Insuring the Net - Zero Transition

A Risk Management Strategy to support Zurich North America's efforts to accelerate the adoption of Net - Zero technologies

SEAS MASTERS PROJECT

FINAL REPORT
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Executive Summary

Zurich North America (ZNA) commissioned this report to explore the rapidly evolving climate tech landscape and identify opportunities for the insurance industry to support and capitalize on the growth of key sectors, with a focus on offshore wind and carbon capture and storage (CCS). The report analyzes market trends, risks, and challenges in these sectors and provides actionable recommendations for ZNA to position itself as a leader in the climate tech insurance space.

Key Findings:

1. Offshore wind and CCS are poised for significant growth in the coming decades, driven by supportive government policies, technological advancements, and the urgent need to decarbonize the energy sector.
2. The global offshore wind capacity is projected to reach 330 GW by 2030, with the US and European markets leading the way. CCS is expected to play a critical role in achieving net-zero emissions targets, with the potential to capture and store up to 15 Gt of CO_2 annually by 2050.
3. Both sectors face unique risks and challenges, including high capital costs, supply chain constraints, regulatory uncertainties, and potential environmental and safety hazards. Insurers can develop specialized expertise and products to effectively manage these risks.

Recommendations:

1. Develop tailored insurance solutions for offshore wind and CCS projects, covering construction, operation, and decommissioning phases, as well as third-party liabilities and environmental risks.
2. Invest in data analytics and digital capabilities to better assess and price risks, monitor asset performance, and optimize underwriting processes.
3. Forge strategic partnerships with key stakeholders, including project developers, technology providers, and research institutions, to stay at the forefront of industry developments and collaboratively address challenges.
4. Enhance risk engineering and loss control services to help clients minimize risks and improve project performance, while incentivizing the adoption of best practices and safety standards.
5. Establish a dedicated Climate Tech Insurance Innovation Lab to foster cross-functional collaboration, develop innovative products and services, and explore new business models and revenue streams.

Potential Impact: By implementing these recommendations, ZNA can establish itself as the go-to insurer for offshore wind and CCS projects, capturing a significant share of these growing markets. This will not only drive premium growth and profitability but also contribute to the global transition to a low-carbon economy. Additionally, ZNA's expertise and innovative solutions in these sectors can be leveraged to explore opportunities in other climate tech domains, such as solar energy, electric transportation, and energy storage.

Ultimately, the climate tech revolution presents a unique opportunity for ZNA to align its business objectives with the urgent need for climate action. By proactively adapting to the changing risk landscape and developing innovative solutions for offshore wind and CCS, ZNA can secure its position as a market leader and make a meaningful contribution to a more sustainable future.

Introduction

The insurance industry finds itself at the precipice of an unprecedented opportunity to reshape its role and impact on the global economy by accelerating the transition to a Net Zero future through a strategic amalgamation of technological and nature-based solutions. This imperative arises from the escalating recognition of the profound risks posed by climate change and the urgent need for prompt and decisive action to mitigate these risks. As key players in risk assessment and management related to climate change, insurance companies are uniquely positioned to spearhead this transition. Their responsibilities encompass addressing physical risks, such as natural disasters and extreme weather events, along with navigating the intricacies of transitional risks arising from policy and technological changes.

This research aims to explore the transformative landscape wherein insurance companies can play a pivotal role by developing innovative risk management capabilities. These capabilities are not only instrumental in mitigating climate-related risks but also serve as a catalyst for generating new business opportunities and gaining competitive advantages. The significance of this research lies in several dimensions:

1. **Investment Influence:** The insurance industry, being one of the largest global investors, wields significant influence over the economy and society. By actively participating in the transition to a net-zero carbon future, the industry can contribute to the decarbonization of its investments and operations.

2. **Resilience Building:** The insurance sector plays a pivotal role in fortifying resilience against the physical risks of climate change. Through the development of net-zero strategies, the industry not only mitigates these risks but also identifies novel avenues for growth and innovation.

3. **Catalyzing Change:** Uniquely positioned, the insurance industry can act as a catalyst for driving sustainable practices across other sectors such as energy, transportation, and agriculture. Through incentivization and support for low-carbon technologies, the industry can spearhead a more sustainable and resilient global economy.

Within the rapidly evolving climate tech landscape (See Appendix for a brief rundown of some other technologies), two sectors have emerged as particularly promising, through both market projections and identified gap in solutions offered by ZNA: offshore wind and carbon capture and storage (CCS). This report focuses on these sectors due to their strategic importance in the climate tech ecosystem and their alignment with ZNA's growth objectives and wanting to build expertise.

Offshore wind has experienced exponential growth in recent years, driven by technological advancements, falling costs, and supportive government policies. With its vast untapped potential and ability to provide clean, reliable energy at scale, offshore wind is poised to play a central role in the global energy transition. Similarly, CCS has gained traction as a critical tool for decarbonizing hard-to-abate sectors, such as heavy industry and power generation. By capturing and permanently storing carbon dioxide emissions, CCS can help bridge the gap between our current carbon-intensive economy and a net-zero future.

As these sectors continue to grow and mature, the insurance industry has a vital role in supporting their development and managing the associated risks. Insurers have the potential to enable the deployment of offshore wind and CCS projects by providing specialized coverage, sharing expertise, and facilitating access to capital. However, to effectively serve these markets, insurers must first develop a deep understanding of the unique risks, challenges, and opportunities they present.

This report aims to provide ZNA with a comprehensive analysis of the offshore wind and CCS markets, focusing on their growth potential, risk landscapes, and implications for the insurance industry. The goals and objectives of this research are as follows:

1. Analyze existing and emerging industry trends and net-zero technologies to identify crucial technologies and industries in the climate-tech space.
2. Evaluate the competitive landscape of ZNA, offering insights into peer products, advisory services, and climate risk assessment tools.
3. Provide key recommendations for ZNA to become the preferred insurer, supporting sectors and companies leading the transition to net-zero.

The report is structured to provide an in-depth examination of the offshore wind and CCS markets, including growth projections, technological trends, and regional developments. It then explores the key risks and challenges associated with these sectors, considering factors such as construction, operation, technology maturity, and regulatory frameworks. Finally, it offers tailored recommendations for ZNA to develop specialized insurance products and services for these sectors, as well as overarching strategies to strengthen its capabilities and market position in the climate tech insurance space. There are 13 intermittent insights denoted with that convey the key relevant information from the section.

By focusing on offshore wind and CCS, this report aims to provide ZNA with actionable insights and recommendations to capitalize on the immense opportunities presented by the climate tech revolution. The insights gathered through this analysis can serve as a foundation for ZNA to develop a comprehensive climate tech insurance strategy, positioning the company as a leader in enabling the transition to a sustainable future.

Methodology

To develop a comprehensive understanding of the climate tech landscape and formulate actionable recommendations for Zurich North America (ZNA), this report employed a multi-faceted research approach, focusing on offshore wind and carbon capture and storage (CCS) as key sectors of interest.

1. Literature Review:
    - Conducted an extensive review of over 200 academic papers, industry reports, and market intelligence to gather insights on the latest trends, technologies, and growth projections for offshore wind and CCS.
    - Analyzed policy and regulatory frameworks at the global and regional levels to identify key drivers and potential barriers to market growth.

2. Competitive Benchmarking:
    - Examined the climate tech insurance offerings and strategies of leading global insurers to identify best practices and potential gaps in the market.
    - Compared the coverage, and risk management approaches of competing insurance products to assess ZNA's competitive position and opportunities for differentiation.

3. Stakeholder Interviews:
    - Conducted in-depth interviews with 7 stakeholders, including 6 ZNA subject matter experts, spanning the Head of Sustainability Underwriting, Sustainability Director, Vice President for Property insurance for Onshore Wind Energy, and Casualty Underwriter for Energy Systems, along with a Policy Expert at a Direct Air Capture company.
    - Gathered insights on the unique risks and challenges faced by offshore wind and CCS projects, as well as the evolving insurance needs and expectations of clients.

4. Risk Assessment Framework:
    - Developed a comprehensive risk assessment framework tailored to offshore wind and CCS projects, considering factors such as technology maturity, supply chain complexity, environmental impacts, and regulatory compliance.
    - Mapped the key risks across the project lifecycle and identified potential risk mitigation strategies and insurance solutions.

5. Collaborative Ideation:
    - Refined and prioritized ideas based on their feasibility, market potential, and alignment with ZNA's strategic objectives.

By employing this comprehensive methodology, the report aims to provide ZNA with a robust evidence base and practical insights to inform its climate tech insurance strategy. The combination of desktop research, competitive benchmarking, stakeholder engagement, and data-driven analysis ensures that the recommendations are grounded in the latest market realities and best practices while remaining forward-looking and adaptable to future uncertainties.

Offshore Wind

I. Market Overview and Growth Potential

The offshore wind industry has emerged as a significant contributor to the global transition towards cleaner and more sustainable energy sources. The global capacity of large-scale wind farms is expected to increase 10-fold, from 34 GW in 2020 to 330 GW in 2030 and spread throughout 24 countries (up from nine today).[1] It estimated $1 trillion would flow into the offshore wind industry over the next decade.[2] This exponential growth translates to a substantial market opportunity for insurers to enable the offshore wind boom through tailored policies.

In recent years, the United States has witnessed great growth in wind energy, with wind power installations outpacing solar power for the first time in several years, representing a $24.6 billion investment. Wind provides more than 10% of electricity in 16 states, and over 30% in Iowa, Kansas, Oklahoma, South Dakota, and North Dakota.[3]

The U.S. Energy Information Administration (EIA) estimates that U.S. electricity demand will grow by 39% from 2005 to 2030, reaching 5.8 billion MWh by 2030.[4] The US Department of Energy estimates that the nation has a technical potential of 2,000 GW of offshore wind capacity, capable of generating 7,200 TWh of electricity annually – nearly twice the total electricity consumption in the US.[5] With over 30 GW of offshore wind projects planned off the U.S. Atlantic coast states by 2030, the industry is poised for significant growth. These projects have the potential to power 10 million homes and cut 78 million metric tons of harmful carbon emissions.[6]

[1] "Sea Change: Navigating the trillion-dollar offshore wind opportunity" Wood Mackenzie, May 2022. Accessed on 29th March 2024, https://www.woodmac.com/horizons/sea-change-navigating-the-trillion-dollar-offshore-wind-opportunity/.

[2] "Explainer: What is offshore wind and what does its future look like?" World Economic Forum, Nov 2022. Accessed on 29th March 2024, https://www.weforum.org/agenda/2022/11/offshore-wind-farms-future-renewables/

[3] "Wind Market Reports: 2021 Edition." Department of Energy, 2021. Accessed on 29th March 2024, https://www.energy.gov/eere/wind/wind-market-reports-2021-edition.

[4] "20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply; Executive Summary" Department of Energy,2008. Accessed on 29th March 2024, https://www.nrel.gov/docs/fy09osti/42864.pdf

[5] "Computing America's Offshore Wind Energy Potential" Office of Energy Efficiency & Renewable Energy, Sept 2016. Accessed on 29th March 2024, https://www.energy.gov/eere/articles/computing-americas-offshore-wind-energy-potential

[6] "OFFSHORE WIND" Department of Energy, accessed on 29th March 2024, https://www.energy.gov/lpo/offshore-wind-project

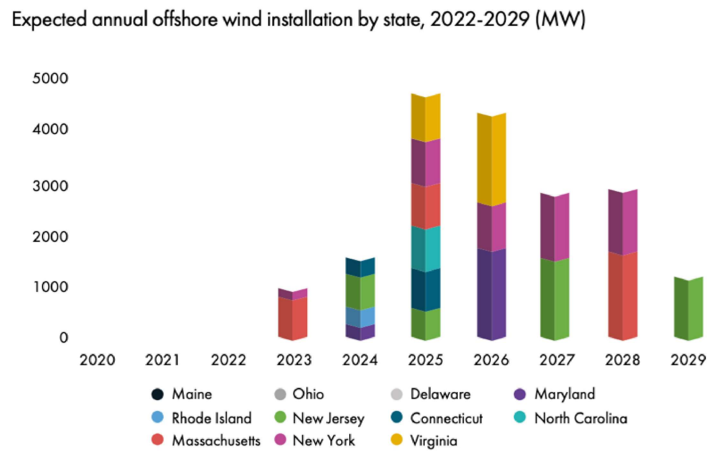

Figure 1: Expected annual offshore wind installation by state (Source: [GWEC | Global Offshore Wind Report 2022](#))

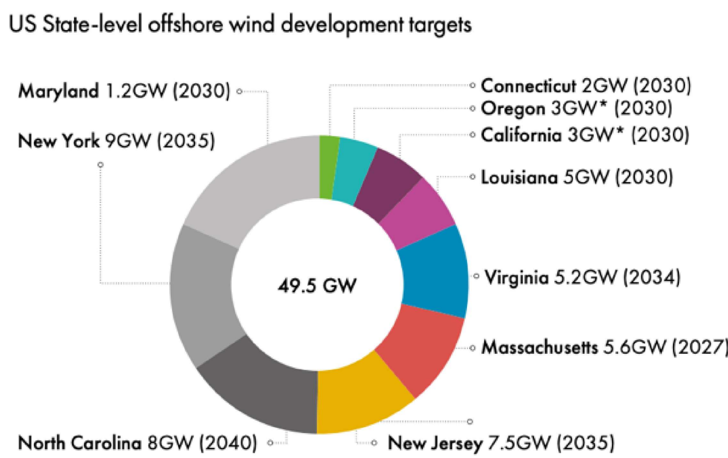

Figure 2: US State-level offshore wind development targets (Source: [GWEC | Global Offshore Wind Report 2022](#))

Figures 1 and 2 showcase the planned offshore wind projects and development targets along the U.S. coast, highlighting the significant potential for growth in the American offshore wind market. These projects, totaling over 49 GW of capacity, are expected to play a crucial role in meeting the nation's growing electricity demand while reducing reliance on fossil fuels and cutting greenhouse gas emissions.

II. Technological Advancements and Foundation Types[7]

Technological advancements have played a crucial role in driving the growth of the US wind energy market. Modern wind turbines are taller, more efficient, and more reliable than their predecessors, enabling them to generate more electricity at lower costs. Two main foundation technologies are utilized for offshore wind turbines – fixed foundations in shallow waters up to 60 meters and floating foundations in deeper waters over 60 meters.

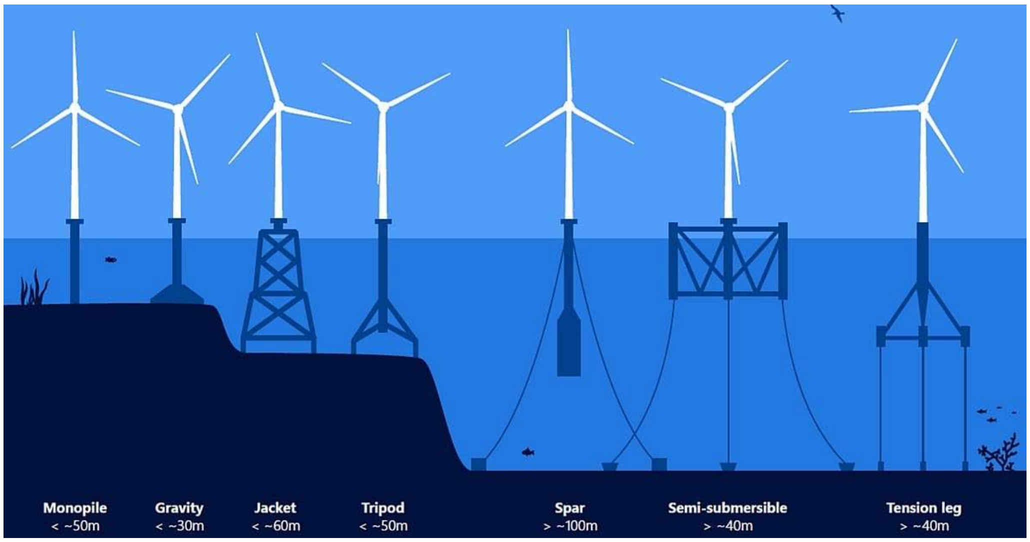

Figure 3: Typical foundation types and applicable water depths (Source: DHI)

Figure 3 illustrates various foundation types used for offshore wind turbines and their applicable water depths. The figure includes both fixed and floating foundation options, showcasing their suitability for different depths and environmental conditions.

