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Low-Carbon Industrial Hubs: Driving Deep Decarbonization for Industry

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As the need for decarbonization grows, "harder-to-abate" sectors can accelerate emissions reduction through strategic participation in emerging low-carbon industrial hubs

The emissions reduction challenge of "harder-to-abate" industries

As the push for decarbonization to combat climate change gains momentum, the adoption of readily available low-carbon solutions is accelerating. In areas such as power, passenger vehicles, and buildings, the deployment of available clean energy technologies—such as solar PV, wind, electric vehicles, and energy efficiency—is driving down costs and spurring increased implementation. However, for sectors where efficiency and green electrification are unable to address the majority of emissions, commercially available solutions remain frustratingly out of reach.

For these sectors, often referred to as "harder to abate," technical and business model gaps compound the challenge of finding cost-effective solutions to address what amounts to be 30 percent of total global greenhouse gas (GHG) emissions.[i] This share is projected to grow as other sectors decarbonize, increasing the urgency for the "harder-to-abate" industries of iron and steel, road freight, aviation, chemicals, cement, and shipping to find ways to bring innovations to market in time to mitigate climate impacts.[ii]

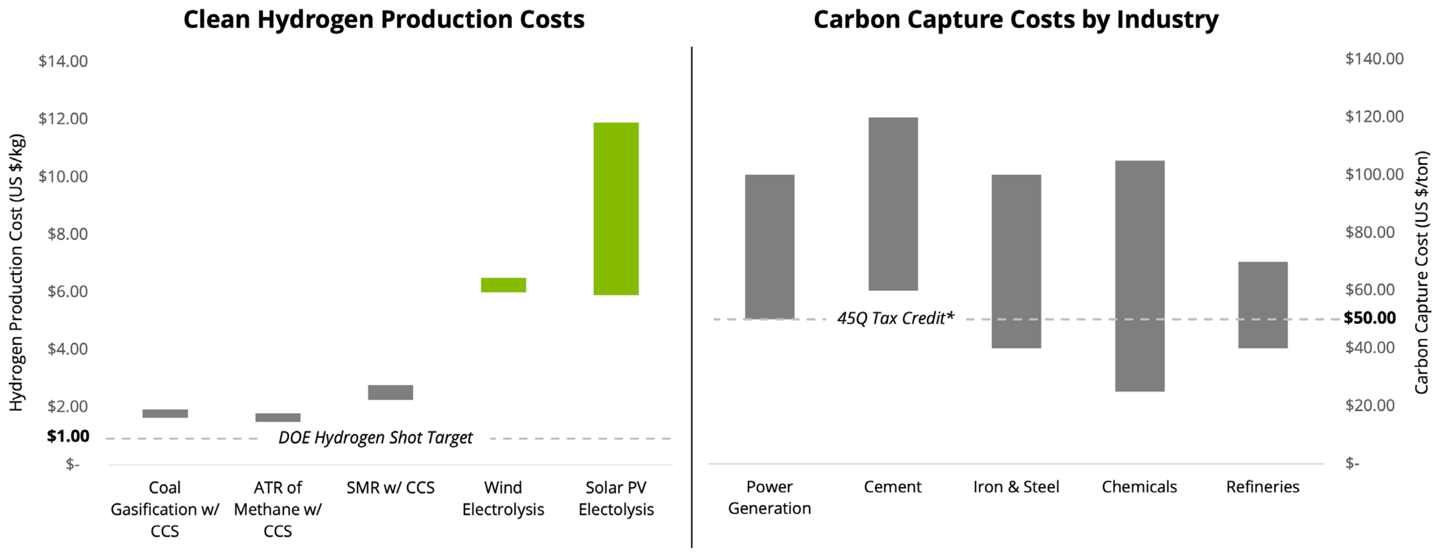
The good news is that there are known technological solutions under development today with the potential to reduce emissions from harder-to-abate sources. The bad news is that many of them are nascent or otherwise cost prohibitive. Among the most promising are clean hydrogen and carbon capture, utilization, and storage (CCUS). Combined, these have the potential to abate over 50% of industrial emissions by 2070.[iii]

However, as shown in Figure 1, the current costs of both of these technologies have yet to reach a point low enough to be deployed at scale. Currently, the production cost of clean hydrogen ranges between $1.60 and $12.00 per kilogram[iv] (depending on the production method) and the cost of carbon capture varies from $25.00 to $120.00[v] per ton based on stream purity and emission source.

