Deloitte.

Beyond Hype

Navigating the Landscape of Climate Solutions

Contents

Introduction

Many of us are familiar with the looming dangers of climate change, and amidst the constant buzz about transformative transition technologies, it's challenging to discern which ones will truly make a difference.

Taking a broader perspective, the journey to net zero emissions requires a substantial reduction in our yearly emissions output that currently hovers around 55 gigatonnes of CO_2eq/year [1]. The solutions can be broadly categorised into two categories: i) reducing efforts, which rely on traditional mitigation technologies to mitigate the CO_2 intensity of various processes, and ii) removal technologies, also known as carbon dioxide removal (CDR), designed to extract CO_2 already released into the atmosphere. While net zero emission scenarios often emphasise the significance of reducing technologies (Figure 1), it is essential to recognise that the net zero goal remains unattainable without the inclusion of effective removal technologies [2].

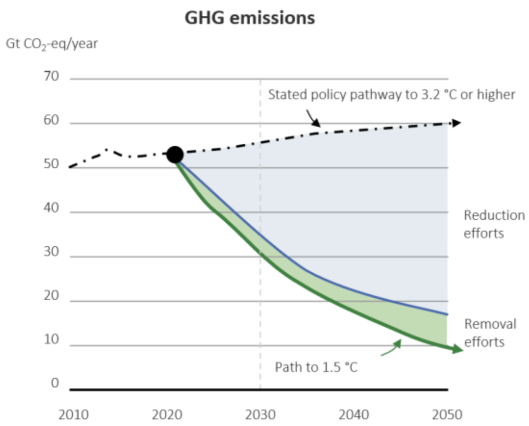


Figure 1. GHG emission pathways for stated policy scenario and path to 1.5 °C with relative contribution of emission reduction from reduction efforts and removal efforts.

In this intricate landscape of climate solutions, it becomes imperative to explore the distinctive realms of reducing technologies and removal technologies. Let's delve into each, examining their roles, economic impacts, technical intricacies, and their combined potential to pave the way toward a sustainable, net zero future.

Reduction Technologies

Energy-Efficient Processes

Implementing energy-efficient technologies and practices can significantly decrease the carbon footprint of various industrial processes. This is particularly beneficial for energy-intensive sectors such as manufacturing and production.

Renewable Energy Integration

Shifting towards renewable energy sources like solar photovoltaic (PV) and wind power can not only reduce emissions, but also enhance the resilience and sustainability of energy-dependent industries.

Energy storage

While solar and wind can provide low emission energy, their intermittent nature will require energy to be stored so that energy demands can be met in times of low production. Energy storage systems like pumped hydro and gas storage have been used for decades. However, we will need advances in short- and long-duration energy storage systems (examples include sensible heat storage, compressed air energy storage, lithium-ion batteries). Hydrogen storage, and potentially continued reliance on nuclear energy, will also be needed supplement renewable energy integration.

Methane emission reduction

Reducing methane emissions from oil and natural gas operations by limiting flaring and use of captured methane.

Carbon Capture, Utilisation, and Storage (CCUS)

Technologies that capture emissions at their source (point source capture, PCS) before they are released into the atmosphere and either utilise or store carbon play a pivotal role in industries where complete decarbonisation may be challenging. Hard-to-abate sectors like cement and steel production can benefit significantly from CCUS.

Sustainable Transportation

Companies can mitigate their environmental impact by adopting alternative forms of transportation (e.g., rail, electric and hydrogen vehicles) and optimising logistics for fuel efficiency.

Circular Economy Practices

Embracing circular economy principles, such as recycling and reusing materials, can reduce resource consumption and minimise waste, contributing to a more sustainable business model.

Removal Technologies

Afforestation and Reforestation

Supporting projects that involve planting trees or restoring forests can be a practical way for companies, if done properly, to contribute to carbon removal to promote biodiversity and ecosystem health (e.g., Old-Vs.-New Growth [5]).

Crop and livestock management

Improving crop and livestock management and carbon sequestration in agriculture (soil carbon management) offer agri-businesses a sustainable pathway to offset their environmental impact.

Biochar

Biochar is a form of charcoal (carbon-rich solid) that remains after the pyrolysis of biomass, which sequesters CO_2 by converting plant carbon into stable molecular structures. Biochar's main application is to improve soil fertility, water retention, and nutrient availability, and is primarily used in agriculture and environmental applications.