Fixed Foundations

Fixed foundations, such as monopiles, jackets, and gravity bases, account for most of the current global offshore wind capacity. Monopiles represent over 70% of installed offshore turbines globally. Gravity bases are extremely durable in harsh marine environments and have lower operation and maintenance costs. Jackets come in a variety of forms (e.g., 4-legged jacket) and can be fabricated in existing U.S. ship and steel yards currently used for the oil and gas industry. Tripods are more expensive and less commonly used but may be a better option for low profiles at the water line and visual impacts. [8]

One of the significant advantages of Fixed Offshore Wind Turbines is their stability. Being directly fixed to the seabed provides a stable static structure, allowing these turbines to withstand harsh weather conditions, including strong winds and rough seas. Fixed turbines

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[7] "Mooring Matters: Fixed vs. Floating Offshore Wind Turbines" DeepWater Buoyancy, July 25. Accessed on 29th March 2024, https://deepwaterbuoyancy.com/comparing-fixed-and-floating-offshore-wind-turbines

[8] "Offshore Wind Energy: Technology Below the Water" NREL, accessed on 29th March 2024, https://www.nrel.gov/docs/fy22osti/83142.pdf

offer relatively straightforward installation and maintenance due to their permanent positioning. This factor reduces maintenance costs and reliability, enabling consistent power generation compared to more dynamic structures. The major limitation lies in water depth constraints, limiting their deployment to relatively shallow waters.

However, fixed foundations also present environmental concerns that vary depending on the foundation type. For example, the installation of monopiles requires pile-driving, which produces incredibly loud noises that can propagate far in the water, potentially affecting marine life. Mitigation strategies such as bubble shields, slow start, and acoustic cladding can help reduce the noise impact. Additionally, the presence of offshore wind farms may pose collision risks to birds and bats, although quantifying the impact is more challenging in offshore environments where carcasses are lost at sea. Other potential environmental concerns include scouring and changes to sediment transport, as well as the possible effects of electromagnetic fields generated by power cables on marine animals that use Earth's natural magnetic field for navigation and orientation.[9]

💡 **I. Fixed foundations present property damage risks, including structural damage from extreme storms and wave loading, vessel collisions during construction and maintenance, corrosion and fatigue over time, manufacturing, and installation defects, and scouring of sediments around the foundation resulting in instability. Liability risks, such as wreck removal if a turbine topples, also exist.**

As the US offshore wind industry matures, insurers will gain a better understanding of damage frequencies and costs associated with fixed foundations. However, uncertainties regarding extreme event damage will likely persist.

[9] "Fixed Offshore Wind" Tethys, accessed on 29th March 2024, https://tethys.pnnl.gov/technology/fixed-offshore-wind

Figure 4: Typical foundation types and applicable water depths (Source: Philipp Beiter, NREL)

Figure 4 shows the general locations of wind resources off the coast of the United States where fixed-bottom (yellow) and floating (blue) offshore wind energy turbines could be installed around the United States to generate clean, renewable energy for the U.S. grid. Data presented do not consider potential siting constraints but do include a maximum water-depth constraint of 1,300 meters.

Floating Foundations

Floating foundations, on the other hand, are a newer technology suited for deeper waters over 60 meters. They consist of a balanced floating substructure moored to the seabed with fixed cables and can be stabilized using buoyancy, mooring lines, or a ballast. Several designs for floating offshore wind substructures exist for various depth ranges, including barges, semi-submersibles, tension leg platforms, and single point anchorage buoys. These substructures are connected via inter-array cables, which transport electricity generated from the turbine to floating offshore substations. High voltage export cables then transport the energy to shore.

The three main types of floating foundations are:

1. Spar buoys -- long cylindrical floats stabilized by ballast weight at the bottom
2. Semi-submersibles -- buoyant platforms with columns stabilized by ballast/water plane area
3. Tension leg platforms -- buoys tethered to the foundation by tensioned cables

Approximately 58% of the U.S. technical offshore wind resource is too deep for conventional fixed-bottom offshore wind turbines, making floating foundations a promising solution. As of 2021, 17,931 MW of floating wind energy have been either announced or installed globally. The smaller installation numbers compared to fixed foundations demonstrate the relative immaturity of floating technology. However, as costs decrease, the adoption of floating wind turbines is expected to grow significantly.[10]

Floating foundations offer some advantages over fixed foundations in terms of environmental impact. For example, floating projects can be constructed onshore and transported out to sea, reducing the noise and vessel-related disturbances associated with on-site construction. However, floating foundations also introduce new environmental concerns, such as the potential for mooring lines to cause minor scouring or pose a risk of collision or entrapment to marine life.

💡 **II. The lack of extensive operational experience with floating technology introduces uncertainties in evaluating damage frequency and severity. Key risks include mooring line failure or anchor instability, dynamic cable failure between the turbine and anchor, reduced stability in harsh weather compared to fixed foundations, system complexity with more failure points, and limited historical data on failure rates and repair costs.**

Insurers will need to carefully assess these risks and gather data from pilot projects and early commercial installations to develop appropriate coverage and pricing models.

[10] "Offshore Wind Energy: Technology Below the Water" NREL, accessed on 29th March 2024, https://www.nrel.gov/docs/fy22osti/83142.pdf

III. Supply chain

Developing a robust domestic supply chain is critical to unlocking the full potential of offshore wind in the US. However, the industry faces daunting challenges in scaling up all aspects of the supply chain to meet national deployment goals. A comprehensive roadmap study by NREL analyzed in detail what it would take to manufacture major wind farm components domestically by 2030.[11] Key findings reveal the sheer magnitude of scale-up required across all supply chain elements:

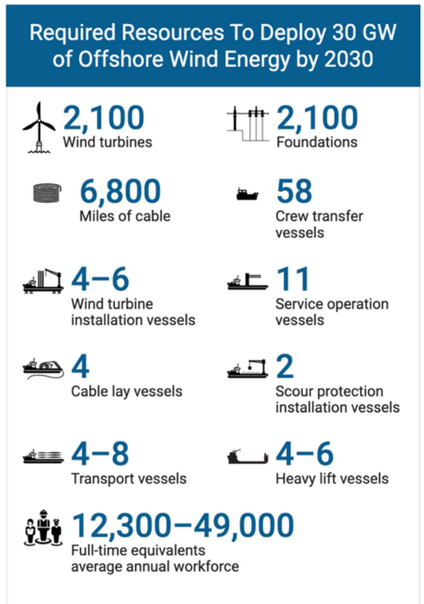

Figure 5: Key supply chain elements required for the US offshore wind industry (Source: NREL)

As shown in Figure 5, the domestic offshore wind industry will require 2,100 wind turbines and foundation, 6,800 miles of cable, about 4-6 specialized installation vessels, 11 service operation vessels and 4 cable lay vessels.

NREL estimates around $22 billion in investments are needed just for ports, vessels, and manufacturing facilities -- with additional costs for workforce training and other supply chain expansion. At least 6-9 years lead time is required to fully establish the domestic industry.

Several high-risk components were identified as bottlenecks for local manufacturing, including bearings, castings, steel plate, and electrical systems. Competition with global demand could constrain supply. Without concerted efforts to build infrastructure and skilled labor proactively, projects totaling half the 2030 target capacity could face delays.

Beyond 2030, floating wind farms will necessitate another round of supply chain upgrades. But successfully leveraging the national target to develop innovative domestic production promises

[11] "Supply Chain Road Map for Offshore Wind Energy in the United States" NREL, 2023. Accessed on 29th March 2024 https://www.nrel.gov/wind/offshore-supply-chain-road-map.html

significant economic benefits and clean energy advances. It will require unprecedented coordination across private and public stakeholders.

> 💡 **III. From an insurer's perspective, the breakneck pace of supply chain development introduces risks of quality issues, cost overruns, and project delays. Supporting resilient and redundant supply infrastructure through incentives and risk management will be key.**

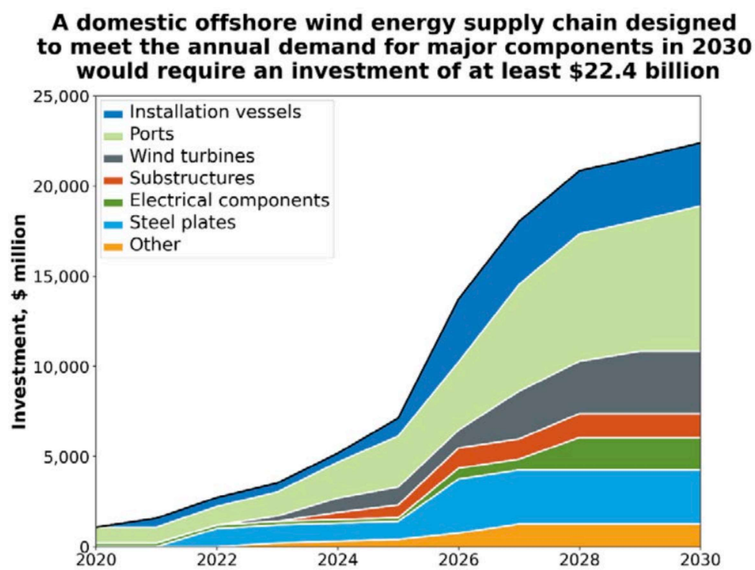

Figure 6: Cumulative investment over time in the major components of a domestic offshore wind energy supply chain. (Source: NREL)

Figure 6 illustrates the investment required for the major manufacturing facilities, ports, and large installation vessels that comprise the domestic supply chain.

A closer look at the key offshore wind supply chain components highlights the scale of investment and strategic planning needed:

1. **Ports** - Most US ports lack the heavy-lift cranes, storage space, and reinforced quaysides required for staging and loading offshore components. The upgrades cost tens of millions per port. Coordinating the optimal port locations and specializations across regions is also critical.
2. **Installation Vessels** - No US-flagged vessels currently meet the specifications needed for transporting and installing today's high-capacity turbines. Bringing in European vessels is costly and represents a major timing risk.

3. **Manufacturing** - Ensuring adequate domestic production capacity for towers, blades, nacelles, and other components requires billions in capital investment as well as workforce training. Strategic incentives may be needed to avoid shortages.
4. **Cables** - Domestic cable fabrication capabilities require expansion, given thousands of miles will be needed. The supply of crucial subcomponents like copper wiring and polymers must also scale up.
5. **Grid Infrastructure** - Connecting offshore wind power will necessitate major transmission system upgrades onshore. Permitting and building this infrastructure takes years of planning.

💡 **IV. A deeper understanding of the offshore wind supply chain components is crucial for insurers to effectively manage risks and capitalize on growth opportunities. By gaining insights into the specific challenges and needs of each component, from port infrastructure upgrades to manufacturing and grid integration, insurers can develop tailored risk management solutions, provide valuable advisory services, and innovate new products and services that align with the evolving demands of the offshore wind industry.**

The complex nature of offshore wind projects, coupled with the specialized components and equipment required, has exposed the industry to various supply chain constraints that can significantly impact project timelines, costs, and overall feasibility. These constraints range from manufacturing delays and shortages of key components to transportation issues and raw material price volatility. As the offshore wind industry continues to grow, addressing these supply chain challenges becomes paramount to ensure the timely and cost-effective delivery of projects. Some key supply chain constraints are:

1. Offshore wind projects rely on a complex supply chain involving various specialized components and equipment, such as turbine blades, nacelles, towers, and subsea cables. Disruptions in this supply chain can have significant impacts on project timelines and budgets[12].

2. One of the primary supply chain risks is the potential for manufacturing delays or shortages of key components[13] . Many of these components are highly specialized and produced by a limited number of manufacturers, increasing the risk of supply chain

[12] “What Ails Offshore Wind: Supply Chains, Ships and Interest Rates’, The New York Times, Dec 2023. Accessed on 29th March, 2024, https://www.nytimes.com/2023/12/11/business/energy-environment/offshore-wind-energy-east-coast.html
[13] “Supply Chain Road Map for Offshore Wind Energy in the United States”, NREL, accessed on 29th March, 2024, https://www.nrel.gov/wind/offshore-supply-chain-road-map.html

bottlenecks. Delays in component delivery can lead to construction delays, potentially resulting in missed project deadlines and increased costs.

3. Transportation issues, such as port congestion, vessel availability, or weather-related delays, can also disrupt the supply chain and impact project schedules. Offshore wind farms often require specialized vessels for turbine installation and maintenance, and any disruptions in vessel availability can cause significant project delays.

The shortages or price volatility of raw materials used in the production of wind turbine components, such as steel, fiberglass, or rare earth metals, can impact the overall project cost and feasibility. Effective supply chain management, including risk assessment, redundancy planning, and supplier diversification, is crucial to mitigate these risks.[14].

[14] "Offshore wind reaches crossroads, as spiralling costs and supply chain issues force developers to reassess projects – EY research", EY, Nov 2023. Accessed on 29th March, 2024, https://www.ey.com/en_gl/newsroom/2023/11/offshore-wind-reaches-crossroads-as-spiraling-costs-and-supply-chain-issues-force-developers-to-reassess-projects-ey-research

IV. Key Risks and Challenges

One of the main challenges the offshore industry faces is the intermittent nature of wind power, which requires the development of energy storage solutions and improved grid management practices. This is particularly important for ensuring the stability and reliability of the electricity supply, especially as the share of wind energy in the grid increases. Along with the need for expanded transmission infrastructure to transport wind power from resource-rich areas to load centers and even potential headwinds from changing political priorities and the phase-out of the Production Tax Credit (PTC). The wind energy industry also faces specific insurance challenges, both for onshore and offshore projects like:

Regulatory Risks - Permitting Delays

Offshore wind projects require various permits and approvals from regulatory bodies at different levels of government, including environmental impact assessments, maritime safety clearances, and land/sea use permits. Delays in obtaining these permits can significantly impact project timelines and budgets[15].

Environmental impact assessments are often a critical part of the permitting process, as they evaluate the potential effects of the project on marine life, coastal ecosystems, and other environmental factors[16]. These assessments can be time-consuming and may require extensive data collection, modeling, and public consultations, leading to potential delays.

Additionally, offshore wind farms must comply with maritime safety regulations, which may involve obtaining permits or clearances from relevant authorities to ensure the safety of navigation and prevent conflicts with other maritime activities[17] Delays in obtaining these clearances can postpone the construction or operation of the wind farm.

Changes in regulatory policies or government priorities can also introduce uncertainties and potential delays[18]. For example, shifts in energy policies or environmental regulations may necessitate additional assessments or modifications to project plans, resulting in extended permitting timelines.

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[15] "Offshore Wind Development: Federal Permitting Program Challenges", HLS Environmental and Energy Law Program, Mar 2020. Accessed on 29th March 2024, https://eelp.law.harvard.edu/2020/03/offshore-wind-development-federal-permitting-program-challenges/

[16] " A turning point for offshore wind", Allianz, Sept 2023. Accessed on 29th March 2024, https://commercial.allianz.com/news-and-insights/reports/offshore-wind-opportunities-risks.html#download

[17] "In Shipping, a Push to Slash Emissions by Harnessing the Wind", the New York Times, Oct 2023. Accessed on 29th March 2024, https://www.nytimes.com/2023/10/03/climate/wind-powered-ships-climate.html

[18] "Offshore Wind Is a Key Solution for the United States to Achieve Its Climate Goals", APACO, Nov 2023. Accessed on 29th March 2024, https://apcoworldwide.com/blog/offshore-wind-is-a-key-solution-for-the-united-states.

New Marine Construction Risks

Anchor failures: Offshore wind turbines are typically anchored to the seabed using various foundation types, such as monopiles, jackets, or gravity-based structures. Monopiles and tri-piles are driven into the seabed and are not well-suited for geological conditions with shallow bedrock, boulders, or coarse gravel layers. Jackets, tripods, and some anchors for floating foundations require soil conditions in which piles or suction caissons can be embedded, but they can tolerate some obstructions better than monopiles. Gravity foundations and dead-weight anchors for floating foundations sit directly on the seabed and can therefore be located where foundation penetration into the seabed is not practical[19].

Additionally, the marine environment presents unique challenges, such as scour (erosion of seabed sediments around the foundation), which can compromise the structural integrity of the foundation over time. Regular inspections and maintenance, as well as the implementation of scour protection measures, are necessary to mitigate the risk of anchor failures[20].

Cable damage: Subsea cables connecting turbines to the onshore grid and transmitting electricity are vulnerable to various types of damage. Anchor strikes from ships or fishing vessels can sever or damage cables, leading to power outages and costly repairs. Additionally, seabed movements, such as landslides or erosion, can expose and damage buried cables, requiring interventions or re-burial operations[21].

Cable damage can also occur during installation or maintenance activities, such as anchor handling or cable laying operations. Proper cable route planning, burial depth assessments, and the use of cable protection systems (e.g., rock dumping or mattressing) are essential to mitigate the risk of cable damage.

Damage During Operations

Once an offshore wind farm is operational, it remains vulnerable to the impacts of severe weather events. Extreme conditions like hurricanes, typhoons, or extratropical cyclones can cause significant damage to wind turbines, offshore substations, and interconnection cables [22].

1. High winds and waves can lead to turbine blade damage, nacelle failure, or even complete turbine collapse, resulting in equipment damage or loss.

