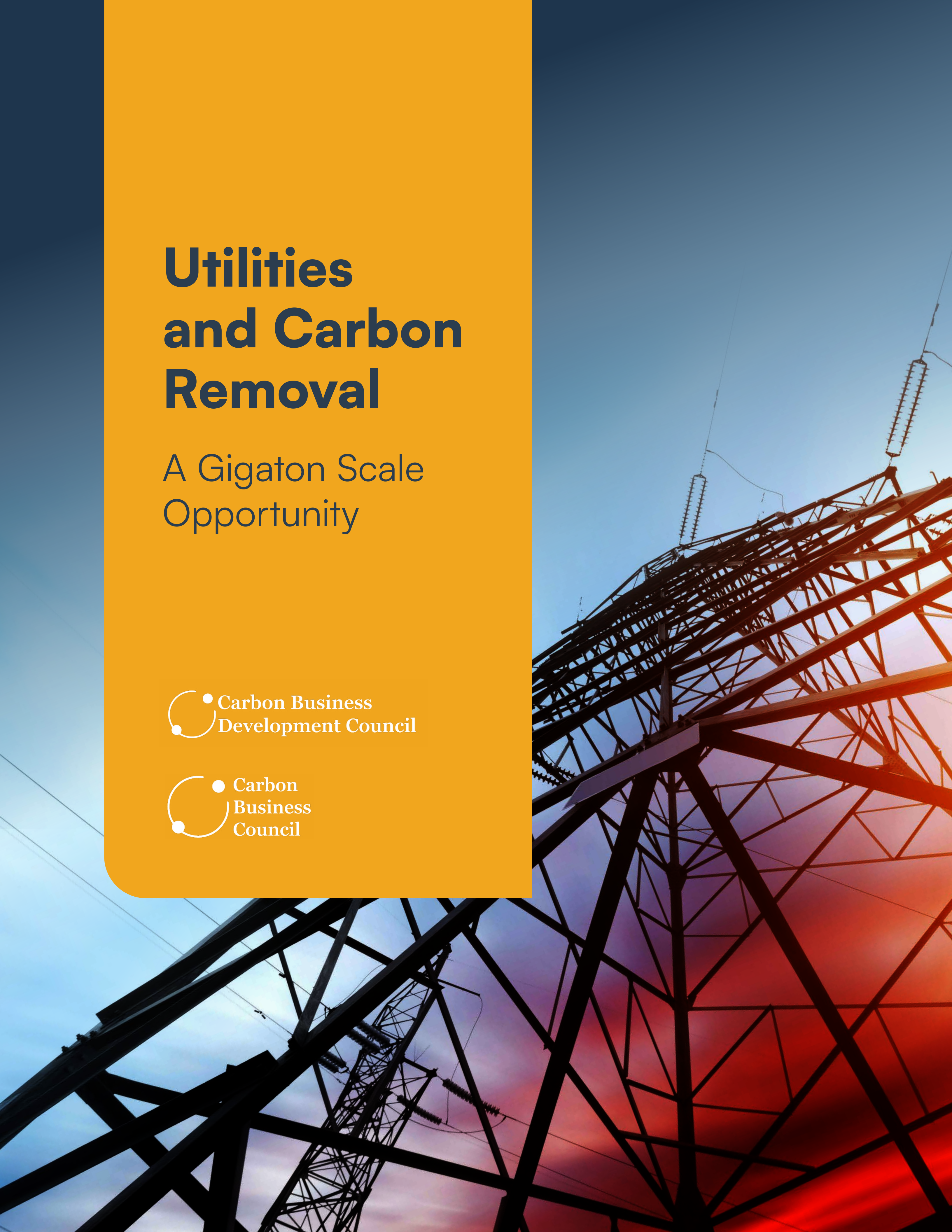
Utilities and Carbon Removal

A Gigaton Scale Opportunity



Carbon Business Development Council

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Carbon Business Development Council

The Carbon Business Development Council (CBDC) is focused on responsibly reaching gigaton-scale carbon removal by supporting innovators who are leading the charge and educating the general public about carbon removal. We act in the public good to help ensure that carbon removal scales responsibly.

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The Carbon Business Council (CO2BC), a member-driven and tech-neutral trade association of companies unified to restore the climate, is the preeminent industry voice for carbon management innovators. Together, the nonprofit coalition represents more than 100 companies across six continents with more than $16.5 billion dollars in combined assets.

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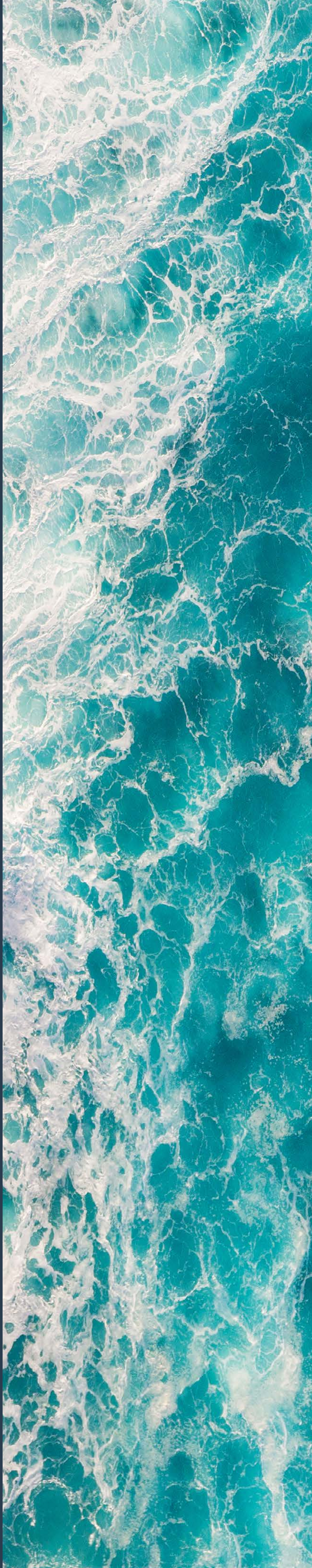


EXECUTIVE SUMMARY

Utilities x Carbon Removal

Energy utilities and Carbon Dioxide Removal (CDR) are important and parallel threads on the path to deep decarbonization. Utilities, especially electric utilities, are leading the energy sector decarbonization efforts — integrating gigawatts of new clean energy resources each year while preparing for surging demand from new climate loads, including transportation and building electrification, clean fuels production, and now carbon removal. **Carbon Removal,** a suite of pathways to draw carbon down from the atmosphere, is emerging as a necessary complement to direct emissions reduction measures for legacy emissions and hard-to-abate sectors.

In this report, we examine four key threads which intertwine energy utilities and carbon removal, articulating synergistic opportunities and challenges and identifying key questions for industry and policy thought leaders:

- **Utility Decarbonization:** What role could CDR play on energy utilities' path to net zero?
- **Climate Loads:** How can energy-intensive CDR access low-cost, low-carbon energy?
- **Utility-CDR Nexus:** How and where can CDR pathways be integrated into utility assets and operations?
- **Utility Regulatory Ecosystem:** How might regulators assess and weight utility CDR investments?

In developing this report, it is apparent that partnerships between the two industries will be critical for their respective success — and achieving those partnerships will require additional engagement, expanded technical expertise, and collaborative policy development on both sides. While many of these issues remain underdeveloped, we strive to identify key recommendations and questions for policymakers and industry thought leaders.

Given the breadth of the subject matter, the report is broken into four freestanding chapters, and is likely to cover 'basics' that may feel redundant to experts within each industry. With that context, we provide the following recommendations for readers to maximize value from the report:

First, for **utilities and utility regulators,** *Chapter 1* considers the role of CDR in broader utility decarbonization plans, identifying the potential need for 'last-mile' reductions to complement a broader 'reductions-first' decarbonization strategy, providing recommendations for incorporating CDR into resource planning models, and considering the impact of climate policy design on CDR consideration.

Second, for **CDR developers,** *Chapter 2* considers how energy-intensive CDR projects can access low-cost, low-carbon electricity, providing a primer on the regulated and deregulated energy markets, utility tariffs and behind-the-meter options, and identifying emerging partnership opportunities to craft programs for emerging industrial climate loads.

Third, for **utilities and CDR developers,** *Chapter 3* explores specific synergies between utility assets, operations, and CDR, exploring utilities' roles as land stewards, capital project developers, and operators of large industrial facilities and identifies opportunities for synergistic utility investments in CDR.

Finally, for **utilities and policymakers,** *Chapter 4* contemplates the unique characteristics of utility regulation and their potential to support best practices in CDR procurement by utilities, integrating a range of policy, economic, and stakeholder concerns to ensure positive policy outcomes.

Key Themes

CHAPTER I.

Utility Decarbonization — CDR on the Path to Net Zero

Energy utilities are the backbone of the modern economy — electricity, natural gas, heating, and other energy utilities represent trillions of dollars in economic activity and provide the basic services which power the world.[1] Energy utilities are broadly viewed as integral to the energy transition, necessitating both urgent cleanup of carbon emissions within existing operations and a significant expansion to serve emerging climate loads, including electrified buildings, heating, and industry, production of clean fuels like hydrogen, engineered and other energy-intensive carbon removal, alongside other emerging loads like hyperscalers for artificial intelligence.

In Chapter 1, we examine the role CDR may play in taking energy utilities to the deep decarbonization finish line — supporting reductions in the 'last mile' which cannot be technically or economically abated through clean energy sources. In line with leading technical analysis, we believe the vast majority of electricity emissions will be addressed through clean energy and storage, including emerging clean firm energy sources and long duration storage resources. We also identify the potential for gaps, such as power engineering constraints necessitating dispatchable generation in urban areas, geographical limitations (particularly for isolated grids), and the urgency of rapid reductions, which may be difficult to meet with new clean energy alone.

In this section, we provide specific recommendations for utilities and policymakers for the consideration of CDR alongside clean energy in the modeling and planning space, endorsing 'twin targets' which identify opportunities for removals while preventing their misuse in applications which are better suited to direct reductions, which is and must remain the priority for energy utilities. We conclude this chapter with a discussion of utility clean energy and emissions policy frameworks, endorsing the ongoing transition from *clean energy-based* climate policies, such as renewable portfolio standards, to more holistic *emissions-based* climate policies, which directly target and analyze carbon emissions and are typically accompanied by more robust technical analysis and planning.

CHAPTER 2.

Climate Loads — Powering Energy-Intensive Carbon Removals

CDR is poised to serve a key role in addressing emissions for activities which may be hard to abate, and is expected to grow into a major industry in coming years. Many CDR pathways require the use of energy as a key input, especially electricity, and will need to have access to low-cost, reliable, emissions-free energy to achieve their full potential.

In Chapter 2, we parse out the key technical, economic, and policy questions presented in powering energy-intensive CDR, seeking to demystify the infamously complex landscape of regulated and deregulated electricity options into a generalized framework of decisions for developers. Specifically, provide a primer on regulated and deregulated electric service, the tariffs and rates likely to be encountered under either paradigm, pathways and pitfalls associated with behind-the-meter service, and the texture of rates and emissions from utility service territories across the United States.