Putting DAC capacity in perspective

Climeworks has made impressive strides in direct air capture (DAC) technology, construction commenced in 2022 on their "Mammoth" DAC facility in Iceland boasting an impressive capture capacity of 36,000 tCO_2/year [3]. While this is a significant achievement, it's worth putting this in perspective: A single GE Haliade-X offshore wind turbine can generate approximately 70 GWh annual energy production, saving up to 50,000 tCO_2/year [4].

Bioenergy with carbon capture and storage (BECCS)

Plants absorb CO_2 when they grow. When biomass is converted into fuels or directly burned to generate energy and the emitted CO_2 is captured, then CO_2 is effectively removed from the atmosphere.

Direct Air Capture (DAC)

Companies can invest in technologies that actively pull CO_2 from the air, providing a direct means of offsetting their emissions. This approach is especially valuable for sectors with limited scope for immediate emission reductions.

Mineralisation

Technologies that turn CO_2 into stable minerals offer a novel approach to carbon removal, potentially providing long-term storage solutions for captured emissions.

Enhanced Weathering

Weathering is the process where rocks and soils deteriorate through contact with water, atmospheric gases such as CO_2, sunlight, and biological processes. By accelerating and 'enhancing' natural weathering processes that absorb CO_2, for example crushing large silicate rocks like basalt into fine particles increasing their surface area and ability to absorb CO_2, companies can explore innovative solutions for offsetting emissions, particularly those tied to industrial activities.

Blue Carbon Initiatives

Protecting and restoring coastal ecosystems, such as mangroves and seagrasses, can sequester significant amounts of carbon and provide companies with opportunities for impactful carbon removal. Improving coastal ecosystems has the added benefit that it improves protection against coastal floods and storm surges (additional climate adaption benefits) and improves biodiversity.

Ocean-Based Solutions

Investing in initiatives like ocean alkalinity enhancement or algae cultivation through ocean fertilisation can help extract CO_2 from the atmosphere and ocean, offering unique avenues for companies to engage in carbon removal efforts.

The roles of these technologies

Reducing and eventually eliminating carbon emissions are crucial to combat climate change. As emphasised by the IEA, the removal of carbon from the atmosphere is expensive, underscoring the importance of preventing its release in the first place. A pivotal strategy in this regard is the tripling of renewables by 2030, a key milestone toward achieving net zero emissions by 2050 [8]. Other key pillars to achieve interim targets by 2030 include doubling the rate of energy efficiency, cutting methane emissions from operations by 75%, establishing large scale financing mechanisms to triple clean energy investment in emerging and developing countries (notably allowing them to directly upgrade their power grid to clean energy without first expanding their fossil fuel capacity), committing to measures to ensure orderly decline of fossil fuel use, and curbing the demand for emission-intensive goods and services [8, 9].

While carbon dioxide removal technologies play a role, it is vital to avoid viewing them as substitutes for substantial emission reductions (cf. Figure 1) [10]. Considerable debate surrounds the effectiveness of publicising and promoting removal efforts, given their relatively minor impact compared to reduction initiatives in achieving climate targets. In this context, the UN stresses the need for differentiated target setting, signaling a prioritisation of emission cuts over removals. This underscores the prevailing understanding that, despite advancements in removal technologies, the primary focus must remain on actively reducing emissions to effectively address the climate crisis.

Table 1. Example technologies, their expected emission abatement contribution in 2050, current deployment status (with respect to technology specific goals), key updates to tracking development, and requirements to meet 2030 net zero ambition.