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[19] "Adapting offshore wind power foundations to local environment", VINDVAL, May 2010. Accessed on 29th March 2024, https://www.naturvardsverket.se/4ac38b/globalassets/media/publikationer-pdf/ovriga-pub/vindval/978-91-620-6367-2.pdf
[20] Xu, Zhang, Liping Sun, Hai Sun, Qiang Guo, and Xu Bai. "Floating offshore wind turbine reliability analysis based on system grading and dynamic FTA." *Journal of Wind Engineering and Industrial Aerodynamics* 154 (July 2016): 21-33. Accessed April 2, 2024. https://doi.org/10.1016/j.jweia.2016.04.005.
[21] "Reducing the risks in offshore wind farms", AXA, May 2023. Accessed on 29th March 2029, https://axaxl.com/fast-fast-forward/articles/reducing-the-risks-in-offshore-wind-farms
[22] "Offshore Wind Market Report: 2023 Edition", Department of Energy, Aug 2023. Accessed on 29th March 2029 https://www.energy.gov/eere/wind/articles/offshore-wind-market-report-2023-edition

2. Subsea cables connecting the turbines to the onshore grid are susceptible to damage from anchors, trawlers, or seabed movements, which can cause power outages and require expensive repairs or replacements. Contractual disputes or liabilities may arise if power outages or equipment damage caused by severe weather events lead to breaches of power purchase agreements or other contractual obligations.
3. Environmental liabilities may arise if severe weather events lead to oil spills, chemical leaks, or habitat destruction due to damaged equipment or infrastructure or damage to nearby properties, maritime vessels, or result in injuries to members of the public.

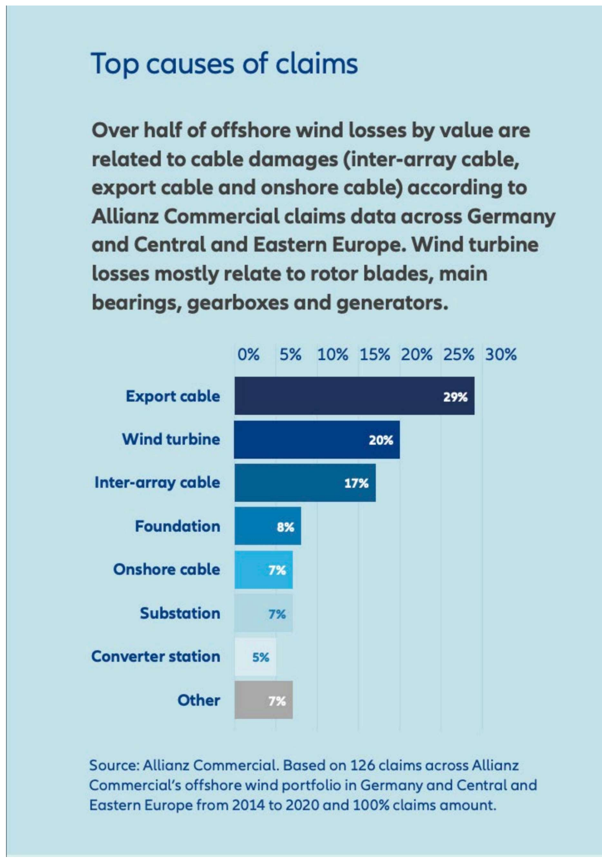

Figure 7: Top causes of offshore wind loss claims (Source: Allianz Commercial)

Figure 7 depicts the top causes of claims in the offshore wind industry based on data from Allianz Commercial. The data covers 126 claims across Allianz Commercial's offshore wind portfolio in Germany and Central and Eastern Europe from 2014 to 2020.The chart reveals that over half of the losses by value are related to cable damages. The data highlights the importance of addressing cable-related risks and wind turbine component failures to minimize losses in the offshore wind industry.

It's important to recognize that the North American market may present some unique challenges, such as the prevalence of hurricanes along the East Coast and in the Gulf of Mexico. The use of floating wind turbines in hurricane-prone areas is an important consideration for both developers and insurers. While floating foundations offer the potential to access deeper

water sites and reduce some environmental impacts, they may also be more vulnerable to damage from extreme weather events like hurricanes. The dynamic nature of floating structures and the potential for mooring line failures or anchor instability during severe storms could lead to higher losses compared to fixed foundations.
Research on the hurricane resilience of floating wind turbines is still limited, as the technology is relatively new and has not yet been widely deployed in hurricane-prone regions.

While there is currently limited data due to the small number of deployments, the twisted jacket foundation may be a promising design for hurricane-prone areas. A foundation of this type used by the oil and gas industry withstood a direct hit from Hurricane Katrina (category 5) in 2005 and emerged unscathed. In a DOE-funded project, NREL designed and analyzed a hypothetical 500-megwatt offshore wind plant to be deployed in 25-meter (over 80-foot) waters in the Gulf of Mexico. Some of the features of this hypothetical wind farm included a twisted jacket foundation from Keystone Engineering and a customized lightweight direct drive generator from Siemens.[23]

Owing to the scalability of floating offshore wind farm technology, more countries and companies are investing in Research and Development of hurricane and typhoon resistant wind turbines. The US Department of Energy has identified 2.8 terawatts of U.S. offshore wind energy potential with floating wind turbines, which is the double of the current need.[24] While Fixed-bottom foundations can still be a viable solution for in-land offshore wind – such as on the Great Lakes, the growth projections for both technology and market point towards Floating bottom foundations.

💡 ***V.* Insurers considering coverage for floating wind projects in hurricane-prone areas will need to carefully assess the design and engineering of these structures, as well as the adequacy of risk mitigation measures such as hurricane response plans and emergency protocols. They may also need to factor in additional reinsurance costs or consider alternative risk transfer mechanisms, such as parametric insurance products triggered by specific hurricane intensity thresholds.**

[23] "U.S. Conditions Drive Innovation in Offshore Wind Foundations", Department of Energy, Dec 2017. Accessed on 29th March 2024, https://www.energy.gov/eere/articles/us-conditions-drive-innovation-offshore-wind-foundations
[24] National Renewable Energy Laboratory. "What Will It Take to Unlock U.S. Floating Offshore Wind Energy?" NREL, Sept 2023. Accessed on 3rd April 2024 https://www.nrel.gov/news/program/2023/what-will-it-take-to-unlock-us-floating-offshore-wind-energy.html.

V. Gap Analysis and Competition Comparison

ZNA has a unique opportunity to differentiate itself in the offshore wind insurance market by tailoring policies to address the specific risks associated with offshore wind farm projects. To ensure their offerings remain competitive, ZNA should regularly benchmark against major competitors in the industry.

Competitive Landscape

1. **Munich Re:** Munich Re is a major reinsurer that collaborates with primary insurers in the wind energy sector. They offer reinsurance solutions covering property, liability, and business interruption, along with expertise in risk modeling and innovative risk transfer mechanisms.[25] They cover insurance for individual, project-related risks targeted at contractors, manufacturers and suppliers in the offshore wind industry[26]

2. **Swiss Re:** Swiss Re offers insurance products for wind energy, covering both onshore and offshore projects. In the offshore sector, Swiss Re's Engineering and Marine teams collaborate to offer facultative and treaty coverage for both construction and operational phases, ensuring a holistic approach to risk management[27].

3. **Allianz:** Allianz Commercial provides insurance coverage solutions across all stages of offshore wind development, construction, and operations[28].

4. **GCube Insurance Services:** GCube specializes in renewable energy insurance, including wind energy projects. They provide insurance for coverage for utility-scale renewable energy projects for property, liability, and cargo[29]. They have strategically partnered with Renew Risk, a risk analytics platform to better understand offshore wind risk and aid underwriting[30].

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[25] "Insurance for renewable energy producers", HSB, accessed on 29th March 2024, https://www.munichre.com/hsb/en/products/commercial-lines-agents-and-brokers/energy-insurance.html
[26] "Offshore wind park insurance", Munich RE, accessed on 29th March 2024, https://www.munichre.com/en/solutions/for-industry-clients/risk-transfer-solutions-for-on-and-off-shore-wind-power.html
[27] "Renewable Energy Risks", Swiss RE, accessed on 29th March 2024, https://www.swissre.com/reinsurance/property-and-casualty/renewable-energy-risks.html
[28] "Offshore wind industry poised for growth, but economic pressures and tech innovation need to be managed", Allianz, Sep 2023. Accessed on 29th March 2024, https://www.allianz.com/en/press/news/commitment/environment/230921-allianz-offshore-wind-industry-poised-for-growth-but-economic-pressures-and-tech-innovation-need-to-be-managed.html
[29]"Products", GCube Insurance Services, accessed March 29th 2024, https://www.gcube-insurance.com/Products.
[30] "GCube Insurance partners with Renew Risk to enhance renewable energy risk analytics" Reinsurance News, Nov 2023. Accessed on 29th March 2024, https://www.reinsurancene.ws/gcube-insurance-partners-with-renew-risk-to-enhance-renewable-energy-risk-analytics/

VI. ZNA Differentiation Strategy

To differentiate itself from competitors and address the unique risks in the offshore wind sector, ZNA could consider offering some of the following insurance products and services:

1. **Extreme Weather Parametric Insurance:** Parametric insurance products that trigger payouts based on predefined weather parameters, such as wind speeds during extreme weather events like hurricanes. This can provide faster and more transparent claims settlements for wind projects impacted by severe weather[31].

2. **Cyber Risk Coverage:** Offshore wind farms are supposedly vulnerable to cyber-attacks[32]. Specialized insurance coverage for cyber risks associated with wind energy projects. This can include protection against data breaches, system vulnerabilities, and cyber-attacks targeting critical infrastructure, helping project owners mitigate the growing threat of cyber threats in the renewable energy sector.[33][34]

3. **Supply Chain Disruption Insurance:** Coverage for supply chain disruptions, addressing delays or losses resulting from interruptions in the offshore wind energy supply chain. This can include protection against manufacturing delays, transportation issues, or disruptions in the delivery of key components[35].

4. **Climate Risk Resilience Assessment Services:** Risk assessment services that evaluate the climate resilience of wind projects. Insights into potential climate-related risks and recommend resilience measures. This proactive approach can help project developers and operators enhance the long-term sustainability of their assets[36].

5. **Energy Storage Integration Coverage**: Insurance coverage specifically tailored for wind projects with energy storage systems.[37] This can include protection against performance degradation, malfunction, or unexpected issues related to the integration of energy storage technologies with wind turbines. [38]

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[31] "When the wind blows; the role of parametric insurance in renewable energy", AXA, June 2021. Accessed on 29th March 2024, https://axaxl.com/fast-fast-forward/articles/when-the-wind-blows-the-role-of-parametric-insurance-in-renewable-energy

[32] "Offshore wind farms are vulnerable to cyberattacks", ScienceDaily, January 24,2024. Accessed March 29, 2024 https://www.sciencedaily.com/releases/2024/01/240124132757.htm

[33] Marsh. Accessed March 29, 2024. https://www.marsh.com/en/industries/energy-and-power/insights.html.

[34] "Renewable Energy Grows in Stature and in Cyber Risk." Deloitte, February 2023. Accessed March 29, 2024. https://action.deloitte.com/insight/3157/renewable-energy-grows-in-stature-and-in-cyber-risk.

[35] "Supply Chain Risk Services." Zurich North America, accessed March 29, 2024. https://www.zurichna.com/risk/supply-chain-risk-services.

[36] Zurich. "Zurich Risk Services and KPMG." Accessed March 27, 2024. https://www.zurich.com/en/commercial-insurance/services/zrs-and-kpmg.

[37] Zurich North America. "Renewable Energy Insurance." Accessed March 27, 2024. https://www.zurichna.com/industries/energy/renewable-energy-insurance.

[38] Munich Re. "Insurance Covers for Electrical Energy Storage Systems." Accessed March 27, 2024. https://www.munichre.com/en/solutions/for-industry-clients/insurance-covers-for-electrical-energy-storage-systems.html.

💡 **VI. ZNA's existing strengths in the energy and marine insurance sectors provide a solid foundation upon which to build a comprehensive and innovative offshore wind insurance offering. To ensure success, prioritizing collaboration with industry partners, investing in research and development, and continuously adapting products and services to meet the evolving needs of the offshore wind industry is necessary.**

By staying at the forefront of this dynamic market, Zurich North America cannot only capture new growth opportunities but also contribute to the sustainable development of the global energy landscape.

Carbon Capture, Utilization and Storage

The imperative to address climate change has brought into focus the urgent need to decarbonize hard-to-abate sectors. Carbon capture and storage (CCS) stands out as a pivotal climate technology offering a promising pathway to achieve significant emissions reductions. CCS involves capturing carbon dioxide (CO2) emissions from point sources or directly from the atmosphere, transporting it via ships or pipelines, and permanently storing it deep underground[39]. While initial costs remain high, accelerating the deployment of CCS infrastructure is paramount to achieving global net-zero emissions targets.

CCS is often complemented with CCUS, i.e., Carbon Capture, Utilization, and Storage.

In the next few sections, we will talk about different components of CCUS, the technologies and risks, the transportation mechanisms in CCUS value chain with its own unique risks, the policies driving investments, along with the competition comparison for the insurance industry offerings. We finally end the section with some differentiation strategy for ZNA.

I. Market Landscape and Trends

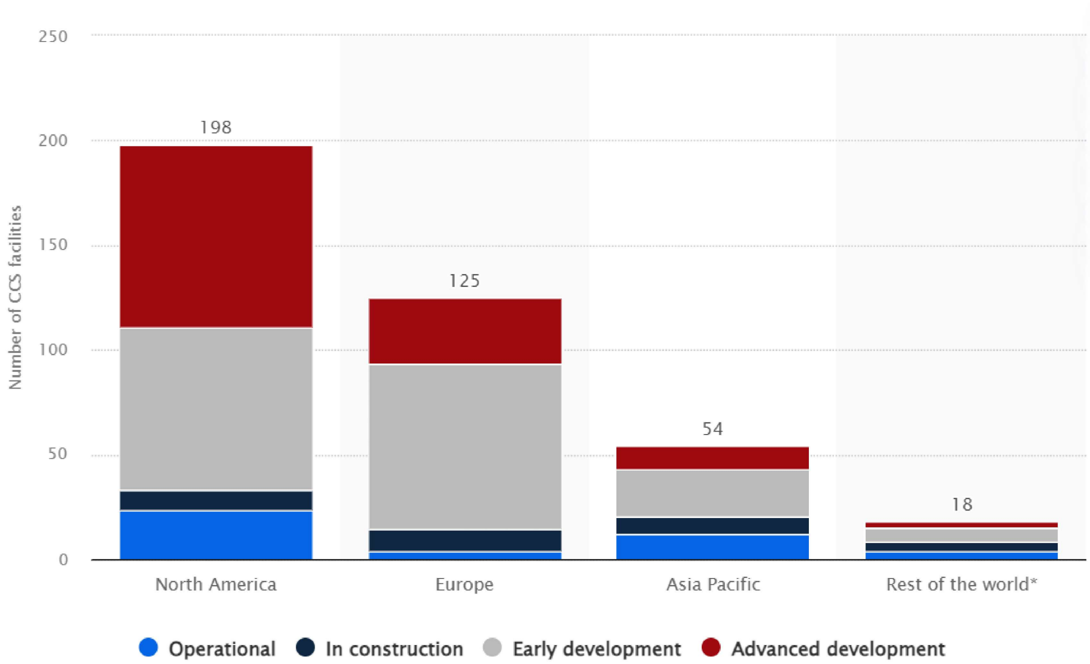

Figure 8: Number of commercial carbon capture and storage (CCS) facilities in select regions worldwide as of 2024, by status. Taken from Statistica," [Worldwide CCS Facilities by Region 2024](#)."

From figure 8, we can see that, as of March 2024, North America led the global count in planned commercial carbon capture and storage (CCS) projects, with around 198 initiatives in the pipeline. Among these, 175 were in various stages of construction or development, while

[39] International Energy Agency. "About CCUS", April 2021. Accessed April 3, 2024. https://www.iea.org/reports/about-ccus.

23 were already operational. In contrast, Europe reported only four operational CCS facilities. These technologies primarily entail capturing CO_2 emissions originating from fossil fuel combustion or industrial operations and subsequently depositing the captured CO_2 into subterranean storage sites.[40]

A cornerstone of US CCS support is the 45Q Tax Credit, initially introduced in 2008 and subsequently revised in 2018 to provide enhanced incentives. This tax credit has played a pivotal role in advancing CCS initiatives by offering financial incentives to entities engaging in carbon capture and storage activities.

In 2022, the enactment of the Inflation Reduction Act (IRA) further refined the framework surrounding the 45Q Tax Credit, signaling continued commitment to incentivizing CCS deployment. The updated credit values, effective post-2026 and listed below, reflect the enhanced support provided to various CCS activities:

- Point-source capture & dedicated storage: increased from US$50/ton to US$85/ton
- Point-source capture & enhanced oil recovery (EOR)/utilization: increased from US$35/ton to US$60/ton
- Direct air capture (DAC) & dedicated storage: from US$50/ton to US$180/ton
- DAC & EOR/utilization: from US$50/ton to US$130/ton

The Infrastructure Investment and Jobs Act (IIJA) of 2021 further underscores the commitment to CCS advancement, allocating over US$12 billion for CCS-related activities over the next five years. This funding encompasses initiatives such as carbon storage validation, hydrogen hubs development, and CCS technology advancement. Global Average annual investments in CCUS could peak close to $175 billion by around 2035[41]. Moreover, regulatory amendments facilitated by the IIJA, notably within the Outer Continental Shelf Lands Act, signify a concerted effort to bolster CCS infrastructure development, including offshore CO_2 storage[42].

