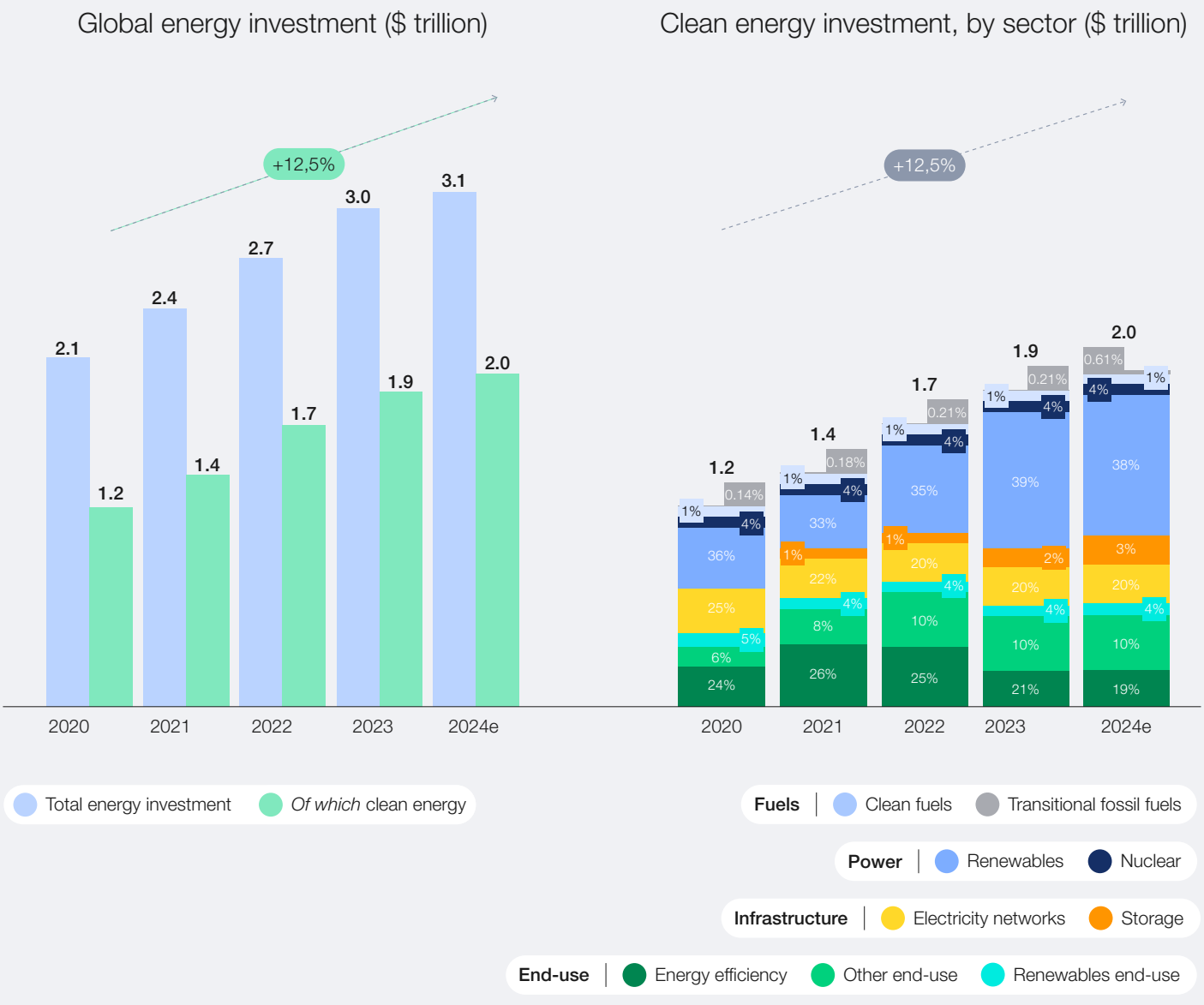
> In 2024, clean energy investment accounted for over 60% of all energy investment, reaching ~$2 trillion. Nearly 40% of that went to renewable power.

Clean energy investment now outpaces fossil fuels

On the investment side, there has been significant movement. Global investment in clean energy has been rising: in 2024, clean energy accounted for over 60% of all energy investment, reaching an estimated $2 trillion.[9] Nearly 40% of that went to renewable power (see Figures 1 and 2).[10]

The story of renewables shows how robust policy frameworks and incentives can help build sustainable, self-sufficient markets capable of competing with legacy energy sources. A similar shift is now needed for clean molecules and the technologies required to decarbonize hard-to-abate sectors.

FIGURES 1&2 **Global energy investment and clean energy investment (2020-2024)**



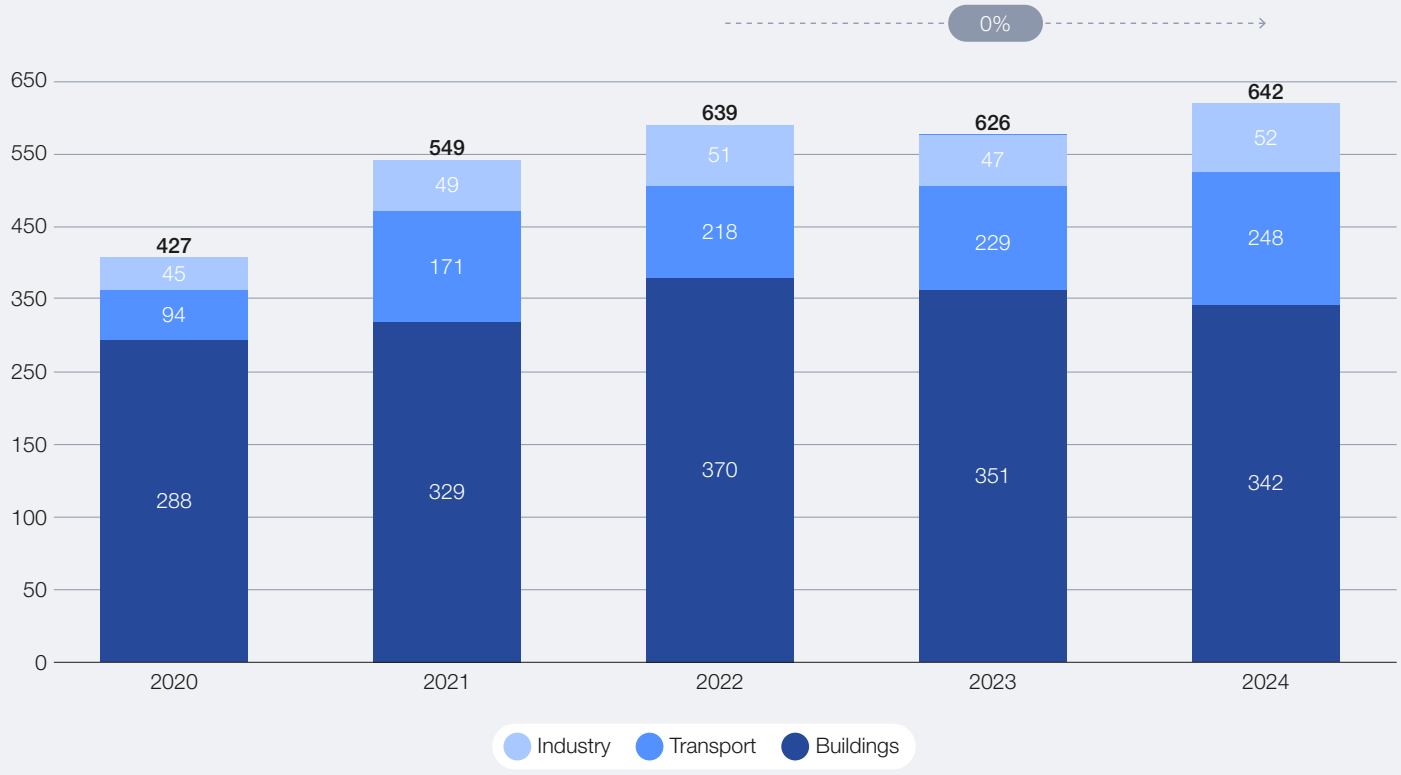
Notes: 2024e means: 2024 values are estimated and may change when data is confirmed. CAGR = compounded annual growth rate.
Source: International Energy Agency (IEA).[11]

Investment in industrial transition has flatlined

Over the past three years, investment in energy efficiency and electrification for end use has remained broadly flat, with capital mostly deployed for "buildings" and "transportation", according to International Energy Agency (IEA) analysis.[12] By contrast, investment for "industry" has averaged around $50 billion annually (see Figure 3).[13, 14]

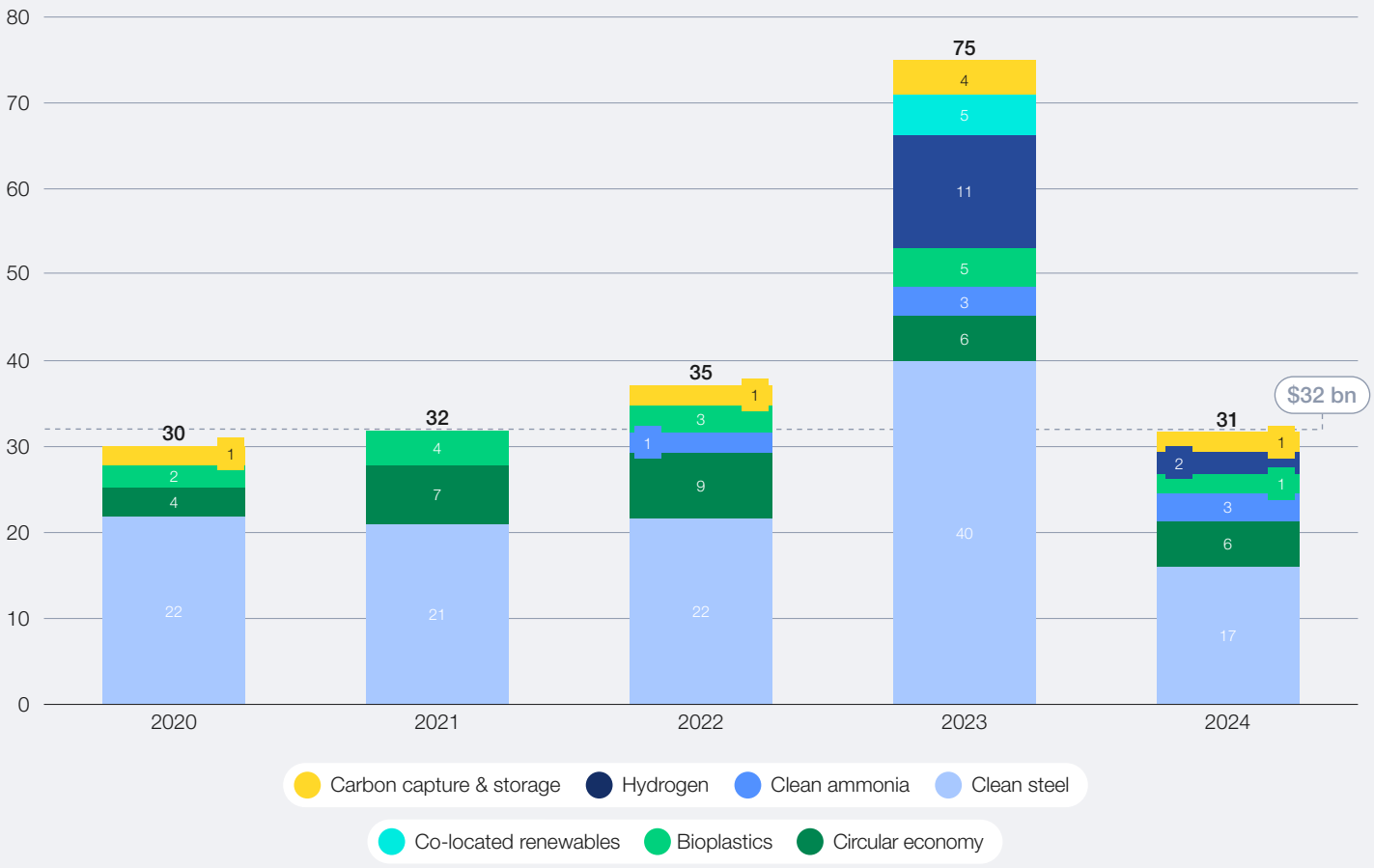
BloombergNEF analysis further indicates that, aside from a significant spike of $75 billion in 2023 largely driven by a surge in commitments for clean steel projects, total investment into the broader "clean industry economy" has averaged just $32 billion per year since 2020 (see Figure 4).[15,16]

FIGURE 3 **Global investment in energy efficiency, electrification and renewables for end uses, by sector ($ billion)**



Source: International Energy Agency.[17]

FIGURE 4 | **Investment in "clean industry economy" by sector ($ billion)**



Note: Grey dashed line is average annual investment for 2020-2024, not including 2023.