Industries that are **"harder to abate"** share several characteristics:

- **Hydrocarbons** are an integral part of core manufacturing or product use, as an energy source or feedstock
- High **energy requirements** for core business
- High **CapEx** required for manufacturing
- **New technologies** are needed and significant R/D

Figure 1: Clean Hydrogen and CCUS Remain Costly



Source: Deloitte analysis using data from Department of Energy (DoE), *Hydrogen strategy: Enabling a low-carbon economy*, July 2020

Source: Deloitte analysis using data from IEA, *Levelized cost of CO_2 capture by sector and initial CO_2 concentration, Updated 2021; GPI, Transport Infrastructure for Carbon Capture and Storage*, June 2020

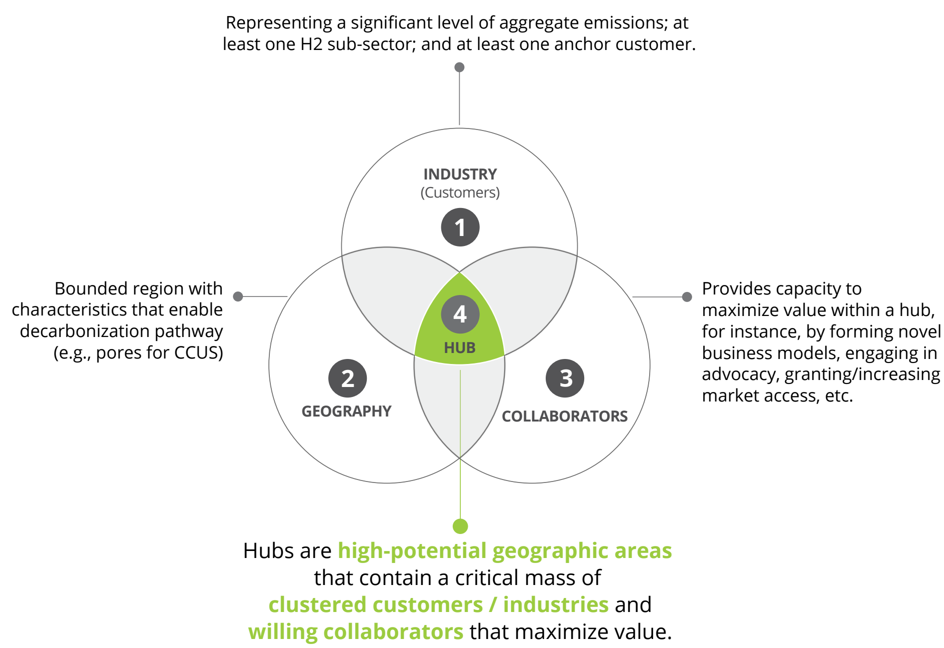
*Not all facilities and captured emissions are eligible for 45Q credit

Although they've been around for decades, hydrogen and CCUS technologies have faced investment headwinds arising from a persistent "chicken or egg" problem: companies are reticent to invest in production or capture technology without being confident that there is a market for their product, while downstream customers have not invested in the market infrastructure or technology to utilize captured carbon or clean hydrogen due to the lack of supply. While this has held back development in the past, the increasing urgency to mitigate climate change and the mounting focus on industrial emitters is driving a concerted effort to resolve this infinite regress scenario. For "harder-to-abate" sectors to decarbonize at the speed needed to keep the planet to less than 1.5-degrees or even 2-degrees of warming, these low-carbon technologies must reach commercial scale in the mid-term as part of the overall solution to achieve net-zero emissions globally by 2050. With investment time horizons of five years or longer, companies need to act now in order to see emissions reduction benefits by 2030 at the latest.

Introducing the "hub" concept

One key pathway to achieving commercially viable low-carbon technologies is by funneling investment to scale up supply in regions with matching, growing demand. By co-locating supply and demand, "hubs" can bring down infrastructure costs and drive economies-of-scale, serving as an aggregation point for local demand before expanding transportation infrastructure to provide dispersed supply elsewhere in the country or for export. Bound by a specific region, representing a significant level of aggregated point-source emissions, and bringing together actors from across value chains and sectors, hubs sit at the intersection of customers, geography, and collaborators that enable organizations to maximize value. As our analysis will later illustrate, collective action in a hub drives significant cost reduction for collaborators when compared to the costs associated with individual investments.

