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CCUS is a net-zero imperative

Here's how we make it a reality

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The evolution of CCUS

Carbon capture technology first emerged a century ago as a separation process and a way to commercialize natural gas by removing the CO_2 found in the reservoirs from the gas that customers wanted to buy. Today CO_2 is captured and injected into oil fields to enhance oil recovery. But the challenges posed by the current energy transition demand that carbon capture, utilization and storage (CCUS) technologies extend beyond oil field applications to specifically address the world's growing global CO_2 emissions.

Indeed, CCUS is uniquely positioned to be an essential part of the transition to a net-zero world. According to Zero Emissions Platform (ZEP), current capture technology has the potential to remove 50% of global CO_2 emissions.[1] However, for the world to meet its net-zero objectives, it is critical we develop and deploy CCUS technologies faster and at a much greater scale than ever before. And scaling up will require enhanced collaboration across the value chain.

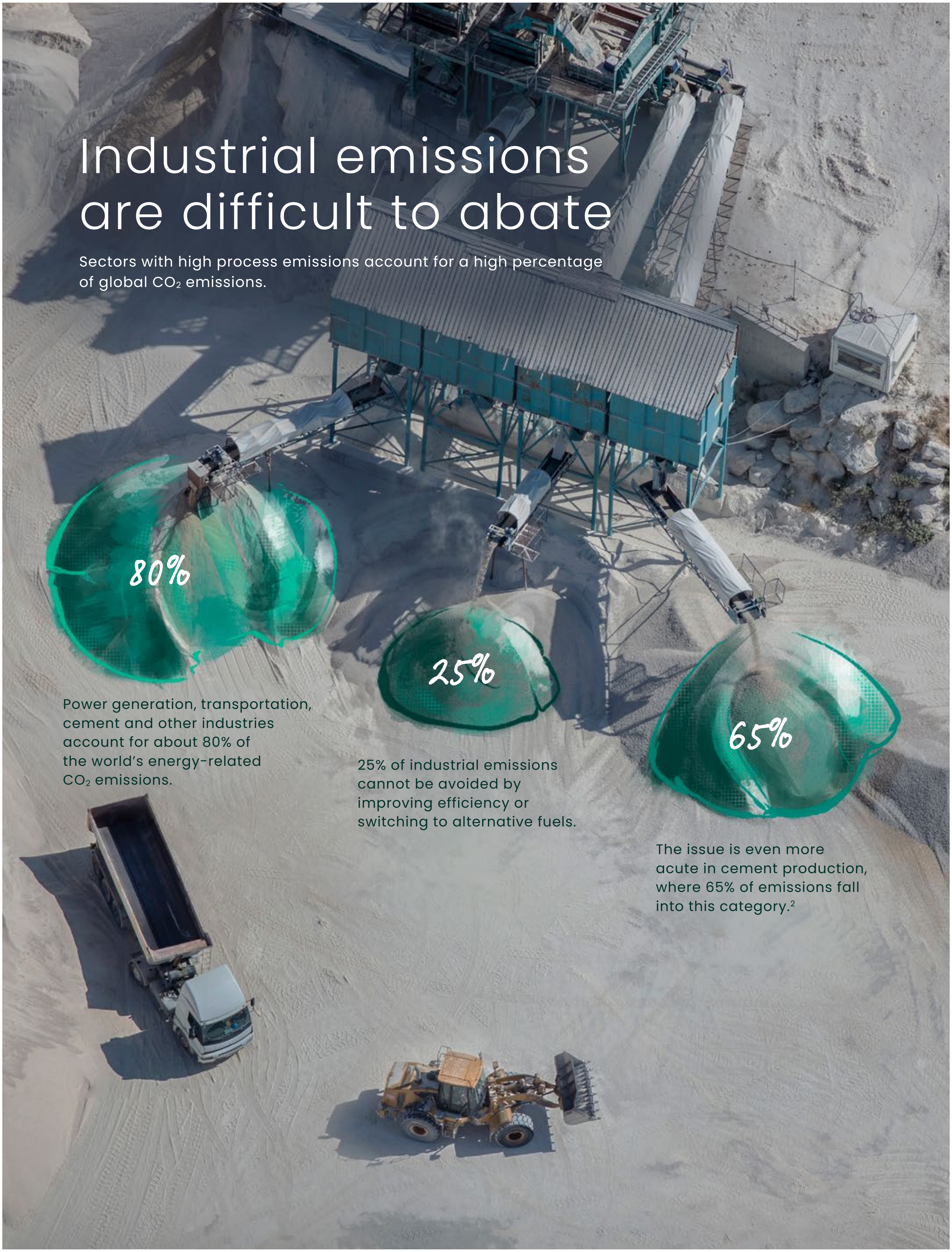
Carbon capture may have been born from necessity in the hydrocarbons sector, but it must be utilized across the global economy as a critical part of meeting ambitious emissions targets. For this transition to occur, we must also accept a few hard truths about CCUS.