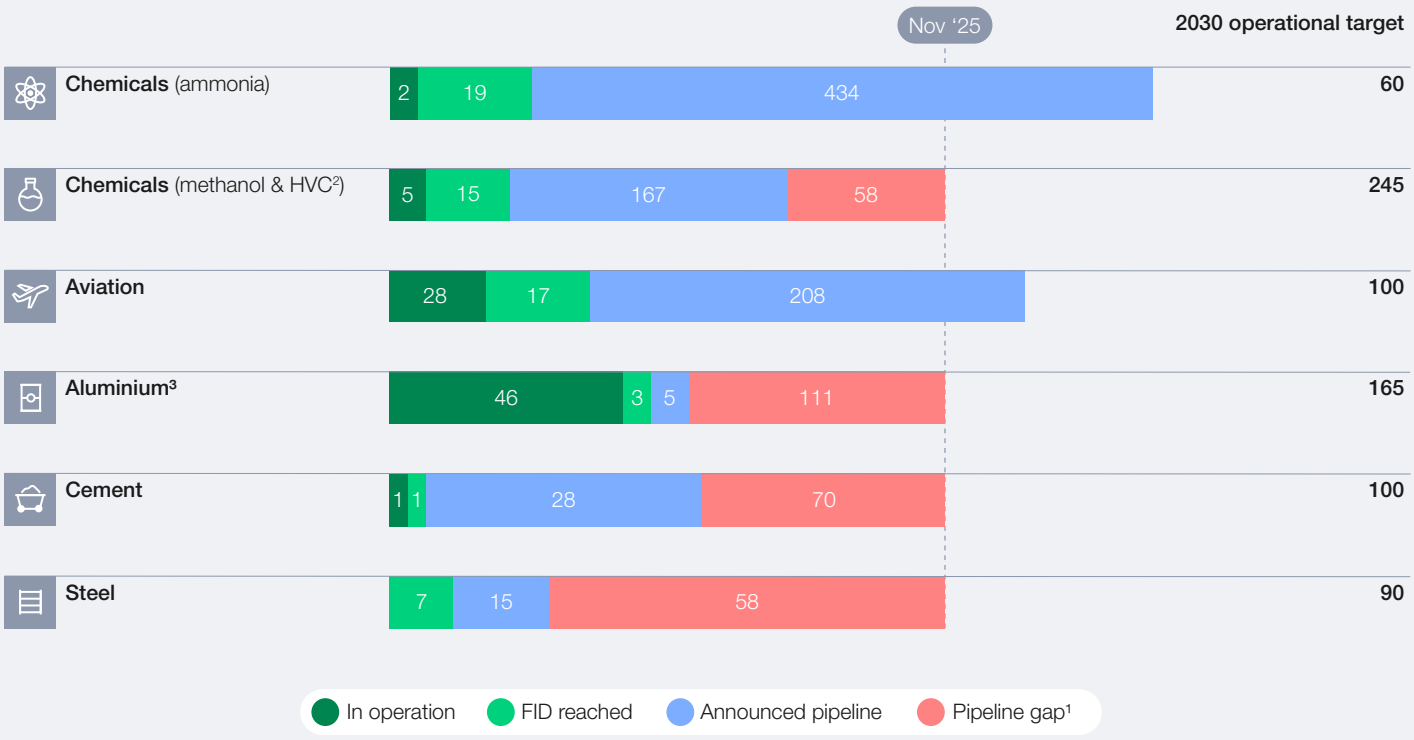
Source: BloombergNEF.[18]

While there is a strong pipeline of ~700 net-zero aligned facilities, only one-fifth of the clean industrial plants needed are currently financed.

The challenge is not a lack of ambition but turning ambition into bankable projects. Some progress is visible: the number of low-carbon projects reaching financial close increased between 2020 and 2024. Yet the overall scale of financing remains insufficient. According to the Mission Possible Partnership Global Tracker, while there is a strong pipeline of ~700 net-zero aligned facilities as of November 2025, only one-fifth of the clean industrial plants needed are currently financed.[19]

To accelerate the industrial transformation, low-carbon projects must become commercially viable so that developers, companies and financiers can justify building new infrastructure and upgrading existing assets. What is missing is a delivery model that can turn a fragmented pipeline into investable scale.

FIGURE 5 | **Commercial-scale clean industrial projects, pipeline tracker (# plants, November 2025)**



Notes: 1. Gap vs. 2030 target. **2.** HVC = high-value chemicals, including olefins and aromatics. **3.** Over half of operational plants are in the aluminium sector, most of which are legacy clean assets – facilities that were already relatively low-carbon before recent net-zero efforts. While this is positive for today's emissions, it also means that part of the current clean asset base reflects historic advantages rather than new transition investment.

Source: Mission Possible Partnership (MPP).[20]

Industrial clusters offer a powerful pathway to accelerate future transition

Industrial clusters are geographic areas where co-located companies and public institutions collaborate around a common vision. Concentrating investment in clusters is a tried and tested approach for governments and industry leaders to accelerate growth and support early-stage market development. Governments have long used clustering as a tool for regional and economic development. Special economic zones (SEZs) are a prime example: by concentrating incentives, pre-permitted land and enabling infrastructure, SEZs in countries such as China have provided administrative "one-stop shops", standardized rules and contracts, and targeted fiscal and regulatory incentives that reduce transaction costs and uncertainty and crowd in foreign direct investment (FDI).

Within this context, the industrial cluster model is emerging as a powerful pathway to unlock financing and accelerate industrial transition. By aggregating demand, enabling shared infrastructure and streamlining processes through centralized governance, clusters create diversified, large-scale investment ecosystems that help de-risk first-of-a-kind (FOAK) projects and make low-carbon technologies more cost efficient and commercially viable.

> **Unlocking the full potential of low-carbon industrial clusters depends on making projects bankable. Predictable regulation, strong governance and flexible sponsors are essential to de-risk complex investments and mobilize capital at scale. Clusters aggregate demand, share infrastructure and open new financing pathways, turning promising pipelines into real projects.**
>
> Carlos Torres Vila, Chair, BBVA

Policy recommendations are now increasingly calling for similar approaches to support low-carbon industrial transformation. In September 2024, a report published by the European Union (EU) entitled *The future of European competitiveness* proposed the coordinated development of "green regional industrial clusters around the EU's EIIs [Energy Intensive Industries]" to support their decarbonization, both by fostering "industrial symbiosis" in existing clusters and by creating new "green regional EII clusters". [21] Likewise, a recent IEA report on advancing clean technology manufacturing highlighted that the costs associated with these facilities are typically lower in China, partly because of its ability to organize "industrial clusters covering the entire value chain".[22] China's National Development and Reform Commission has referenced industrial parks and clusters as a central part of its "administrative measures for the special management of investment in the central budget for energy saving and carbon reduction".[23]

Co-locating in clusters strengthens the business case for clean technology

For first movers in hard-to-abate sectors, clusters help overcome a key barrier to financing: the ability to lock in credible offtakers.

Today's leading clean industrial clusters are maximizing the benefits of co-location. Port and industrial zones are establishing dedicated routes for transporting hydrogen and captured carbon, through shared pipelines and other transport networks. Proximity gives companies a natural advantage in securing users for shared infrastructure and buyers for energy products, making individual projects more attractive investment platforms. For first movers in hard-to-abate sectors, clusters help overcome a key barrier to financing: the ability to lock in credible offtakers.

1.3 Report scope and methodology

Building on the World Economic Forum's January 2025 report, *Unleashing the Full Potential of Industrial Clusters: Infrastructure Solutions for Clean Energies*, which set out the case for clusters, governance models and early implementation lessons,[24] this white paper zooms in on the financing and business case for shared energy infrastructure within clusters.

To inform this analysis, the project team conducted 13 in-depth interviews between August and September 2025 with cluster administrators, financiers and project developers across select industrial clusters. These interviews, carried out specially for this report and complemented by targeted desk research, underpin the individual case studies and most of the findings presented here.

Drawing on the above research, this white paper:

- **Illustrates the financial and business case** for low-carbon industrial clusters, focusing on optimizing capital structures, cost-sharing mechanisms, risk mitigation strategies and key success factors.
- **Spotlights clusters at various stages of maturity on their journey towards FID** – from early-stage clusters starting to show the financing benefits of an integrated approach, to advanced clusters leveraging shared infrastructure and collaboration to accelerate funding.
- **Captures key learnings and recommendations** for project developers and policy-makers seeking to scale up industrial transition through clusters.

2 Cluster approach: multiple benefits for low-carbon projects

Industrial clusters provide an immediate and efficient opportunity for transformative action, particularly in hard-to-abate sectors.

2.1 What we can learn from select low-carbon clusters

The World Economic Forum's Transitioning Industrial Clusters initiative comprises 40 active industrial clusters, which collectively deliver an estimated 877 million tonnes of CO_2e abatement potential, contribute $508 billion towards global GDP and protect or create 4.6 million jobs.[25]

40
active industrial clusters in the Forum's Transitioning Industrial Clusters initiative

877 million
tonnes of estimated CO_2e abatement potential

$508 billion
contribution towards global GDP

4.6 million
jobs protected or created

Progress in these clusters relies on both low-carbon projects – such as hydrogen production or carbon capture – and the development of shared, enabling infrastructure. Low-carbon infrastructure includes transport and storage (T&S) or hydrogen pipelines and storage hubs that connect multiple projects.

This report highlights the following three broad models or archetypes for financing and developing low-carbon projects within industrial clusters (see Table 1):

Government-enabled financing

In countries with a robust and supportive policy environment, where investors have a clear view of government support mechanisms, projects can raise financing from multiple sources, including commercial project financing alongside capex investment from developers.

Public capital-led financing

This approach occurs in locations where there is some strategic policy direction, but – given that external investors and financiers sense less certainty around government incentives – cluster administrators play a more active role in de-risking projects.