Figure 2: The Hub Concept



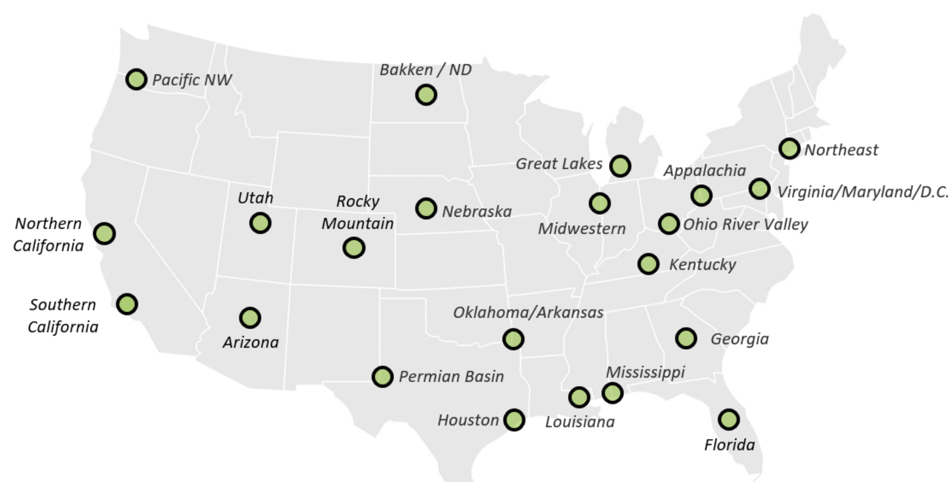
Source: Deloitte Analysis

Often integrating clean hydrogen production and CCUS for industrial emissions, low-carbon industrial hubs, by definition, require facilities with high GHG emissions, access to large geological formations capable of CO_2 sequestration at scale, hydrogen production and geological storage capabilities, and the ability to utilize or construct transportation infrastructure.

Beyond these considerations, true hubs create an ecosystem of financiers, start-ups, equipment manufacturers, professional service providers, suppliers, and customers across different sectors and segments. Through ecosystem collaboration, hubs can accelerate technological development, encourage downstream adoption of clean hydrogen and/or carbon capture for multiple end-uses, and drive long-term decarbonization transformation across industrial value chains. "Co-opetition" amongst hub members creates conditions which may accelerate hub success by both lowering the perceived risk of investment—as participants see others in their industry investing—as well as by creating more tangible competition. For ecosystems to work well, companies will have to give up old notions of "competitive advantages" in which most moves are exclusively zero-sum and instead think about the value of "collaborative advantage" and "adaptive advantage" which comes from working with others—even erstwhile competitors.

Typically centered around geographies with regional advantages (e.g., endemic natural geological storage formations, existing infrastructure, a skilled workforce, favorable regulatory conditions, tax incentives, etc.), successful hubs benefit from solution integration and scale, and reap the rewards of increased innovation, access to human capital, investment flows, and more. Based on these criteria, several low-carbon hub locations have already been identified across the United States, many involving multiple planned or announced projects (Figure 3).

Figure 3: Examples of Announced Hubs



Source: Deloitte Analysis

Due to its cost advantages of natural gas, endemic geological storage resources, wind and solar potential, industrial manufacturing capabilities, and existing export and pipeline infrastructure, North America, and in particular the United States, is one of a few regions in the world identified by the IEA as being primed for low-carbon hub development and clean hydrogen export.[vi] However, with national low-carbon strategies, supportive funding and regulatory regimes, and several announced projects underway, other industrial regions like Australia, Europe, and China have so far led the world in hub development. Though the United States lags behind, recent policy support has signaled that this may not be the case for long.

There are a multitude of hub projects under development globally, each with its own complexities and operating model considerations. At their core, however, we see hubs as being either *supply-led* or *demand-led*.

Supply-led hubs leverage a differentiated supply base to attract customers by establishing supply in areas primed to support it, in the hopes that such actions can create demand. These hubs can either be ***asset-led*** in which hub development is focused on acquiring or leveraging a specific asset such as pipelines or salt caverns, or they can be ***product-led*** where the hub is stood up with the intention of producing a specific end product – such as hydrogen or carbon black.

Demand-led hubs organize downstream industrial subsectors to aggregate hydrogen and carbon dioxide demand by creating an attractive market for lower emission solutions at scale and emphasizing collaboration. These hubs can either be ***off-loader led*** where hub development is driven by high emitting industries looking to off-load captured CO_2 and thereby driving demand for capture, utilization, and sequestration services, or they can be ***off-taker led*** in which industries look to utilize clean hydrogen and captured CO_2 to decarbonize their operations and products (think carbon cured cement, green methanol, or clean hydrogen as a feedstock).

REPRESENTATIVE HUB: HOUSTON

- **Key Attributes:** Contributing roughly 90% of current US hydrogen production, Houston seeks to leverage its existing asset base including natural underground storage, extensive pipeline network, and export terminals in rail or shipping for a differentiated supply base.
- **Emissions:** Houston hub area emissions are derived from a variety of industrial processes, primarily from downstream oil & gas including: refineries, coal- and gas-fired power plants, petrochemicals, and natural gas reforming.
- **Hub development:** Given Houston's advantages in natural gas and CCUS technology, Houston is expected to leverage CCUS to reduce hub emissions and produce blue hydrogen. There are multiple projects proposed by individual O&G majors taking the lead (e.g., ExxonMobil) as well as local PPP consortia coordination (e.g., H2Houston Hub led by the Center for Houston's Future).