Hard truths about CCUS

The first hard truth is that without CCUS technology it will be nearly impossible to remove emissions from large parts of the global economy. As both public and private entities accelerate the implementation of large-scale decarbonization solutions across economic sectors, CCUS represents one of the most effective options for carbon abatement where greater efficiency or alternative energy sources are unlikely to result in emission reductions.

For example, CCUS may be the only way we can address a significant proportion of industrial emissions. Power generation, transportation, cement production and other energy-intensive industries account for more than three-quarters of the world's energy-related CO_2 emissions, and nearly 25% of industrial emissions cannot be avoided by simply moving to alternative fuels, because these emissions come from the industrial process activity.

1st truth



Industrial emissions are difficult to abate

Sectors with high process emissions account for a high percentage of global CO_2 emissions.

Power generation, transportation, cement and other industries account for about 80% of the world's energy-related CO_2 emissions.

25% of industrial emissions cannot be avoided by improving efficiency or switching to alternative fuels.

The issue is even more acute in cement production, where 65% of emissions fall into this category.[2]

The second hard truth is that CCUS needs to grow at an exponential rate to capture enough carbon to meet the Paris Agreement climate goals. According to the IEA's Net-Zero Emissions by 2050 Scenario released this year, CCUS capacity will have to increase from roughly 40 million tons per annum (Mtpa CO_2) today to 1,670 Mtpa CO_2 a decade from now. By 2050, the IEA estimates a required capacity of 7,600 Mtpa CO_2.

In 2020 there were only 26 commercially active CCUS projects, representing approximately 40 million Mtpa of carbon capture capability.[3] Currently there is a handful of CCUS facilities currently under construction, with a few more in advanced development and several more in early development. However, these facilities collectively represent less than 100 Mtpa of carbon capture capacity set to come online.[4]

2nd truth

"The CCUS ecosystem is both a technology and infrastructure play. To deploy at scale, innovation and collaboration need to be at the core. From developing breakthrough technology, to experimenting with new business models, or adopting a cluster approach for project development, the name of the game is driving a shift in mindset to create a new market while pursuing a common goal of decarbonization."

– Daniela Abate, Vice President CCUS, Baker Hughes

The third truth is that there is no one-type-fits-all CCUS technology solution. We will need a mix of proven, effective technologies that can meet societal needs and economics.

Despite its long history and relative maturity, the application of CCUS still involves uncertainties associated with emerging technologies. These include the economic viability of individual projects and legal liabilities associated with the long-term storage of carbon. There is existing expertise in the field of carbon capture, utilization and storage, especially in the oil and gas industry, where companies have a track record of capturing carbon from field operations and safely injecting it subsurface.

However, for CCUS to reach its full potential, this existing expertise will have to be applied in new ways to new sectors while leaving room for the emergence of new technologies that address specific niches in carbon abatement.

A number of established and emerging technologies are poised to transform CCUS. It's important that we continue investing in research to pilot and scale the CCUS technologies that have the potential to deliver the most significant results. Partnerships that can bring elements like existing reservoir and pipeline technologies together with new developments like advanced capture tech will be key to commercializing and deploying CCUS technology.