Technology	Solar PV	CCUS	DAC
Absolute Expected Abatement Contribution in 2050 (% of Today's Emissions)	6 GtCO2/year (~10%)	6 GtCO2/year (~10%)	< 1 GtCO2/year (<1%)
Current Development Status	On Track	Not On Track	Partially On Track
Key Updates	In 2022, Solar PV energy production increased by 26% reaching almost 1,300 TWh (cf. ~ 30,000 TWh total electricity produced). This was the largest growth of all renewable technologies in 2022 and matches growth rates envisaged to reach the 2030 interim targets set out in the IEA NZE scenario.	There are roughly 40 commercial facilities already in operation capturing > 45 MtCO2/year, but deployment has not met past expectations. There is optimism as momentum has grown in recent years with over 500 projects in various stages of development. However, current project development would still fall well below the ~ 1.2 GtCO2/year removal that is required by 2030 in the IEA NZE scenario.	Currently, there are 27 DAC facilities commissioned world-wide with capture capacity of around 0.01 MtCO2/year. There are plans for at least an additional 130 DAC facilities already under various stages of development. If all advance as planned, even those currently at early development stages, then DAC deployment would achieve the 75 MtCO2/year 2030 goal set out in the IEA NZE scenario.
What's Needed	Solar PV electricity generation needs to grow three-fold from 2022 to 2030, requiring continuous policy ambition and effort from public and private stakeholders.	Substantial technological, political, and financial support to spark investment and operationalisation. A bright spot: From 2010 to 2020 there were consistently no more than 100 capture facilities in the pipeline each year. Yet, in 2021 that number grew to over 200, and before the year end in 2023 it was more than 500.	Current plant lead times suggest deployment could meet NZE scenario objectives with adequate policy support. Continued development of market mechanisms and policies are needed to make DAC feasible.

Source: Abatement contribution in 2050 from IEA Net Zero Roadmap [6]; Status updates from IEA Tacking Clean Energy Progress 2023 [7].

Adopting a systems approach to achieve a low-carbon future

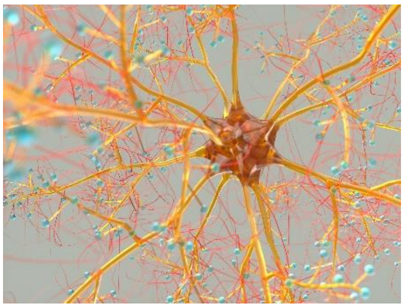
Companies must play an active role in the global fight against climate change by strategically integrating reducing and removal technologies into their operations, promoting sustainability and resilience amid environmental challenges. Shifting from a traditional inward perspective to a systems approach, as suggested by Deloitte Insights, is essential for navigating the evolving low carbon economy [11]. This shift is particularly crucial for energy systems, responsible for approximately 73% of global emissions [12]. Below are two examples of transition systems:

Utility company incorporating renewable energy

The move towards renewable energy sources, which is already economically viable in some regions, is a key aspect of this transformation [2]. When a utility company incorporates renewable energy sources, adopting a system view expands the ecosystem beyond conventional practices. Utility companies can achieve greater success by encompassing innovative grid technologies, dynamic load balancing solutions from software companies, and emerging energy storage systems like hydrogen, batteries, and compressed air energy storage.

Carbon Storage Hubs

Notably, removal systems are being developed in tandem with reducing systems. The proliferation of CCUS hubs across Europe exemplifies this integrated systems approach. Storage hubs, strategically located along the North Sea and Iceland coasts (e.g., Porthos - NL, Northern Lights - NO, and Coda Terminal - IS), intelligently combine resources common to point-source-capture CCUS. These hubs leverage existing shipping and pipeline infrastructure, proximity to offshore geologic storage sites, and proximity to (renewable-)energy production and emissions-generating facilities. This model enables a synergistic combination of reduction and removal technologies, as they are further supported by including BECCS and DAC removal initiatives. While Europe is at the forefront of these efforts, it is noteworthy that the U.S. Department of Energy (DOE) is actively contributing to the cause. The DOE has allocated $3.5 billion in federal support for four regional DAC hubs, in addition to providing further assistance to enhance the technical readiness of other DAC projects, highlighting a global commitment to advancing these critical technologies [1].



Systems thinking

Systems thinking is holistic, acknowledging that a business functions as a component within an interconnected ecosystem with numerous non-linear feedback loops that contribute to the collective. Through the adoption of systems thinking approaches, organisations become attuned to shifts within their ecosystem and demonstrate increased agility in adapting to changes in operational environments. This approach enables companies to perceive and react to diverse entities, thus contributing to a comprehensive understanding of the collective whole.

Accelerators

To expedite the transition towards sustainable practices, the integral roles of financial services, governments, and technological innovations are paramount for companies to achieve their net zero targets. These three pillars collectively wield significant influence, contributing indispensably to the acceleration of climate-conscious initiatives and fostering a greener, more resilient future.

Two breakthroughs in Europe

Two major releases by the European Commission on climate goals and industrial energy strategy on February 6th, 2024.