REPRESENTATIVE HUB: APPALACHIA

Key Attributes: The concentration of industrial emitters in steel and power generation is driving demand for low-carbon solutions. Primarily aimed at reducing the emissions of these sectors, the Appalachia Hub seeks to leverage this aggregated demand as well as advantages in shale NG production to construct a hub.

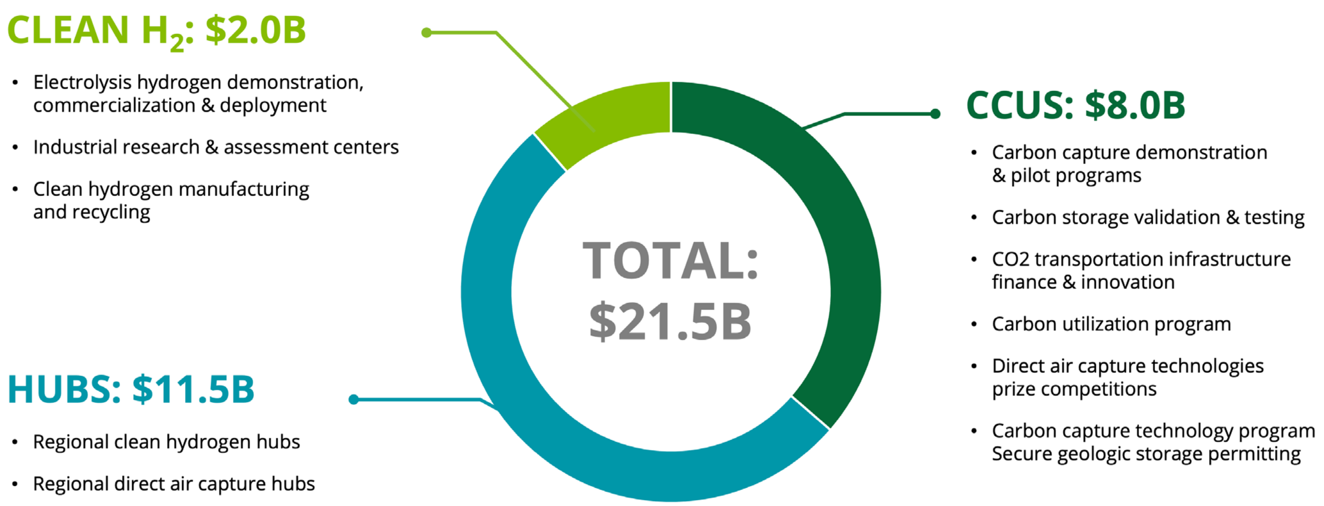
Emissions: Appalachia hub area emissions are derived primarily from steel and coal-fired power generation, at 115.7 MT annually.

Hub development: Hub development is being advocated by regional state legislators for WV, PA, and OH, but one private-led consortia driven by downstream emitting industries (steel and power generation) is leading the way.

Catalyzing development: federal funding for hubs

As the United States looks to achieve the emission reductions goals set by the Biden administration, the Department of Energy (DOE) is stepping up support for hubs as a pathway for industrial decarbonization. The Infrastructure Investment and Jobs Act (IIJA), passed in November 2021,[vii] sets aside over $21 billion in fiscal years 2022-2026 in support of technologies that will be key parts of low-carbon hub value chains (clean hydrogen and CCUS), as well as $8 billion and $3.5 billion in direct funding for individual hydrogen and direct air capture (DAC) hubs respectively (Figure 4). Several states have also individually announced their intent to form and support regional hydrogen hubs.