1 While the broader utility segment has substantial synergistic potential with CDR, this report focuses on energy utilities — primarily electricity — as the largest utility segment and that which has the greatest intersecting decarbonization potential with CDR.

In this section, we provide specific recommendations for developers to identify key questions upfront in project development and to coordinate closely with local utilities and regulators to assess options, concluding with a brief discussion of emerging tariffs designed collaboratively between utilities and emerging industrial loads (primarily data centers) which may inform future collaboration between utilities and CDR developers.

CHAPTER 3.

The Utility-CDR Nexus — Utility Assets and Operations

For most utilities, the energy commodity itself is only about half of the utility's total economic activity. Beyond serving kilowatt-hours and therms, utilities operate extensive infrastructure networks, including transmission and distribution service (pipes and wires) and, for many utilities, the portfolio of power generation resources which serve energy to customers. In this role, utilities are extensive land owners and land managers, with many utilities owning and stewarding extensive forests and other wildlands surrounding hydroelectric assets and transmission infrastructure.

In Chapter 3, we explore what direct potential for CDR could exist within the utility infrastructure and operational space, providing a taxonomy of removal pathways and linking them to specific elements of the utility vertical. Moreover, we identify how these pathways can be more than good environmental practice — they may present opportunities to generate revenue which offsets cost drivers for utilities, particularly in the context of improved forestry management in which emerging best practices can reduce fire risk, vegetation handling and disposal costs, and generate carbon removal revenue. Similarly, creative partnerships may be economically beneficial for utilities in integrating removal pathways into their thermal assets, many of which generate waste heat, or to make beneficial use of unused barrier spaces around high-voltage infrastructure through the application of biochar or enhanced weathering (where applicable).

In this section, we seek to identify 'win-win' opportunities for CDR developers and utilities in support of further exploration and due diligence, recognizing that projects within the regulated utility ecosystem will need to present economic benefits for utility customers while navigating complex technical and regulatory constraints inherent in the utility operating world.

CHAPTER 4.

The Utility Regulatory Ecosystem — Carbon Removals on the Commission Docket

Energy utilities are a heavily regulated segment of the economy in the United States — a unique characteristic which may support both early action on carbon removal and provide for a robust process to vet and approve carbon removal projects which consider environmental, economic, and community benefits, and other policy considerations.

In Chapter 4, we provide a primer on how the utility regulatory system operates, the emerging sphere of environmental regulation, particularly for electric utilities, and how this regulatory ecosystem has been applied to early investments in other climate technologies, ranging from high-efficiency light bulbs to the transformative investments in renewables and energy storage currently underway. We also identify the inherently local natural of utility regulation — much of which takes place at the state level — and the need to consider the importance of community impacts, both positive and negative, for carbon removal proposals which may go before a regulatory commission.

In this section, we identify both the precedent for regulated investments in climate technologies which pave a clear path for utility investments in CDR, while highlighting the novel policy questions which are likely to arise as utilities undertake more serious consideration of CDR within their decarbonization portfolios.

Key Recommendations

We conclude our report with a discussion of recommendations, summarized as follows:

1. Utility Decarbonization | *CDR on the Path to Net Zero*

- Utilities and policymakers should incorporate CDR as a decarbonization strategy within Integrated Resource Plans, recognizing its critical role in addressing residual, residual and legacy emissions.
- Utilities and policymakers should normalize the 'twin targets' policy framework in net zero targets, which establishes defined goals and guardrails for the role of CDR to support its development while ensuring that the important work of direct emissions reductions (i.e. through clean energy) continues.
- Utilities and policymakers should simultaneously consider the role of emissions-based policies that directly target carbon, rather than just clean energy production, to ensure CDR and other non-energy emissions reduction pathways are incorporated into long-term planning.
- Utilities and policymakers should proactively consider the potential load impacts of new CDR resources and identify strategies to mitigate the environmental and reliability impacts of these new loads.

2. Climate Loads | *Powering Energy-Intensive CDR*

- CDR companies should proactively plan for energy supply while considering pairing with carbon storage locations (where needed), and should become familiar with the tariffs, rules, and techno-economic impacts of different energy options.
- CDR companies should collectively and individually work with utilities to develop new policy frameworks and tariffs to enable CDR access to decarbonized energy supply at reasonable costs.
- CDR companies should explore different operational configurations to enable economic, reliability, and environmental benefits through load flexibility and on-site resources.

3. The Utility-CDR Nexus | *Assets and Operations*

- Utilities should consider the role of utility assets and operations for pursuing CDR projects, with specific focus on projects with potential for operational benefits and projects which may benefit the local community which the utility serves.
- CDR developers should proactively engage utilities to understand their needs and develop business models aligned with high-potential utility demand which are structured to integrate into or dovetail with utility processes.
- Utilities should assess their properties and easements for CDR projects that integrate with existing forest management and wildfire risk mitigation activities, improving carbon and economic outcomes for existing vegetation management programs.
- Utilities should consider capital project initiatives to include green materials, particularly the incorporation of carbon-negative cement, low-carbon steel, and alternative wood products into large construction projects through materials quotas or bidding preferences.
- Utilities should consider opportunities to integrate CDR into other operations, including bioenergy for power generation and fleets and integration of CDR into existing processes for thermal power plants.

4. Utility Regulation | *Policymakers and Stakeholders*

- Utility and CDR thought leaders should lean into the potential benefits of the utility regulatory ecosystem to drive early investments and leverage the interrogative process to develop best practices and models in CDR procurement in and beyond the electric sector.

- Policymakers should extend their legacy of market transformation through utility procurement to CDR, a parallel to the robust history of utility-led commercialization of solar, energy storage, light emitting diodes, and many other technologies over decades.
- Utilities and policymakers should leverage utility experience with capital projects and access to low-cost capital to facilitate early CDR deployment at larger scales, again with parallels to solar resource project growth.
- Utilities and policymakers should use the regulated utility planning framework to support the development of best practices in CDR deployment, facilitating both policymaker deliberation and broad stakeholder engagement to weigh economic, environmental, and community tradeoffs and co-benefits.

CHAPTER 1

Utility Decarbonization — CDR on the Path to Net Zero

ENABLING CARBON REMOVAL IN UTILITY DECARBONIZATION

In the grand arc of deep decarbonization, the path both begins and ends with energy utilities. The arc begins with early ambition and progress from utilities — implementing clean energy solutions far ahead of other economic sectors — and ends with a critical assist from decarbonized utilities, providing emissions-free energy to power and heat harder-to-decarbonize sectors, including transportation, buildings, and industry. Policymakers around the world have enshrined this path in technical analysis, transition pathways, and climate policies.

While energy utilities, particularly electric utilities, are making great strides, there is increasing recognition that challenges remain on the path to net zero for utility sector emissions.

- **Deploy.** First and foremost, long-term decarbonization studies show that utilities should rapidly deploy currently commercial clean energy and storage technologies — solar, wind, and energy storage, planned thoughtfully and integrated with transmission and demand-side management, capable of driving deep emissions reductions in the near future.
- **Innovate.** Second, and critically for this report, these analyses suggest that emerging technologies — including CDR — will be necessary to achieving net zero.

Technical limitations to solar, wind and storage, set against technological, economic, and geographic questions for emerging clean energy technologies, suggest a role for emerging technologies necessary to resolve residual 'last-mile' carbon emissions from remaining conventional combustion on the electric system. There are several driving technical constraints behind these last-mile emissions, and many utilities are just beginning to identify and engage with these constraints in a robust fashion. While it is likely that emerging clean energy generation will address gaps, it is also very likely that CDR technologies will be in many cases necessary and in other cases the compelling choice among limited and expensive options.

In this section, we explore how utilities can better integrate CDR into their modeling, planning, and procurement frameworks for deep decarbonization, providing technical guidance on incorporating CDR pathways while parsing the impacts and considerations of best practices in policy design. While we endorse integrated modeling for deeper technical and economic engagement with CDR as a potential resource, a bifurcated procurement approach — “twin targets” — is critical to ensure utility decarbonization strategies retain their primary focus on direct emissions reductions within the sector.

Finally, we conclude with a recognition of the legacy and non-energy (“Scope 3”) emissions from utilities, which are historically significant and have no other clear resolution beyond carbon management.

Key Recommendations

- **Recognize the Need for Technology Innovation:** Utility decarbonization modeling and planning should recognize the emerging consensus that technology innovation, including carbon management strategies, will be necessary on the path to net zero, and should integrate best practices in technical analysis accordingly.
- **Model and Target Carbon Directly:** Utility modeling and policy frameworks should evolve from *clean energy-based analyses* to *emissions-based analyses* to facilitate more substantive engagement with the potential role of CDR in meeting decarbonization targets in parallel with clean energy; this analysis can inform appropriate, distinct targets for clean energy and carbon management.

Primer: Decarbonizing Electric Utilities

The electric sector has extensive decarbonization potential with current technologies — solar, wind, and energy storage can support deep decarbonization on regionally interconnected grids — yet studies have increasingly identified gaps that must be addressed with new technologies and strategies which have not yet been resolved. In this section, we provide a technical background on the utility decarbonization process and the limitations which may drive the need for carbon removal strategies.

Among industry segments, the electric sector is arguably farther along the decarbonization pathway than any other sector of the economy. While much of the global economy remains un- or under-regulated on climate, policies for utility decarbonization have become commonplace, with many jurisdictions establishing aggressive legal requirements for immediate decarbonization actions ramping up to full decarbonization within two to three decades. As of December 2023, twenty-nine states have passed clean energy policies[2] with twenty-three committing to 100% clean energy goals[3]. At least twenty-five utilities have publicly stated goals to meet 80% requirements — either 80% reductions in emissions or 80% clean energy — by 2030[4].

Electric utilities have made great strides in clean energy investments since 2015, and the pace of change is expected to increase rapidly on the path to 2030. Solar and wind resource deployment has skyrocketed, and some large regions are seeing over a third of their energy sourced from renewables.

2 Renewable & Clean Energy Standards.” NC Clean Energy Technology Center, DSIRE, Dec. 2023, https://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2023/12/RPS-CES-Dec2023-1.pdf.

3 “Table of 100% Clean Energy States.” *Clean Energy States Alliance*, https://www.cesa.org/projects/100-clean-energy-collaborative/guide/table-of-100-clean-energy-states/. Accessed 6 Sept. 2024.