The potential impact of CCS as a mitigation technology is substantial, with estimates ranging from 7.6 Gt CO_2 per year by 2050 to around 15 Gt CO_2 per year suggesting significant CO_2 emissions reduction potential by 2050. However, realizing this potential entails navigating various challenges inherent in the CCS value chain, including financing complexities and risk mitigation strategies.

For insurers, CCS presents a unique opportunity to play a pivotal role in de-risking projects and facilitating innovative finance mechanisms, such as carbon capture bonds, to lower overall project costs. Prioritizing investments in transport infrastructure and early-stage, high-potential ecosystems could be instrumental in driving meaningful impact. Furthermore, the development

[40] "Worldwide CCS Facilities by Region 2024." Accessed April 3, 2024. https://www.statista.com/statistics/1308723/worldwide-ccs-facilities-by-region/.

[41] McKinsey & Company. "Global Energy Perspective 2023: CCUS Outlook." Accessed April 22, 2024. https://www.mckinsey.com/industries/oil-and-gas/our-insights/global-energy-perspective-2023-ccus-outlook.

[42] International Energy Agency. "Net Zero by 2050: A Roadmap for the Global Energy Sector." Oct 2021. Accessed April 3, 2024. https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf.

of robust risk management frameworks may help unlock the full potential of CCS to align with climate goals[43].

[43] Oxford Institute for Energy Studies. "Capture Carbon Capture Value", Feb 2024. Accessed April 3, 2024. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2024/02/CM08-Capture-Carbon-Capture-Value_Final.pdf.

II. CCUS Implementation and Risks

Carbon Capture

Within the realm of CCS, carbon capture emerges as a crucial component. CCS encompasses two primary techniques: point source carbon capture and utilization at coal plants or industrial facilities, and direct air capture (DAC) using chemical solvents.[44] Point source capture, being more mature, can be retrofitted to existing facilities, while DAC presents a nascent technology offering greater flexibility in site selection.

Recent trends and breakthroughs have accelerated the application, efficiency, and affordability of carbon capture technologies, aiding the energy industry in minimizing its carbon footprint. Material developments, particularly in metal-organic frameworks (MOFs)[45], are enhancing carbon capture potential. MOFs, acting like high-absorbency sponges, capture specific gas molecules, offering high-volume CO2 collection and promising more efficient methods of carbon capture. Additionally, aluminum formate (ALF), a type of MOF, shows potential for large-scale use in coal-fired power plants, boasting better performance and stability compared to other adsorbents.

New advancements in direct air capture (DAC) methods are making strides in scaling up carbon sequestration efforts. Companies like Climeworks[46] and Heirloom Carbon Technologies are pioneering innovative approaches to DAC. Climeworks' modular DAC plants, powered by renewable or residual energy, utilize minimal land space and are adaptable to various project sizes. Heirloom Carbon Technologies' use of CO2-deprived limestone accelerates carbon mineralization, offering a rapid method for CO2 removal from the atmosphere. There is an accelerated growth of technologies and innovations in the space with both private and public research and development activities[47]. These developments signify a shift towards wider-scale DAC programs, crucial for global carbon reduction efforts.

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[44] International Energy Agency. "CCUS in the Transition to Net-Zero Emissions." In CCUS in Clean Energy Transitions, Analysis - IEA. Accessed April 3, 2024. https://www.iea.org/reports/ccus-in-clean-energy-transitions/ccus-in-the-transition-to-net-zero-emissions.

[45] Raptopoulou CP. Metal-Organic Frameworks: Synthetic Methods and Potential Applications. Materials (Basel). 2021 Jan 9;14(2):310 https://doi.org/10.3390/ma14020310 . PMID: 33435267; PMCID: PMC7826725.

[46] Climeworks. (n.d.). Net-zero strategy. Retrieved from https://climeworks.com/net-zero-strategy

[47] Davies, Bryan. "5 Key Carbon Capture Technology Trends for 2023." Elsevier. May 24, 2023. Accessed 4th April 2024 https://www.elsevier.com/connect/5-key-carbon-capture-technology-trends-for-2023.

Technologies for Capture

The technologies for carbon dioxide (CO2) capture can be categorized into three main approaches: post-combustion, pre-combustion, and oxy-combustion[48].

Post-Combustion CO2 Capture: This approach is used primarily in conventional natural gas and pulverized coal-fired power generation plants. It involves separating CO2 from the flue gas emitted after combustion. Challenges include the dilute concentration of CO2 in the flue gas, trace impurities that can degrade capture processes, and the energy-intensive process of compressing captured CO2. Established technologies in this area include chemical solvents like amines, but their cost-effectiveness for large-scale power plants remains uncertain.

Pre-Combustion CO2 Capture for Gasification Application: Pre-combustion capture is employed in gasification plants, where the fuel undergoes partial oxidation to produce synthesis gas (syngas). CO2 removal from syngas is facilitated by its high partial pressure, potentially making pre-combustion capture less expensive than post-combustion methods. Current research focuses on absorption processes like Selexol, membranes, and sorbents to improve capture efficiency and reduce costs.

Oxy-Combustion CO2 Capture: Oxy-combustion involves burning coal in an oxygen-rich environment, resulting in flue gas primarily composed of CO2 and water vapor. The captured CO2 can be condensed from the exhaust stream. Oxy-combustion offers benefits like reduced NOx emissions and increased mercury removal compared to conventional combustion methods. However, the process requires significant amounts of oxygen, leading to higher costs.

Large-scale integration challenges

Property risks

Integrating CCS systems into existing industrial facilities or power plants often requires significant retrofitting and modifications, increasing the risk of equipment damage, operational disruptions, or conflicts with existing processes. Scale-up challenges from pilot projects to commercial-scale operations can lead to unforeseen technical issues, performance shortfalls, or equipment failures, potentially damaging physical assets[49].

Liability risks

Contractual disputes or liabilities may arise when integrating CCS systems with third-party facilities or infrastructure, particularly regarding issues such as performance guarantees, operational responsibilities, or cost-sharing arrangements. CCS operations may also impact neighboring properties or communities through increased emissions, noise, or traffic, potentially leading to legal liabilities or public relations concerns].

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[48] "Carbon Dioxide Capture Approaches." Gasifipedia. National Energy Technology Laboratory. Accessed April 3, 2024. https://netl.doe.gov/research/carbon-management/energy-systems/gasification/gasifipedia/capture-approaches.

[49] “Challenges and opportunities in carbon capture, utilization and storage: A process systems engineering perspective”, Oct 2022, Hasan et. al. Accessed April 3 2024. https://www.sciencedirect.com/science/article/abs/pii/S0098135422002630

💡 **VII. Increased public and private investment in research, development, and demonstration of CCUS technologies, as seen in initiatives like the Carbon Negative Shot, aim to drive down costs and improve performance. Insurers can stay abreast of these technological advancements to refine their risk assessment and product offerings for the evolving CCUS landscape.**

Uncertainties and Risks

The capture of carbon dioxide (CO2) from various sources, such as power plants and industrial facilities, is a crucial component of carbon capture and sequestration (CCS) projects[50]
Some of the uncertainties are:

- **Cost Uncertainty**: The actual costs of implementing carbon capture technologies at large scale remain uncertain, particularly for post-combustion and pre-combustion methods.
- **Performance Risks**: The performance of capture technologies in real-world power plants may vary from laboratory tests or theoretical projections, leading to potential operational challenges.
- **Energy Penalty**: Carbon capture processes often require additional energy, which could increase the overall energy consumption and impact the efficiency of power generation.
- **Environmental Impacts**: Some capture methods, such as solvent-based processes, may produce waste streams or emissions that could pose environmental risks if not properly managed.
- **Scale-Up Challenges**: Scaling up novel capture technologies from laboratory prototypes to industrial-scale applications may encounter technical, logistical, and economic challenges.

Property risks

Many capture technologies, such as advanced solvents, membranes, and solid sorbents, are still in the development or pilot stage, posing risks of underperformance or technical issues when scaled up to commercial operations[51]. Equipment failures or material degradation due to the harsh operating conditions (e.g., high temperatures, pressures, corrosive environments) can

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[50] "Capture Approaches." Gasifipedia. National Energy Technology Laboratory. Accessed April 3, 2024. https://netl.doe.gov/research/carbon-management/energy-systems/gasification/gasifipedia/capture-approaches.
[51] "Carbon capture and storage (CCS): the way forward". Bui et. al, 2018. Accessed April 3, 2024 https://pubs.rsc.org/en/content/articlelanding/2018/ee/c7ee02342a

lead to damage or loss of physical assets. The high capital and operating costs of capture technologies, which can account for 70-80% of the overall CCS costs[52], also pose risks to the project's economic viability and potential for financial losses.

Liability risks

As new capture technologies emerge, intellectual property disputes and patent infringement claims may arise, leading to potential legal liabilities. Additionally, the use of certain solvents or chemicals in capture processes can pose environmental and public health risks if not properly handled or contained, potentially leading to liabilities for damages or clean-up costs[53].

💡 **VIII. The development of robust regulatory frameworks for CO2 transport, storage, and monitoring is crucial to facilitate the large-scale deployment of CCUS. Insurers can work closely with policymakers and CCUS project operators to understand evolving regulations and ensure their liability products adequately address the risks around pipeline safety, underground injection, and long-term storage integrity.**

[52] International Energy Agency. CCUS in Clean Energy Transitions, Sept 2020. Accessed April 3, 2024. https://www.iea.org/reports/ccus-in-clean-energy-transitions

[53] Rosa M. Cuéllar-Franca, Adisa Azapagic,"Carbon capture, storage and utilisation technologies: A critical analysis and comparison of their life cycle environmental impacts.", March 2015. Accessed April 3, 2024. https://www.sciencedirect.com/science/article/pii/S2212982014000626?via%3Dihub

Utilization

Carbon capture and utilization (CCU) encompasses various applications wherein CO_2 is captured and utilized either directly (without chemical alteration) or indirectly (via transformation) to produce a range of products. Presently, approximately 230 Mt of CO_2 are utilized annually, primarily in direct applications within the fertilizer industry for urea manufacturing (approximately 130 Mt) and in enhanced oil recovery (approximately 80 Mt).

Emerging utilization pathways, including the production of CO_2-based synthetic fuels, chemicals, and building aggregates, are gaining traction. The current project pipeline indicates that by 2030, around 10 Mt of CO_2 per year could be captured for these novel purposes, with approximately 7 Mt CO_2 earmarked for synthetic fuel production. If all announced projects come to fruition, they could collectively achieve roughly half of the CO_2 utilization target for synthetic fuel production by 2030 as outlined in the Net Zero Emissions by 2050 (NZE) Scenario.

Furthermore, to align with the NZE Scenario, all captured CO_2 must originate from air or biogenic sources, a criterion currently met by only about 4 Mt CO_2 per year of planned CCU capacity for fuel production by 2030[54].

Enhanced Oil Recovery (EOR)

One strategy for CO_2 utilization involves employing it in enhanced oil recovery processes. EOR entails injecting CO_2 gas into oil fields to extract residual oil that conventional primary or secondary recovery methods cannot access. This technique leverages the properties of CO_2 to displace and mobilize unrecovered oil reserves, thereby enhancing overall extraction efficiency. In the United States, crude oil extraction from reservoirs typically progresses through three phases: primary, secondary, and tertiary (or enhanced) recovery. Primary recovery relies on natural reservoir pressure and artificial lift methods, yielding around 10% of original oil reserves. Secondary recovery methods, such as water or gas injection, recover an additional 20 to 40% of original reserves.

To extract more challenging reserves, tertiary techniques, also known as enhanced oil recovery (EOR), are employed. Three main categories of EOR are used: thermal recovery (utilizing heat to lower oil viscosity), gas injection (using gases like CO_2 to displace oil), and chemical injection (employing polymers or surfactants). While these methods show promise, their high costs and variable effectiveness remain challenges.

CO_2-EOR, particularly, has garnered significant attention due to its potential benefits. Initially implemented in Texas in 1972, CO_2 injection has been successful in various regions, including the Permian Basin. Traditionally sourced from natural reservoirs, CO_2 is now being produced from industrial processes like natural gas processing and fertilizer production. For

[54] International Energy Agency. "CO2 Capture and Utilisation." Accessed April 22, 2024. https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage/co2-capture-and-utilisation.

instance, a project in North Dakota delivers CO2 via pipeline to Saskatchewan, Canada, where it is injected to extend oil field productivity.

The Department of Energy (DOE) is spearheading research and development into next-generation CO2-EOR techniques. These innovations aim to enhance economic viability and broaden applicability, potentially unlocking over 60 billion barrels of oil reserves. Strategies include increased CO2 injection volumes, novel flood designs, and improved mobility control, with the goal of expanding CO2-EOR beyond its current geographic scope[55].

The risks associated with EOR are similar to the ones highlighted in the upcoming storage section.

Diversification of Applications

Alternatively, CO2 can be utilized in the production of various alternative materials, thereby diversifying its applications beyond traditional extraction methods. By redirecting CO2 towards the creation of construction materials, alternative fuels, chemicals, and other innovative products, industries can mitigate environmental impact while simultaneously fostering economic growth. This approach capitalizes on CO2 as a valuable resource for sustainable material synthesis, offering solutions that align with evolving environmental and market demands.

Utilizing CO2 in various chemical processes presents a promising avenue for carbon reduction. By employing catalysts, CO2 can be broken down into its constituent components, enabling the synthesis of valuable products like methanol, urea for fertilizers, and polymers for durable goods. Projections suggest that by 2050, this approach could potentially utilize 0.3-0.6 gigatons of CO2 annually, with associated costs ranging from -$80 to $300 per ton.

Another strategy involves combining hydrogen with CO2 to produce hydrocarbon fuels such as methanol, synfuels, and syngas. While this approach could tap into existing transport infrastructure, current costs remain prohibitively high. Nevertheless, CO2 fuels have the potential to utilize 1-4.2 gigatons of CO2 per year by 2050, albeit at a significant cost of up to $670 per ton.

Microalgae offer another avenue for CO2 utilization, with the potential to fix CO2 efficiently and convert biomass into fuels and high-value chemicals. However, complex production economics currently constrain widespread adoption, with costs ranging from $230 to $920 per ton of CO2. Projections indicate that by 2050, microalgae-based processes could utilize 0.2-0.9 gigatons of CO2 annually.

[55] U.S. Department of Energy. "Enhanced Oil Recovery." Accessed April 22, 2024. https://www.energy.gov/fecm/enhanced-oil-recovery.

CO_2 also finds application in the production of concrete building materials, where it can aid in cement curing and aggregate manufacture. This approach not only stores CO_2 over the long term but also displaces emissions-intensive conventional cement. Despite challenges posed by regulatory frameworks, the utilization and storage potential for CO_2 in concrete materials could reach 0.1-1.4 gigatons by 2050, with current costs ranging from -$30 to $70 per ton[56].

[56] Carbon Brief. "Guest post: 10 ways to use CO2 – and how they compare." July, 2019. Accessed April 22, 2024. https://www.carbonbrief.org/guest-post-10-ways-to-use-co2-and-how-they-compare

Storage

Carbon sequestration

Carbon sequestration is a critical process aimed at securing carbon dioxide to prevent its release into the atmosphere, thereby mitigating the impact of greenhouse gasses on climate change. The two primary types of carbon sequestration are biological and geological. Biological sequestration involves storing carbon dioxide in vegetation, soils, and oceans, such as in forests and grasslands. Geological sequestration, on the other hand, entails storing carbon dioxide in underground geologic formations or rocks, usually captured from industrial or energy-related sources.