Figure 4: Total DOE Funding for Hub-Related Activities



Source: Deloitte Analysis

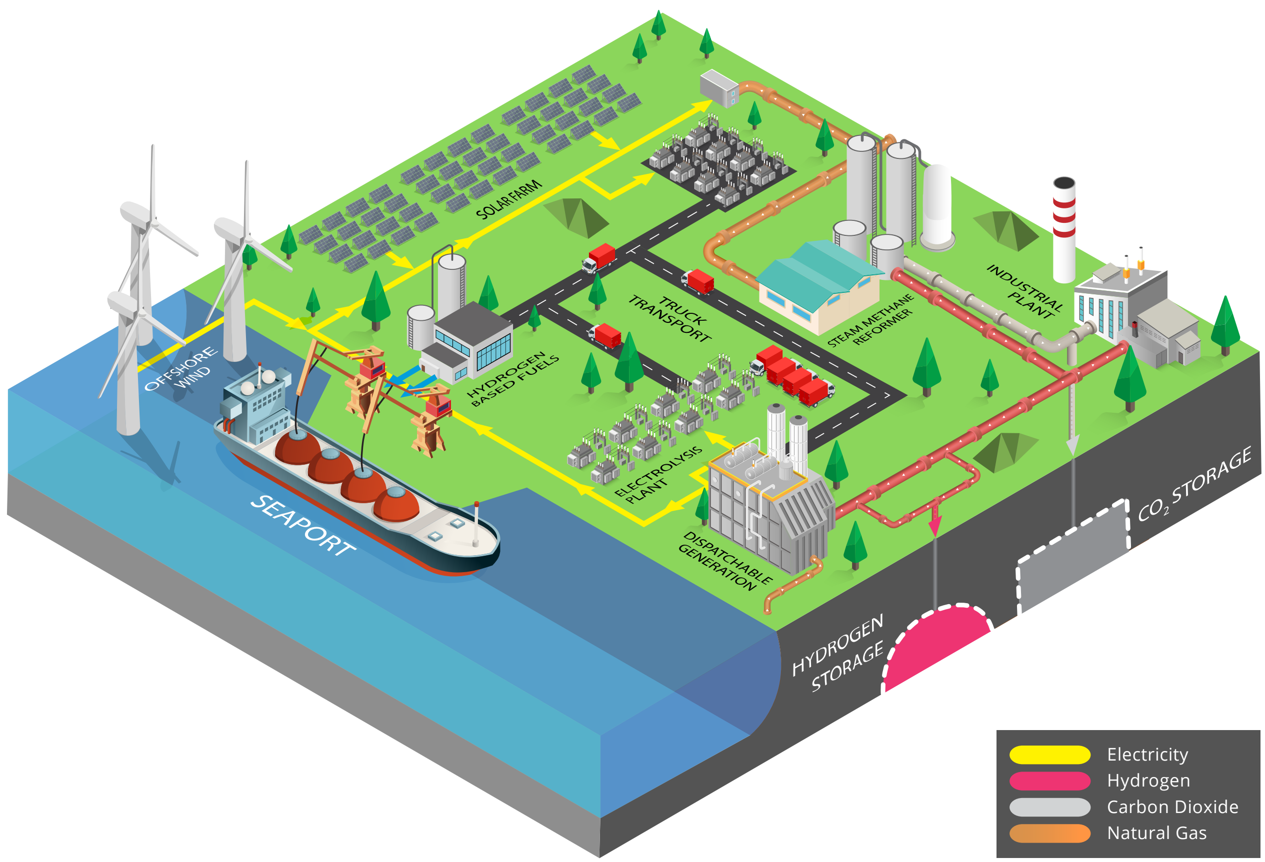
Though significant, the DOE funding is estimated to be only a portion of the investment needed to establish U.S. hubs and drive down the cost of clean hydrogen and CCUS on a global scale. By some estimates, the annual global spend on these technologies that will be required to reach net zero by 2050 must exceed $900B in 2026 – up from $24B in 2021.[viii] While this remaining gap in investment will have to come largely from the private sector, federal funding can serve to de-risk private investment and catalyze hub development. Competition for this funding is therefore expected to be fierce, but hubs will have to have a strong enough business case on their own to entice sufficient private investment.

The value proposition of hubs

Fortunately, even without government support, hubs present a significant value proposition for participating companies seeking to reduce emissions and meet customer demand for low-carbon products and services.

Deploying clean hydrogen and CCUS in the United States at the scale necessary to reach net zero by 2050 will require that a large amount of the CapEx spent by "harder-to-abate" industries be directed to retrofitting facilities or constructing new greenfield sites for these new technologies. For CCUS, that means growing the U.S. capacity from 25 million metric ton per annum (Mtpa) in 2020[ix] to over 1 billion tons per annum by 2050.[x] Companies will need to equip facilities with carbon capture equipment, expand hydrogen production, and build out the necessary pipeline network to aggregate, compress, and move carbon dioxide and hydrogen to downstream consumers or geological storage. Figure 5 illustrates how these pieces may work together within a low-carbon hub, which coordinates and aggregates the infrastructure investment required to maximize efficiency.