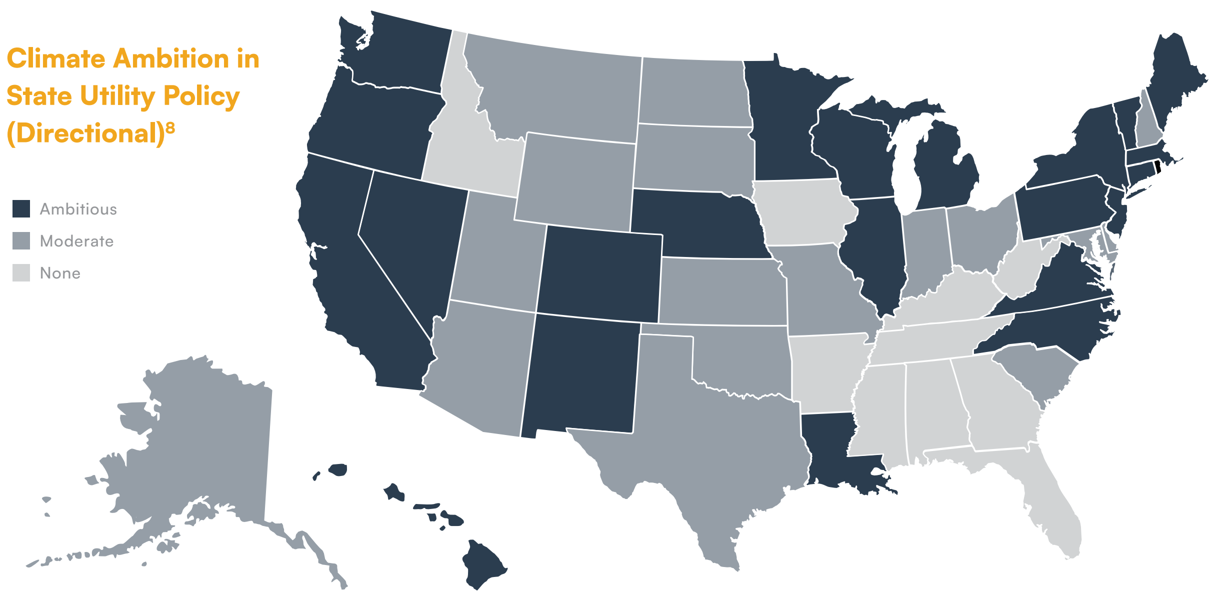
4 “These 25 Utilities Are United by One Big Goal: 80% Less CO_2 by 2030.” *Canary Media*, 28 Sept. 2023, https://www.canarymedia.com/articles/utilities/these-25-utilities-are-united-by-one-big-goal-80-less-co2-by-2030.

Electric utilities typically procure a mix of energy resources to serve customer load, which must be balanced instantaneously at all times to maintain reliable service. Energy resources include: thermal resources, such natural gas, oil, and coal; conventional clean energy resources, including hydroelectricity and nuclear power; renewable technologies, including solar, wind, geothermal, and bioenergy; and energy storage, including lithium-ion batteries and pumped storage hydro. Historically, the vast majority of clean energy has come from hydroelectric and nuclear resources, with major growth in solar, wind, and storage in the last two decades. Looking ahead, this mix is expected to include emerging technologies, including enhanced geothermal energy, hydrogen, next-generation nuclear power ("small modular reactors"), long-duration energy storage, and other developing technologies.

The Emergence of Utility Climate Policy

Utility climate policy has undergone a rapid proliferation in recent years. Decarbonization has become a key policy driver for many utilities, joining affordability, reliability, and safety as one of the new "four pillars" of utility service. This has led to significant carbon reductions in the electric sector, with much broader plans under development for further decarbonization across electricity and gas. Since 2012, the US has reduced its electric sector emissions by 23%[5] through investment in renewable energy and by shifting from coal to natural gas[6].

Nearly two-thirds of US states now have some form of climate policy, and twenty-three states have formal requirements to achieve "80% goals" — either 80% reductions in emissions or 80% clean energy[7]. Traditionally, these policy frameworks were built around renewable portfolio standards (RPS), which required utilities to purchase minimum quotas of clean energy on an annual or multi-year basis, in some cases with specific carveouts- for specific resource categories. RPS programs have been highly effective at stimulating the renewable energy industry, and were an appropriate, streamlined policy framework for the initial phase of electric sector decarbonization.



Climate Ambition in State Utility Policy (Directional)[8]

5 "Electricity Data." *U.S. Energy Information Administration (EIA)*, EIA, 27 Aug. 2024, https://www.eia.gov/electricity/data.php.

6 McGrath, Glenn. "Electric Power Sector CO_2 Emissions Drop as Generation Mix Shifts from Coal to Natural Gas." *U.S. Energy Information Administration (EIA)*, EIA, 9 June 2021, https://www.eia.gov/todayinenergy/detail.php?id=48296.

7 https://www.cesa.org/projects/100-clean-energy-collaborative/guide/table-of-100-clean-energy-states/

8 "Renewable & Clean Energy Standards." *NC Clean Energy Technology Center*, DSIRE, Dec. 2023, https://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2023/12/RPS-CES-Dec2023-1.pdf.

Electricity Decarbonization: Technical Hurdles and the "Last Mile"

The electric system is a unique marketplace — unlike virtually all other commodities, electricity supply and demand must be balanced instantaneously at all times. Historically, this has been achieved through momentary adjustments in the output of dispatchable thermal and hydroelectric units, with supply following demand. The recent emergence of solar and wind resources, which have variable production profiles driven by weather conditions, has significantly increased the value of storage, load flexibility, and regional interconnection. To integrate variable renewables, utilities are deploying vast quantities of battery storage, which can shift energy production from renewable-rich periods to periods of high demand. Utilities are also providing financial benefits to customers for load shifting and flexibility and are pursuing major investments in transmission networks, which can interconnect large, diverse regions which bring load and resource diversity to better manage supply variability.

While solar, wind, storage and transmission will have major decarbonization impacts, emerging analysis of deep decarbonization increasingly identifies gaps which will be difficult or extremely costly to fill with solar, wind, and storage alone. These constraints fall into several categories:

- **Temporal Constraints:** Solar and wind resources can serve load under the vast majority of weather conditions, but certain weather patterns, such as extended 'renewable droughts' — multiple days with low solar and wind production — can starve the system of much-needed energy to charge batteries and maintain reliability.
- **Locational Constraints:** Solar and wind resources are sufficient for system demand, but are unable to provide technical attributes necessary to respond to a system contingency, such as an outage of a large generating station or transmission resource serving a constrained load pocket.
- **Development Constraints:** Solar and wind resources may not be viable due to insufficient or unsuitable land to develop resources at the scale necessary, which serves as a critical constraint for islands, dense urban areas, and remote isolated grids lacking resource and load diversity for renewables. Development constraints may also include inability to develop clean resources at the pace necessary to mitigate emissions.

These 'last-mile' constraints are increasingly recognized in utility planning dockets — unfortunately, often unresolved and underexamined[9]. An increasingly common trope within utility planning proceedings is a presumption that a low-cost, dispatchable, emissions-free energy resource will materialize in the very moment of need (e.g. 2045 or 2050, when policy constraints bind), permitting the utility to continue reliance on existing infrastructure without replacement. This presumption has the unfortunate effect of reducing the focus on near-term reductions with commercial clean energy resources (e.g. solar, wind, and storage), reducing pressure to examine emerging clean energy and storage technologies which could fill the gap (e.g. geothermal or pumped hydroelectric energy storage), and reducing pressure to meaningfully examine non-energy alternatives, including carbon management, demand-side solutions, transmission expansion, or other strategies.

While more direct and robust engagement with these future technical constraints will be critical for serious consideration of carbon management within electric sector decarb, it is important to recognize that this engagement will also be necessary for utilities to interact more meaningfully with other emerging technologies, as noted above. This will be necessary to further progress direct reductions on the electric system, and which, if successful, may ultimately obviate the need for carbon removals for electricity, leaving carbon removal potential for harder-to-abate sectors. This would be a very positive outcome.

9 The practice is sufficiently widespread so that it may be found in most regions with aggressive climate goals and long-term plans, therefore we will not cite any specific utility planning dockets here.

Policy Design: Refocusing Policies from Energy to Carbon

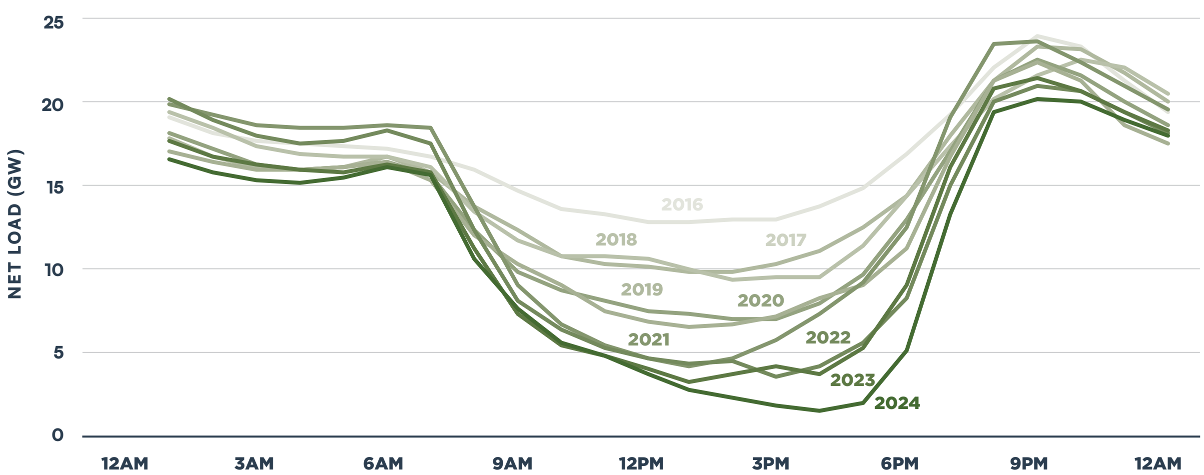
For most utilities and jurisdictions, utility climate policy began with a renewable energy target, often referred to as a "Renewable Portfolio Standard" (RPS). Increasingly, states and utilities have been refocusing on carbon emissions, enabling more focused technical analysis, more targeted requirements and incentives to address emissions, and, in some cases, expanding the scope of eligibility from clean energy to a broader suite of decarbonization strategies.[10] Looking ahead, this transition is critical for successful decarbonization broadly and for deeper examination of the potential and challenges specifically.

While the RPS framework has provided utilities with clear direction to build renewables, there have been growing concerns that energy-based policies may not provide the necessary incentives for utilities to meet net zero climate goals. Specifically, energy-based policies may fail to incentivize diverse renewables (e.g. offshore wind) which have complementary production profiles to oversaturated ones (e.g. solar) or to install battery storage. They also may fail to fully mitigate emissions at thermal plants which have bigger operational swings to address diurnal production swings, or the need for minimum operations to maintain reliability at specific nodes.

While this is not likely to be a material issue in the early stages of decarbonization, energy-based programs are more likely to break down at higher renewable penetrations. At high renewable penetrations, RPS programs begin to diverge from the target — emissions reductions — as operational limits and economic incentives drive renewable curtailment and slow the pace of emissions displacement. More impactfully, the focus on clean energy production — at times coupled with simplified operational analysis for these new resources — can blur the need to focus on complementary strategies, which are not effectively captured in the models or the planning frameworks. Beyond missing carbon removals, this simplification can fail to capture more cost-effective, societally-optimal investments in resource efficiency, fuel switching, demand management, or even investments in complementary storage and transmission resources critical to clean energy integration.

The "Duck Curve" grows deeper as renewables increase

CAISO lowest net load day each May (2016-2024) on the California Independent System Operator Grid[11]



DATA SOURCE: California Independent System Operator (CAISO)

10 See California's 100 Percent Clean Energy Act (SB 100), Oregon's Clean Energy Targets (HB 2021), and Washington's Clean Energy Transformation Act (SB 5116).