Single developer-led financing

In locations where projects cannot directly access government support, but there is strong demand for clean technologies, individual developers often deploy substantial capital to move projects forward, taking on early-stage technology and market risk. A key enabler in these cases is their ability to drive down costs and secure long-term offtake agreements.

TABLE 1 **Three cluster archetypes**

Government-enabled financing	Public capital-led financing	Single developer-led financing
Policy environment: Advanced, clear regulations and incentives for projects.	**Policy environment:** Moderate, with some strategic direction and enabling regulation but less certainty.	**Policy environment:** Limited incentives or guidance for low-carbon projects in clusters.
Financing: Projects achieve bankability due to regulatory certainty, unlocking private sector investment at scale.	**Financing:** Cluster administrators (often public authorities) act as anchors – seeding projects, offering guarantees or directly co-investing.	**Financing:** A single developer drives project and infrastructure development.
Governance: Cluster administration is largely facilitative; private actors set the pace.	**Governance:** Cluster administrators often intervene financially and play a central role to align stakeholders and de-risk investment.	**Governance:** Little coordination at the "supra-cluster" level; project success relies on the sponsor's commitment and available capital.

2.2 Financing benefits of low-carbon clusters

From a financing perspective, there are multiple advantages to low-carbon projects being situated in an industrial cluster (see Table 2).

TABLE 2 **Benefits of industrial clusters**

Garner institutional support from government

Public policies, funding programmes and regulatory frameworks encourage growth and competitiveness within the cluster.

Share infrastructure

Businesses have access to common facilities, transport links, utilities and specialized services to reduce duplication and improve efficiency.

Centralize project coordination

Effective collaboration between stakeholders within clusters accelerates project delivery, ensuring more efficient allocation of capital.

Aggregate demand & supply

Proximity concentrates the market, making it easier for suppliers to find buyers and vice versa.

Decrease costs

Shared resources, bulk purchasing and reduced transport distances help to achieve economies of scale, lowering operating expenses.

Promote innovation & knowledge sharing

Frequent interaction between companies, research institutions and skilled workers promotes the development of innovative technology.

Market & policy set-up · Technical development · Market realization · Learning & development

Garner institutional support from government

Long-term, targeted regulatory support from government, particularly when paired with broader support from local communities, improves investor risk appetite to deploy capital for low-carbon projects.

Share infrastructure

Multi-user access to shared infrastructure – for example, by multiple CO_2 emitters or H_2 users – reduces duplication and enables cost sharing. This lowers necessary investment per user and increases asset utilization.

Centralize project coordination

Effective collaboration between stakeholders within clusters enables more efficient capital allocation. This reduces the possibility of overlapping investment requests, streamlining access for financiers, building confidence and ultimately enabling more efficient capital allocation. By aligning roles and responsibilities across multiple actors, clusters also help rebalance risk towards those best able to manage it, reducing single-project exposure and improving overall bankability.

In addition, by facilitating alignment across stakeholder interests and constraints, the cluster approach helps ensure buy-in, reducing risk of disruptions.

Another notable advantage of the cluster model is that permitting processes can be faster, which helps limit delay and cost overrun.

Aggregate demand and supply

Co-locating the supply of energy and technology near demand generates larger production volumes for underlying infrastructure, increasing credibility for commercial lenders and government funding bodies.

In addition, locating industrial processes behind the meter alongside energy supply, when supported by abundant renewable resources, can mitigate risks from high grid access costs and grid congestion.

Decrease costs

Opportunities for bulk procurement and construction efficiencies allow clusters to achieve greater economies of scale. For example, pre-existing clusters can offer the opportunity to adapt existing infrastructure, such as pipelines and storage terminals. This can lower initial capex

while ensuring assets meet changing needs. However, retrofits are still capital intensive and careful management of hidden costs and added complexity is necessary to realize cost savings.

Clustering also creates the opportunity for additional users already in proximity – such as fast followers – to efficiently connect and benefit from cost advantages, further spreading risk.

Promote innovation and knowledge sharing

The ability to collaborate on research and development with other organizations and to share best practice helps to reduce technology risk, accelerate project delivery and drive low-carbon projects towards cost parity with traditional technologies and energy sources.

The six benefits of industrial clusters highlighted above help to strengthen the strategic case for clusters when seeking funding. Interviewees for this report noted that, in funding applications, demonstrating unified support from stakeholders across the value chain increased the perceived relevance and credibility of projects, providing concrete proof-points to unlock public capital. These institutional advantages can also compress time-to-permit, codify shared-use infrastructure (e.g. pipelines, CO_2 storage and grid interconnections) and establish more predictable frameworks that lower risk and mobilize capital for first movers.

2.3 Four considerations determine project investability

The presence of a cluster, however, does not automatically confer "financeability". Four key considerations determine whether projects within a cluster clear investment barriers:

- Coordination and integration drive value, but **fragmented ownership raises complexity:** the role of the cluster administrator is vital.
- Infrastructure projects may provide the anchor for low-carbon development, but it is the **commitment of first movers** and offtakers that catalyse investment.
- **Government support is essential**, but there is no one-size-fits-all approach. Public sector de-risking should be leveraged in ways that maximize efficiency and cover risks that cannot be covered any other way.
- The "halo" effect created by a cluster can reduce overall risk, but each project needs to **clear investment hurdles independently.**

Fragmented ownership raises complexity: cluster administrators play a vital role

The coordination benefit of clusters – aggregating demand and sharing assets – creates financial efficiencies but requires careful management of the complexity that can arise from multiple owners and stakeholders.

The role of the cluster administrator is vital, if the financing benefit of clusters is to be fully realized. A cluster administrator is typically a single project developer or public entity (such as a port authority) with the resources, authority and incentive to ensure project alignment and manage the shared interests of relevant parties. They are often pivotal for ensuring effective governance, project delivery and successful collaboration among stakeholders.

Aligning diverse interests becomes more challenging as regulations, markets and technologies evolve, increasing the need for strong governance and skilled stakeholder management. This is especially true where several privately owned organizations are involved in the cluster compared with publicly owned entities that often have more flexibility on return expectations and risk appetite.

Commitment from offtakers catalyses investment

Securing large-scale offtake contracts from first movers provides revenue certainty, strengthening lender and investor confidence and anchoring demand for asset owners. In the case of the Chifeng Net Zero Industrial Park, a long-term offtake agreement for green ammonia with Marubeni Corporation has allowed Envision to commit to building a commercial green ammonia plant (see Chapter 3.3). Similarly, TotalEnergies' commitment to the ELYgator electrolyser project at the Port of Rotterdam ensures guaranteed demand for the clean hydrogen being developed (see Chapter 3.2).

In clusters located on greenfield sites, where there is no existing infrastructure (particularly in emerging markets), it is important to ensure this broader value chain is developed by, for example, investing in smaller suppliers and skills development.

Government support is essential, but there is no one-size-fits-all approach

Active public sector involvement is often pivotal for FOAK projects. Financiers require confidence in regulatory stability and broader societal support to reduce the risk of disruptions. However, this support manifests itself in different ways:

- In the Netherlands, state-owned organizations anchored early infrastructure investment in Porthos – the first Dutch carbon capture and storage (CCS) project to reach FID. They accepted lower investment returns and managed regulatory and permitting risks to enable private organizations to focus their capital on developing carbon capture projects.

> It is essential that government de-risking is used as efficiently as possible and focused on risks that markets cannot reasonably absorb.

- In the UK, by contrast, private organizations in both HyNet North West and Humber clusters have led project development and financing, under a government-backed regulatory framework and clear business models that provide long-term revenue certainty.

- In the Cartagena industrial cluster in Colombia, private organizations are leveraging their own balance sheets to pilot and build hydrogen facilities, while relying on government for non-capital support such as permitting, regulatory clarity and strategic policy signals.

  This illustrates a model where the public sector enables and coordinates, with private developers carrying a larger share of the upfront investment.

As public sector budgets become increasingly constrained, it is essential that government de-risking is used as efficiently as possible and focused on risks that markets cannot reasonably absorb. In this context, non-capital measures – such as streamlined permitting and clearer, more predictable regulation – will play a growing role.

Each project needs to clear investment hurdles independently

> Speed to market often emerges as the most critical determinant, shaping both financing and operational choices.

While the cluster's "halo" effect can boost the attractiveness of investment, there are rarely blanket or pooled financing structures. Individual projects within clusters still face their own due diligence and risk thresholds. As demonstrated by the financing blueprints in the following chapter, a wide spectrum of capital types and financing structures – including project finance, capex investment, equity, grants and contracts for difference (CfDs) – can be leveraged to support large-scale transition projects.

Additionally, the diversity of operating models – such as joint ventures, partnership agreements and sole operators – underscores the adaptability required to effectively balance project risks, stakeholder interests and shifting market dynamics. Speed to market often emerges as the most critical determinant, shaping both financing and operational choices.

It is important to note that project-on-project construction risk, where the financial viability of one project is dependent on successful completion of another, presents a particular challenge. The scale and complexity of projects often require multiple contractors to develop infrastructure, given the extent of delivery risk and technical expertise needed. As discussed above, in this context, the presence of a cluster administrator with strong coordinating and convening power is pivotal.

3 Viable pathways for heavy industry's transition through industrial clusters

Different industrial clusters demonstrate how shared infrastructure, government coordination and innovative financing can accelerate heavy industry's transition.

In the transition of heavy industry, regulation shapes demand – and the cost premium of low-carbon solutions means collaboration models vary by regulatory framework. This chapter focuses on the three financing archetypes observed in practice: government-enabled financing, public capital-led financing and single developer-led financing.

Drawing on international cluster experience, it highlights how shared infrastructure, government coordination and innovative financing can accelerate the transition for heavy industry across these archetypes. Within this broader set of examples, the report develops detailed financing "blueprints" for select clusters where project maturity and public information are sufficient to credibly illustrate capital structures and risk allocation in practice.

These clusters rely on tailored mixes of private capital, public support and risk-sharing mechanisms. By concentrating demand from multiple emitters and potential users of clean energy, while leveraging strong public-private partnerships, these clusters feature projects that have either reached, or are close to reaching, FID.

While valuable lessons can be drawn from these examples, it is important to recognize that there is no one-size-fits-all solution: each cluster's financing strategy is shaped by its local context, regulatory environment, stakeholder dynamics and project requirements. Furthermore, as the blueprints are based solely on publicly available information, they should be regarded as indicative rather than exhaustive.

Additional context and detail for each of the profiled clusters can be found in the Appendix.

3.1 Government-enabled financing

The following case studies illustrate cluster formation in contexts with relatively strong regulatory certainty. In the UK, long-term policy direction, targeted support schemes and clear roles for the public sector give developers and lenders enough confidence to combine balance-sheet investment with commercial debt.

The following section focuses on two UK clusters, HyNet North West and Humber, which illustrate how government-enabled models can translate policy ambition into financeable cluster projects.

CASE STUDY 1 | HyNet North West

HyNet North West, led by Eni, is one of the UK's flagship low-carbon industrial clusters. HyNet North West is pioneering the integrated deployment of carbon capture and storage across Northwest England and North Wales. This includes carbon capture from existing hard-to-abate industries, along with the transport and storage (T&S) of CO_2 in depleted offshore gas reservoirs. The cluster is also developing a future hydrogen production and distribution network.