3rd truth

No single technology, but a lot of possibilities… and flexibility

No two projects are the same. Because of this, CCUS is a bespoke solution that is applied to projects that vary in everything from capture size and geographic region to CO_2 concentration.

Fortunately, while CCUS is often referred to in terms that suggest it is a single solution, it is actually a large, integrated solution containing many technologies that can be reconfigured to apply to many different scenarios and deployed at scale across multiple industries and locations. For example, carbon can be captured using pre-combustion, oxy-combustion and post-combustion technologies and through direct air capture (DAC). Each of these methods can have different applications that create flexibility in how and where carbon capture can be utilized. For example, pre-combustion capture processes convert fuel into a gaseous mixture of hydrogen and CO_2. The hydrogen is separated out while the CO_2 is then compressed for transport and eventual storage.

Oxy-combustion uses pure oxygen in combustion processes, which ensures that flue gases contain only CO_2 and steam. This allows for effective and relatively affordable CO_2 separation, but the process of obtaining pure oxygen by separating it from air can add significant costs to the process. DAC is different in that it captures CO_2 from the air rather than from flue gases. This allows you to capture carbon directly from the atmosphere, meaning you do not have to place capture units in the same place as the emission source. Instead, you can capture carbon in

The different CO_2 capture systems

	Advantages	Drawbacks
Pre-combustion	Low cost of capture, based on mature technologies	Only suitable for use in new facilities or to specific industrial processes (e.g., natural gas treatment, steam methane reforming)
Post-combustion	Several options are available and can be easily retrofitted	Separation process has high energy costs
Oxy-combustion	It produces a CO_2 stream as a result of combustion	Oxygen separation is expensive
DAC	Delivers negative emissions, can be installed everywhere (not linked to emission source)	Capturing CO_2 at very low concentration requires large, energy intensive plants, technology is in early stage and expensive

the same place you intend to store it, cutting down on transportation. DAC could be an important carbon capture technology in the future, but it remains untested at scale.

With post-combustion processes, CO_2 is captured from exhaust gases using solvents, sorbents and membranes. Different post-combustion technologies offer different benefits and can be applied to capture CO_2 emitted by different sources; for example, cement factories, gas turbines, waste-to-energy plants, reformers and steel mills.

Even within post-combustion processes there is no single “leading” technology, with the choice dependent on specific considerations based on factors that are not only project-specific and site-specific but also customer-specific. Some technologies can be brought online faster, others use less energy, and still others require fewer resources, like a lower rate of water use.

Some examples of promising post-combustion carbon capture technology are the chilled ammonia process (CAP) and mixed salt process (MSP), which combine an efficient process configuration with a novel solvent formulation that makes the solutions more efficient as well as more environmentally friendly. The CAP technology is already commercially available today, while the MSP technology is progressing through commercialization.

Carbon capture varies not just in application, but also in size

While there has been a focus on developing larger carbon capture projects to take advantage of economies of scale, creating smaller low-cost carbon capture units also opens new opportunities for certain applications.

Smaller and lightweight CO_2 capture technology, like the Baker Hughes compact carbon capture technology, is a solvent-based post-combustion technology that enhances the carbon capture process resulting in up to 75% smaller footprints and lower capital expenditures. This technology is in development and beyond serving greenfield applications, it is slated to also serve space-challenged applications such as retrofits and carbon abatement of offshore platforms.

Ultimately, the choice of a capture system will depend on many factors. Both the source of the emissions and the overall quantity and concentration of CO_2 being emitted are important. At the same time, the amount of energy required for different capture systems can vary greatly, meaning that the energy sources available can also help determine which system is best for a particular project.

You’ve got to move it

On its own, carbon capture is only part of the solution. Once captured, the CO_2 has to be transported, both for potential utilization and for safe permanent storage. The infrastructure required to transport carbon is not only massive, but also highly specialized. That means transportation costs will continue to represent a considerable portion of the overall CCS cost structure.