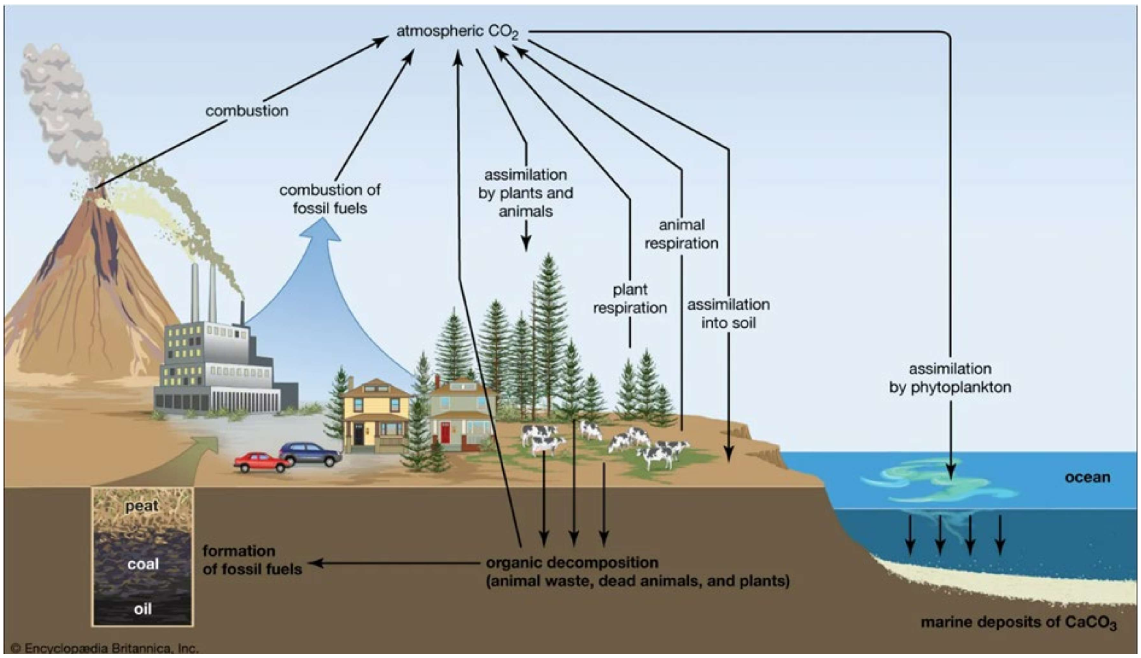

Figure 9: The carbon cycle. Source: Britannica

Figure 9 shows the Carbon Cycle. There is a need to remove excess carbon in the atmosphere that is not produced naturally.

Scientists are exploring technological advancements in carbon sequestration, aiming not only to capture and store carbon but also to repurpose it as a resource. For example, the use of carbon dioxide as a raw material for graphene production demonstrates how carbon can be utilized in specific industries, showcasing the potential for reducing emissions from the atmosphere. However, carbon sequestration also raises environmental considerations, such as ocean acidification resulting from the absorption of carbon dioxide by the upper layer of the ocean. Despite challenges, efforts are underway to monitor and adapt practices in areas like fishing to address the impacts of carbon sequestration.

Geological Storage

Geologic formations suitable for CO2 storage are essential components of CCUS projects. These formations must have the capacity to store large volumes of CO2 while minimizing the risk of leakage safely and permanently. Several types of geologic formations are being considered for CO2 storage. Suitable storage formations can occur in both onshore and offshore settings, and each type of geologic formation presents different opportunities and challenges. The U.S. Department of Energy (DOE) is investigating five types of underground formations for geologic carbon storage[57]:

- Saline formations
- Oil and natural gas reservoirs
- Unmineable coal seams
- Basalt formations
- Organic-rich shales

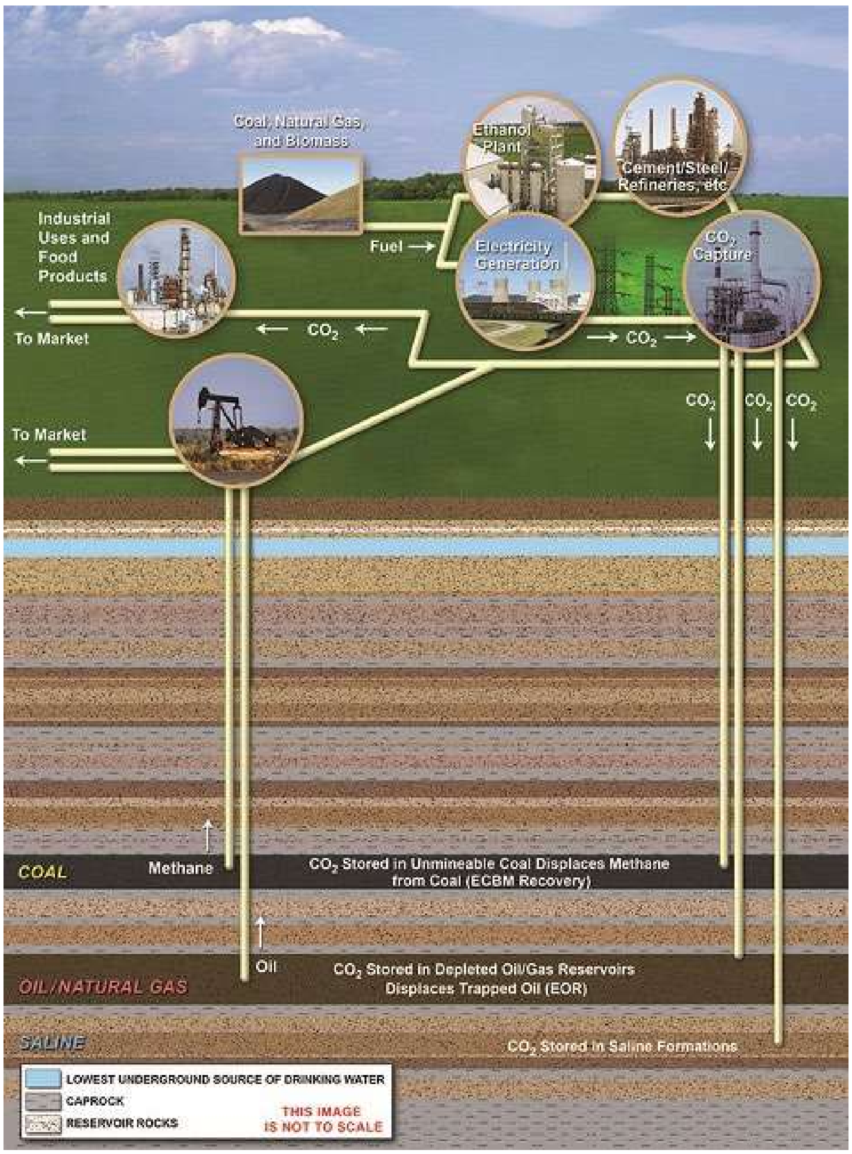

Figure 10: Image showing various types of carbon storage setups. Source [NETL](#)

[57] "Carbon Storage FAQs." National Energy Technology Laboratory (NETL). Accessed April 3, 2024. https://netl.doe.gov/carbon-management/carbon-storage/faqs/carbon-storage-faq

Figure 10 shows various types of carbon storage setups: saline formations, oil and natural gas reservoirs, unmineable coal areas, organic-rich shales, and basalt formations. Each setup includes (1) a confining layer above the storage zone, separating stored CO_2 from drinking water sources and the surface; (2) strong integrity within the storage formation and sealing layers; (3) ample porosity and permeability for CO_2 storage; and (4) being at supercritical depth for concentrated storage.[58] Let's look at a few of them in some detail:

Saline Formations

Saline formations, characterized by porous structures filled with brine, are significant targets for Carbon Capture and Storage (CCS). These formations, found deep underground, have high potential for storing carbon dioxide (CO_2) globally. The United States, with extensive saline formations in large sedimentary basins, is exploring these sites as a crucial option for geologic carbon storage. Studies emphasize the vast volume potential of saline formations and their capacity to contribute to CO_2 mitigation efforts[59].

Oil and Natural Gas Reservoirs

Oil and natural gas reservoirs, prevalent in various locations globally, offer promising geologic storage sites for CO_2. Once hydrocarbons are extracted, the resulting permeable volumes can efficiently accommodate CO_2 storage. These reservoirs, having held hydrocarbons for extended periods, provide favorable conditions for secure CO_2 storage. Additionally, injecting CO_2 can enhance oil production through enhanced oil recovery (EOR), a dual-benefit approach.

Unmineable Coal Seams

Unmineable coal seams, deemed unsuitable for extraction due to geological and economic factors, present opportunities for CO_2 storage. The ideal coal seam, considered unmineable, should exhibit sufficient permeability. The injection of CO_2 into coal seams, a process known as enhanced coal bed methane (ECBM) recovery, not only allows for CO_2 storage but also facilitates the production of methane. The chemically trapped CO_2 in coal seams ensures permanent storage.

Basalt Formations

Basalt formations, created by cooled lava flows, are recognized as suitable candidates for CO_2 storage. Spread across the United States in buried deposits, basalt's chemical and physical properties enable CO_2 to react with minerals like magnesium and calcium. This reaction forms stable carbonate minerals, calcite, and dolomite, leading to permanent CO_2 trapping through mineralization. Basalt formations are considered highly secure for CO_2 storage.

[58] "Carbon Storage FAQs." National Energy Technology Laboratory (NETL). Accessed April 3, 2024. https://netl.doe.gov/carbon-management/carbon-storage/faqs/.

[59] "Carbon Storage Atlas, Fifth Edition (Atlas V)", National Energy Technology Laboratory (NETL), Oct 2018. Accessed April 6, 2024. https://www.netl.doe.gov/node/5841.

Organic Shale Formations

While shale formations are typically low-porosity and low-permeability, certain organic-rich shales exhibit properties similar to coal. These shales can trap CO2 through adsorption, releasing methane in the process. Despite being primarily confining zones, the potential for CO2 storage in organic-rich shales makes them intriguing. Basins containing such shales across the United States are being explored for their CO2 storage capabilities.

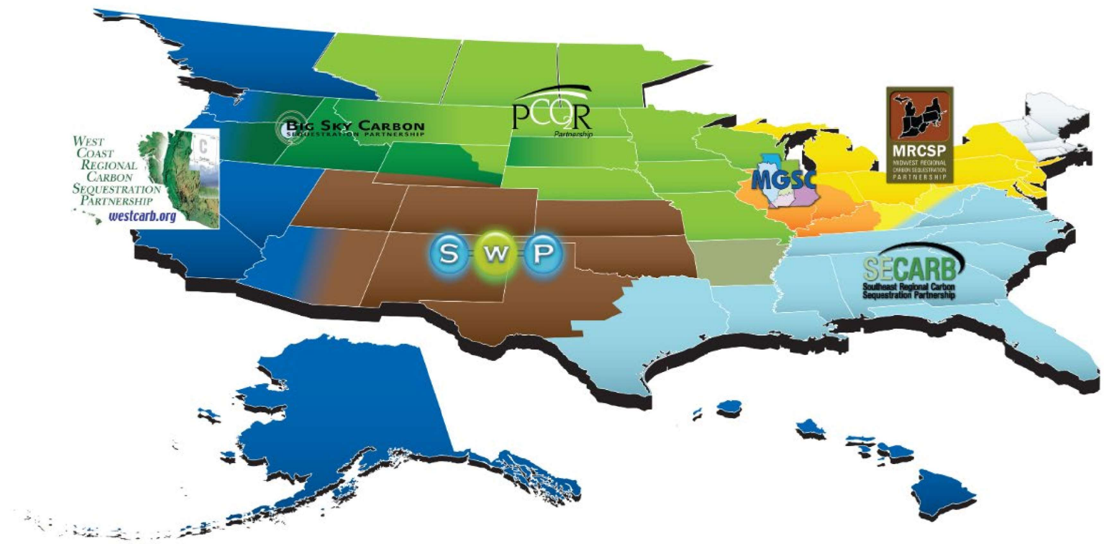

Figure 11: Regional Carbon Sequestration Partnerships (RCSPs), Department of Energy. Source [NETL]

Figure 11 shows the nationwide network of seven Regional Carbon Sequestration Partnerships (RCSPs), developed early in the Carbon Storage Program by the Department of Energy.
A complete GIS reference can be found at [The Carbon Storage Open Database] developed and maintained by the Department of Energy

Storage permeability, leakage risks

Property risks
Inadequate site characterization or improper selection of storage formations can lead to CO2 leakage, potentially damaging the storage reservoir or surrounding rock formations through processes such as cap rock fracturing, wellbore degradation, or induced seismicity. Geological disturbances, such as earthquakes or fault reactivation, could also compromise the integrity of the storage formation and lead to CO2 leakage, posing risks to the physical infrastructure and assets.

Liability risks
CO2 leakage from storage formations can have severe environmental consequences, including groundwater contamination, ecosystem damage, and potential harm to human health through exposure to elevated CO2 levels[60]. Project developers, operators, or owners may face legal liabilities for environmental damage, remediation costs, or compensation claims resulting from CO2 leakage. Additionally, there are regulatory compliance risks related to CO2 storage permitting, monitoring, and reporting requirements.

Long-term liability uncertainties

Property risks
Uncertainty surrounding the long-term integrity and performance of CO2 storage formations poses risks to the physical assets and infrastructure associated with CCS projects. For example, unforeseen geological or geochemical processes over decades or centuries could compromise the storage formation, leading to potential asset damage or loss[61].

Liability risks
The lack of clear legal frameworks or regulations governing long-term liability for CO2 storage sites creates significant uncertainties for project developers, operators, or owners. Potential liabilities related to future environmental impacts or claims arising from stored CO2, even after the project's operational phase, may persist indefinitely. Additionally, there are uncertainties regarding the transfer of liability from project operators to regulatory bodies or other entities over the long term.

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[60] Simon Shackley, David Reiner, Paul Upham, Heleen de Coninck, Gudmundur Sigurthorsson, Jason Anderson, "The acceptability of CO2 capture and storage (CCS) in Europe: An assessment of the key determining factors: Part 2. The social acceptability of CCS and the wider impacts and repercussions of its implementation", May 2009. Accessed April 22, 2024. https://www.sciencedirect.com/science/article/pii/S1750583608000947?via%3Dihub
[61] "Long-Term Liability For Carbon Capture And Storage In Depleted North American Oil And Gas Reservoirs - A Comparative Analysis", Allan Ingelson, Anne Kleffner, and Norma Nielson, Feb 2023. Accessed April 3, 2024 https://www.eba-net.org/wp-content/uploads/2023/02/10-20_431_ccs_liability.pdf

💡 **X. Improper selection or inadequate characterization of CO_2 storage formations can lead to leakage, potentially damaging the storage reservoir or surrounding areas through processes like cap rock fracturing or induced seismicity. Long-term integrity and performance of storage sites also poses risks, as unforeseen geological or geochemical changes over decades or centuries could compromise the storage. This creates significant uncertainties around long-term liabilities for storage site operators.**

Transport

Once captured, the CO_2 must be transported from the capture site to a storage or utilization location. Several methods can be employed for CO_2 transport, each with its own advantages and considerations.

Pipelines

Pipelines are the most common and cost-effective method for transporting large volumes of CO_2 over long distances. CO_2 is compressed and transported as a dense-phase fluid through buried pipelines, similar to the existing natural gas pipeline network.

Pipeline transport is particularly suitable for large-scale carbon capture projects located near suitable storage or utilization sites. However, the construction of new pipelines can be capital-intensive and may face challenges related to land acquisition, permitting, and public acceptance[62].

Ships

For offshore storage sites or locations where pipelines are not feasible, CO_2 can be transported by ships. The captured CO_2 is liquefied and loaded onto specialized CO_2 carriers, similar to liquefied natural gas (LNG) tankers.

Ship transport offers flexibility in terms of routing and access to offshore storage locations. However, it involves additional steps, such as liquefaction and regasification, which can increase energy consumption and costs[63].

Rail

Rail transport can be an option for transporting CO_2 over shorter distances or in areas where pipelines or ships are not practical. CO_2 is liquefied and loaded into specialized rail tankers or containers for transport.

Rail transport offers flexibility in routing and can be used to connect capture sites to pipeline networks or storage locations. However, it is generally less cost-effective than pipelines for large volumes and long distances[64].

Trucks

Truck transport is typically used for smaller-scale CO_2 transport operations or as a component of a multimodal transport system. Liquefied or compressed CO_2 is loaded into specialized tanker trucks for transport.

Truck transport offers flexibility and can be used for shorter distances or to connect capture sites to larger transport networks. However, it is generally less cost-effective and has a higher environmental impact than pipelines or ships for large-scale transport.

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[62] "A state-of-the-art review of techno-economic models predicting the costs of CO2 pipeline transport", Knoop, Ramirez, Faaij, Aug 2013. Accessed April 3, 2024. https://doi.org/10.1016/j.ijggc.2013.01.005

[63] X. Su and Y. Wang, "Modeling and optimization of CO2 pipeline transportation system," ISCTT 2022; 7th International Conference on Information Science, Computer Technology and Transportation, Xishuangbanna, China, 2022, pp. 1-4. https://ieeexplore.ieee.org/document/10071825

[64] Center for Climate and Energy Solutions. "Carbon Dioxide Transport 101." Center for Climate and Energy Solutions, Feb 2023. Accessed April 6, 2024. https://betterenergy.org/blog/carbon-dioxide-transport-101.

Transport Infrastructure Needs and Risks

Property risks
The construction and operation of CO_2 transport infrastructure, such as pipelines, ships, or rail, face risks related to equipment failures, leaks, or accidents, potentially leading to damage or loss of physical assets. Existing infrastructure may require upgrades or modifications to accommodate CO_2 transport, increasing the risk of operational disruptions or equipment damage during the retrofit process.

Liability risks
CO_2 leaks or accidents during transport can have environmental consequences, such as ecosystem damage or groundwater contamination, potentially leading to legal liabilities for environmental damage or clean-up costs. There are also legal and regulatory compliance risks related to the construction, operation, and maintenance of CO_2 transport infrastructure, including permitting, safety standards, and emissions regulations. Contractual liabilities or disputes may arise with third-party service providers or infrastructure owners involved in CO_2 transport, particularly regarding issues such as liability allocation, indemnification, or performance guarantees.