> **The UK's legislative framework to incentivise CCS projects has played a pivotal role in attracting private finance to scale the CCS industry, providing the regulatory certainty and investment signals needed for private sector participation in clean energy infrastructure. Eni is proud to have helped kickstart this important industry through our Liverpool Bay CCS project, as the backbone of the HyNet cluster. The success of this project will lay the foundation for further growth and innovation as the sector continues to evolve.**
>
> Claudio Descalzi, Chief Executive Officer, Eni

Hynet's innovative financing journey highlights key mechanisms and market/government dynamics required to scale up investment to decarbonize heavy industry.

FIGURE 6 **HyNet North West – overview of impacts**

Emissions reduction
10 Mt CO_2e
Potential annual capacity from 2030

Gross value-add contribution
£811 million
Annually until 2050

Jobs
2,800
Additional jobs from network expansion

Source: HyNet North West, Amion Consulting, UK Government.[26]

There are six major projects being prioritized within the HyNet cluster, helping to drive decarbonization:[27]

Infrastructure:

- **Eni's Liverpool Bay T&S:** This flagship project provides the backbone for the HyNet cluster. Once constructed, industrial emitters will be able to connect to the T&S infrastructure, which will see the CO_2 captured and permanently stored in depleted gas reservoirs in the Irish Sea. The network will have an initial capacity of 4.5 million tonnes (Mt) of CO_2 per year with potential to expand to up to 10 Mt dependent on demand. Eni reached financial close on the project in April 2025, with the award of an economic licence by the UK authorities.

Industry:

- **Encyclis waste-to-energy:** The UK's first full-scale carbon capture plant at a waste-to-energy facility will be developed at Encyclis' Protos Energy Recovery Facility, from which the CO_2 will be transported and stored through Eni's pipeline infrastructure. The project, which reached FID in September 2025, will prevent the release of around 370,000 tonnes of CO_2 per year.

- **Heidelberg Materials cement plant:** Heidelberg Materials is constructing one of the world's first carbon capture facilities to enable fully decarbonized cement production, with plans to be operational by 2029. There is potential for up to 1 million tonnes of CO_2 to be captured at the plant. Heidelberg Materials' Padeswood CCS facility in North Wales reached FID in September 2025, after final agreement with the UK authorities.

- **Hydrogen production plant:** Essar Energy Transition (EET) is developing a 350 MW blue hydrogen plant, creating hydrogen from natural gas feedstock with an integrated carbon capture, utilization and storage (CCUS) facility. Production is expected to start before 2030, with capacity to capture ~600,000 tonnes of CO_2 per year. Phase 2 of the project is targeting 1,000 MW with potential to capture 1.9 million tonnes of CO_2 per year.[28]

- **Low-carbon electricity production:** Uniper is developing a new CCS-enabled low-carbon power plant at Connah's Quay, with plans for the combined-cycle gas turbine (CCGT) power station to be operational by 2030. The plant is expected to provide around 1.1 GW of low-carbon electricity in two phases, with the option to expand to up to 1.38 GW of capacity.[29]

- **Bioenergy carbon capture project:** Evero's energy from waste-wood plant aims to become the UK's first bioenergy with carbon capture and storage (BECCS) facility, targeting the removal of more than 200,000 tonnes of CO_2 per year by 2029.[30]

These industry projects represent a potential first phase of users of Eni's CO_2 T&S infrastructure. An additional five projects are lining up for later connection: Viridor and Enfinium waste-to-energy plants, a further hydrogen production plant (developed by EETH), a refinery capture project (developed by Essar), and a direct air capture (DAC) project (developed by Climeworks). These projects have already been identified by the UK authorities for future connection to the Liverpool Bay T&S network, demonstrating the high level of future demand.

Future hydrogen T&S infrastructure development is also anticipated, with Cadent (the regional gas distribution company) leading on pipeline transport and Inovyn (an Ineos company) leading on hydrogen storage using re-purposed salt caverns.

Specific financing benefits enjoyed by the cluster are summarized in Table 3.

TABLE 3 | **HyNet North West – financing benefits**

CLUSTER BENEFIT
Garner institutional support from government

The UK's robust regulatory framework has been critical for attracting private sector investment and commercial financing.

The UK government-issued economic licence and the Office of Gas and Electricity Markets (Ofgem) regulated network code, along with revenue guarantees provided by the Low Carbon Contracts Company (LCCC), have protected investors during project ramp-up.

Grant funding from UK Research and Innovation (UKRI) was important for Eni and consortium partners during early development stages.

CLUSTER BENEFIT
Centralize project coordination

As the system operator, Eni's leadership in developing the underlying infrastructure (reaching FID in April 2025) for carbon transportation was pivotal for subsequent development of carbon capture projects in the cluster, two of which reached FID in September 2025.

CLUSTER BENEFIT
Aggregate demand & supply

Eni has worked in close collaboration with industrial emitters to confirm five initial users of the CCS network: Encyclis, Heidelberg Materials, EET, Uniper and Evero.

This helped convey to financiers that there is a viable market for the CCS infrastructure.

CLUSTER BENEFIT
Decrease costs

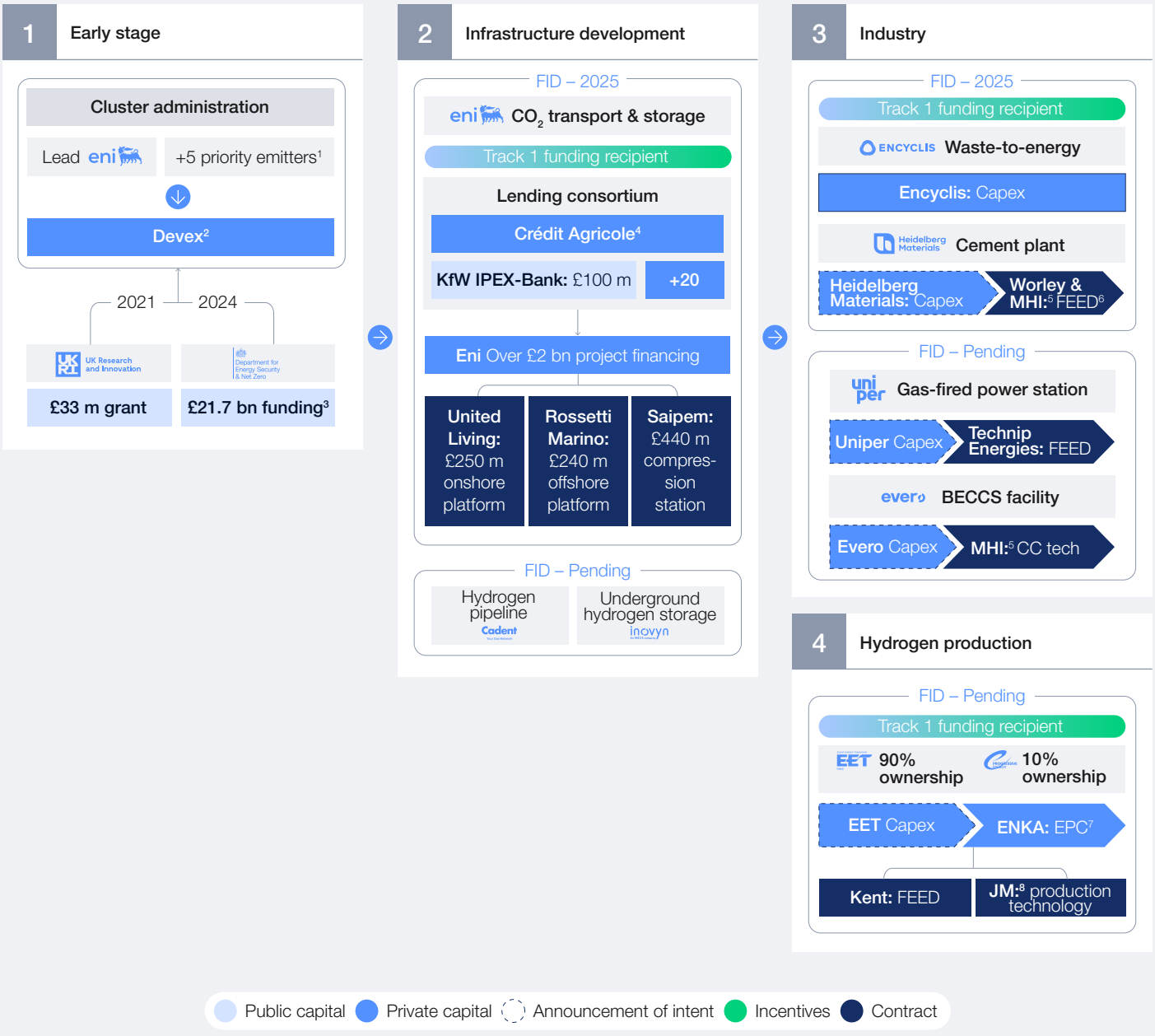
Eni is re-using ~150 km of existing pipelines to transport captured CO_2, significantly reducing project costs.

INEOS Inovyn is repurposing salt caverns, currently used to store natural gas, to hold 35,000 tonnes of hydrogen.

"The UK's favourable regulatory frameworks, along with a viable market for CCS, enabled Eni to secure £2.5 billion of project financing from a consortium of 20+ banks.

The combination of the UK's favourable regulatory and licencing frameworks, along with a clear demonstration of a viable market for CCS, supported project bankability. This enabled Eni to secure a £2.5 billion project financing package from a consortium of over 20 banks.

FIGURE 7 | **HyNet North West – financing blueprint**



Notes: 1. Priority emitters: EET/Essar, Encyclis, Evero, Heidelberg Materials and Uniper. **2.** Devex = development expenditure. **3.** To be committed over 25 years for the first two "Track-1" clusters, with £9.4 billion earmarked for CCUS projects by 2029. **4.** Sole financial advisor, mandated lead arranger & hedging bank. **5.** MHI = Mitsubishi Heavy Industries. **6.** FEED = front-end engineering design. **7.** EPC = engineering, procurement and construcuon. **8.** JM = Johnson Matthey.

CASE STUDY 2 | Humber

The Humber region, home to the UK's largest concentration of CO_2-emitting industries, sits at the heart of national net-zero ambitions.[31] Its journey towards financing decarbonization involves multiple CCS, hydrogen and bioenergy projects. Unlike HyNet, the Humber "cluster" is defined more by geography than by a single central governance structure. It operates through two major project groupings: Viking CCS, a carbon capture and storage project led by Harbour Energy, and the East Coast Cluster – which brings together the Northern Endurance Partnership (NEP, a CO_2 transport and storage joint venture) and Net Zero Teesside Power (NTZP), both led by BP and Equinor.

FIGURE 8 **Humber – overview of impacts**

Emissions reduction
16-18 Mt CO_2e
Annually by 2040

Gross value-add contribution
£4 billion
Contributed by 2035

Jobs
22,800
New jobs created by 2030

Source: ERM, Viking CCS.[32]

There are several organizations in the Humber developing clean technology. Six major projects that are helping to drive decarbonization include:

Infrastructure

- **Viking CCS:** This partnership between Harbour Energy and BP is building initial CO_2 storage capacity of 400 million tonnes with plans to store 15 million tonnes per year by 2035.
- **Northern Endurance Partnership (NEP):** NEP serves both Teesside and the Humber (known as the East Coast Cluster) to store CO_2 under the North Sea. This joint venture between BP, Equinor and TotalEnergies will transport CO_2 from select carbon capture projects in the Humber region. The UK Government's Department for Energy Security and Net Zero (DESNZ) will select the eligible projects through the East Coast Cluster expansion process.
- **Aldbrough Hydrogen Storage:** A partnership between Equinor and SSE (formerly Scottish and Southern Energy), this facility is expected to have an initial capacity of up to 420 million cubic metres. Forming a part of the shared infrastructure for the East Coast Cluster, the hydrogen stored at Aldbrough will be transported across industrial sites in the Humber region.