11 California Independent System Operator (CAISO). *Open Access Same-Time Information System (OASIS)*. CAISO, Aug. 2024, http://oasis.caiso.com/mrioasis/logon.do.

A classic example of this challenge is the infamous "duck curve," which illustrates the impacts of solar overgeneration on the California electric grid as solar generation grows to be approximately a third of California's overall penetration.[12] While these impacts were directionally predicted by some market participants, the cannibalizing technical and economic impacts of solar saturation were not clearly visible until they arrived. In the context of a decades-long transition with years of lead time necessary for key infrastructure decisions, clearer and more proactive analysis and policymaking will be critical.

While utility emissions models and accounting frameworks vary in their level of detail, utilities are increasingly representing complex operational mechanics within their models, reflecting minimum operating loads for conventional units, even during periods of high solar penetration, and identifying must-run requirements associated with local transmission risks. This more robust approach is more effective at identifying the specific temporal and spatial texture of the decarbonization need — and, unfortunately, is increasingly identifying conventional resources which cannot be readily replaced with today's renewable energy and storage resources.

Analyzing Carbon Management in Utility Planning and Procurement

Assessing the potential for CDR within a utility's decarbonization portfolio is far easier for a utility which has centered the role of carbon reductions in its plan. However, the specific mechanics for modeling CDR potential may vary considerably based on the utility jurisdiction. In this section, we provide a high-level overview of how CDR potential could be modeled within a utility planning framework.

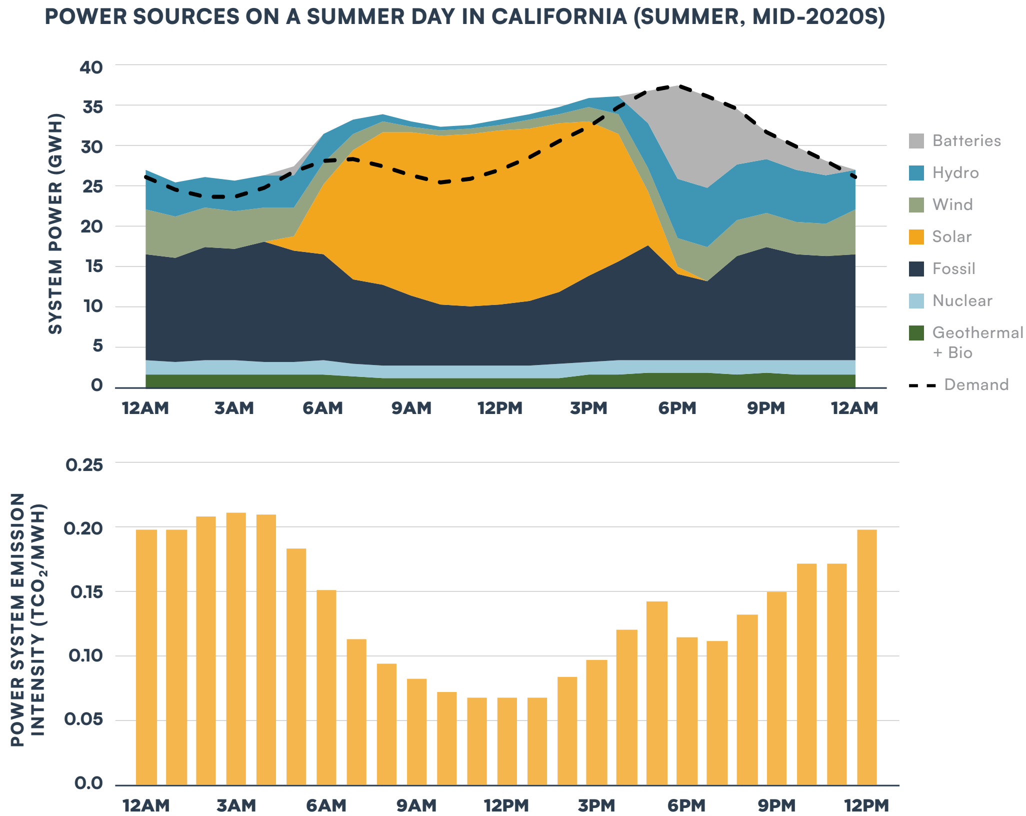
To date, CDR has not featured prominently in utility:

- **Capital Costs:** How much does it cost to finance and develop the CDR resource?
- **Operating Costs:** How much does it cost to operate the CDR resource? Are these costs fixed (annual) or variable (per tonne)?
- **Operational Characteristics:** How does the CDR resource operate? What is its flexibility or its limitations?
- **Emissions Reductions:** What is the net emissions reduction of the CDR resource?
- **Energy Demand:** How much electricity does the CDR resource utilize?

For CDR resources with material energy inputs, it will be valuable to model CDR endogenously as a new load on the electric system — one which can be operated flexibly to maximize resource benefits while mitigating cost and impacts to the electric system. In this way, the resource's operating profile and economics can be co-optimized within the planning model. This approach permits the model to operate the CDR asset in a manner which best integrates with its broader portfolio in place. For instance, limiting its operations during periods of reduced supply or high emissions-intensity, and identifying new clean energy resources which best match the CDR resource's operating needs. This approach enables the model to granularly assess the costs and benefits of a CDR resource as a grid asset.

12 "As Solar Capacity Grows, Duck Curves Are Getting Deeper in California." *U.S. Energy Information Administration (EIA)*, EIA, 21 June 2023, https://www.eia.gov/todayinenergy/detail.php?id=56880.

Utility modeling tools can effectively endogenize CDR opportunities within the utility's broader energy portfolio[13]



This integrated approach may also provide insights on which CDR resources best fit with the utility's operational characteristics. For example, a CDR resource which is capital-intensive may need to operate continuously to pencil out economically, fitting well with a region with significant geothermal potential. The utility could further assess the resource's benefits of permitting modest downtime — perhaps 5% of hours associated with peak loads — relative to 100% uptime — a tradeoff which could substantially reduce the total cost (and corresponding charges) placed on the utility system.

Conversely, the same analytical exercise could show benefits from CDR resources which are energy-intensive, rather than capital-intensive, capable of flexibly following solar or wind resources on a grid with high penetrations of renewable energy.

Beyond Net Zero: Legacy and Non-Energy Emissions

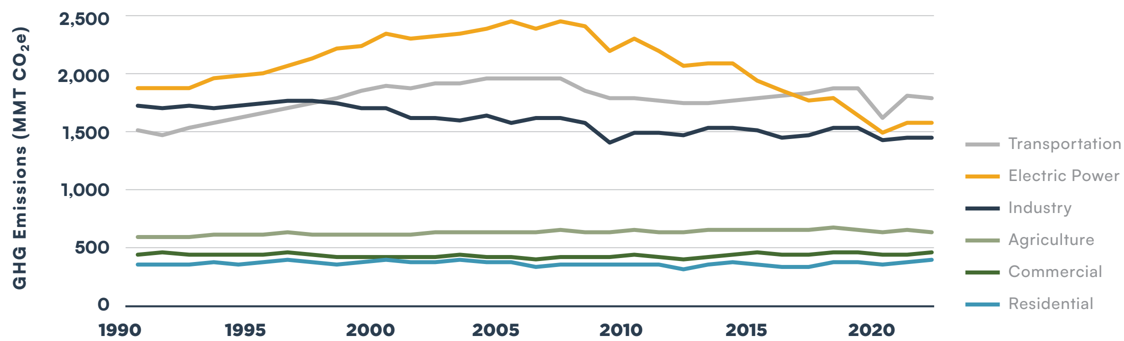
While utility decarbonization policies today focus on reducing emissions from utilities' energy portfolio, the utility sector has the unfortunate distinction as being the top cumulative emitting sector, and also has substantial non-energy operating emissions. While today's policy focus is understandable — meeting net zero in future years is itself a huge undertaking — a complete energy transition will require more robust accounting and planning for operational and legacy emissions.

Operational emissions reflect the reality that carbon emissions arise from almost all human activities. In the utility sector, this includes operations — fleets, buildings, and chemicals used in the operations and maintenance of the power grid — as well as construction — embedded carbon exists in utility cement, steel, distribution poles, and much more. Even land use change, such as the biogenic transformation of a valley ecosystem into a hydroelectric reservoir, can have substantial impacts. These emissions can continue to be traced down the value chain.

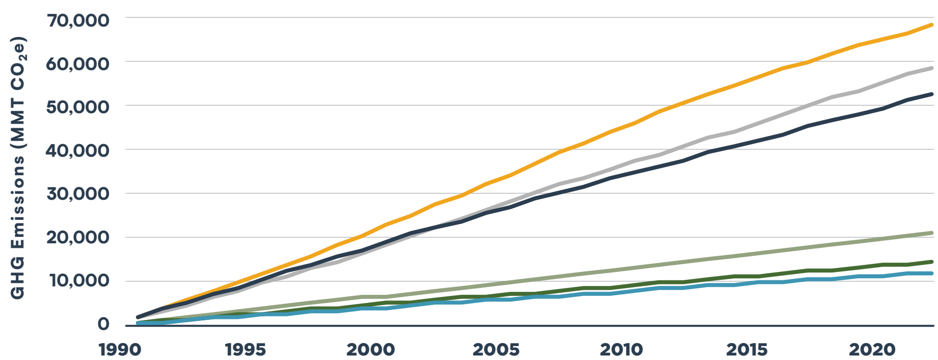
13 California Public Utilities Commission (CPUC). Clean System Power (CSP) Calculator. 30 MMT GHG, 15 July 2022, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2022-irp-cycle-events-and-materials/csp_30mmt.xlsb.

Electric power generation has contributed more to climate change than any other US sector[14]

US ANNUAL EMISSIONS BY SECTOR



US CUMULATIVE EMISSIONS BY SECTOR



DATA SOURCE: U.S. EPA Greenhouse Gas Inventory 2024

Legacy utility emissions account for a considerable share of all emissions introduced into the atmosphere since 1990, and addressing the totality of these legacy emissions is a project that will likely take decades to address. As these emissions cannot be mitigated, they will be necessary to remove.

Utility x CDR Vision: Incorporating CDR into Utility Decarbonization

What could a future vision of CDR as a utility decarbonization asset look like? In this chapter, we've identified a growing consensus that emerging technologies will be needed for deep decarbonization, with strong potential for CDR to play a role alongside clean energy investments to reach net zero. We've also identified the limitations of current utility clean energy policies in their failure to consider non-energy climate solutions, including CDR, and the benefits of transitioning to policies oriented around emissions reductions. Finally, we've discussed the need to track and manage legacy and Scope 3 emissions to meet true net zero moving forward.

14 "Greenhouse Gas Inventory Data Explorer." *U.S. Environmental Protection Agency (EPA)*. EPA, 25 Apr. 2024, https://cfpub.epa.gov/ghgdata/inventoryexplorer/.

CDR on the Utility Path to Net Zero

Key Takeaways

Overview: While utilities are making great strides towards decarbonization, there is a growing recognition that current technologies are likely insufficient to fully mitigate operational emissions in the electric sector, leaving a gap for which carbon removal shows significant potential. However, utility decarbonization policies and resource planning frameworks must evolve to consider the role of CDR as part of a broader decarbonization trajectory.