Figure 5: Illustrative Hub Architecture

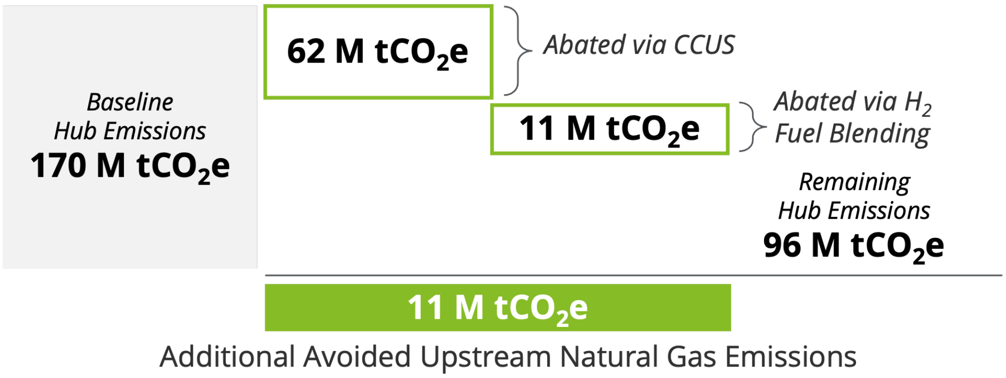


Source: Deloitte Analysis

To further explore the business case for hubs, we modeled the cost savings and emissions reduction resulting from two real U.S. hub locations representing the supply-led and demand-led operating models.

In an example supply-led hub (Figure 6), with existing production infrastructure, ample CO_2 storage, and emissions totaling over 170M tons of carbon dioxide equivalent (tCO_2e) per annum from the oil & gas, chemicals, and power sectors, our analysis showed that a combination of hydrogen fuel blending and CCUS deployed by half of emitting facilities could reduce emissions by over 70 Mtpa. Of this total, CCUS accounted for ~62 Mtpa, with fuel blending contributing an additional ~11 Mtpa (Figure 6). Aside from this direct abatement, replacing some natural gas supplies with clean hydrogen fuel contributes an additional ~11 Mtpa in upstream avoided emissions (including CO_2 and methane). Deeper emissions reductions—up to 80% across the hub—could be achieved as more facilities deploy CCUS and incorporate fuel blending, with the remaining emissions addressed either through fuel switching, electrification, or alternative feedstocks.

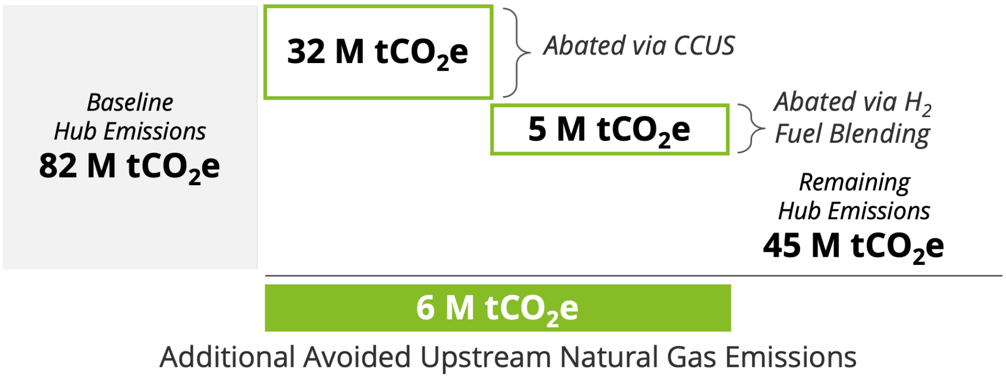
Figure 6: Emissions Reduction from an Example Supply-Led Hub



Source: Deloitte Analysis

For comparison, in an example demand-led hub (Figure 7), where development is driven by the need to create a CO_2 offtake for over 80M tCO_2e emissions coming from a diverse set of oil & gas, power, chemicals, iron & steel, and cement facilities, our analysis showed that total abatement could reach 45% through the hub approach. Of this, CCUS accounted for ~32 Mtpa with an additional ~5 Mtpa coming from clean hydrogen produced at the hub. This abatement potential could be increased to 85% if all emitting facilities deployed CCUS and used a fuel blend of 20% hydrogen by volume for all on-site combustion.

Figure 7: Emissions Reduction from an Example Demand-Led Hub



Source: Deloitte Analysis

To enable the above emission reduction at these hubs, significant capital investment will be needed—in excess of $15 billion and $10 billion respectively—across sectors to retrofit existing infrastructure for CCUS and construct transportation and storage for CO_2 and hydrogen. For reference, the U.S. chemicals industry spent $27 billion on capital equipment and structures in 2020.[xii] This will require both a sizeable increase in the amount, and change in focus, of CapEx in "harder-to-abate" industries.