Industry

- **Drax BECCS:** Renewable energy company Drax plans to remove 8 million tonnes of CO_2 each year through two bioenergy with carbon capture and storage (BECCS) units.
- **Humber H_2ub:** Energy company Uniper is developing a low-carbon hydrogen production facility at its Killingholme site, with electrolytic green hydrogen production capability. Initial capacity will be up to 120 MW, with potential to reach over 200 MW.
- **Humber Zero:** As part of the Viking CCS cluster, two carbon capture facilities are being developed: one for Vitol Power International (VPI)'s Immingham Combined Heat and Power Plant and one for Phillip 66 Limited's Humber oil refinery. These are the first two potential emitter projects for Viking CCS.

Specific financing benefits enjoyed by the cluster are summarized in Table 4.

TABLE 4 **Humber – financing benefits**

CLUSTER BENEFIT
Garner institutional support from government

Early-stage public funding from UKRI catalysed significant investment from private organizations involved in the cluster. UKRI's Industrial Decarbonization Challenge provided £58 million in grants to projects in Humber, matched by £78 million from project developers.

The UK's Advanced Fuels Fund, a government initiative dedicated to scaling-up production of low-carbon fuels, is also providing grant support for FOAK commercial and demonstration-scale projects in the UK. The third window of awards in July 2025 saw five Humber-based organizations receive funding out of the total 17 grants awarded.

CLUSTER BENEFIT
Centralize project coordination

From a governance perspective, the presence of two "sub-clusters" within the Humber can create challenges when trying to optimize financing.

Such complexity prompted the creation of the Humber Energy Board in 2024 to coordinate pan-cluster strategy and infrastructure questions across the distinct projects.

CLUSTER BENEFIT
Aggregate demand & supply

In 2024, H_2ub, a hydrogen production plant being developed by Uniper, signed a collaboration agreement with Phillips 66 Limited to supply its Humber refinery with green hydrogen produced via electrolysis.

CLUSTER BENEFIT
Decrease costs

For Viking CCS, an existing subsea pipeline is being upgraded to transport CO_2 to an offshore storage site, while a new onshore pipeline will be built to transport CO_2 captured by industrial emitters.

Nearby port infrastructure provides the option for import by ship.

CLUSTER BENEFIT
Promote innovation & knowledge sharing

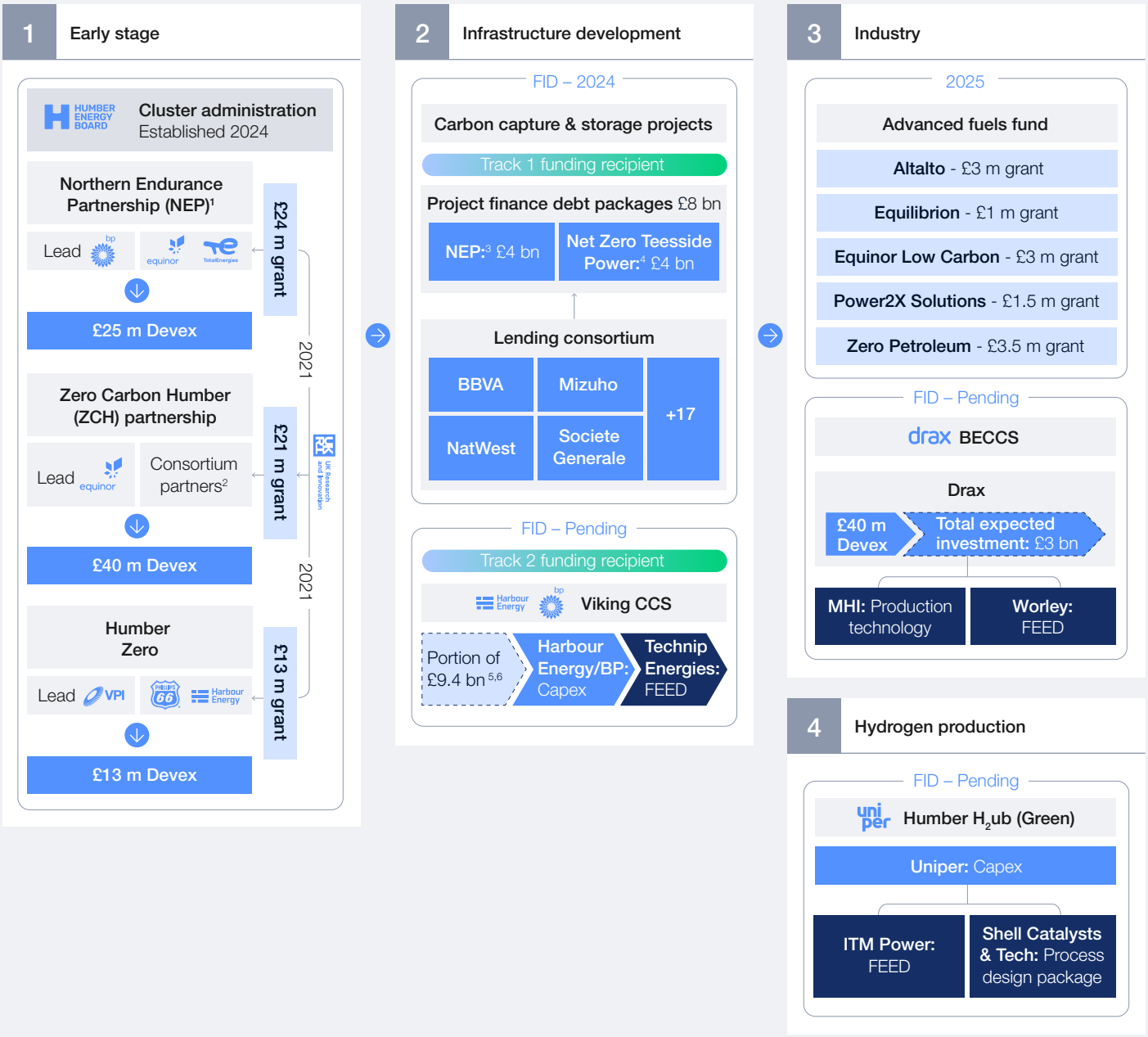
Close collaboration with Humber's university and college network ensures upcoming talent is being equipped with the skills required to develop low-carbon technology.

Industrial representatives sit on cross-collaborative bodies like the Humber Energy Board and the Construction Industry Trading Board to communicate emerging skills gaps.

Humber also benefits from the UK's regulatory approach to low-carbon industrial clusters, enabling a joint £8 billion financing package from 21 banks.

Like HyNet, Humber also benefits from the UK's regulatory approach to developing low-carbon industrial clusters. Paired with close collaboration across NEP and NTZP, a joint £8 billion financing package was secured from 21 commercial banks. Given the links between the projects and the shared risks, several banks lent money across both deals.

FIGURE 9 | **Humber – financing blueprint**



Notes: 1. NEP comprises BP (45%), Equinor (45%) and TotalEnergies (10%); across Humber & Teesside. **2.** ZCH consortium partners: Associated British Ports, British Steel, Centrica Storage, Drax, Mitsubishi Power, PX, SSE Thermal, Triton Power, Uniper & University of Sheffield. **3.** Shared infrastructure across Humber Cluster and Teesside Cluster. **4.** Not linked to Humber, but joint financing arrangement. **5.** Allocated to support CCUS and hydrogen projects until end of current spending review. **6.** Government support announced for Viking and Acorn clusters to "advance delivery".

This model, where the government drives cluster formation and essentially acts as guarantor, is unique to the UK context but has proven particularly successful in attracting project financing from private financiers.

3.2 Public capital-led financing

The following examples illustrate public-capital-led models, where there is strategic policy direction but less certainty around long-term incentive frameworks. In this context, cluster administrators take a more active role as conveners and balance-sheet investors, using their own capital and credibility to de-risk projects and crowd in external finance.

CASE STUDY 3 | Port of Antwerp-Bruges

The Port of Antwerp-Bruges hosts one of Europe's largest petrochemical and logistics hubs and is a leader in low-carbon transition for heavy industry. Its ambitious decarbonization vision is anchored in cluster-scale CO_2 T&S, hydrogen and ammonia infrastructure. The Port of Antwerp-Bruges demonstrates the opportunity created, particularly to drive early-stage project development, through effective public-private financing.

> **As a port authority, we are uniquely positioned to act as a community builder for the more than 1,400 companies active in our port area. That role is essential to the success of decarbonization projects, which rely on shared infrastructure and on industry partners reaching FID.**
>
> Jacques Vandermeiren, Chief Executive Officer, Port of Antwerp-Bruges

FIGURE 10 **Port of Antwerp-Bruges – overview of impacts**

Emissions reduction	Gross value-add contribution	Jobs
50% of CO_2	**€20.8 billion**	**160,000**
Captured by 2030	4.5% of GDP	Direct and indirect

Source: Port of Antwerp-Bruges.[33]

There are several projects which are helping the port to realize ambitious climate and industrial goals, including:

Infrastructure

- **Antwerp@C CO_2 Export Hub:** An open-access infrastructure to transport, liquefy and load CO_2 onto ships for permanent offshore storage. CO_2 captured on industrial players' sites on the port platform will be collected and transported via an intra-port open-access pipeline network. A shared liquefaction and export terminal will be built, including a CO_2 liquefaction unit, buffer storage and marine loading facilities for cross-border shipping. This innovative project will be one of the first and largest multimodal open-access CO_2 export facilities in the world. Kairos@C, phase one of the project, will see BASF and Air Liquide connect CO_2 emissions from five of their plants. The Port Authority is playing a key role in coordinating the consortium of eight organizations involved in the project, while infrastructure developer Fluxys is driving development of the CO_2 network within the port.
- **Hydrogen ecosystem:** Across five organizations the underlying infrastructure to enable production of clean hydrogen is being developed. These include:
  - **Air Liquide:** The ENHANCE project will see Air Liquide build, own and operate an ammonia cracking plant and a hydrogen liquefier. An existing hydrogen production unit will be retrofitted to use ammonia as a feedstock instead of natural gas.
  - **Fluxys and Advario:** The pair have a 50-50 partnership to develop an ammonia terminal

leveraging the existing infrastructure and jetty at the Advario Gas Terminal in the port.

  - **Vopak:** This infrastructure provider has acquired a former refinery to develop a green energy and chemicals hub. As part of the plant, Vopak is developing an ammonia terminal.

  - **VTTI:** Under Project Amplifhy, storage provider VTTI is providing a network of ammonia import terminals and crackers across Europe.

Industry

- **Vioneo:** Vopak's Energy Park is already attracting inward investment, with AP Moller Holding committing a €1.5 billion equity investment into subsidiary company Vioneo to develop a fossil-free plastics plant on the repurposed site.[34]

- **Green hydrogen consumers:** The underlying infrastructure in the port gives industrial companies access to hydrogen from international sources:

  - **TotalEnergies**' Antwerp refinery will be supplied with green hydrogen from Air Liquide's electrolyser (more detail on the project can be found under the Port of Rotterdam case study where the electrolyser is based).