IX. The different CO_2 transport methods - pipelines, ships, rail, and trucks - all carry inherent risks of equipment failures, leaks, and accidents that can lead to damage to physical assets as well as environmental contamination. These risks expose transport infrastructure operators to potential liabilities for environmental cleanup and regulatory compliance

III. Policy for Carbon Dioxide Removal (CDR) Technologies

Effective policies are urgently needed to drive the growth of carbon dioxide removal (CDR) technologies, aligning with international climate change goals. The current "removal gap" underscores the necessity of bolstering existing policies and establishing longer-term frameworks to bridge the disparity between current efforts and the required scale of CDR. However, there's a notable lack of focus on financing mechanisms for CDR, incentivizing private sector involvement, and addressing key policy questions surrounding technology improvement and interaction with emissions reduction policies[65].

Stimulating CDR Adoption Through Policy Measures[66]

Forest Carbon Removal: Federal programs administered by the USDA offer subsidy payments for afforestation, reforestation, and forest carbon management. Additionally, financial incentives provided by acts like the Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA) play a pivotal role in stimulating forest carbon sequestration, alongside voluntary markets and emissions reduction regulations.

Direct Air Capture (DAC) and Bioenergy with Carbon Capture (BEC): Expanded tax credits under the IRA, such as the 45Q tax credit, incentivize investments in DAC and BEC technologies. These policies, coupled with robust research, development, and demonstration (RD&D) initiatives, aim to reduce the cost barriers associated with DAC and BEC, fostering innovation and scalability in CDR technologies.

RD&D Policies and Investment Initiatives: Emphasis on RD&D policies, including supply-push strategies and initiatives like the Carbon Negative Shot program and the Storing CO2 and Lowering Emissions (SCALE) Act, seeks to drive down the costs of DAC and BEC technologies. These measures aim to achieve cost targets, increase utilization, and support regional hubs and carbon storage initiatives.

Regulatory Frameworks for CO2 Transport and Storage: Regulatory frameworks addressing safety measures for CO2 pipelines, environmental approvals for underground injection, and liability for storage integrity are essential for facilitating the long-distance transmission of captured CO2, vital for CCS, BECCS, and DAC facilities.

Equity Considerations in CDR Expansion: Implementing community benefits agreements (CBAs) and community benefits plans (CBPs) is crucial for ensuring equity in CDR projects,

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[65] International Energy Agency. CCUS in Clean Energy Transitions, Sept 2020. Accessed April 6, 2024. https://www.iea.org/reports/ccus-in-clean-energy-transitions

[66] Resources for the Future. Policy Incentives to Scale Carbon Dioxide Removal: Analysis and Recommendations, Feb 2024. Accessed April 3, 2024. https://www.rff.org/publications/reports/policy-incentives-to-scale-carbon-dioxide-removal-analysis-and-recommendations/

with initiatives like the Justice40 Initiative striving to allocate benefits to disadvantaged communities[67].

💡 **XI. Policies focused on ensuring equitable distribution of benefits from CCUS projects to disadvantaged communities, such as through community benefits agreements, introduce additional stakeholder and reputational risks that insurers can consider when underwriting CCUS-related coverage.**

CCS - Tax credits

Carbon capture and storage (CCS) offers major emissions reduction potential, but faces challenges around costs and deployment at scale. Insurers can enable CCS projects by supporting risk management and new incentives.

The recent Inflation Reduction Act (IRA) significantly boosted tax credits for CCS in the US:

a. Direct air capture projects can qualify for up to $180/ton of CO2 captured.
b. Industrial carbon capture projects are eligible for up to $85/ton.
c. Carbon sequestration receives up to $50/ton for secure geologic storage.[68]

Credits are available for 12 years after a project is placed in service and an extension of the credit for a full ten years (i.e. all projects beginning construction by the end of 2032).

The IRA tax credits are projected to spur deployment of CCS. The challenge to scale carbon dioxide removals is vast. We need to increase our global carbon dioxide removal capacity from several million today to the multi gigaton scale by 2030. 2030 targets for carbon dioxide removals deployment range from 2 to over 5 billion tons per year across a range of methods. These are largely based upon in depth research by Fuss et al (2018), Griscom et al (2017), Roe et al (2019, 2021) and others. While there is a range in the targets themselves it is clear that the step up is significant and will require exponential growth in a short space of time.[69]

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[67] Inflation Reduction Act: A Historic Investment in Climate, Communities, and Jobs". Publisher: U.S. Department of Energy, 2023. Accessed April 3, 2024. https://www.energy.gov/sites/default/files/2023-03/IRA-and-Carbon-Management-Opportunities-in-Tribal-Nations.pdf

[68] "The Inflation Reduction Act Includes Significant Benefits for the Carbon Capture Industry." Gibson, Dunn & Crutcher LLP, Aug 2022. Accessed April 3, 2024.https://www.gibsondunn.com/the-inflation-reduction-act-includes-significant-benefits-for-the-carbon-capture-industry/.

[69] "Carbon Dioxide Removals." UNFCCC Climate Champions. Accessed April 3, 2024. https://climatechampions.unfccc.int/system/carbon-dioxide-removals/.

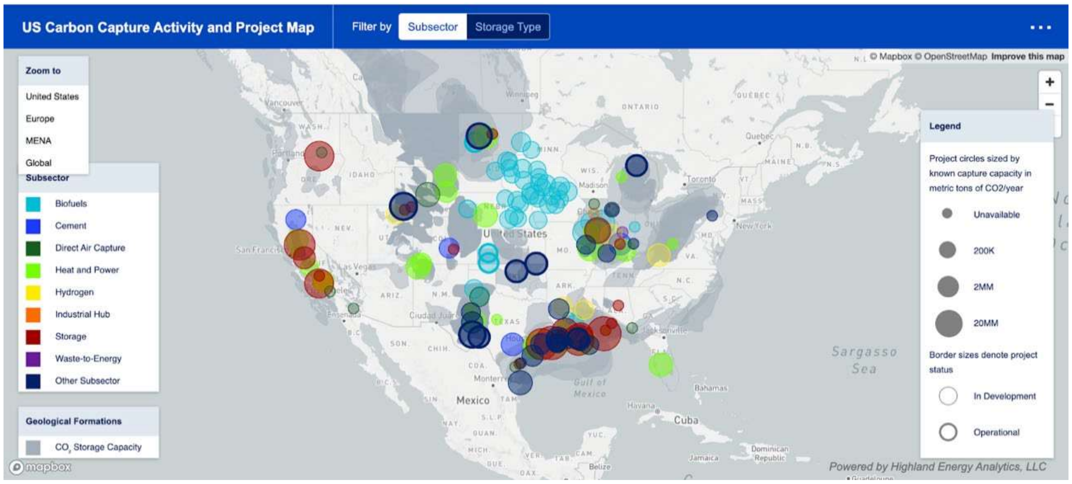

Figure 12: US Carbon Capture Activity and Project Map. Source: [Clean Air Task Force]

Figure 12 shows a screenshot from the interactive map by the Clean Air Task Force, depicting the US Carbon Capture activity.[70]

The USA's $280 billion CHIPS Act, includes $1 billion authorization for carbon dioxide removal research and development. The Act will provide funding to the US Department of Energy, more than doubling the department's existing four-year budget.[71]
However, some key limitations remain around credit eligibility and uncertainty beyond 12 years. Ongoing policy incentives will likely be needed.

XII. The expanded tax credits for direct air capture, bioenergy with carbon capture, and carbon sequestration under the Inflation Reduction Act provide strong financial incentives to drive investment and deployment of CCUS technologies. Insurers can support this growth by developing tailored risk management solutions to cover the operational and long-term liability risks

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[70] "CCS Map US." Clean Air Task Force (CATF). Accessed April 3, 2024. https://www.catf.us/ccsmapus/.
[71] "Carbon Dioxide Removals." UNFCCC Climate Champions. Accessed April 3, 2024. https://climatechampions.unfccc.int/system/carbon-dioxide-removals/.

Several large engineering firms provide risk management services for CCS projects in the US:

a. **Fluor** - Fluor offers complete engineering, procurement and construction (EPC) solutions for carbon capture projects, including CO2 compression and transportation. Fluor Econamine FG PlusSM is a propriety carbon capture solution with more than 30 licensed plants and more than 30 years of operation. This technology uses a solvent to capture CO2 from post-combustion sources.[72]
b. **Bechtel** - Involved in 20+ CCS projects globally. Examines storage permanence, induced seismicity.
c. **Schlumberger** - Leverages oil/gas knowledge for CCS subsurface analysis. Focuses on well integrity management.
d. **Baker Hughes** - Provides monitoring technology for CO2 storage. Looks at containment assurance over time.

Insurers partnering with these active CCS risk engineering experts can stay abreast of emerging project risks like leakage, induced seismicity, measurement uncertainties and develop mitigation strategies. More data sharing on risks across projects is also key.

Though CCS costs remain relatively high, the IRA tax credits combined with rigorous risk management provides momentum for wider deployment. Insurers can enable projects through tailored liability solutions to cover issues like gradual leakage. CCS will play a vital role for decarbonizing heavy industry.

[72] "Carbon Capture." Fluor. Accessed April 3, 2024. https://www.fluor.com/market-reach/industries/energy-transition/carbon-capture

IV. Competition Comparison

Major players in the carbon capture market, such as Carbon Clean Solutions, Climeworks, offer different technological approaches. Analyzing competitors' strengths and weaknesses, understanding their market share, and identifying unmet needs can guide the development of unique value propositions.

Munich Re:

Munich Re has introduced the Technology Performance Guarantee Insurance. This solution provides essential coverage for the new technologies driving the transition. It encompasses guarantees for revenue and production output during both plant start-up and long-term operations, ensuring stability and performance. The insurance offering further addresses potential challenges such as incorrect design or engineering by providing coverage for major equipment repair and replacement. With a flexible multi-year policy that extends up to 10 years, Munich Re's solution offers a comprehensive framework for supporting and securing investments in energy transition projects, including protection for both debt and equity structures[73].

Insurance Products:

1. Parametric Insurance: Munich Re helped a Chinese local insurer introduce the first parametric insurance policy for carbon storage on grasslands in Inner Mongolia, using satellite remote sensing (SRS) technology[74].
2. Climate Risk: Munich Re has also launched a corporate venture called TreeTrust, that aims to capture 600,000 metric tons of CO_2[75].

Swiss Re:

Swiss Re has a broad portfolio covering various technologies and industries. They offer insurance solutions for renewable energy projects, including wind and solar, and have shown interest in supporting initiatives related to carbon capture, utilization, and storage (CCUS). Their coverage extends to areas such as energy infrastructure and emerging technologies.

Insurance Products:

1. Partnering with Direct Air Capture: Swiss Re and Climeworks, a specialist in carbon dioxide air capture technology, have partnered and signed the world's first long-term purchase agreement for direct air capture and storage of carbon dioxide, worth USD 10 million over ten years[76].

[73] "Corporate venture TreeTrust facilitates high-quality afforestation projects for carbon removal" Munich Re, May 2022. Accessed April 3, 2024. https://www.munichre.com/en/company/media-relations/media-information-and-corporate-news/media-information/2022/media-information-2022-05-31.html

[74] "First parametric carbon storage insurance launched in Mongolian Grasslands in China," Munich Re, Aug 2022. Accessed April 3, 2024. https://www.munichre.com/en/insights/natural-disaster-and-climate-change/first-parametric-carbon-storage-insurance-launched-mongolian-grasslands-china.html

[75] "Corporate venture TreeTrust facilitates high-quality afforestation projects for carbon removal" Munich Re, May 2022. Accessed April 3, 2024. https://www.munichre.com/en/company/media-relations/media-information-and-corporate-news/media-information/2022/media-information-2022-05-31.html

[76] "Swiss Re and Climeworks Partner to Pioneer Direct Air Capture Solutions for Green Hydrogen Production." Swiss Re. August 25, 2021. Accessed April 3, 2024 https://www.swissre.com/media/press-release/nr-20210825-swiss-re-climeworks-partnership.html

2. Nature-based solutions (NBS): Swiss Re has explored innovative insurance products focused on resilience and adaptation to climate-related risks. Assigning value to nature prompts protective measures and investments and draws parallels between insuring tangible assets like buildings and cars and the need to extend insurance coverage to the immense environmental, economic, health, and societal benefits derived from natural assets[77].

Allianz:

Insurance Products:

1. Data and Cyber Risk Insurance: Allianz has been active in providing insurance solutions for data protection and cyber risks. As technologies in the carbon capture sector become more interconnected and reliant on data, insurance against cyber threats and data breaches is likely to be a key offering[78]
2. Business Interruption Insurance: Allianz offers business interruption insurance, and they may tailor these products to address specific risks faced by technology-driven projects, including those in the carbon capture sector. This could cover revenue losses resulting from unexpected events.

[77] "Insurance to Protect and Enable Nature-Based Solutions." Swiss Re. Accessed April 3, 2024. https://www.swissre.com/our-business/public-sector-solutions/insurance-to-protect-and-enable-nature-based-solutions.html.

[78] "Cyber Insurance." Allianz. Accessed April 6, 2024. https://commercial.allianz.com/solutions/cyber-insurance.html.

V. ZNA Differentiation Strategy

1. **Parametric Carbon Capture Performance Insurance:**
   Develop parametric insurance products that link premiums and payouts to the actual performance of carbon capture projects. Parameters could include the amount of carbon captured, storage efficiency, or adherence to emission reduction targets. This innovative approach provides financial incentives for optimal project performance.
2. **Carbon Credit Price Protection Insurance:**
   Offer insurance coverage that protects against fluctuations in carbon credit prices. This product would appeal to carbon capture project owners and investors, providing financial stability by mitigating risks associated with market volatility in the carbon credit trading market.
3. **Supply Chain Resilience Insurance:**
   Design insurance solutions to cover risks associated with supply chain disruptions for carbon capture projects. This can include coverage for delays or losses resulting from interruptions in the supply chain for critical components, chemicals, or materials essential to the projects.
4. **Data Security and Cyber Resilience for Carbon Capture Projects:**
   In response to the increasing reliance on data-driven technologies in carbon capture, ZNA can offer specialized coverage for data security and cyber risks. This insurance product protects against unauthorized access, data breaches, and cyber-attacks targeting critical infrastructure in carbon capture projects.

XIII. As an insurer with a robust sustainability team well-versed in CCUS technologies, ZNA can differentiate its underwriting approach by drawing on this in-house technical expertise. By deeply understanding the evolving landscape of CCUS projects, including the latest advancements in direct air capture, bioenergy with carbon capture, and storage solutions, ZNA can develop more nuanced risk assessments and tailor its liability products to the specific needs of CCUS operators. This differentiated underwriting approach, backed by specialized technical knowledge, can position ZNA as a preferred insurance partner for CCUS projects, helping to drive wider deployment of these crucial carbon removal technologies.

Implementing these innovative insurance products can not only strengthen ZNA's position in the rapidly evolving climate and carbon capture sectors but also contribute to advancing sustainable practices and risk management in the industry. Regular collaboration with industry stakeholders, ongoing market analysis, and adaptability to emerging trends will be crucial for ZNA's success in this space.

Recommendations

Based on the analysis of the climate tech market landscape, trends, and risks across renewable energy, energy storage, electric transportation, and carbon capture and storage in the United States, we propose the following practical and achievable recommendations for Zurich North America to accelerate the adoption of net-zero technologies and capitalize on the growing opportunities in the climate tech sector over the next five years.

A. Develop Specialized Insurance Products for Key Climate Tech Sectors

i. Solar Energy: Introducing a performance guarantee insurance product for solar projects, covering a minimum level of energy output or financial performance to reduce risk for investors and lenders. Launch a decommissioning and recycling insurance product to cover the costs and liabilities associated with end-of-life management of solar panels.
ii. Offshore Wind: Create a comprehensive insurance package for offshore wind projects, including coverage for weather-related delays, supply chain disruptions, and property damage during construction and operation. Develop risk assessment tools and models specific to fixed and floating foundation technologies.
iii. Electric Transportation: Offer a battery performance warranty insurance product for EV manufacturers and fleet operators, covering the costs of repair, replacement, or disposal due to premature degradation or failure. Introduce a charging infrastructure insurance product for the installation, maintenance, and operation of EV charging stations.
iv. Carbon Capture and Storage (CCS): Partner with leading CCS project developers and engineering firms to provide specialized risk management services, including site selection, storage integrity assessment, and long-term liability coverage. Develop a CCS project insurance package that covers property damage, business interruption, and environmental liability risks.

B. Invest in Data Analytics and Digital Capabilities

i. Establish a dedicated data analytics team focused on climate tech risks and opportunities, leveraging advanced analytics, machine learning, and artificial intelligence to enhance risk assessment, underwriting, and pricing capabilities.
ii. Partner with Climate Tech startups and technology providers to pilot and scale innovative solutions for climate tech risk management, such as real-time monitoring, predictive maintenance, and automated claims processing.