The current pipeline infrastructure for CO_2 is limited, and there will need to be significant investment to scale it up to levels that can support exponential growth in carbon capture. According to the Net-Zero America Project, the United States, currently the global leader in carbon transportation with 85% of CO_2 pipelines globally, will need to spend up to $230 billion on 110,000 kilometers of additional CO_2 pipeline by 2050.

While the bulk of CO_2 transport will likely take place via pipeline, some will also take place by truck or ship. However, road, rail or water transportation are only cost-effective if the CO_2 is liquefied. To turn gaseous CO_2 into a liquid roughly the same density as water, it needs to be kept under pressure at a temperature below 31°C (87.8°F). The process shows similarities to the liquefaction of natural gas, which means expertise in natural gas liquefaction and transportation is a valuable asset in the further development of safe and efficient carbon transport.

CO_2 must also be treated and compressed prior to transport. As a result, compressors that have flexible applications and can be used in various environments will play an important part in the development of CCUS transportation. Just as importantly, compressors will need to be made of materials that can withstand corrosive conditions. The same applies to the pipelines that transport CO_2, since any exposure to water produces a highly corrosive liquid byproduct that could damage the pipeline.

The technical demands posed by CO_2 transport will require ongoing innovation in material science. Some important elements, like durable composite piping, are already available in the marketplace. Because this type of pipe has shown utility in the corrosive environments that characterize CO_2 transport, it will likely play a key role in the developing carbon infrastructure. There are even versions of composite pipe that are spoolable, making them easier to transport and deploy with less manpower than comparable steel pipe.

However, the scale and diversity of future CCUS projects will require additional material advancements, which will likely rely on partnerships that can not only develop innovations in material sciences, but also deploy these new developments in the field at scale.

You've got to store it

In addition to expertise in materials science, knowledge of subsurface conditions will also be important to the continuing development of CCUS. Storage outlets will largely be underground, with depleted oil and gas reservoirs and saline aquifers serving as important locations for storing carbon. Estimates put global storage capacity at 6,000 Gt to 42,000 Gt for onshore sites, with additional capacity offshore ranging from 2,000 Gt to 13,000 Gt.[5]

While global capacity for storage is plentiful, it is not evenly distributed. The Global CCS Institute estimates that storage capacity of 205,000 Mt CO_2, two-thirds of current global capacity, is in the United States. The uneven distribution of capacity may actually have some advantages. Successful storage requires subsurface characterization, which already exists in depleted reservoirs in the United States.

But subsurface data is not the only element that carbon storage must borrow from the oil and gas industry. An understanding of reservoir dynamics will be critical to developing safe and reliable storage sites. Safe underground storage will require the expertise of oil and gas companies in understanding subsurface chemistry, regional distress profiles and preexisting faults and fractures.

While complex, when done correctly subsurface storage has the advantage of being a permanent solution for carbon. The CO_2 injected underground will exist in several different phases in the subsurface, but will eventually take a solid mineral form. This returns the carbon essentially back to the state it was in when it was first extracted.

Successful and safe long-term carbon storage will require working with partners who both understand the intricacies of transportation and have a demonstrated track record of subsurface capabilities, including a record of safety and a reputation for precision. Leveraging the existing knowledge base will be key to scaling up storage in a relatively short time period.

"A majority of the technologies that we already have from our oil field operations can be pulled into the CCUS space. It's not a completely new space that we're operating in, we're just learning how to do it differently."

-Jessica Raines, Reservoir Technology Service Discipline Lead, CCUS, Baker Hughes

You've got to use it

While there will be a strong market for carbon sequestration as the global capacity for carbon capture increases, a critical priority for the industry is to find a way to utilize carbon. While carbon utilization has been around for decades in the form of enhanced oil recovery in the hydrocarbons sector, more innovative methods of utilization are starting to emerge.