  - In September 2025, ammonia producer **CF Industries Holdings** shipped 23,500 tonnes of low-carbon ammonia to the Port of Antwerp for chemicals and materials manufacturer Envalior to use as feedstock.[35]

Other linked projects:

- **Antwerp Refinery Carbon Capture and DeNOx (ARCaDE):** An earlier stage project, ARCaDE aims to be the "first large-scale CCS, retrofitted on hard to abate process emissions in an EU refinery".[36] TotalEnergies has committed €400 million to the project for its Antwerp Refinery and the EU Innovation fund has provided a €228 million grant to accelerate development.[37]

- **Ecluse:** A pipeline network in the port providing steam from Indaver's waste-to-energy site to five companies. The companies use the steam as needed, allowing them to turn off their own steam boilers.

- **Warmtenetwerk Antwerp North:** A residual heat network will be developed utilizing residual heat from Indaver's rotary kilns. Malting company Boortmalt has signed a long-term commitment for the first phase of the project. In the second phase, grid operator and multi-utility company Fluvius will link a district heating network.

Specific financing benefits enjoyed by the cluster are summarized in Table 5.

TABLE 5 | **Port of Antwerp-Bruges – financing benefits**

CLUSTER BENEFIT
Garner institutional support from government

Both Kairos@C and Antwerp@C have received significant support from the European Commission in the form of grants and subsidies totalling €380 million.

While this has helped early-stage project development, in the future private sector organizations such as BASF have noted the need for "increased government support" as projects like Kairos@C reach their operational stage (i.e. CfDs, Opex support).

CLUSTER BENEFIT
Centralize project coordination

As overall cluster administrator, the Port Authority plays a central role in driving projects and convening stakeholders, for example:

– Overseeing a centralized funding desk for external financing support.

– Providing land in concession (e.g. to develop Air Liquide and Fluxys' liquefaction and export terminal).

For Antwerp@C active financing support from the Port Authority has supported development of the CO_2 pipeline network. The pipeline is being developed through a joint venture between Fluxys, Pipelink (80% owned by the Port Authority) and Air Liquide.

As a public entity, the Port Authority can accept slightly lower return expectations to support project feasibility.

CLUSTER BENEFIT
Aggregate demand & supply

Phase 1 of Antwerp@C already sees Air Liquide and BASF committing to connect CO_2 emissions from five of their nearby plants.

CLUSTER BENEFIT
Decrease costs

By acquiring a former refinery to develop the energy park, Vopak can leverage/upgrade existing infrastructure (including vessel, barge, truck and rail access) to develop the proposed ammonia terminal.

The Port Authority has assumed significant financing responsibility for development of shared T&S infrastructure, which emitters will pay to access. Significant grant funding from the European Commission has supported project development.

FIGURE 11 | **Port of Antwerp-Bruges – financing blueprint**

Notes: 1. Consortium partners: Air Liquide, BASF, Borealis, ExxonMobil, INEOS & TotalEnergies. **2.** Pipelink partly owned (majority ownership of 80%) by Port of Antwerp-Bruges.

CASE STUDY 4 | Port of Rotterdam

The Port of Rotterdam, Europe's largest seaport, is at the forefront of the continent's industrial decarbonization through integrated CCS, hydrogen and ammonia projects.

FIGURE 12 **Port of Rotterdam – overview of impacts**

Emissions reduction
9.3 Mt CO_2
Annually by 2030

Gross value-add contribution
€29.6 billion
3.2% of GDP

Jobs
192,000
Direct and indirect in Rotterdam-Rijnmond

Source: Offshore Energy, Port of Rotterdam.[38]

> **Porthos shows how public and private partners can secure real investment for decarbonization. By leveraging public ownership to provide stability and by signing long term transport and storage agreements with customers, we've made CO_2 transport and storage feasible — and easier for industry to join.**
>
> Boudewijn Siemons, Chief Executive Officer, Port of Rotterdam

Four interconnected projects serve as the backbone for CCS and hydrogen production in the cluster:

Infrastructure

- **Porthos CCS:** A landmark "public-private" venture, Porthos was the first CCS project to reach FID in the Netherlands in 2023. Following previous attempts by the private sector, Porthos is a state-owned JV between EBN, Gasunie and Port of Rotterdam Authority.
- **Aramis:** A partnership between EBN and Gasunie, Aramis extends the reach of Porthos via additional pipelines to emitters in the port as well as providing links to other industrial clusters in the region.
- **CO_2next:** Led by Gasunie and Vopak, this project provides network access (via ship, with potential to expand to rail) for industrial emitters not connected to the pipeline network through its liquefaction terminal.

Industry

- **ELYgator:** Air Liquide is developing a 200 MW electrolyser complex to diversify its production capacity. Around 23,000 tonnes of renewable hydrogen will be produced per year, 130 MW of which will be used to supply TotalEnergies' Antwerp platform. In return, TotalEnergies will supply electricity produced from its OranjeWind offshore wind farm.

Other linked projects include:

- **Hynetwork** (a 100% subsidiary of Gasunie), developing a green hydrogen distribution network across industrial clusters in the Netherlands and the rest of Europe.
- **WarmtelinQ** (also led by Gasunie), a residual heat pipeline, currently under construction, to provide residual heat from the port to heat homes in South Holland.

Specific financing benefits enjoyed by the cluster are summarized in Table 6.

TABLE 6 | **Port of Rotterdam – financing benefits**

CLUSTER BENEFIT
Garner institutional support from government

Port of Rotterdam's decarbonization projects benefit from strong public policy support, including grants, subsidies and long-term contracts via schemes such as SDE++ ("stimulation of sustainable energy production and climate transition"). This scheme is the Dutch government's flagship subsidy programme, designed to bridge the gap between CCUS investment and carbon market prices, ensuring revenue certainty for projects such as Porthos and ELYgator.

CLUSTER BENEFIT
Share infrastructure

In the Port of Rotterdam, three interconnected infrastructure projects (Porthos, Aramis and CO2next) are providing CO_2 storage capacity alongside transport routes via pipeline and ship.

This collaborative approach to infrastructure development will ensure that emitters in the Port, as well as other industrial clusters in the region, such as the Port of Antwerp-Bruges, can access the network.

CLUSTER BENEFIT
Centralize project coordination

The Port Authority acts as both a project orchestrator and critical infrastructure owner, often partnering with private-sector leaders to drive delivery.

The involvement of state-owned entities to develop Porthos infrastructure has been crucial for managing permitting risk.

Given the broader societal return from developing the infrastructure, these entities have a higher appetite to navigate potentially complex permitting processes.

CLUSTER BENEFIT
Aggregate demand & supply

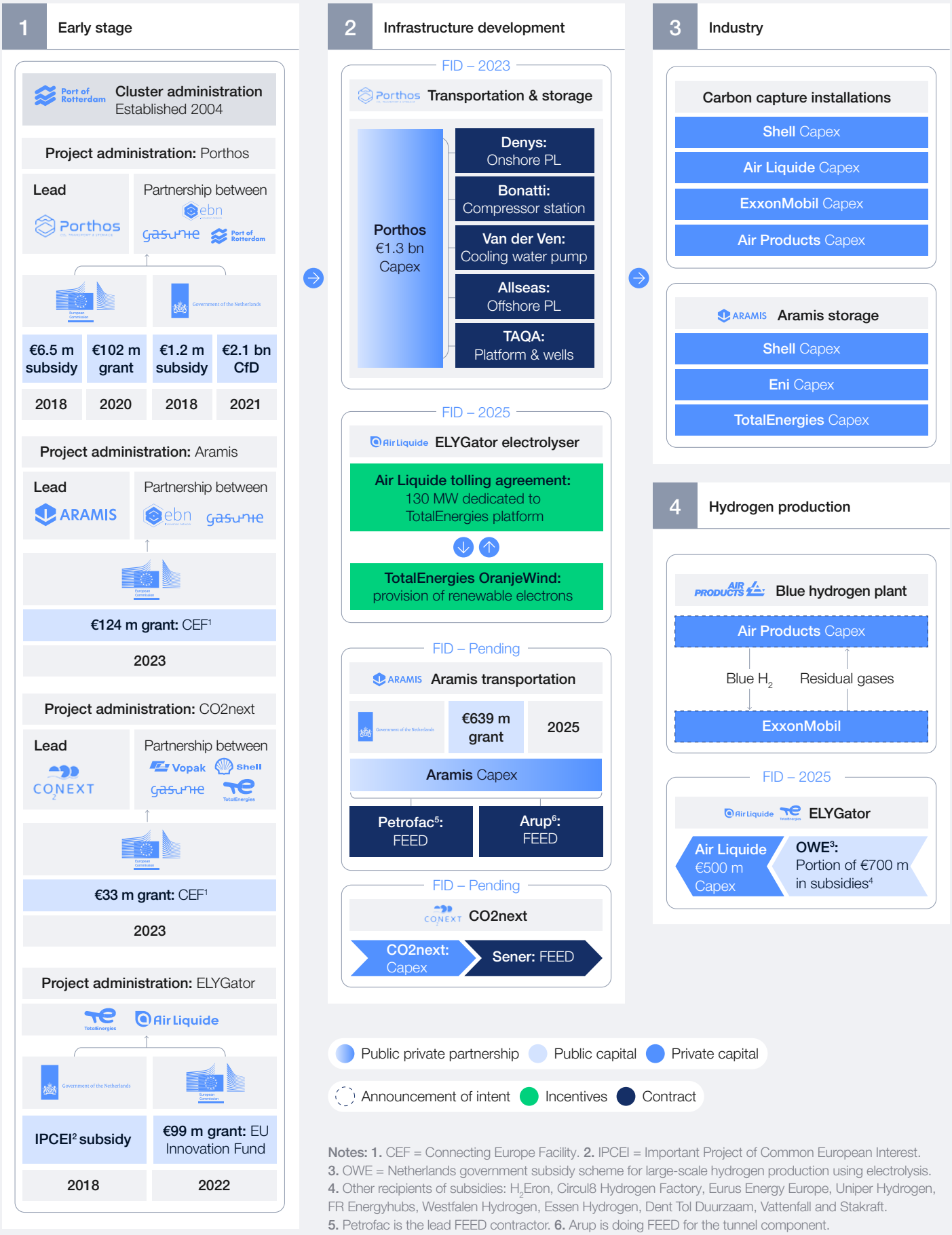
The ELYgator project benefits from proximity to offshore wind power through TotalEnergies' OranjeWind farm. The farm will supply electricity power to the electrolyser in return for 130 MW of renewable hydrogen.

CLUSTER BENEFIT
Promote innovation & knowledge sharing

In partnership with the Port Authority, Exxon Mobil, Shell, Air Products and Air Liquide are engaged in a project support initiative to share knowledge and best practice to problem-solve and accelerate the development of the Porthos project.

Note: For flagship projects, government capital has been key for de-risking, while strategic partnerships – such as Air Liquide's agreement with TotalEnergies for ELYgator – have guaranteed long-term demand.