C. Build Strategic Partnerships and Ecosystem Engagement

i. Collaborate with leading renewable energy developers, EV manufacturers, and CCS project owners to co-develop insurance solutions tailored to their specific needs and risk profiles, and gain insights into emerging technologies and market trends.

ii. Engage with industry associations, such as the American Council on Renewable Energy (ACORE), the Energy Storage Association (ESA), and the Carbon Capture Coalition, to share best practices, and build relationships with key stakeholders.
iii. Partner with academic institutions and research organizations, such as the National Renewable Energy Laboratory (NREL) and the Electric Power Research Institute (EPRI), to support research and development efforts related to climate tech risk assessment and mitigation strategies.

D. Enhance Risk Engineering and Loss Control Services

i. Expand ZNA's risk engineering capabilities to include specialized expertise in solar energy, wind, electric transportation, and CCS, providing clients with technical guidance and best practices for project design, construction, and operation.
ii. Develop a suite of loss control services for climate tech clients, including site inspections, risk assessments, and training programs, to help mitigate potential losses and improve project performance.
iii. Offer incentives, such as premium discounts or favorable coverage terms, for clients who implement recommended risk mitigation measures or adopt industry best practices.

E. Launch a Climate Tech Insurance Innovation Lab

i. Establish an internal innovation lab dedicated to developing and testing new insurance products, services, and business models for the climate tech sector, fostering a culture of experimentation and collaboration within ZNA.
ii. Allocate a portion of ZNA's annual research and development budget to the Climate Tech Insurance Innovation Lab and set clear performance metrics and targets for product development and launch.
iii. Engage with external stakeholders, such as climate tech startups, entrepreneurs, and investors, to identify emerging trends, challenges, and opportunities, and co-create innovative insurance solutions that address market needs.

By implementing these practical and achievable recommendations over the next five years, Zurich North America can position itself as a leading insurance provider for the climate tech sector in the United States, while managing the associated risks and creating long-term value for its clients, shareholders, and society. These recommendations strike a balance between creativity and feasibility, enabling ZNA to adapt to the rapidly evolving climate tech landscape and capture the growing market opportunities, while maintaining a strong focus on risk management and financial sustainability.

Conclusion

Throughout this report, we have explored the dynamic and rapidly evolving landscape of climate tech, with a particular focus on the offshore wind and carbon capture, utilization, and storage (CCUS) sectors. As the world transitions towards a low-carbon economy, these sectors have emerged as critical drivers of change, presenting significant opportunities for insurers to support and accelerate their growth.

The offshore wind industry is poised for exponential growth, with global capacity projected to increase 10-fold by 2030. This growth is fueled by technological advancements, declining costs, and supportive government policies. However, the industry also faces unique risks and challenges, ranging from weather-related construction delays to supply chain disruptions and regulatory uncertainties. Insurers, have a vital role to play in enabling the offshore wind boom by providing tailored risk management solutions and fostering industry-wide collaboration.

Similarly, CCUS has gained traction as a crucial tool for decarbonizing hard-to-abate sectors and bridging the gap to a net-zero future. As CCUS projects scale up, they require specialized insurance coverage and risk assessment capabilities to address the complex risks associated with carbon capture, transport, and storage.

The key takeaways from this report underscore the importance of ZNA's proactive engagement in the climate tech sector:

1. By developing comprehensive insurance solutions tailored to the unique needs of offshore wind and CCS projects, ZNA can position itself as a market leader and enable the deployment of these technologies at scale.
2. Investing in data analytics, modelling capabilities, and risk engineering expertise specific to these sectors will allow ZNA to better assess and price risks, ultimately supporting the sustainable growth of the industry.
3. Collaborating with stakeholders across the value chain and promoting risk management best practices will contribute to the overall resilience and long-term viability of climate tech projects.

The recommendations presented in this report, including the development of innovative risk transfer solutions, fostering cross-industry collaboration, and leveraging data-driven insights, have the potential to significantly impact ZNA's business, clients, and society at large. By implementing these recommendations, ZNA can:

1. Capture new business opportunities in the rapidly growing offshore wind and CCUS markets, diversifying its portfolio and driving premium growth.
2. Strengthen its relationships with clients by providing value-added services and demonstrating a deep understanding of their unique risk profiles and needs.
3. Contribute to the global fight against climate change by supporting the deployment of clean technologies and facilitating the transition to a low-carbon economy.

Hence, ZNA has a critical role to play in supporting the growth of the climate tech sector and shaping a more sustainable future. By embracing the opportunities and proactively managing the risks associated with offshore wind, CCUS, and other emerging technologies, ZNA can establish itself as a trusted partner and thought leader in this dynamic space. The insights and recommendations provided in this report serve as a foundation for ZNA to develop a comprehensive climate tech strategy that aligns with its business objectives while contributing to the urgent global effort to combat climate change.

Appendix – A look at other technologies

The renewable energy sector in the US has seen rapid growth and technological advances in recent years. This creates opportunities and risks for insurers as projects scale up to meet decarbonization goals. Key market trends across major renewable technologies in the US are summarized below from an insurer perspective.

Geothermal Energy

Geothermal energy is a clean, renewable, and reliable source of power that harnesses the Earth's internal heat to generate electricity and provide heating and cooling. In 2022, the United States had geothermal power plants in seven states, which produced about 0.4% (17 billion kilowatt-hours) of total U.S. utility-scale electricity generation. In 2021, 27 countries, including the United States, generated about 92 billion kWh of electricity from geothermal energy. Indonesia was the second-highest geothermal electricity producer after the United States—at about 16 billion kWh—which was about 5% of Indonesia's total electricity generation. Kenya was the eighth-highest geothermal electricity producer, at about 5 billion kWh, which was equal to about 43% of Kenya's annual electricity generation. Kenya had the largest percentage share of electricity generation from geothermal energy among all countries with geothermal power plants.

The IRA extends the investment tax credit (ITC) and the production tax credit (PTC) for renewables, including geothermal, through 2024. It also provides a 30% tax credit, up to $2,000, for the purchase of a heat pump (geothermal or air source), as well as funding for states to offer rebates on household efficiency improvements. The 2021 Bipartisan Infrastructure Law includes $84 million for the Geothermal Technologies Office to stand up 4–7 enhanced geothermal system (EGS) pilot demonstration sites over the next four years. The new law focuses on projects that demonstrate EGS technology in different geologic and geographic settings—including one in the eastern portion of the United States—using a variety of techniques and well completions.[79]

Advances in geothermal technology have helped to improve the efficiency and cost-effectiveness of geothermal power plants. These advancements include enhanced geothermal systems (EGS), which allow for the creation of geothermal reservoirs in areas with hot rock but insufficient water or permeability. The Enhanced Geothermal Shot™ is a department-wide effort to dramatically reduce the cost of EGS by 90%, to $45 per megawatt hour by 2035.[80] Other innovations include advanced drilling techniques, improved power plant designs, and the use of binary cycle technology to generate electricity from lower-temperature geothermal resources.[81]

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[79] "Geothermal FAQs." U.S. Department of Energy. Accessed April 6, 2024. https://www.energy.gov/eere/geothermal/geothermal-faqs.
[80] "Enhanced Geothermal Systems." U.S. Department of Energy. Accessed April 6, 2024. https://www.energy.gov/eere/geothermal/enhanced-geothermal-systems-0.
[81] "Electricity Generation." U.S. Department of Energy. Accessed April 6, 2024. https://www.energy.gov/eere/geothermal/electricity-generation.

One of the main challenges facing the geothermal industry in the US is the high upfront cost and risk associated with geothermal exploration and development. Additionally, geothermal resources are location-specific, which limits the potential for widespread deployment. However, the US Department of Energy estimates that the country has a vast untapped geothermal potential, with the ability to provide up to 60 GW of clean, reliable power.[82]

The future of geothermal energy in the US looks promising, with the potential for growth through the development of new geothermal resources, the application of advanced technologies, and the expansion of direct use and heat pump applications.[83] As the country transitions to a cleaner energy future, geothermal energy can play a valuable role in providing a reliable, renewable baseload power source.

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[82] "Geothermal Basics." U.S. Department of Energy. Accessed April 6, 2024. https://www.energy.gov/eere/geothermal/geothermal-basics

[83] 2021 U.S. Geothermal Power Production and District Heating Market Report , Accessed April 6, 2024

Hydropower

Hydropower is one of the oldest and most established forms of renewable energy in the United States. It harnesses the energy of moving water to generate electricity, providing a reliable and flexible source of clean power. In 2022, hydroelectricity accounted for about 6.2% of total U.S. utility-scale electricity generation and 28.7% of total utility-scale renewable electricity generation. Hydroelectricity generation varies annually, and its share of total U.S. electricity generation generally decreased from the 1950's through 2020, mainly because of increases in electricity generation from other sources.[84]

Hydropower development in the US is subject to various federal and state regulations, including the Federal Energy Regulatory Commission (FERC) licensing process, which can be lengthy and complex.[85] However, the industry has benefited from policies such as the Hydropower Production Incentive, which provides incentive payments for electricity generated by qualified hydropower facilities.

While hydropower is a mature technology, there have been ongoing advancements to improve the efficiency, sustainability, and environmental performance of hydropower systems. These include the development of fish-friendly turbines, the use of advanced materials and coatings to reduce wear and tear, and the application of digital technologies to optimize plant operations.[86]

One of the main challenges facing the hydropower industry in the US is the environmental impact of large-scale dams and reservoirs, which can disrupt river ecosystems, affect fish populations, and alter water quality. Additionally, many of the best sites for hydropower development have already been utilized, limiting the potential for new large-scale projects. However, there are opportunities for growth in the US hydropower market through the development of small-scale and low-impact projects, such as run-of-river systems and the addition of hydropower to existing non-powered dams.

As the US continues to transition to a cleaner energy future, hydropower will likely play a crucial role in providing reliable, flexible, and renewable electricity. By addressing environmental concerns and leveraging technological advancements, the hydropower industry can contribute to the nation's clean energy goals while supporting grid stability and resilience.

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[84] "Hydropower." U.S. Energy Information Administration. Accessed April 6, 2024. https://www.eia.gov/energyexplained/hydropower/.
[85] "Hydroelectric Production Incentives." U.S. Department of Energy. Accessed April 6, 2024. Hydropower | Federal Energy Regulatory Commission
[86] "Water Power Technologies Office Projects Map." U.S. Department of Energy. Accessed April 6, 2024. https://www.energy.gov/eere/water/water-power-technologies-office-projects-map

Energy Storage

The rapid growth of the energy storage market creates both risks and opportunities for the insurance industry. Storage technologies like lithium-ion batteries are enabling larger deployments of solar, wind, and distributed energy resources (DERs) on the grid. This transition could expose insurers to new risk landscapes even as it presents chances to build more climate resilient infrastructure.

Growth Trajectory

The global energy storage market is forecast to expand at a 23% CAGR through 2030.[87] Much of this growth will be driven by transportation electrification and the integration of renewable energy. Solar and wind paired with storage can provide resilient backup power during grid outages. However, interconnection barriers, wholesale market participation challenges, and strained supply chains constrain the industry currently.

Emerging Risk Landscapes

While advances in storage technology promise a more renewable and resilient future, their rapid deployment introduces new risks such as battery fires, component failures, and raw material shortages. Lithium-ion batteries contain flammable electrolytes posing safety issues if cells become damaged or overheated. New chemistries also lack extensive track records. At the same time, surging battery demand strains supply chains for key minerals like lithium and cobalt. Proactively addressing vulnerabilities through stringent safety testing, installation safeguards, improved designs, and recycling measures is critical.

Insurance Cost Trends

Even as deployment accelerates, data limitations pose challenges in pricing insurance products for battery storage systems. However, emerging experience is driving incremental improvements. Specialist underwriters focusing on the industry have observed declining average rate quotes as loss ratios moderate given maturing technologies and standards.[88] More data to inform detailed risk profiles will further support cost declines.

Risk Management and Growth Opportunities

Insurers play dual roles in responsibly accelerating storage while managing risks. They can incentivize resilience by offering coverage for storage projects and premium discounts for robust safety features. Developing specialized grid-scale storage insurance products is also an opportunity. Incorporating storage into resilience planning for assets insured against weather disruptions creates mutual benefits. Furthermore, investing in battery innovations, reuse systems, and recycling companies helps strengthen supply chains while hedging materials risks. The net-zero transition requires urgent action, and insurers can leverage storage's potential while keeping pace with evolving risk landscapes.

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[87] "Global energy storage market to experience 23% CAGR until 2030: BNEF." Energy Storage News. Accessed April 6, 2024. https://www.energy-storage.news/global-energy-storage-market-to-experience-23-cagr-until-2030-bnef/.

[88] "Emerging Risks & Opportunities in Battery Energy Storage Insurance." Jenoa. Accessed April 6, 2024. https://jenoa.com/en/insights/emerging-risks-opportunities-in-battery-energy-storage-insurance/.

Solar Energy

In the last decade alone, solar has experienced an average annual growth rate of 24%. Thanks to strong federal policies like the solar Investment Tax Credit, rapidly declining costs, and increasing demand across the private and public sector for clean electricity, there are now more than 162 gigawatts (GW) of solar capacity installed nationwide, enough to power nearly 30 million homes.[89]

Solar has added the most generating capacity to the grid each of the last five years. 53% of all new electric capacity added to the grid in 2023 came from solar, marking the first time in 80 years a renewable energy resource has captured a majority of new capacity added. Solar's increasing competitiveness against other technologies has allowed it to quickly increase its share of total U.S. electrical generation - from just 0.1% in 2010 to over 5% today.

Due to pricing and procurement challenges, solar growth slowed in 2022, with annual deployment 16% lower than in 2021.[90] However, strong deployment in the first three quarters of 2023 has put the industry on track for another record-breaking year, with nearly 33 GW of projected solar installations.[91] The solar industry is expected to nearly triple in cumulative deployment by 2028, as the Inflation Reduction Act provides key tax incentives and long-term certainty that will spark demand for solar and storage and accelerate the transition to renewable energy.

From an insurance viewpoint, risks for large utility-scale solar farms include weather damage, supply chain disruptions, and grid integration complexities from variable output. Innovations in panel efficiency, energy storage integration, and climate resiliency offer opportunities.

Solar PV generation increased by a record 270 TWh (up 26%) in 2022, reaching almost 1300 TWh. It demonstrated the largest absolute generation growth of all renewable technologies in 2022, surpassing wind for the first time in history.[92] Solar's increasing competitiveness against other technologies has allowed it to quickly increase its share of total U.S. electrical generation - from just 0.1% in 2010 to over 5% today.[93] This rapid growth has been driven by declining costs, supportive policies, and increasing demand for clean energy. However, the solar industry also faces significant risks and challenges that must be addressed to ensure its long-term sustainability and competitiveness.

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[89] "Solar Industry Research & Data." Solar Energy Industries Association (SEIA). Accessed April 6, 2024. https://www.seia.org/solar-industry-research-data.

[90] "Solar Market Insight Report 2022 Year in Review." Solar Energy Industries Association (SEIA). Accessed April 6, 2024. https://www.seia.org/research-resources/solar-market-insight-report-2022-year-review

[91] "Chart: The US installed more solar in 2023 than ever before." Canary Media, Accessed April 6, 2024. https://www.canarymedia.com/articles/solar/chart-the-us-installed-more-solar-in-2023-than-ever-before

[92] Solar - IEA Accessed April 6, 2024

[93] Solar Industry Research Data | SEIA Accessed April 6, 2024

Gap Analysis and Competition Comparison

As the solar energy industry continues to grow and evolve, comprehensive and innovative coverage solutions from insurers will help to meet the unique risks and challenges faced by solar projects. This section will provide a gap analysis comparing the solar insurance offerings of various insurance firms in the US, Europe, and other parts of the world. Additionally, it will explore potential ideas for new insurance products and services that could support the further growth and development of the solar energy industry.

Several insurance companies offer coverage for solar energy projects, including:

1. Munich Re: Offers a PV Warranty Insurance.[94]
2. Chubb: Provides a range of insurance solutions for solar energy projects, including property, liability, and specialty coverages.[95]
3. Allianz: Offers a comprehensive solar energy insurance program, including all-risk property damage, business interruption, and liability coverage[96].
4. Swiss Re: Provides a range of insurance solutions for solar energy projects, including property damage, and construction risk.[97]

Despite the relative maturity of the European solar insurance market, there are still opportunities for insurers to innovate and expand their offerings, particularly in terms of coverage for emerging technologies like floating solar and agrivoltaics.
To support the continued growth and development of the solar energy industry, insurers could consider offering new and innovative products and services, such as:

1. Performance guarantee insurance: Coverage for solar projects that guarantees a minimum level of energy output or financial performance, helping to reduce risk for investors and lenders
2. Cyber insurance: Coverage for solar projects against risks related to data breaches, cyber-attacks, and other digital threats, which are becoming increasingly common as solar systems become more interconnected and automated
3. Decommissioning and recycling insurance: Coverage for the costs and liabilities associated with decommissioning and recycling solar panels at end of life, helping to ensure responsible and sustainable management of solar waste
4. Integrated risk management services: Offering risk assessment, mitigation, and management services alongside traditional insurance coverage, helping solar project developers and operators to identify and address risks proactively

[94] PV Warranty Insurance backing your solar investment | Munich Re Accessed April 6, 2024
[95] Renewable & Alternative Energy Industry Insurance Solutions | Chubb Accessed April 6, 2024
[96] Solar Power Operational All Risks Policy Overview | Allianz Insurance Accessed April 6, 2024
[97]"Energy Insurance Solutions." Swiss Re Corporate Solutions. Accessed April 6, 2024. https://corporatesolutions.swissre.com/insurance-solutions/energy.html.