Utilities are poised to play a transformative role in the energy transition; CDR can be a critical tool to address residual and legacy emissions.

- Electricity and heat are the single largest contributor to global carbon dioxide emissions, accounting for approximately 15 billion tonnes in 2020.[15]
- While clean energy investments, particularly solar and wind, are significantly reducing energy sector emissions, the scale of the decarbonization challenge remains immense and challenges remain on the path to full utility decarbonization.
- CDR is among several emerging technologies — alongside emerging clean energy technologies — which may prove effective at addressing the last 10-20% of electric utility emissions.

Technical and policy evolution will improve utilities' ability to identify long-term decarbonization gaps and integrate CDR as a potential candidate resource.

- Utilities are increasingly extending their planning horizons out to 2050 and incorporating deep decarbonization analysis.
- Planning models and policies are evolving to better reflect constraints, and incorporate non-energy solutions, including efficiency, storage, transmission, and, in the future, carbon removal.
- Effective, accurate modeling of CDR will necessitate specific data from CDR developers on cost, operational characteristics, energy demand, co-benefits, and other parameters.

Regulators should consider 'twin targets' informed by modeling and policy needs to procure both clean energy and carbon management.

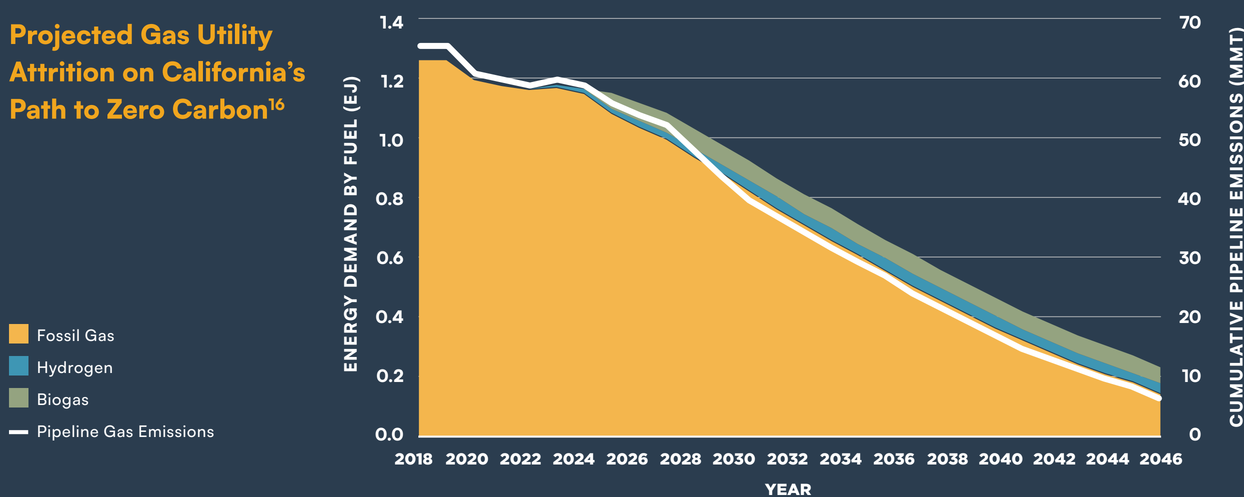
- Policymakers should identify and pursue the long-term potential for carbon removals in the utility modeling ecosystem, while ensuring new clean energy resources remains the primary decarbonization focus.

15 Ritchie, Hannah, et al. "Breakdown of Carbon Dioxide, Methane and Nitrous Oxide Emissions by Sector." *Our World in Data*, Jan. 2024. ourworldindata.org, https://ourworldindata.org/emissions-by-sector.

What Role Might CDR Play for Gas Utilities?

Decarbonizing gas utilities is an important challenge with few easy answers. At their core, gas utilities serve natural gas, a gas primarily composed of methane, which is combusted onsite by customers for heating and other applications. While policy interest in gas decarbonization has grown substantially, drop-in technological solutions to displace gas fuel have been elusive, with significant technical limitations to the sourcing and distribution of renewable natural gas and hydrogen, the two leading alternatives.

Projected Gas Utility Attrition on California's Path to Zero Carbon[16]



Demand Destruction / Building Electrification

Recognizing the limitations around decarbonizing gas, policymakers have begun contemplating broader, structural shifts in demand, primarily by pivoting away from a demand for gas and towards the electric sector, an approach known as "Building Electrification". This pivot relies on the electrification of heating needs, an approach which parallels the electrification of transit, and will leverage significant technical advancements in heat pumps. While electrification will certainly play a major role in the decarbonization of heating services, gas utilities are expected to continue serving customers in their traditional capacity for decades to come, and alternative decarbonization solutions will be necessary.

Renewable Natural Gas

Gas utilities have focused their efforts on renewable natural gas, including biogas and hydrogen. Renewable natural gas (RNG) refers to a category of alternative methane-based fuels derived from non-fossil sources, such as landfills, wastewater facilities, and dairy farms, which, with some purification and refinement, can serve as a drop-in replacement for conventional gas. Biogas and biomethane, similarly, can be used for example for bioenergy carbon capture and storage (BECCS) processes. Utilities have deployed significant RNG nationally, leveraging policy support primarily from California's Low Carbon Fuels Standard program, which provides an additional credit for the captured methane which would otherwise be released atmospherically by these facilities. While RNG has seen significant growth in recent years, the total available supply of RNG is widely viewed as being far below that which would be necessary to displace today's conventional gas demand.

16 2022 Scoping Plan for Achieving Carbon Neutrality. California Air Resources Board, Dec. 2022, https://ww2.arb.ca.gov/sites/default/files/2022-12/2022-sp_1.pdf.

Hydrogen

Hydrogen, a chemical energy storage medium with potential across a range of industries, is an emerging technology which appears poised for significant growth following breakthroughs in both technology, specifically electrolyzers, and policy support, specifically the green hydrogen subsidies incorporated into the Inflation Reduction Act (45V tax credit). In contrast to RNG, hydrogen has significant technical and operational differences from conventional gas. Hydrogen molecules (H_2) are significantly smaller than methane (CH_4), resulting in higher permeability through existing infrastructure not designed or built for the purpose of carrying hydrogen — including the three million miles of existing gas pipeline in the US.[17]

Leakage poses two serious risks. From a safety perspective, hydrogen leaks are highly flammable and difficult to detect due to its clear flame. From an environmental perspective, atmospheric hydrogen has significant global warming potential due to its interactive effects with other molecules resulting in longer lifetimes for atmospheric methane.[18] While hydrogen blending may be viable for niche segments of the gas system — those relying on large, arterial pipelines which may be relatively low cost to retrofit — it is unlikely to be viable on the veiny, tendrilled distribution system without costly trenching, replacement, and testing of millions of miles of pipeline.

A prominent US Department of Energy study concluded that blending may be feasible up to 30% without needing to retrofit existing pipeline infrastructure.[19] However, because of hydrogen's lower energy density and because of the energy and emissions necessary for its production, a 30% H_2-natural gas blend would only reduce lifecycle greenhouse gas emissions of the delivered gas by about 6%[20].

If not mitigation, removal?

Unfortunately, the last-mile problem for gas includes much more of the journey than the last-mile problem in electricity. Because of the lack of clear drop-in substitutes, it is expected that emissions reductions in the gas sector will be slower and will largely occur outside of the gas sector itself. However, that leaves a sizeable share of emissions which may need to be abated through removal strategies.

17 Natural Gas Explained: Natural Gas Pipelines, US Energy Information Administration

18 Sand, Maria, et al. "A Multi-Model Assessment of the Global Warming Potential of Hydrogen." Communications Earth & Environment, vol. 4, no. 1, June 2023, pp. 1–12. www.nature.com, https://doi.org/10.1038/s43247-023-00857-8.

19 U.S. Department of Energy (DOE). "HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines." Energy.Gov, DOE, https://www.energy.gov/eere/fuelcells/hyblend-opportunities-hydrogen-blending-natural-gas-pipelines. Accessed 10 Sept. 2024.

20 U.S. Department of Energy (DOE). "October H2IQ Hour: HyBlend Initiative: Text Version." Energy.Gov, DOE, https://www.energy.gov/eere/fuelcells/october-h2iq-hour-hyblend-initiative-text-version. Accessed 10 Sept. 2024.

CHAPTER 2

Climate Loads — Powering Energy-Intensive CDR

Certain CDR pathways, notably Direct Air Capture (DAC), require significant energy to support mechanical, chemical, or other processes. This energy will need to be sourced from low- to no-carbon sources to achieve desired climate benefits, which is a primary economic consideration for these resources.

However, navigating the complex landscape that is energy procurement is no easy task. CDR developers will need to be prepared for complex economic, regulatory, and technical questions to solve for their unique energy procurement needs. In this section, we explore key considerations for CDR developers as well as for utilities seeking to serve these new climate loads in a cost-effective and environmentally responsible way.

While limits vary by jurisdiction, legal constraints on how electricity is bought and sold are nearly universal. As a general rule, electric customers have a legal obligation to purchase electricity via the incumbent utility under a default rate. This stands unless the jurisdiction has provided for an exception, for example: options for self-generation, the opportunity to procure wholesale electricity through a registered supplier, or a green tariff option provided by the utility. Each of these options will have specific economic and environmental implications for the CDR developer.

Utility and policymaker engagement with these issues from the perspective of interested customers remains relatively nascent — investigation of defined clean energy tariffs for customers is gaining traction but remains underdeveloped. In this section, we explore these themes and identify areas for utilities and CDR developers to collaborate to improve offerings for customers seeking clean, reliable, low-cost electricity.

Aren't Wind and Solar Too Cheap to Meter?

There has been a rising chorus of news articles and discussion of rapidly declining costs for renewables and the emergence of negative prices in some energy markets, notably Texas and California. Unfortunately for energy consumers, the reality on the ground is far more complex.

In most jurisdictions, customers are legally obligated to take service under a standardized tariff (or a variant thereof), obligating the customer to share in a wide range of costs for grid services (transmission and distribution, efficiency programs, and so on) and to pay for a share of the generating fleet, including past investments and ongoing costs for clean energy resources. In regions with negative pricing, these negative prices occur during a fraction of hours — the majority of energy purchased on the market is not free or negative.

For customers with self-generation, such as a solar facility, this may offset costs during the daytime hours but is unlikely to address overnight demand, which must be paid to the utility, unless the CDR asset is sufficiently flexible to strictly follow production during solar hours, which may allow for 30-40% utilization of the CDR asset.

On-site energy storage can support additional flexibility, but storage durations and economic considerations with current technologies limit the viability of providing firm, 24/7 energy from on-site resources in most locations. Emerging strategies to integrate solar, wind, and storage may facilitate this pathway for optimal locations in the future, in addition to geographically-specific opportunities with access to firm on-site clean energy.