To achieve the 16 Mtpa of emissions reductions from hydrogen fuel blending across these two hub locations, approximately **1.7 million metric tons of new clean hydrogen production is required** to meet internal demand from hub industrial facilities. To put that into context, that is approximately 17% of the current production volume of the entire United States (10Mt) in incremental capacity.

Moreover, given that only 1% of today's production comes from cleaner sources[xi] (fossil fuels with CCUS or electrolysis powered by renewable electricity), this is a 170x increase in clean hydrogen production from today, just to satisfy the demand for clean hydrogen as a low-carbon fuel for industrial facilities in only two hub locations in the United States, highlighting the scale of development that will be required.

Despite their sizable price tags, when compared to individual companies deploying CCUS by themselves, all companies, regardless of size and industry, see a reduction of between 20% and 95% in the capital investment required. Outside of a hub, a company's investment in transport infrastructure is governed by the volume of emissions from their own operations, limiting the pipelines they can deploy to smaller diameters with lower annual capacities and significantly less favorable unit economics. By aggregating emissions from other point sources, companies can drive towards more efficient pipelines and lower the per-ton cost of CO_2 transported. Hydrogen producers and consumers in the hub can expect similar transportation and storage cost reductions due to economies-of-scale.

This relationship plays out in our hub examples shown in Figure 8. Although the demand-led and supply-led examples have significantly different industry configurations and total emissions, each industry participating sees an impactful cost reduction compared to what it would have been to pursue the same level of abatement alone. However, the level of cost reduction ranges depending on a company's size, volume of emissions, and share of the hub's total emissions.

Figure 8: CCUS Cost Reduction and Addressable Emissions, by Industry, for Example Hubs

	Supply Led		Demand Led	
	% of Hub Emissions	Cost Reduction	% of Hub Emissions	Cost Reduction
Chemicals	30% *(50 Mtpa)*	40-80%	5% *(4 Mtpa)*	80-95%
Oil & Gas	35% *(60 Mtpa)*	30-70%	13% *(10 Mtpa)*	75-95%
Power	35% *(60 Mtpa)*	20-60%	39% *(30 Mtpa)*	35-75%
Iron & Steel	-	N/A	39% *(30 Mtpa)*	30-75%
Cement	-	N/A	4% *(3 Mtpa)*	85-95%

20% — Cost Reduction Range — 95%

Large Enterprises — Small and Medium Enterprises

Source: Deloitte Analysis using 2019 EPA FLIGHT DATA

Overall, the results tell us that the greatest cost reductions arising from a hub approach are experienced by small and medium enterprises in industries that make up a relatively smaller share of the overall hub emissions footprint. When compared to the cost of going at it alone, these companies benefit the most from scaled pipeline capacity and more favorable per-unit transport cost.

We recognize that not all companies will be able to directly participate in hubs for a variety of economic and geographic reasons. However, these companies can still accelerate and enable hub formation by signing off-take agreements and generating demand for low-carbon products that will be produced at the hub. For these downstream customers, purchasing products with a lower "carbon backpack" will result in a reduction of their upstream Scope 3 emissions, one of the most difficult categories for organizations to address.

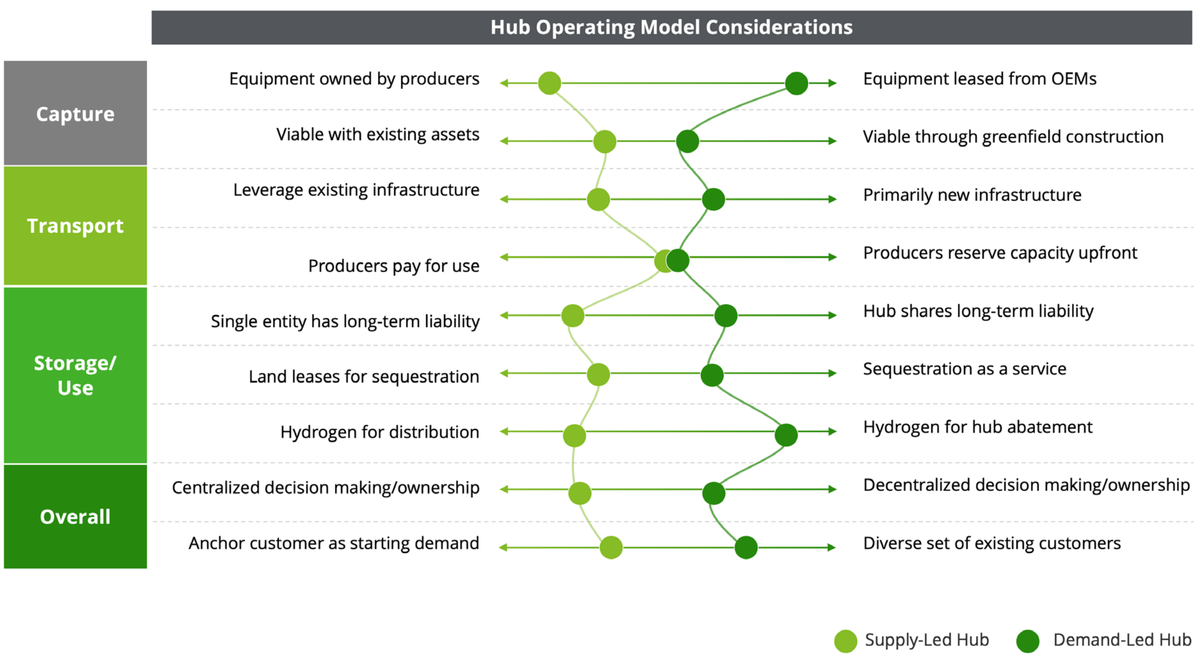
What makes a successful hub? Strategic considerations for hub development