The EU's industrial carbon management strategy aims to facilitate the deployment of CO_2 storage capacity of at least 50 $MtCO_2$/year by 2030 and corresponding transport infrastructure consisting of pipelines, ships, rail, and road [21]. The strategy focuses on CCS, removing CO_2 from the atmosphere (e.g., DAC & BECCS), and capturing CO_2 for utilisation (CCU). The Commision aims to establish a single market for CO_2 and will continue to develop a specific regulatory package to optimise the transportation infrastructure. The Commission intends to create inventive financing methods and grants to aid carbon management practices. This strategy will have a significant impact on industrial CO_2 emitters, industrial CO_2 users, the oil-and-gas industry, as well as public and financial services.

These advances in industrial carbon management feed into the European Commissions paper on its 2040 Climate Goals, where they set a of 90% net reduction target in greenhouse gas emissions by 2040 for the EU and EEA [22]. This is a primary progression towards a framework for climate and energy polices beyond 2030. Achieving these ambitious targets will require a faster deployment of low carbon technologies, full decarbonisation of the electricity and transport sectors, and the role of the agriculture sector in ensuring food security and increasing carbon storage. The automotive, chemicals, industrial products, construction, oil and gas, and financial services industries will be most affected, requiring significant investment and transformation of business models and production processes.

Financial Services

Private and public funding are both set to play a pivotal role in financing the adoption of reduction and removal technologies.

- **Clean Energy Spending Surge**
  The trajectory of clean energy spending is poised for a remarkable ascent, projected to increase from $1.8 trillion in 2023 to a substantial $4.5 trillion annually by the early 2030s [6]. This surge signifies a significant financial commitment to advancing sustainable initiatives. To put that in perspective, we must shift our financial capital away from fossil fuels who still obtained over $7 trillion in direct and indirect subsidies in 2022 [13].

- **Capital Investment for net zero**
Deloitte estimates the global demand for $30 trillion to $60 trillion of additional capital investment to achieve net zero emissions by 2050 [11]. This funding is expected to support the rapid expansion of proven low-emission technologies and infrastructure, while simultaneously driving investments in emerging solutions like DAC.
- **Opportunity for Financial Players**
Within the financial services industry, a substantial opportunity emerges to support sectors poised for rapid growth. Leading banks and asset managers are already directing billions of dollars to restructure high-emitting companies, facilitating their transition towards sustainability.
- **De-risking Capital Flows**
Given the costs, uncertainties, and time horizons surrounding low-emission technologies and business models, cooperation among multiple financial players and governments is deemed crucial to finding ways to share investment risks and help direct capital flows towards climate solutions combining both physical and financial efficiency.
- **Enhancing Synergies and Co-Benefits**
Recognising the multifaceted nature of the climate challenge, financial strategies are increasingly focused on enhancing synergies and co-benefits. For example, financial institutions can provide financing for energy efficiency projects in buildings, industries, and transportation. These projects can reduce greenhouse gas emissions and also lower energy cost for businesses and households, improve air quality, and create jobs in the green sector. This approach ensures a more comprehensive and effective utilisation of financial resources in driving sustainable practices.

Governments

Initiating a successful transition requires pivotal policy and regulatory changes, essential for overcoming obstacles and creating an enabling environment that propels the shift towards sustainable practices.

- **Government subsidies**
Incentivising investment in green technologies and providing early seed funding will continue to drive both reducing and removal technology development and deployment. Examples include the Inflation Reduction Act (IRA), which granted $370 billion to improve energy security and accelerate clean energy transition, the EU's Green Deal and RePowerEU, and in 2023 the budget announced in the UK included funding up to £20 billion for CCUS applications.
- **Creating Supportive Policy Frameworks**
Policies supporting CDR technologies are still relatively rare, with only a few governments, such as Switzerland, incorporating them into their comprehensive climate strategies [16]. Governments are urged to create policy and regulatory frameworks that incentivise the creation of viable markets. This includes the establishment of carbon trading markets based on standardised transparent credits so that removal technologies can have a place in the market. If carbon is not priced fairly, markets will not naturally adapt, and we will require more intrusive regulatory and fiscal policies to reach our goal of achieving net zero emissions.
- **Changing regulations**
In the last 18 months, European countries have undertaken significant policy and regulatory changes to streamline permitting processes for renewable energy, surpassing the entire previous decade [17]. While this proactive approach is intended to facilitate and expedite climate-friendly initiatives,