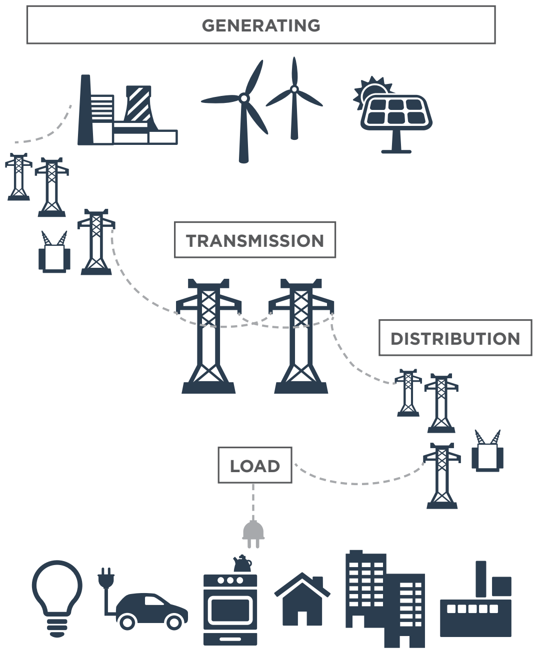
Background: Utility Deregulation

Electric utilities are regulated by design — the policy construct is intended to provide a regulated utility with captive customers on whose behalf it can make resource investments and manage the grid. As an outflow of this policy framework, policymakers have historically required all customers — including new customers, like CDR resources — to purchase electricity from the incumbent utility at a defined retail rate. Under this construct, the CDR asset would be obligated to pay a standard rate and receive a standard 'product' (emissions attributes) which may or may not fit with its business strategy.

However, while much of the utility sector remains regulated, significant efforts toward deregulation have taken place since the 1990s, particularly in regions with strong climate policies that would drive CDR resource development, including California and the Northeast United States. While policies vary, they tend to focus on deregulation of the commodity — electricity or gas, for example — while retaining the same regulatory structures described above over the delivery infrastructure.

Deregulation may offer opportunities for energy-intensive CDR resources to source energy from other providers beyond their local utility and enter into contracts for cleaner or lower-cost energy supply. This could include direct contracts with suppliers in deregulated states, regulated green tariffs with the utility in regulated states, the installation and use of "behind-the-meter" resources, or the use of virtual power purchase agreements with clean resources to offset conventional energy provided through a regulated tariff. Under the right circumstances, these alternative energy sourcing methods may provide lower lifecycle emissions and lower costs for CDR.

A Typical Deregulated Electricity Market in the United States



Generation | COMPETITIVE

Generation assets are privately owned and compete in a competitive wholesale market managed by an Independent System Operator

Transmission | REGULATED

Transmission assets are owned and operated by the utility but orchestrated by Independent System Operator

Distribution | REGULATED

Distribution assets are owned and operated by utility

Load | DEREGULATED

Customers are free to select among various competitive providers, increasingly including self-generation resources

Tariff Sheets: Options for Accessing Energy

Successful development of energy-intensive CDR assets will require electricity which is simultaneously low-cost and low-carbon. Access to different structures will vary by jurisdiction and utility, but largely falls into several categories:

- **Standard Utility Tariff:** Under the standard utility tariff, the customer pays a standard rate (volumetric + demand charge) and receives a standard product with the utility's average emissions rate.
- **Utility Green Tariff:** Under a utility green tariff, a CDR facility would receive electricity through a designated clean energy tariff offered by the utility which guarantees specific thresholds of clean energy.
- **Virtual Power Purchase Agreement (vPPA):** Under a virtual PPA, a CDR facility would receive electricity under a utility's standard tariff while contractually procuring an equivalent share of clean energy from an emissions-free resource.
- **Self-Generation:** Under a self-generation construct, a CDR facility would utilize electricity generated on-site, likely using paired solar, wind, and energy storage resources optimized for its load.
- **Combination:** While self-generation can occur 'off-grid', without connection to the utility, self-generation typically augments utility service. A combination approach could utilize self-generation for a portion of a CDR facility's load while procuring the remainder from the utility green tariff or through a vPPA.

Regardless of the pathway, the options and participation rules will be dictated by the laws and regulation of the jurisdiction the CDR facility operates in, which in turn govern the tariffs and rules of the utility itself. The CDR facility will be obligated to participate as a customer under the utility's retail tariffs, which typically includes energy charges ($/kWh) and demand charges ($/kW) to cover the cost of service. For a regulated region, this will include the cost of providing energy in addition to transmission and distribution service. In a deregulated region, energy may be paid to a separate entity.

Depending on the jurisdiction, various tariff options may be available. Typically, most utilities have a designated rate for large customers taking service at transmission voltage which is lower per kilowatt-hour than residential rates. Increasingly, utilities offer an elective 'green tariff' which sources clean electricity for the customer, typically at a premium, and often using annual energy accounting practices, which may or may not be sufficient for the CDR operator. In a deregulated region, the customer can elect to take service from a competitive provider, replacing the generation component of the bill with an agreement with another entity — it is important to note that deregulated service does not eliminate the transmission and distribution charges from the distribution utility, which can be significant (often as much as half) of the total cost of energy.

It is likely that many CDR assets will be paired with on-site renewables as an environmental benefit and as a cost-saving measure. There are two general pathways for this. The vast majority of utility customers using on-site resources remain connected to the grid, supplementing grid service with paired renewables, often solar but in some cases wind. For a CDR asset which is capital intensive, it will likely be necessary for the customer to maintain high utilization, which is likely to necessitate drawing from the grid overnight and during low-solar seasons, which has economic and environmental implications discussed below. Some CDR assets may elect to operate off-grid with paired renewable resources. While this enables the resource to access far lower electricity costs, it is also likely to result in relatively low utilization of the CDR asset as a function of the energy availability of the paired resource, as discussed below.

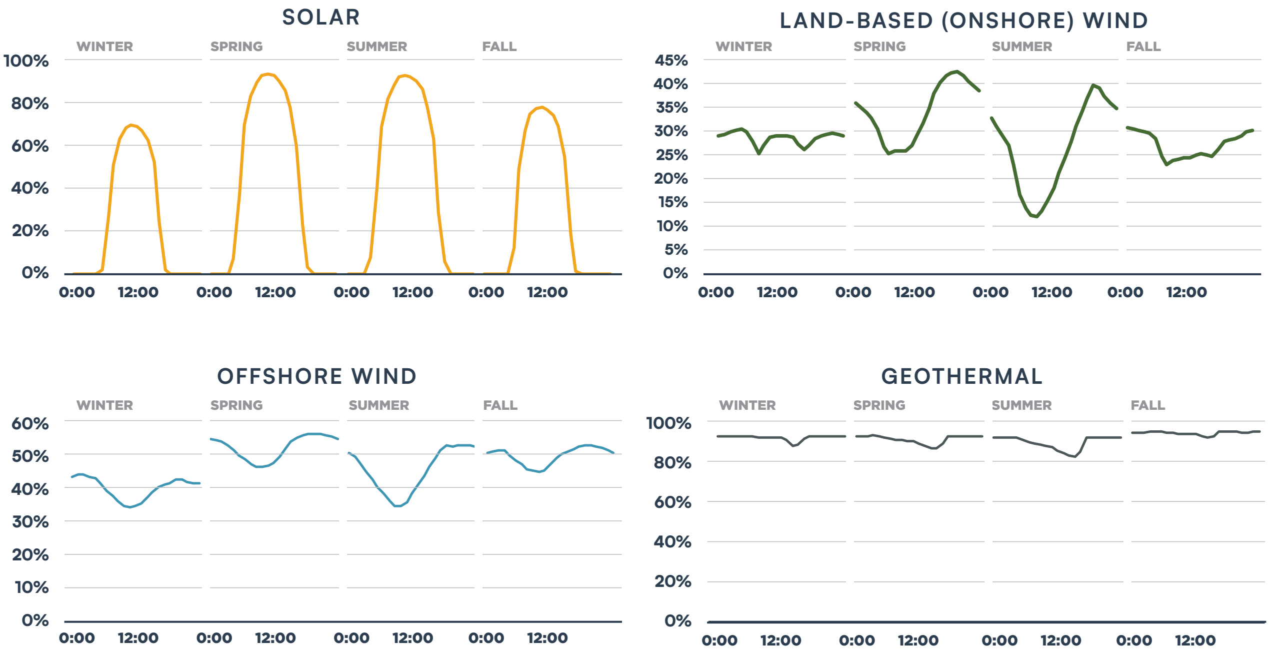
Aligning CDR Demand with Renewable Production

Electricity has the unique property that it must be in perpetual balance — electricity demand must always match electricity supply in real-time. While this is not a new requirement within the laws of physics, it has come to the fore as a core technical challenge for electric sector decarbonization based on the operating realities of solar and wind resources, which are both weather-dependent, variable resources. CDR, in contrast, is likely to operate similarly to most other industrial processes: continuously in order to maximize its utilization and amortize fixed costs.

This has two significant impacts for CDR resources. First, it significantly complicates the prospects of developing off-grid CDR resources which directly leverage the reduced costs of renewable resources, as off-grid resources will only be able to operate when the paired renewable resource is available. CDR, like other industrial processes, is likely to require high utilization to make the economics viable — high fixed costs need to be amortized over extended operating periods and cannot be limited to production during the 20-40% of sunny daylight hours of a given region. While energy storage resources can assist in balancing intermittent renewables, the scale of storage needed to flatten a demand curve can be a significant economic penalty to the project's design.

Seasonal hourly operating profiles of solar, onshore wind, offshore wind, and geothermal[21]

Illustrative month-hour profiles for resources in the Southwest US



Second, the operating characteristics of these resources as part of a broader portfolio of resources creates unique hourly and seasonal emissions dynamics which will likely impact the net emissions benefits of CDR resources. These variable patterns are significant, with utilities forecasting significantly higher emissions profiles during nights and low-solar seasons.

21 California Public Utilities Commission (CPUC). *Clean System Power (CSP) Calculator*. 30 MMT GHG, 15 July 2022, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2022-irp-cycle-events-and-materials/csp_30mmt.xlsb.

Could Co-Located Clean Firm Resources Support CDR?

What CDR resources could be powered with low-cost, on-site clean firm resources like enhanced geothermal or advanced nuclear? While clean firm technologies tend to be higher cost, there has been growing interest in the use of clean firm technologies to power data centers,[22] hydrogen electrolysis[23], and other emerging loads, including direct air capture[24]. Co-locating resources with loads reduces overall costs as customers have the potential to avoid transmission and distribution surcharges and other costly tariff requirements associated with utility service.

The Great Rift Valley, a series of volcanic and other geological features paralleling the East African coastline, has been identified as a unique location to align CDR production, like direct air capture, with on-site geothermal production. This is due to its unique combination of strong geothermal potential and positive geology for long-duration carbon storage via mineralization in the basalt aquifer, which has led some to rename it the "Great Carbon Valley."[25] Companies like Octavia Carbon have started development in this region.[26] Climeworks has taken a similar approach to locate their direct air capture technology along a geothermal power plant and basalt aquifer for carbon storage in Iceland (with CarbFix).

Rate Considerations: Not Yet Too Cheap to Meter

The economics of an energy-intensive CDR project will depend heavily on the applicable electricity rate where it is developed, and whether it is possible to use self-generation resources, such as on-site solar generation, to reduce overall costs. As discussed above, rates will vary on a number of factors, including both total energy (volumetric charges), peak periods (time-of-use), and demand on- and off-peak (demand charges).