The success of different hubs and hub projects will ultimately be driven less by the amount of public funding secured, or the number of participants involved, but more by how well hub organizers are able to navigate the complexity surrounding hub development. This will include sending the right demand signals to ecosystem collaborators, making near-term investment decisions for bottom-line impact down the road, and reorienting mid- and long-term business goals and capital expenditure to meaningfully advance hubs for lower emissions.

In surveying the landscape of currently operational and newly announced hub projects, no two are alike. Geographic and geologic variation, diversity of partners, the range of different technologies deployed, the extent of government involvement, and the leadership of different industries are among the many different factors determining the diversity in approach to hub development globally. As a result, there is no singular blueprint, playbook, or framework that governs the development of hubs.

These differences lead to strategic considerations across each aspect of the value chain that will shape the hub. To better understand the decisions that hub developers and hub participants will need to make, a series of strategic tensions have been outlined that will influence the hub's eventual operating model. These are not binary and are not meant to drive towards a single answer. Rather, hub developers and participants should use them to develop a perspective on what would be the most beneficial for their hub and to identify a final hypothesis on how the hub will operate.

Figure 9: Hub Operating Model Considerations



Source: Deloitte Analysis

In addition to these choices, organizations will need to navigate tactical and logistical decisions at the individual project level, such as contract structuring, pipeline access, tax structuring, monitoring and reporting, community engagement, environmental impact, and more. Each of these decisions and tensions may not require consensus, but they do need an open and transparent dialogue between civic and corporate leaders, technical experts, governments (federal, state, local), labor unions, community members, and a number of other interested and invested participants.

As a result, hubs will typically encompass a multitude of partners with inherently mismatched capabilities, motivations, and timelines. Where Deloitte has been invited into hub development, it has been to provide the interstitial matter to fill these gaps; convening like-minded partners and providing a third-party perspective to drive towards shared objectives while rounding out hub capabilities with additional services as hub projects evolve. In our experience, hubs that can accelerate alignment across their interdependent and complex stakeholder network will thrive, while those that cannot are unlikely to make it past the planning phases.

Conclusion

As the pressure to reach net zero mounts from investors, regulators, customers, and other stakeholder groups, and the demand for low-carbon products and solutions grows, "harder-to-abate" sectors are rightfully seeking pathways to achieve meaningful emissions reduction while preserving value for shareholders. Hubs present a relatively accessible option for industry in the near term to make good on emissions reductions pledges and demonstrate action on climate change.

Our analysis shows that while new federal funding has kickstarted hub formation around the country and sparked fierce competition for grants and incentives, there is a considerable business case for cross-sector collaboration within low-carbon industrial hubs even without government support. How a hub is configured—involving the right partners, securing demand amongst diverse end-uses, engaging the complete value chain, structuring agreements governing shared infrastructure, coordinating amongst various stakeholders, and more—will ultimately be important determinants of success.

Facing technical and business model barriers to reducing emissions, "harder-to-abate" industries must embrace collective ecosystem approaches like low-carbon industrial hubs to accelerate beyond incremental change and to catalyze tipping points in low-carbon innovation. Strategic participation in hubs is a quick win, attainable in this decade, for sectors that don't have many options—reducing the cost of abatement, enabling further technological innovation, and unlocking emissions reduction benefits now while enabling deep decarbonization down the road.

Contact us to learn more.

Our insights can help you take advantage of change. If you're looking for fresh ideas to address your challenges, we should talk.

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Acknowledgements

Special thanks to co-authors **Alex Beutel, Matt Floyd,** and **Ian Goulding** for their significant contributions to this study.

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Endnotes

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