Swiss Climate and Innovation Act

Switzerland focuses its ambition on achieving net zero by 2050. The law, which was confirmed by popular referendum in June 2023, sets out sector specific guidance and targets for the buildings, transportation, and industry. The details of the regulation, that is currently in consultation, aims to provide financial incentives to expand thermal grids, develop long-term carbon and energy storage facilities, and provide financial assistance for businesses to help meet net zero targets The replacement of oil, gas, and electric heating systems with climate-friendly heating systems will receive CHF 2 billion, with an additional subsidy package of CHF 1.2 billion targeting innovated climate technologies **[14, 15]**. The law also requires a climate-friendly alignment of financial flows, which can play an important supporting role given the size and global relevance of the Swiss financial marketplace.

the same cannot be said for the USA and UK, where unpredictability and backtracking on ESG policy has caused reluctance within the private sector to engage in transition investments. This has had ramifications on companies operating in other jurisdictions.

- **International Cooperation**
  Acknowledging the immense scale of the climate challenge, strong international cooperation is identified as crucial. The IEA emphasises the need to separate climate efforts from geopolitical considerations, highlighting the importance of a collective and unified global approach.
- **Incorporating science-based taxonomies**
  Investment frameworks based on scientific criteria, such as the EU Taxonomy for Sustainable Activities, are a necessary tool to evaluate the impact of different transition technologies. This allows for financing to be appropriately allocated and ensures that the environmental impact of these technologies is taken into consideration. Transparency and Information: Ensuring transparent information about expected levels and types of CDR, mandatory inclusion in National Determined Contributions (NDCs), and robust measurement, reporting, and verification systems are deemed essential for effective policy making and fostering public understanding.
- **Ecosystem Architect Role**
  Governments are positioned as catalysts in the climate action landscape, playing a vital role as ecosystem architects. This involves proactively building and nurturing cross-cutting networks that bring together public sector agencies, businesses, academics, NGOs, and citizens for the collaborative development and rapid scaling of innovative climate solutions.

Technology

Acknowledging the dynamic nature of our fight against climate change, it is crucial to recognise that a significant portion of the necessary reduction and removal efforts will likely stem from technologies that are still yet to be invented. Continuing to focus on carbon reduction efforts to prevent further climate change should be our main priority, rather than assuming that we will be able to deploy capital tomorrow as a substitute for active mitigation today (an optimistic approach known as 'weak sustainability' [18]). In their most recent update, the IEA suggests that a substantial (35%) of the solutions required to meet our climate goals will emerge from innovations that have yet to be conceived [6]. This underscores the paramount importance of nurturing and empowering continued investment in research and development, fostering a culture of innovation, and supporting education in fields crucial to climate science will be instrumental in unlocking unprecedented technological breakthroughs.

- **Formative Phase for Innovation**
  According to the UN and IEA, a formative phase is crucial for new technologies. This underscores the necessity for a conducive environment that supports and facilitates innovation in the pursuit of sustainable solutions.
- **Strengthening business ties to research centers**
  Higher education and advanced research institutions are at the forefront of technological innovation. Businesses that build relationships with universities and start-up incubators can directly tap into innovation insight.
- **Technological Applications in Transition**
  Today's powerful technologies — such as big data analytics, advanced AI, and blockchain — have extensive applications in the transition to and operation of emerging low-carbon systems. Though, digitalisation and AI don't come without their own environmental downside. Both are drastically increasing

the need for energy, emissions, and water [19, 20], shifting the onus on technology firms to make their own advances in climate stewardship. This dynamism highlights the tightrope between increasing environmental pollution and the significant potential of technology in both reducing and removing carbon emissions [11].

Outlook

Governments in most developed countries are increasingly setting clear and strong climate commitments and are developing programs that provide a wide and increasing range of regulatory incentives and subsidies (more of the former in the EU, Switzerland and California at the time of writing, and more of the latter at the US federal level) to prompt companies and the economy to become more effective in their efforts to reach net zero targets.

Companies will have to play a vital role in ensuring that they are part of the solution. The challenges posed by climate change demand an ongoing commitment to pushing the boundaries of what we know, ensuring that the solutions we devise are not only effective but also adaptive to the evolving nature of the climate crisis.