22 "Google Partners with Nevada Utility for Geothermal to Power Data Centers." *Reuters*, 13 June 2024. www.reuters.com, https://www.reuters.com/business/energy/google-partners-with-nevada-utility-geothermal-power-data-centers-2024-06-13/.

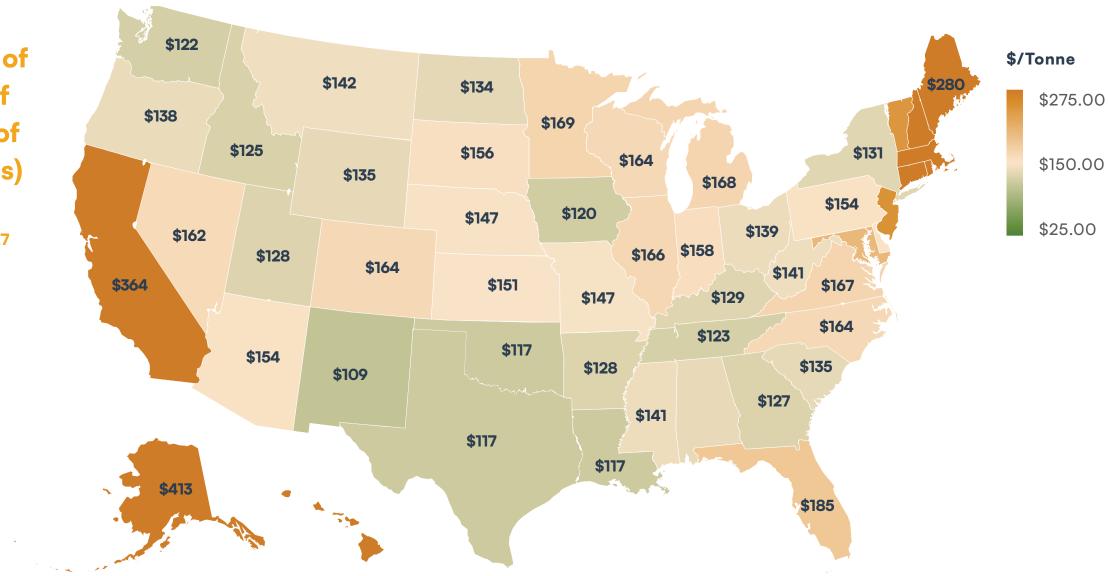
23 "3 Nuclear Power Plants Gearing Up for Clean Hydrogen Production." *Energy.Gov*, U.S. Department of Energy (DOE), 9 Nov. 2022, https://www.energy.gov/ne/articles/3-nuclear-power-plants-gearing-clean-hydrogen-production.

24 "Fervo Energy to Develop Combined Geothermal and Direct Air Capture Facility." *Fervo Energy*, Fervo Energy, 23 Feb. 2023, https://fervoenergy.com/fervo-energy-to-develop-combined-geothermal-and-direct-air-capture-facility/.

25 Payton, Ben, and Ben Payton. "Kenya Gears up for Direct Air Capture Push in 'Great Carbon Valley.'" *Reuters*, 13 Nov. 2023. www.reuters.com, https://www.reuters.com/sustainability/climate-energy/kenya-gears-up-direct-air-capture-push-great-carbon-valley-2023-11-13/.

26 https://www.bloomberg.com/news/articles/2023-07-19/first-southern-hemisphere-direct-air-capture-plant-planned

Average Retail Price of 2 Megawatt-Hours of Electricity (1 Tonne of DAC-based Removals) Delivered to an Industrial Customer[27]



A typical DAC asset may use approximately two megawatt-hours of electricity per metric ton of CO_2. As a baseline reference, the average retail rate for industrial customers in December 2023 was $0.08 per kilowatt-hour ($76/MWh). For a CDR project utilizing two megawatt-hours per metric tonne of CO_2, this would equate to energy costs of $150/tonne. This cost can rise to over $350/tonne in California, which has higher-than-average electricity rates.

It is likely that many CDR projects will be paired with lower-cost on-site renewables. As a highly simplified example, adding a $35/MWh solar asset sized to the maximum demand of the CDR resource (in megawatts) *could* result in an average cost of $125/tonne.[28] However, this simplified example likely underestimates actual costs — depending on the plant's operating characteristics, some of the avoided costs would be retained as demand charges for transmission and capacity service during peak hours, depending on rate design. To the extent the facility's demand remained unchanged overnight, it is likely that the solar resource would only partially offset costs in the CDR operator's bill.

Two strategies hold promise for CDR economics. One will be to pair CDR with emerging clean resources which are capable of providing firm, baseload energy to power their industrial processes, enabling off-grid applications leveraging low-cost renewables. The second strategy will be to work with the utility and regional policymakers to design a tariff which enables the utility to optimize the CDR facility's operations in a manner to take advantage of fluctuations in system pricing. While the latter may result in lower costs than the baseline utility tariff, it is likely that it may suffer from the same structural challenges as behind-the-meter solar (low utilization) and may ultimately not provide for favorable project economics.

Environmental Considerations: Electricity Emissions

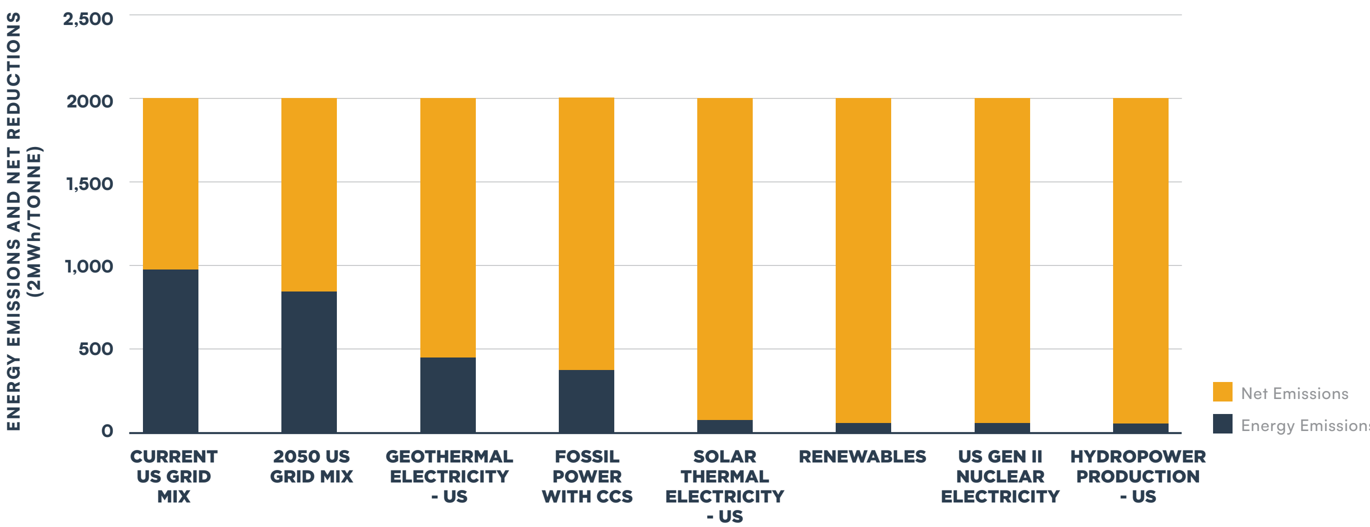
How CDR customers track and report their emissions will likely be a function of what policy structures they operate under. Currently, voluntary carbon market registries typically permit electricity emissions to be 'offset' through the purchase of an equivalent number of renewable energy credits in the same year.

27 "Electric Power Monthly." *U.S. Energy Information Administration (EIA)*, EIA, 23 Aug. 2024, https://www.eia.gov/electricity/monthly/epm_table_grapher.php.

28 In this simplified analysis, the CDR resource is assumed to receive ~30% of its electricity at $35/MWh from the on-site solar resource and ~70% of its electricity at $76/MWh, neglecting any consideration of more granular rate design components.

The 45Q tax credit for carbon oxide sequestration (Section 45Q) under the Internal Revenue Code, which offers a $180/tonne subsidy for certain CDR pathways, requires the completion of a lifecycle analysis (LCA) reflecting the input energy of the CDR process and appears to endorse an annual energy accounting framework.

Energy Emissions and Net Reductions for a 2MWh/Tonne CDR Asset using 45Q LCA



Using electricity to remove carbon from the atmosphere has long been a source of research and debate among academics and policymakers, and recent tax credits have only served to heighten that discussion. For example, a customer which may be using significant non-renewable energy at night and during winter periods may be offsetting their demand with renewable energy credits from solar or wind resources from a location in which those assets are fully saturated (e.g. solar in California or wind in Texas), resulting in little if any avoided emissions from those renewable resources. In contrast, 45V guidance is anticipated to require hourly matching for hydrogen electrolysis.

Similarly, many large customers are pivoting their emissions tracking to be more granular, with "24/7"[29] and "emissionality"[30] frameworks which they are likely to apply to CDR procurement. 24/7 is designed to match load with supply on a regional basis, while emissionality attempts to assign emissions rates to each MWh of energy produced and consumed. Both are intended to provide more specific signals to effectively net out emissions from energy demand.

Emerging Tariff Solutions: Clean Transition Tariff

Surging interest in time-matched green tariff programs — driven primarily by data centers but with emerging interest from hydrogen electrolysis and other industries — is driving policy innovation. While traditional green tariff programs have provided for annual procurements, emerging tariffs offer customers the opportunity to access time-matched renewable energy, and increasingly offer pathways for customers to provide their own resources to support their specific demand profiles. This could offer interesting new pathways for CDR resources.

29 "Tracking Our Carbon-Free Energy Progress." Google Sustainability, https://sustainability.google/progress/energy/.
30 WattTime. "How Salesforce Used Emissionality to Inform Its Groundbreaking D-Recs Procurement." WattTime, 23 Feb. 2023, https://watttime.org/news-and-insights/how-salesforce-used-emissionality-to-inform-its-groundbreaking-d-recs-procurement/.

In Nevada, NV Energy, Google, and Fervo Energy recently announced a landmark tariff to provide Google with 24/7 clean energy for Google's electrical loads within the utility's footprint[31]. Similarly, Duke Energy recently proposed a parallel tariff with data center and steel manufacturing partners to provide clean firm energy from a portfolio of resources to participating customers[32]. While these tariffs would not eliminate the requirement for energy-intensive CDR users to pay for transmission and distribution costs, it would enable them to directly support CDR with clean resources which may be a better fit or more economic than utility-procured clean energy.

Utility x CDR Vision: Clean, Affordable Energy for CDR

What could a future vision of affordable, reliable, clean energy for CDR look like? We've identified the current state of customer options for energy service, including traditional utility service, self-generation, and emerging clean tariff options. We've also covered the technical limitations to directly powering CDR with renewable resources, with emphasis on the need to identify clean firm resources to provide continuous power for CDR resources. We have attempted to benchmark the economic and environmental implications of drawing electricity from the grid, identifying a diverse range of costs and emissions associated with procuring energy from different regions and from different sources. Looking ahead, it is clear that the path for climate loads to access clean, affordable energy is just beginning — and will need to continue to evolve to support desired outcomes.