FIGURE 13 | **Port of Rotterdam – financing blueprint**



Notes: 1. CEF = Connecting Europe Facility. **2.** IPCEI = Important Project of Common European Interest. **3.** OWE = Netherlands government subsidy scheme for large-scale hydrogen production using electrolysis. **4.** Other recipients of subsidies: H_2Eron, Circul8 Hydrogen Factory, Eurus Energy Europe, Uniper Hydrogen, FR Energyhubs, Westfalen Hydrogen, Essen Hydrogen, Dent Tol Duurzaam, Vattenfall and Stakraft. **5.** Petrofac is the lead FEED contractor. **6.** Arup is doing FEED for the tunnel component.

Other international examples of public-capital led financing

Public capital-led financing was the most common archetype that emerged out of the clusters engaged. Across all examples, key to success is the innovative use of public capital to drive early-stage project development:

- **Malaysia: Sarawak H2 Hub.** The Sarawak Economic Development Corporation's new energy arm and wholly owned subsidiary, SEDC Energy (SEDCE), is integral to project pipeline management and financing coordination in the Sarawak H2 Hub. SEDCE blends grants, green bonds and international investment to accelerate hydrogen production through shared infrastructure development. SEDCE is the majority shareholder for the H2ornbill and H2biscus hydrogen projects within the H2 Hub. Both projects are slated to supply Japan and South Korea initially, but will subsequently open to other markets and products. SEDCE is collaborating with strategic partners to develop the hydrogen supply chain in Sarawak and is looking to develop facilities for hydrogen refuelling and electrolyser assembly.

- **India: Mumbai Green Hydrogen Cluster.** India's Ministry of New & Renewable Energy's National Green Hydrogen Mission has driven cluster formation, providing concessional loans and CfDs. Alongside financing support of up to $1.8 billion committed between the national government and the Asian Infrastructure Investment Bank (AIIB), the Maharashtra Government's Green Hydrogen Policy provides discounted utilities, stamp duty exemptions and up to 30% capex subsidies.[39] This will help the cluster reach its goal of producing 10 kilotonnes of hydrogen per year.

3.3 Single developer-led financing

In the single developer-led financing approach, momentum is derived from a single organization with the scale, expertise and resources to drive delivery of infrastructure. From a financing perspective, this means the organization is using its balance sheet to finance a large proportion of the project, creating fewer interconnections between governments, multilateral development banks and other de-risking bodies, as seen in the above financing blueprints.

Examples of this approach can be seen in:

- **China: Chifeng Net Zero Industrial Park.** Developed against the backdrop of a strong national push by China's National Development and Reform Commission (NDRC) to establish industrial parks, Envision Group is financing a multi-GW renewable and green hydrogen production plant that integrates wind, solar and ammonia at scale. The first phase of the plant is already operational, with around $5.5 billion in investment expected across the three phases. Despite relatively limited domestic financial incentives, industry has moved ahead: a single commercial anchor, in the form of a green ammonia offtake agreement with Marubeni Corporation – made possible by favourable Japanese hydrogen policies – has accelerated deployment.[40]

- **Colombia: Cartagena Industrial Cluster.** In 2022, Promigas and Ecopetrol launched pilot projects for solar-powered electrolysers at their Cartagena facilities in Colombia.[41] Ecopetrol has since announced that it will invest $28.5 million to build a green hydrogen plant at its refinery in Cartagena with capacity to produce 800 tonnes of green hydrogen per year.[42] Furthermore, Frontera Energy, working through its subsidiary Puerto Bahia, is developing a $50-60 million LPG facility in the Bay of Cartagena. The aim is to develop and operate a port terminal capable of importing and storing over 20,000 tonnes of LPG.[43]

- **Saudi Arabia: Jubail Industrial City CCUS Hub.** In Saudi Arabia, Aramco has been central in orchestrating investments in the CCUS Hub. The company's balance sheet strength, together with sovereign support, allows Aramco to commit $1.5 billion to the project, partnering with Linde and SLB to deliver the infrastructure.[44] Aramco is also acting as the anchor CO_2 supplier, with 6 Mt of the 9 Mt/year capacity dedicated to capture from Aramco gas plant facilities and the remaining 3 Mt from neighbouring emitters.

- **Japan: Kawasaki Carbon Neutral Industrial Complex.** In Japan, private organizations such as Iwatani, Kawasaki Heavy Industries and Taiheiyo Cement are leveraging their own balance sheets to finance hydrogen and CCS-related projects in the Kawasaki coastal area. Kawasaki City's role focuses on non-capital support, convening companies through dedicated councils, streamlining approvals and environmental compliance, and working to secure national subsidies and enable shared infrastructure rather than directly funding the projects.

4 Conclusion and way forward

Diverse regulatory contexts and strategies reveal multiple pathways for clusters to unlock investment and scale up industrial transformation in energy ecosystems.

Delivering industrial transformation at scale requires a fundamentally new business case – one rooted in financial innovation, risk-sharing and purposeful public-private collaboration. Across the three archetypes examined in this report, the lesson is consistent: with the right mix of financial instruments and supportive regulation, industrial transformation becomes investable rather than aspirational.

The case studies show how different regulatory frameworks and risk-sharing approaches can bring complex, capital-intensive projects to (or close to) FID. These varied strategies demonstrate that there is no single template, but many workable pathways for closing the gap between ambition and bankable projects.

Addressing persistent barriers to investment and project scalability is therefore essential if industrial clusters are to realize their full potential in accelerating industrial transition. While enthusiasm for decarbonization has created robust project pipelines, converting intent into commercial reality depends on enabling regulation, workable risk-sharing arrangements and credible offtake.

Drawing on these lessons, four key drivers emerge that offer a structured way forward for industry and government.

4.1 Drivers of success

For industry

Driver 1 Establish a cluster administrator to coordinate financing and project development

Early-stage cluster projects often struggle due to fragmented governance and unclear responsibilities, which can lead to higher transaction costs and slower development timelines. By identifying a dedicated cluster administrator, stakeholders can streamline key processes such as project origination, permitting, financial coordination and stakeholder engagement.

The approach for cluster administration can vary. In some clusters, a single company with a vested interest in infrastructure development takes on the administrator role. In others, an established public authority assumes these responsibilities.

Ultimately, the right model depends on local context, but centralized coordination enhances efficiency and increases attractiveness for investors. The most successful clusters, from a financing perspective, have an overarching project sponsor who has the incentive, technical expertise and capital to ensure project delivery.

Driver 2 Leverage opportunities to optimize financing within clusters by pooling resources and future-proofing infrastructure

Clusters offer unique opportunities to reduce costs and spread risk through collaborative financing and resource sharing. By pooling capital and co-investing in key infrastructure – such as pipelines, grid interconnections or CO_2 storage – companies and financiers can decrease unit costs and collectively de-risk their commitments.

Cluster administrators could take a strategic approach, coordinating procurement activities and future-proofing infrastructure against anticipated market and/or regulatory changes. Notably, best-practice clusters often leverage central funding desks to pursue public funding opportunities. A case can be made to expand this method beyond individual project applications, advocating holistic approaches that optimize financing across the cluster and capital types.

Driver 3 Continue establishing strong offtake agreements to guarantee commercial viability at the operational stage

The collaboration models used by industrial clusters across different regulatory frameworks offer a valuable playbook for leveraging the proximity clusters create between infrastructure developers, clean energy suppliers and heavy industry offtakers. The four clusters profiled in the previous chapter illustrate how offtake agreements between these actors can accelerate commercial success by demonstrating tangible and viable markets.

From a lender perspective, protective measures such as take-or-pay clauses help to ensure that contractually agreed-upon revenue streams and operational continuity are maintained even in the face of counterparty default or market disruptions. By clearly signalling market viability and sharing risk across the supply chain, clusters can secure increased financial support and convince investors of a project's commercial potential.

For governments

Driver 4 Deploy a range of financial instruments with non-standard or concessional terms to stimulate market formation across the project lifecycle

Financiers require upfront visibility into government mechanisms across the full project lifecycle to accurately assess risk and allocate capital. Transparent and early communication of available support helps unlock private investments, as investors and lenders are better able to structure financing according to evolving project needs.

This is especially critical for early-stage, capital intensive technologies that drive many low-carbon projects, where traditional funding mechanisms can be insufficient. Useful instruments to leverage across project lifecycles include:

- **During development:** grants and technical assistance to de-risk feasibility, permitting and design.
- **During construction:** guarantee facilities to lower financing costs and crowd-in lenders.
- **During operations:** CfDs and availability/capacity payments to stabilize revenues.

This phase-appropriate financing mix – deployed alongside green bonds and subsidized loans, where relevant – could help first movers overcome risk concentration and accelerate commercial viability in markets not yet ready for purely private finance.

Given the highly regional nature of clusters, the importance of engagement and support from local governments cannot be overstated. Local governments can play a key role in ensuring financial instruments align with local market dynamics and infrastructure needs to maximize the impact of concessional finance.

Taken together, these actions can turn industrial clusters into powerful platforms for delivery. By combining clearer policy signals, smarter risk-sharing and better-aligned capital, clusters can convert today's project pipelines into bankable portfolios – moving industrial decarbonization from promising pilots to transformation at scale.

Appendix

Additional detail and context on the four case studies

HyNet North West

HyNet, one of the UK's flagship low-carbon industrial clusters, is pioneering the integrated deployment of carbon capture, T&S and future hydrogen production in Northwest England and North Wales. Its innovative financing journey highlights key mechanisms and market/government dynamics required to scale up investment to decarbonize a wide range of industrial activities, particularly in hard-to-abate sectors. HyNet was one of two UK clusters chosen under Track 1.[45] Track 1 refers to the initial group of two industrial decarbonization clusters that were selected by the UK government for early support and fast-track development of low-carbon technologies.

These clusters receive priority access to funding and policy mechanisms to accelerate project deployment. The UK Government has committed to allocating £21.7 billion over 25 years for CCS and projects in the first two Track 1 clusters. HyNet cluster will house one of the UK's first large-scale blue hydrogen plants (EET Hydrogen at Stanlow) and aims to capture up to 10 million tonnes of CO_2 annually by the 2030s.[46]

Project structure and regulatory context

The UK's regulated model, through the economic licence and supporting government packages, has been the central incentive driver, particularly for infrastructure development. The T&S scheme operates as a regulated entity under the Office of Gas and Electricity Markets' oversight and a binding "network code", which sets technical and commercial entry terms for users (i.e. emitters). The economic licence gives Eni, as HyNet's T&S operator, formal authorization to develop, own and operate the T&S network. While Eni acts as a system operator, all entry and revenue agreements remain subject to government determination and ongoing regulatory review.

However, in the early stages of development, Eni's leadership allowed the consortium of organizations to present a robust "cluster" narrative, pairing a credible operator (Eni) with a pipeline of capture projects to assure the government and solidify Track 1 CCUS status.

Financing sources and structures

Eni reached final investment decision (FID) in April 2025, securing a £2.5 billion package from a syndicate of more than 20 commercial banks for T&S infrastructure. Commercial interest was so abundant, including from Crédit Agricole, Mizuho and Standard Chartered, that alternative options from development banks and infrastructure funds were unnecessary. The anchor for bankability was a robust economic licence and a revenue support agreement with the government's Low Carbon Contracts Company (LCCC). LCCC, a government-owned entity, is the independent counterparty to support low-carbon energy projects.[47]

In the context of HyNet, LCCC guarantees a minimum level of revenue regardless of the level of CO_2 captured or stored in initial ramp-up years. This insulates investors against low initial utilization, guaranteeing "allowed revenue" while capture projects ramp up. Having reached FID on the T&S network in April 2025, two carbon capture plants (Heidelberg's Padeswood cement manufacturing plant and Encylis-Protos' waste-to-energy facility) reached FID in September 2025.