To achieve this, companies need to adopt holistic approaches and develop long-term strategic targets to meet net zero objectives. These long-term goals must be complemented with concrete short-term actions and science-based transition plans that should first focus on reducing the company’s emissions. Concrete actions are supported by sustainability systems-thinking. This includes building business ecosystems and fostering public-private partnerships that enhance resilience and drive innovation.

Fostering an environment that encourages creativity and exploration, companies can pave the way for innovations that hold the potential to redefine our approach to climate solutions, ultimately steering us closer to a net zero world.

Authors

Jérôme Crugnola-Humbert
Director, Sustainability Services
jcrugnolahumbert@deloitte.ch

Dr. Quinn Wenning
Assistant Manager, Sustainability Services
qwenning@deloitte.ch

Dr. Ramona Achermann
Consultant, Sustainability Services
rachermann@deloitte.ch

References

[1] United Nations Environment Programme, “Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again),” Nairobi, 2023.

[2] IEA, “World Energy Outlook,” 2023.

[3] Climeworks, “Mammoth: our newest facility,” 2022. [Online]. Available: https://climeworks.com/plant-mammoth. [Accessed 2024].

[4] GE, “Halide-X offshore wind turbine,” [Online]. Available: https://www.ge.com/renewableenergy/wind-energy/offshore-wind/haliade-x-offshore-turbine. [Accessed 2024].

[5] Endangered Ecosystems Alliance, “Old-Growth Forests vs. Second-Growth Plantations - The Differences,” 2023. [Online]. Available: https://www.endangeredecosystemsalliance.org/video. [Accessed 2024].

[6] IEA, “Net Zero Roadmap A Global Pathway to Keep the 1.5 °C Goal in Reach,” 2023.

[7] IEA, “Tacking Clean Energy Progress 2023,” 2023. [Online]. Available: https://www.iea.org/reports/tracking-clean-energy-progress-2023.

[8] IEA, “What does COP28 need to do to keep 1.5 °C within reach? These are the IEA's five criteria for success,” [Online]. Available: https://www.iea.org/commentaries/what-does-cop28-need-to-do-to-keep-1-5-c-within-reach-these-are-the-iea-s-five-criteria-for-success.

[9] IPCC, “Sixth Assessment Report of the IPCC,” 2021.

[10] D. T. Ho, “Carbon dioxide removal is an ineffective time machine,” *Nature,* 2023.

[11] S. Corwin and D. M. Pankratz, “Systems approach to a low-carbon future,” Deloitte Insights, 2021.

[12] H. Ritchie, “Sector by sector: where do global greenhouse gas emissions come from?,” Our World in Data, 2020.

[13] IMF, “Fossil Fuel Subsidies Data: 2023 Update,” 2023.

[14] Swiss Federal Council, “Verordnung zum Bundesgesetz ueber die Ziele im Klimaschutz, die Innovation und die Staerkung der Energiesicherheit (Klimaschutz-Verordnung, KIV),” 2024 (proposal). [Online]. Available: https://www.fedlex.admin.ch/filestore/fedlex.data.admin.ch/eli/dl/proj/2024/8/cons_1/doc_1/de/pdf-a/fedlex-data-admin-ch-eli-dl-proj-2024-8-cons_1-doc_1-de-pdf-a.pdf.

[15] Swiss Federal Council, “Klima- und Innovationsgesetz: Abstimmung am 18. Juni 2023,” 2024. [Online]. Available: https://www.bafu.admin.ch/bafu/de/home/themen/klima/dossiers/klimaschutzgesetz.html.

[16] Swiss Federal Council, “Carbon Capture and Storage (CCS) and negative emission technologies (NETs),” 2022.

[17] IEA, “Renewable Energy Market Update,” 2023.

[18] R. U. Ayres, J. C. van den Bergh and J. M. Gowdy, “Viewpoint: Weak versus strong sustainability,” *Tinbergen Institute Discussion Paper,* 1998.

[19] MIT Technology Review, “AI’s carbon footprint is bigger than you think,” 2023.

[20] Forbes, “A.I. tools fueled a 34% spike in Microsoft’s water consumption,” 2023.

[21] European Commission, “Towards an ambitious Industrial Carbon Management for the EU,” Directorate-General for Energy, 2024.

[22] European Commision, *Commission presents recommendation for 2040 emissions reduction target to set the path to climate neutrality in 2050,* Press Release, 2024.