Though not yet widespread, the technology exists to turn CO_2 into chemicals and synthetic fuels. Carbon dioxide can also be used in production of construction materials such as aggregates or to enhance properties of cement. Commercializing captured carbon will help offset costs associated with capture and storage, but we must dedicate time and resources to the process. Collectively, we will need to invest in and further develop all these technologies — not only to understand which ones will scale, but also because

CO_2 can be turned into biofuel feedstocks like the kind seen here.

there are a number of industries that can benefit from carbon utilization.

Carbon utilization will contribute to reaching greenhouse gas emission reduction targets in different ways. Synthetic fuels created by combining captured CO_2 and green hydrogen represent a route to low-carbon or net-zero fuels that can be used in the transportation industry. Regulatory frameworks are already being defined that make synthetic fuels eligible for carbon credits and acknowledge their contribution toward renewable energy content targets.

Also, synthetic fuels can serve as a form of energy storage, allowing excess renewable energy to be stored in the form of hydrocarbons in existing infrastructure. This supports further renewable penetration, providing revenue streams for excess renewable energy and contributes to the decarbonization of sectors such as heating and transportation.

Finally, CO_2 utilization in construction materials represents a form of permanent storage, so that the construction industry can contribute with negative emissions in reaching targets.

Nevertheless, all these technologies are still in early stages and markets are yet to be formed. Advancement in technologies to reduce costs, and incentives to adopt carbon capture and ultilization technologies, are crucial to form relevant markets and value chains, and to trigger adoption at scale.

"Every aspect of CCUS needs to be cost-competitive and sustainable. While there are still a lot of questions to answer, the key is going to be finding and supporting the technologies that can lower costs of carbon capture and the products that will utilize the captured carbon."

-Rod Christie, Executive Vice President of Turbomachinery and Process Solution, Baker Hughes

The future of CCUS

While the breakthrough in utilization has yet to happen, CCUS technologies are already crossing the line from the pilot phase to commercial use. But without ways to offset the costs of carbon capture or improved utilization, the economics of CCUS will remain a roadblock. To take advantage of the promise of CCUS, we must ensure it grows at scale, and that means investing in promising technologies.

Policy drivers that encourage investment are an important part of future CCUS development. Major global economies are now demonstrating a commitment to CCUS that will help overcome some of the challenges facing the sector. In Europe, STRATEGY CCUS is an ambitious three-year project funded by the European Union to support the development of low-carbon energy and industry in eight regions of southern and eastern Europe considered promising for CCUS. In the United Kingdom the government has announced it will invest up to £1 billion to support the establishment of CCS in four “industrial clusters” and plans to capture 10 Mtpa of CO_2 by 2030.

The United States has approved provisions for carbon capture, removal, use and geologic storage that together amount to over $6 billion in funding over five years. Recent legislation removed a 75 Mtpa cap for qualifying projects and minimum capture requirements, meaning a more diverse set of projects will qualify for support. A 2018 amendment also increased the value of a tax credit for permanently stored carbon to $50/ton, creating a greater incentive for domestic storage.

In China the government has begun including CCUS technologies as part of its official carbon mitigation strategies. This includes funds for development. The People’s Bank of China (PBoC) and the National Development and Reform Commission (NDRC) also released a new draft green bond catalogue in 2020 that included CCUS projects for the first time. This paves the way for additional funding for CCUS in China.

The support from policy makers underscores that governments recognize the enormous technology opportunity represented by the development of CCUS. But its future still depends on smart partnerships that leverage expertise in the private sector. Existing know-how in the subsurface realm, the ability to develop and scale up new technologies, and the capability to handle complex projects will all be central to commercializing and deploying carbon capture, storage and utilization.

Source Information:

[1] https://zeroemissionsplatform.eu/wp-content/uploads/ZEP-Future-CCS-Technologies-report.pdf

[2] https://www.iea.org/reports/transforming-industry-through-ccus

[3] https://www.reuters.com/article/us-climate-change-ccs-idUSKBN28B3SZ

[4] Global CCS Institute, Global Status of CCS 2020

[5] B of A Global Research, Carbon Capture: The $1tn Key to Unlock Net-Zero

Endnotes