Policy Landscape
The growth of solar energy in the US has been supported by a range of federal and state-level policies, including tax credits, net metering, renewable portfolio standards, and interconnection standards. The most important federal policy has been the Investment Tax Credit (ITC), which provides a 26% tax credit for residential and commercial solar systems.[98] The ITC has been extended several times and is currently set to phase down to 10% for commercial systems and expire for residential systems by 2024.

At the state level, California has been a leader in solar energy policy, with a renewable portfolio standard of 60% by 2030 and 100% clean electricity by 2045.[99] Other states, such as New York, New Jersey, and Massachusetts, have also set ambitious solar energy targets and have implemented policies to support deployment.[100]

However, the policy landscape for solar energy is also subject to uncertainty and change. The recent shift in federal policy under the Biden administration, including the proposed extension and expansion of the ITC, could provide a significant boost to the industry. On the other hand, some states have taken steps to roll back net metering policies or impose new fees on solar customers, which could slow adoption.[101]

Risk Management Solutions
To address the risks and opportunities of solar energy, the industry and its stakeholders are developing a range of risk management solutions. One key solution is the use of parametric insurance structures, which provide coverage based on predefined triggers or indices, such as solar irradiance, temperature, or grid availability. Parametric insurance can provide faster and more transparent claims payments, as well as incentives for risk mitigation and resilience.
Another risk management solution is the use of resilience incentives, such as premium discounts or coverage enhancements for solar projects that incorporate best practices for design, operations, and maintenance. These incentives can help to reduce the frequency and severity of losses, as well as improve the overall performance and reliability of solar energy systems.

The solar energy industry presents significant opportunities for climate tech investment and risk management, but also faces a range of challenges and uncertainties. To achieve the full potential of solar energy, the industry and its stakeholders must address these risks through a combination of technology innovation, policy support, and collaboration. Insurers can play a key role in this effort by providing risk transfer solutions, as well as investing in research and development to improve the resilience and sustainability of solar energy systems. By working together, the solar industry and the insurance sector can help to accelerate the transition to a clean energy future and create value for all stakeholders.

[98] Solar Investment Tax Credit (ITC) | SEIA Accessed April 6, 2024
[99] Renewables Portfolio Standard (RPS) Program Accessed April 6, 2024
[100] State Solar Policy | SEIA Accessed April 6, 2024
[101] State Solar Policy | SEIA Accessed April 6, 2024

Electric Transportation

Electric transportation, encompassing electric vehicles (EVs), e-mobility, and associated charging infrastructure, represents a major opportunity within the climate tech landscape. Rapid growth is anticipated in this sector driven by improving battery technology, declining costs, evolving policy landscapes, and increasing climate change concerns. However, risks also exist related to new technologies that the insurance industry needs to consider.

EV Sales Growth and Charging Infrastructure Needs

Global EV sales have grown rapidly from only 120,000 vehicles in 2013 to over 6.6 million by 2021.[102] Growth is projected to accelerate further, with EVs forecast to account for over 60% of new car sales globally by 2040.[103] This phenomenal growth is being enabled by better battery performance and declining costs, along with policy support and automaker commitments to phase out internal combustion engine (ICE) vehicles.

As the number of EVs on roads multiplies, charging infrastructure build-out emerges as a critical enabler. Recognizing infrastructure needs, governments globally have announced major funding commitments, like the $7.5 billion for EV chargers in the U.S. Infrastructure Bill.[104] Still, investments lag demand growth, underscoring risks around insufficient convenient charging access inhibiting further adoption. The EV insurance market is expected to grow significantly, from $49 billion in 2022 to a projected $507 billion by 2033, with a compound annual growth rate (CAGR) of over 19%.[105]

Commercial Vehicle, Aviation, and Shipping Electrification

Beyond passenger vehicles, electrification of commercial vehicles and transportation sectors like aviation and shipping also presents major opportunities while posing technology and risk management challenges.

Electric commercial vehicles are gaining share rapidly, aided by lower operating costs and emissions regulations. Electrified buses and trucks require tailored insurance products that account for unique risk profiles of new drivetrains and battery technologies. Aviation and shipping remain harder to abate but demonstrations of battery and hydrogen fuel cell powered planes and ships signal future adoption. Insurers can support these transitions by funding pilots and offering risk management expertise.

Risks – Battery Defects, Grid Overload

While the EV transition presents opportunities, risks around evolving battery chemistries, potential defects, and grid overload challenges also bear monitoring. Most concerning, EV fires can burn hotter and longer than ICE counterparts. Insurers can incentivize safety through

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[102] "Global EV Data Explorer." International Energy Agency (IEA). Accessed April 6, 2024. https://www.iea.org/articles/global-ev-data-explorer.

[103] "Electric Vehicles Are Forecast to Be Half of Global Car Sales by 2035." Goldman Sachs. Accessed April 6, 2024. https://www.goldmansachs.com/intelligence/pages/electric-vehicles-are-forecast-to-be-half-of-global-car-sales-by-2035.html

[104] "Fact Sheet: The Bipartisan Infrastructure Deal." The White House. November 8, 2021. https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/08/fact-sheet-the-bipartisan-infrastructure-deal/. Accessed April 6, 2024

[105] "EV Insurance: Impact of Electric Vehicles on Insurance." Be Insure. Accessed April 6, 2024. https://beinsure.com/ev-insurance-impact-of-electric-vehicles-on-insurance/.

products and advising on issues like emergency response protocols. Grid overload risks may also emerge as clusters of EVs simultaneously charge during peak times, necessitating insurance products that account for potential outages.

Electric transportation has emerged as a key solution for reducing greenhouse gas emissions and mitigating the impacts of climate change. In recent years, the adoption of electric vehicles (EVs) has accelerated rapidly, driven by falling battery costs, improving vehicle performance, and supportive government policies. . In 2022, global EV sales reached 10.5 million units, representing a 68% increase from the previous year and accounting for 14% of total passenger vehicle sales. Electric car sales in the United States – the third largest market – increased 55% in 2022, reaching a sales share of 8%. [106]

Despite this impressive growth, the transition to electric transportation still faces significant challenges and risks, including the need for widespread charging infrastructure, the impact of EV adoption on the electricity grid, and the potential for supply chain disruptions and critical mineral shortages. As the EV market continues to evolve and mature, it is crucial for stakeholders, including policymakers, automakers, utilities, and insurers, to collaborate and innovate to address these challenges and unlock the full potential of electric transportation.

Gap Analysis

As the electric vehicle market continues to grow, insurance companies are developing specialized products and services to meet the unique needs of EV manufacturers, charging infrastructure providers, and fleet operators. These offerings aim to address the specific risks and challenges faced by EV companies, such as battery performance, charging infrastructure reliability, and cybersecurity threats.

Battery Performance Insurance: One of the key concerns for EV companies is the performance and longevity of vehicle batteries. Battery performance insurance products can help mitigate the financial risks associated with battery degradation and failure. These policies may cover the costs of battery repair, replacement, or disposal, as well as any associated business interruption losses.

Charging Infrastructure Insurance: Another critical area for EV companies is the deployment and maintenance of charging infrastructure. Charging infrastructure insurance can provide coverage for the installation, operation, and repair of EV charging stations, as well as any associated liabilities or business interruption losses. These policies may also include coverage for cybersecurity risks, such as data breaches or system failures. Aligned have developed specialized charging infrastructure insurance products for EV companies and charging station operators[107]

[106] "Executive Summary." International Energy Agency (IEA). Accessed April 6, 2024. https://www.iea.org/reports/global-ev-outlook-2023/executive-summary.
[107] "Electric Vehicle Charging Station Insurance." Aligned Insurance. Accessed April 6, 2024. https://www.alignedinsurance.com/electric-vehicle-charging-station-insurance/.

Cybersecurity Insurance: As EVs and charging infrastructure become increasingly connected and digitized, cybersecurity risks are a growing concern for EV companies. Cybersecurity insurance can provide coverage for losses resulting from cyber-attacks, data breaches, and system failures, as well as any associated legal and regulatory liabilities. These policies may also include risk assessment and incident response services to help EV companies identify and mitigate potential vulnerabilities.

Fleet Electrification Services: For companies and organizations transitioning their vehicle fleets to EVs, insurers are offering specialized fleet electrification services. These services may include risk assessment and consulting, data analytics and telematics, and customized insurance coverage for EV fleets. By leveraging data and expertise, insurers can help fleet operators optimize their EV deployment, reduce costs, and improve safety and sustainability. Insurers such as Allianz Insurance have enhanced its Motor Fleet (15 or more vehicles) and Small Fleet (4-14 vehicles) products to provide cover for electric vehicles as well as a wide range of services to support fleet electrification.[108]

Policy Landscape

The growth of electric transportation in the US has been driven by a combination of federal and state policies, including vehicle emissions standards, tax incentives, and infrastructure investments. At the federal level, the most significant policy has been the EV tax credit, which provides a credit of up to $7,500 for the purchase of a new EV.[109] The credit has been instrumental in driving EV adoption, but it has also been subject to controversy and uncertainty, with the credit phasing out for some automakers and the eligibility criteria changing over time.

In addition to the EV tax credit, the Biden administration has proposed several new policies to accelerate the transition to electric transportation, including:

1. The Bipartisan Infrastructure Law: A $7.5 billion in EV charging, $10 billion in clean transportation, and over $7 billion in EV battery components, critical minerals, and materials.[110]
2. The Inflation Reduction Act: The bill includes an estimated $369 billion in expenditures related to "climate change and energy security," including tax and other incentives to promote US production of electric vehicles ("EVs"), renewable energy technologies, and critical minerals, representing the "single biggest climate investment in US history.[111]

[108] "Allianz enhances EV insurance proposition." Fleet News, September 22, 2021. https://www.fleetnews.co.uk/news/latest-news/2021/09/22/allianz-enhances-ev-insurance-proposition.
[109] "How EV Tax Credits Work." Car and Driver. Accessed April 6, 2024. https://www.caranddriver.com/shopping-advice/a32586259/how-ev-tax-credits-work/.
[110] "Fact Sheet: Biden-Harris Administration Announces New Standards and Major Progress for a Made-in-America National Network of Electric Vehicle Chargers." The White House. February 15, 2023. https://www.whitehouse.gov/briefing-room/statements-releases/2023/02/15/fact-sheet-biden-harris-administration-announces-new-standards-and-major-progress-for-a-made-in-america-national-network-of-electric-vehicle-chargers/
[111] "New US climate bill seeks onshore electric vehicle supply chain." White & Case. Accessed April 6, 2024. https://www.whitecase.com/insight-alert/new-us-climate-bill-seeks-onshore-electric-vehicle-supply-chain.

At the state level, California has been a leader in driving the transition to electric transportation, with a goal of phasing out the sale of new gasoline-powered vehicles by 2035.[112] Other states, such as New York, New Jersey, and Washington, have also adopted ambitious EV targets and policies, such as zero-emission vehicle mandates, EV rebates, and charging infrastructure investments. [113]

However, the policy landscape for electric transportation is also subject to uncertainty and variability across different states and regions. The lack of a consistent and comprehensive national policy framework for EVs has created challenges for automakers, charging providers, and consumers, who must navigate a patchwork of different regulations and incentives across different jurisdictions.

Some of the key liability exposures related to EVs and charging infrastructure include:

1. Battery safety: EV batteries can pose fire and explosion risks, especially in the event of a crash, overcharging, or manufacturing defect. These risks can create liabilities for automakers, battery suppliers, and charging providers, as well as first responders and emergency services.
2. Cybersecurity: EVs and charging stations are increasingly connected and digitized, which creates new vulnerabilities to cyber-attacks, data breaches, and privacy violations. These risks can create liabilities for automakers, charging providers, and fleet operators, as well as consumers and third parties.
3. Product liability: EVs and charging equipment are complex and technologically advanced products that are subject to strict safety and performance standards. Any defects, malfunctions, or failures in these products can create liabilities for manufacturers, suppliers, and distributors, as well as retailers and service providers.
4. Infrastructure damage: The installation and operation of EV charging infrastructure can cause damage to buildings, sidewalks, streets, and utilities, which can create liabilities for property owners, charging providers, and contractors. The weight and size of EVs can also cause increased wear and tear on roads and bridges, which can create liabilities for transportation agencies and infrastructure managers.
5. Environmental liabilities: The production, use, and disposal of EVs and batteries can create environmental liabilities related to resource extraction, greenhouse gas emissions, and waste management. These liabilities can affect automakers, battery suppliers, recyclers, and policymakers, as well as communities and ecosystems.

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[112] "Governor Newsom Announces California Will Phase Out Gasoline-Powered Cars, Drastically Reduce Greenhouse Gas Emissions & Improve Air Quality." California Air Resources Board (ARB). Accessed April 6, 2024. https://ww2.arb.ca.gov/news/governor-newsom-announces-california-will-phase-out-gasoline-powered-cars-drastically-reduce

[113] "U.S. State Clean Vehicle Policies and Incentives." Center for Climate and Energy Solutions (C2ES). Accessed April 6, 2024. https://www.c2es.org/document/us-state-clean-vehicle-policies-and-incentives/.

Risk Management Solutions

To address the unique risks and opportunities of electric transportation, insurers and EV companies are developing and adopting new risk management solutions. One key area of innovation is the use of telematics and advanced driver assistance systems (ADAS) to assess and mitigate the risks of EV operation. By collecting and analyzing real-time data on EV performance, driving behavior, and environmental conditions, insurers can better understand and price the risks of EV insurance, as well as provide personalized feedback and incentives for safe and efficient driving.

Another important risk management solution is the development of specialized EV repair and maintenance networks. Unlike traditional vehicles, EVs require specific skills, tools, and parts to diagnose and fix problems related to batteries, power electronics, and software. To ensure the safety, reliability, and performance of EVs, insurers are partnering with automakers, dealers, and independent repair shops to establish certified EV repair networks that meet rigorous standards for training, equipment, and quality control. These networks can help to reduce the costs and downtime of EV repairs, as well as improve customer satisfaction and loyalty.

In addition, insurers are exploring the use of advanced analytics and artificial intelligence (AI) to predict and prevent EV risks. By leveraging large datasets from telematics, claims, and other sources, insurers can identify patterns and correlations that indicate the likelihood and severity of EV accidents, thefts, and breakdowns. Based on these insights, insurers can develop proactive risk management services, such as predictive maintenance alerts, anti-theft device recommendations, or driver coaching programs, that help EV owners to avoid or mitigate potential losses.[114]

The electric transportation revolution presents significant opportunities and challenges for insurers, as well as for automakers, charging providers, policymakers, and consumers. As EVs become more affordable, available, and attractive to buyers, they are poised to disrupt the traditional vehicle market and create new ecosystems of products, services, and experiences. To enable and accelerate this transition, insurers can develop innovative and specialized insurance solutions that address the unique risks and needs of EVs and charging infrastructure, while also providing value-added services and partnerships that enhance the EV ownership experience.

However, the EV market is still in its early stages and faces significant uncertainties and barriers, such as supply chain constraints, charging infrastructure gaps, consumer awareness and acceptance, and policy and regulatory challenges. To navigate these complexities and capture the full potential of electric transportation, insurers can work closely with stakeholders

[114] "Insurance 2030: The Impact of AI on the Future of Insurance." McKinsey & Company. Accessed April 6, 2024. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/insurance-2030-the-impact-of-ai-on-the-future-of-insurance.

across the EV value chain, including automakers, charging providers, utilities, regulators, and consumers, to co-create and co-deliver integrated and seamless EV solutions.

Moreover, insurers can also embrace and leverage the power of data, analytics, and technology to better understand, assess, and manage the risks and opportunities of electric transportation. By harnessing the insights and capabilities of telematics, AI, blockchain, and other emerging technologies, insurers can not only improve the efficiency, accuracy, and customization of EV insurance, but also create new sources of value and differentiation in the market.

Ultimately, the success of electric transportation will depend on the ability of all stakeholders, including insurers, to collaborate, innovate, and adapt to the rapidly evolving landscape of mobility. By working together to address the technical, economic, social, and environmental challenges of EVs, and by creating compelling and sustainable value propositions for EV owners and society at large, insurers can play a vital role in shaping the future of transportation and contributing to a cleaner, safer, and more resilient world.