Humber

The Humber region, home to the UK's largest concentration of CO_2-emitting industries, sits at the heart of national net-zero ambitions.[48] Its journey towards financing decarbonization projects involves multiple CCS, hydrogen and bioenergy ventures.

Cluster structure and governance

Unlike HyNet, the Humber "cluster" is defined more by geography than strict central governance. The Humber operates through two major "subclusters" – the Viking CCS project (led by Harbour Energy) and the East Coast Cluster – Northern Endurance Partnership (NEP) and Net Zero Teesside Power (NTZP) – led by BP and Equinor. The East Coast Cluster covers the regions of the Humber and Teesside. Each infrastructure project controls its own pipeline and storage assets.

While projects such as Drax (BECCS) and Phillips 66 (combined power and heat plant) are exploring the option to connect to both, capacity limits dictate the extent to which there can be complete integration across projects. This multi-operator arrangement can create complexities when considering how best to optimize project links and network flows but also has potential to broaden financing opportunities. The region is served by both Track 1 (East Coast Cluster/NEP) and Track 2 (Viking CCS), with significant government support committed to accelerate business model maturation, lower risk and enable FID on T&S and capture projects.[49]

Recognizing the challenge in managing such complexity, the Humber Energy Board (HEB) was established in 2024, to provide regional coordination, acting as a forum for infrastructure, policy and strategic "pan-cluster" questions that transcend single sub-cluster interests.

Financing sources and structures

To support early-stage project development, Humber received significant grant funding from UKRI's Industrial Decarbonization Challenge fund.[50] The IDC was a flagship initiative to accelerate reduction of greenhouse gas emissions in the UK's most energy intensive industries. Launched in 2019, it was designed to support the development and deployment of low-carbon technologies and infrastructure in six major UK industrial clusters. Across NEP, the Zero Carbon Humber Partnership and Humber Zero, Humber received £58 million in grant funding which was matched with £78 million in devex from recipient organizations.

In 2024, FID was reached to develop infrastructure for CCS projects across NEP and NTZP. This achievement highlights the power of cross cluster collaboration, with an £8 billion financing package being secured across a consortium of 21 commercial banks (including BBVA, ING and Mizuho) to split between the two.

With Track 2 funding confirmed in June 2025 and government consent given for pipeline development in April 2025, FID is also expected for Viking CCS.[51] Drax is targeting FID in 2026 for its BECCS power unit.[52] This £3 billion investment from the company will have the capacity to produce around 2 terawatt hours (TWh) of renewable electricity from sustainable biomass, alongside capacity to capture around 3 Mt of CO_2 per year.

However, a key component to unlocking long-term private investment in large-scale projects such as BECCS and CCS in the Humber (and more broadly) is the development of credible carbon dioxide removal (CDR) markets. Projects need to be able to sell CDR credits on voluntary markets to ensure the use of permanent CO_2 storage is commercially beneficial long term. This requires the presence of markets that organizations can "forward sell" into, to support project bankability.

In addition to advances in CCS, the Humber region is also seeing increased investment in sustainable aviation fuel (SAF) technologies. This acceleration is supported by the UK's Advanced Fuels Fund, a major government initiative dedicated to scaling-up production of low-carbon fuels. The fund provides grant funding for FOAK commercial and demonstration-scale projects in the UK.[53] The third window of awards in July 2025 saw five Humber based organizations receive funding out of the total 17 grants awarded.[54]

Port of Antwerp-Bruges

The Port of Antwerp-Bruges is home to one of Europe's largest petrochemical and logistics hubs and a leader for low-carbon transition in heavy industry. Its ambitious decarbonization vision is anchored in cluster-scale CO_2 T&S, hydrogen and ammonia infrastructure. Port of Antwerp-Bruges demonstrates both the opportunity created when combining public-private financing, new regulation and network economics across industrial players. Major projects, including the Antwerp@C CO_2 network and the Vopak Energy Park, showcase how collective demand and layered financing strategies can help to realize ambitious climate and industrial goals.

Cluster structure and governance

As the body overseeing the entire cluster, the Port Authority plays a role as both overall cluster administrator and a project administrator for key infrastructure projects. The authority plays a particularly important role orchestrating common infrastructure, convening stakeholders and enabling financing – especially for major shared assets such as pipelines and import/export terminals. Separate joint ventures (e.g. Kairos@C) build specific links in the regional value chain. The Port Authority maintains oversight through majority ownership of key organizations such as Pipelink (80% stake), coordination of a centralized funding desk for external financing support and provision of land in concession for private organizations.

Such an approach allows for more efficient and effective communication between private organizations operating in the cluster and facilitates a more coordinated approach to engagement with external funding agencies such as the European Commission.

Financing models and structures

Antwerp@C is a consortium of eight partners, coordinated by the Port Authority. The project aims to connect six large emitters to liquefaction and export facilities, with the port supporting land and regulatory enablement and partners investing development capital. In the first phase, Kairos@C, BASF and Air Liquide will connect CO_2 emissions from five of their plants[55] (one ammonia, two hydrogen plants and two ethylene oxide plants). FID for Kairos@C is currently on hold, with BASF noting the need for "increased government support",[56] in particular, a guarantee of more direct financial support when the project reaches its operational stage.

Despite this, key to project development has been the installation of the "CO_2 backbone". This pipeline network, currently under construction, is controlled by Fluxys c-grid Antwerp, a JV between Fluxys (70% stake), Pipelink (20% stake) and Air-Liquide (10% stake).[57] With Pipelink being majority owned by Port of Antwerp-Bruges, the authority can ensure that infrastructure is appropriate for the various emitters that could connect. Being a public entity, the authority can accept lower returns given the public incentives also being served.

In addition to Porthos, Vopak Energy Park is a notable example of industrial repurposing to accelerate industrial transition. In 2023, global infrastructure provider Vopak acquired a former refinery, developing it into a green energy and chemicals hub with deep-sea, river, pipeline and rail access. The site is being configured for new hydrogen, ammonia and methanol terminals and is supported by strategic collaboration with the Port Authority and proximity to existing cluster infrastructure. For example, A.P. Møller Capital has already committed to a €1.5 billion equity investment into subsidiary company Vioneo.[58] Vioneo will build a 300,000 tonnes per annum (tpa) fossil-free polypropylene and polyethylene plant at Vopak Energy Park Antwerp (targeting FID in 2025).[59] This world-first facility will use green methanol (from biomass/low-carbon hydrogen) as feedstock and renewable power, cutting approximately 1.5 $MtCO_2$/year.

Building on these initiatives, the Port of Antwerp is also advancing another milestone project: ARCaDE. Though in the earlier stages, ARCaDE (Antwerp Refinery Carbon Capture and DeNOx) aims to be the "first large-scale CCS, retrofitted on hard to abate process emissions in an EU refinery".[60] TotalEnergies has committed €400 million to the project, which will see its Antwerp Refinery capturing CO_2 from the fluid catalytic cracking (FCC) unit and transported (via Antwerp@C export infrastructure) to Rotterdam for storage using Hybrid LNG barges.[61] The initiative has secured substantial backing from the EU Innovation Fund, with a €228 million grant awarded to help accelerate the project's implementation and de-risk early-stage development. FID is expected by the end of 2027.[62]

Port of Rotterdam

The Port of Rotterdam, Europe's largest seaport, is at the forefront of the continent's industrial decarbonization through integrated CCS, hydrogen and ammonia projects. The Porthos CCS project is a landmark public-private venture, while new hydrogen infrastructure through ELYgator and the linked Aramis CCS scheme further accelerate transition by enabling large-scale production.

Cluster structure and governance

The Port Authority is both a project orchestrator and critical infrastructure owner, partnering with private organizations to catalyse project development. Three major projects serve as the backbone for CCS in the cluster: Porthos, Aramis and CO2next. Porthos, a state-owned JV between EBN, Gasunie, Port of Rotterdam Authority, manages shared transport and offshore storage. Aramis (EBN and Gasunie) extends CCS reach via additional pipelines and cross-cluster links. CO2next (led by Gasunie and Vopak) provides network access for industrial emitters not connected to the pipeline network through its liquid CO_2 terminal.

Another major project linked to Rotterdam is ELYgator, a flagship 200 MW electrolyser complex led by Air Liquide, integrating proton exchange membrane (PEM) and alkaline electrolysis technologies (the first of its kind at this scale in Europe) to diversify production capacity.[63] ELYgator will produce around 23,000 tonnes per year of renewable hydrogen;[64] 130 MW of volume will be used to supply green hydrogen to TotalEnergies' Antwerp platform, again showing increasing use of inter-cluster connections. In return, TotalEnergies will supply electricity produced from its OranjeWind offshore wind farm.

The Port of Rotterdam is also driving development of two additional infrastructure projects central to industrial transition in the Netherlands and Europe more broadly. First, the Hynetwork, a 100% subsidiary of Gasunie, completed its initial 32-kilometre pipeline from Maasvlakte 2 in Rotterdam to Shell Pernis refinery in 2025.[65] Once complete, Hynetwork will connect five industrial clusters in the Netherlands to other industrial hubs in Germany and Belgium to distribute green hydrogen.

Alongside this, the WarmtelinQ (also led by Gasunie) residual heat pipeline project, currently under phased construction, will provide residual heat from the Port of Rotterdam to heat homes in South Holland.[66] By harnessing and redistributing industrial heat that would otherwise be wasted, it significantly reduces CO_2 emissions and supports the region's climate goals and circular economy ambition.

Finance models and structures

Given previous failed attempts to develop CCS technology in the cluster, Port of Rotterdam initiated Project Porthos, engaging organizations that have significant knowledge to develop the underlying infrastructure. Execution responsibilities (and financing commitments) have been allocated based on partner expertise. Responsibility for and investment into the onshore infrastructure is a 50:50 split between Gasunie and Port of Rotterdam. For the compressor and offshore storage, it is a 50:50 split between EBN and Gasunie. Responsibility for Porthos system operations is a 50:50 JV between EBN and Gasunie.

The three organizations are equal shareholders for overall project execution and oversight of the Porthos commercial entity. Such sharply defined responsibilities ensure that shareholders have a clear mandate on the specific areas to invest in, also limiting the need for project financing. Between the European Commission and the Dutch government, Porthos has benefitted from market-leading support, with a range of financial products being deployed over the years, including pure grants, subsidies and CfDs through the SDE++ scheme.

The SDE++ scheme is the government's flagship subsidy programme which closes the gap between CCUS costs and carbon market prices.[67] In addition, industrial emitters (Air Liquide, Air Products, ExxonMobil, Shell) have long-term contracts with Porthos to store CO_2 – providing revenue certainty. In the case of ELYgator, support from the European Commission (a €99 million EU Innovation Fund grant) and the Dutch government (an Important Project of Common European Interest subsidy) was crucial in supporting early project development.

In addition, as one of 11 recipients of the Netherland's OWE subsidy scheme for large-scale hydrogen production, the government will cover up to 80% of project capital costs and provide an operating subsidy per kilogram of hydrogen produced. However, most notably, the partnership agreement arranged between Air Liquide and TotalEnergies in early 2025 has provided guaranteed long-term demand, allowing Air Liquide to commit its own €500 million capex investment. The remaining supply will be distributed through Air Liquide's regional pipeline network for use across industry and heavy mobility in the Netherlands and Belgium.

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