31 "How We're Working with Utilities to Create a New Model for Clean Energy." *Google*, 11 June 2024, https://blog.google/outreach-initiatives/sustainability/google-clean-energy-partnership/.

32 "Responding to Growing Demand, Duke Energy, Amazon, Google, Microsoft and Nucor Execute Agreements to Accelerate Clean Energy Options." *Duke Energy* | News Center, 2024, https://news.duke-energy.com/releases/responding-to-growing-demand-duke-energy-amazon-google-microsoft-and-nucor-execute-agreements-to-accelerate-clean-energy-options.

Powering CDR

Key Takeaways

Overview: Many CDR pathways require significant energy to support mechanical, chemical, or other processes — and will need to receive this energy from decarbonized sources to maximize their climate benefits. CDR developers will need to be prepared for the complex, regulated energy procurement landscape to achieve the optimal mix of low-carbon and low-cost energy. This includes how energy will be sourced, which is often constrained by local regulatory requirements, how much the energy will cost, and how emissions from the energy source will be attributed to the CDR asset under relevant regulatory frameworks.

Many CDR pathways require energy inputs, including significant electricity input for mechanical, chemical, thermodynamic, and other processes.

- For many CDR pathways, electricity is a key input, driving the need for low-cost, low-emissions electricity to cost-effectively achieve their intended environmental benefits.
- The archetypal energy-intensive CDR process is direct air capture; DAC utilizes industrial-scale fans to process ambient air through different chemical processes and requires approximately 2 megawatt-hours per metric tonne of carbon dioxide removed.

Options for energy access may be limited by regulation, but typically include variations of grid-tied electricity supply and self-generation.

- In most jurisdictions, customers are bound to take energy service from a single incumbent utility under defined rates and products.
- In addition to a standard electricity rate, the utility may offer a green tariff and/or rates for self-generation; in some jurisdictions, the customer may have a broader suite of options from deregulated suppliers for wholesale power.
- Separately, a CDR resource may procure electricity indirectly through a third-party which is used to offset the non-renewable energy offered by the utility under its standard rate.
- Each of these options will bring different economic and environmental outcomes for the CDR facility and should be weighed carefully.

While cheap renewables and negative pricing are real, directly accessing low-cost clean energy resources is complex.

- CDR developers, like those of other emerging loads, have eyed the decline in solar and storage pricing and the emergence of negative pricing with enthusiasm.
- However, directly accessing wholesale prices is challenging, and negative pricing represents a small fraction of total hours.
- Increasingly, large loads are seeking to work with utilities to develop innovative pathways to access clean energy resources through tariff structures in which the customer purchases specified clean resources through a utility program.
- Self-generation may be viable in specific cases, but may face technical challenges (e.g. low utilization, intermittency) and policy hurdles.

CHAPTER 3

The Utility-CDR Nexus: Utility Assets and Operations

CARBON REMOVAL OPPORTUNITIES ABOUND AT UTILITIES

Utilities are extensive organizations with operations spanning engineering, construction, operations and maintenance, property management, procurement, and much more. In this section, we identify key utility operational areas and the CDR opportunities which are best aligned with utility assets and operations. While this paper focuses primarily on electric utilities, similar applications and conclusions are likely applicable to other utility segments, including gas, water, and telecommunications, which share similar infrastructure, regulatory, and operational considerations.

Approximately half of utility bills go to the construction and maintenance of the transmission and distribution system, and utility capital expenditures are over $150 billion annually.[33] Energy-adjacent CDR opportunities can include projects on natural and working lands, especially related to wildfire mitigation; capital investments, such as procurement opportunities for low-carbon cement and steel; and in fuels, particularly biofuels (bioenergy) paired with carbon capture and storage (BECCS).

Specifically, we explore the following three categories:

- **Natural and Working Lands:** Utilities own and operate vast quantities of land associated with power generation, transmission and distribution. These lands can also serve other uses, such as for biochar (from

33 Edison Electric Institute (EEI). *Industry Capital Expenditures.* EEI, 2022, https://www.eei.org/-/media/Project/EEI/Documents/Issues-and-Policy/Finance-And-Tax/Industry-Capital-Expenditures.pdf.

waste forest biomass extracted from wildfire management), enhanced weathering, and other potential CDR.

- **Built Environment/ Green Construction:** Utilities are responsible for extensive materials procurement for construction and maintenance, including some of the largest concrete structures ever built and many millions of miles of pipes and wires. This creates a clear opportunity to jump-start low-carbon and carbon-negative cement, and other industries like low-carbon steel, supporting the broader decarbonization ecosystem.
- **Fuels and Operations:** As forest managers with large, central combustion plants for heat and power generation, utilities are prime candidates for bioenergy projects. Additionally, heat and other processes at existing combustion generation may be integrated with other CDR pathways, such as bioenergy carbon capture and storage (BECCS), biochar, or similar, or to deliver heat produced to direct air capture facilities as energy.

Background: Defining CDR

Carbon Removal is emerging as a critical component of the global strategy to tackle climate change. CDR refers to the broad range of pathways which result in removal of carbon dioxide from the atmosphere[34]. The rising interest in CDR reflects three trends: the growing urgency of action to address climate change; increasing recognition that some share of current emitting activities will continue due to their difficulty or impossibility to fully abate; and the significant advancements in CDR methods which are improving availability, reducing cost, and increasing confidence and trust in their role as a climate mitigation strategy.

Nature-based solutions refer to pathways that leverage the natural carbon cycle, such as enhancing existing land and agricultural practices, expanding forest coverage (via reforestation and afforestation), and restoring coastal wetlands. Historically, forestry served as the primary focus of nature-based CDR, but scientific and technical developments supporting improved carbon outcomes for soils, rocks, and marine systems have broadened the scope of pathways moving forward.

Technological CDR refers to built approaches that draw carbon down from the atmosphere, such as Direct Air Capture (DAC), which removes carbon from ambient air, or Bioenergy with Carbon Capture and Storage (BECCS), an alternative to coal or gas power leveraging biofuels while capturing combustion emissions at the source. These solutions tend to leverage existing energy and industrial processes, and typically require electricity or heat (or both) as key inputs.

There are also a variety of approaches which can be seen as "hybrid", bridging between nature-based and technological, such as enhanced weathering (EW), biochar, and some marine carbon dioxide removal (mCDR) solutions. It should be noted that there's also a variety of digital mechanisms which have helped scale and build trust in the carbon management ecosystem, acknowledging the important work of registries, standards, marketplaces, insurers, and other providers. The Carbon Business Council published an issue brief on Defining Carbon Removal[35] with additional information and resources, and a fully taxonomy details these below.

Climeworks direct air capture technology

34 Note: Carbon dioxide removal is considered a distinct category from carbon capture and storage (CCS), which pairs emitting infrastructure, such as a power plant or refinery, with specialized equipment to capture a share of the facility's carbon emissions at the source.

35 "Defining Carbon Removal: Issue Brief." *Carbon Business Council*, https://www.carbonbusinesscouncil.org/news/definingcdr. Accessed 6 Sept. 2024.

A Taxonomy of Carbon Removal Methods

CDR Method	Description	Utility Nexus	Wider Intersections
Biomass Carbon Removal and Storage (BiCRS)	**BiCRS:** Includes a suite of approaches that facilitate the usage of biomass to remove and store carbon dioxide	Pyrolysis, combustion, gasification, and other usage with biomass can generate electricity or hydrogen.	Utility vegetation management (e.g. wildfire risk mitigation); biochar or enhanced weathering applications to forests where wood may be managed and/or harvested, where appropriate. More below.
	Bioenergy with Carbon Capture and Storage (BECCS): Fuel switching to bioenergy inputs (e.g. woody biomass) paired with carbon capture	Carbon-negative fuel alternative for existing (or new) utility thermal power infrastructure	Woods removed for wildfire mitigation can go into processes, such as BECCS
	Biochar Carbon Removal: Biomass pyrolysis (non-combustion) with agricultural or forestry residuals to create biochar	Biochar production can also create electricity; biochar can be stored in cements for utility construction sites.	Water filtration and/or sustainable urban drainage systems (stormwater runoff, etc) with applications from biochar; alternative amendment to cement (via biochar). Burial or biochar dispersing may occur on utility properties or rights-of-way. Waste heat can provide some energy to DAC plants (modular). *Down the value chain:* Biochar can be used in croplands and potentially better crop yield for biofuels.
	Terrestrial biomass storage: woody biomass stored in environments where it does not decompose	Forest residues removed can be sequestered for terrestrial biomass storage	Utility electricity distribution poles can be 'disposed' into terrestrial biomass storage
Direct Air Carbon Capture and Storage (DACCS)	Mechanical and chemical process to filter, process, and remove ambient CO_2	High energy and electricity demand	Additional opportunities for hydrogen fuels production
Marine Carbon Dioxide Removal (mCDR) (various)	Various ocean-based CDR pathways, including alkalinization, marine biomass storage, and more	Land management: can have coastal restoration on utility lands; integration with cooling systems on utility infrastructure. For some utility water-cooling processes, the water flow returned to the ocean could provide a cost-effective way to deliver soluble minerals into the ocean.	Desalination plant utility usage where applicable; Usage on decommissioned structures (including in the ocean) Algae and macroalgae biomass at some coastal sites can be repurposed into things like biochar or biofuels at coastal utilities zones*.
Enhanced Mineralization & Weathering	Pulverization and distribution of minerals for long-term sequestration on land or among marine environments	Rocks for EW can be spread on certain natural and working lands that utilities own and operate (in acceptable environments) including around solar arrays.	Enhanced weathering can help decarbonize crop production and and strengthen crop output for biofuels production. Down the value chain: Steel slag produced for steel products (used in Utility construction) can be mixed into aggregate for road construction (with mineralized slag), then used for roads built on utility lands.
Nature-Based Solutions	Support natural carbon sequestration pathways, such as reforestation, afforestation, and wetlands management	Forest management and reforestation where applicable. Improved management and utilization of extensive utility properties, including electrical safety corridors (rights-of-way, substation properties) and solar and wind farms.	Healthier forests may reduce wildfire risk.

CDR Method	Description	Utility Nexus	Wider Intersections
Built Environment/ Green Construction	Carbon storage in materials or manufacturing processes (long-lived products).	Opportunities for facilitation with biomass storage, cement, and steel. Integration of green materials into utility infrastructure and capital projects, e.g. cement foundations for hydroelectric or nuclear resources or transmission towers (biochar into alternative, carbon-negative cement). Enhanced wood materials into buildings.	Industries beyond utilities can consider these products for their own construction projects. Waste forest biomass pyrolyzed into biochar and the biochar later put into cement could be one such vision of multiple CDR solutions interacting together. Alternative graphite application from biochar for lithium-ion and sodium-ion batteries.

This list is not extensive of the wide range of solutions that are available today, and are yet to be developed.
**You can find more at content.govdelivery.com/accounts/USDOEOFE/bulletins/39592ce.*

Background: Utility Verticals

Understanding the potential for utility CDR investments benefits from having a comprehensive view of how utilities are structured. Typically, utility assets and operations are focused in two divisions:

- **Power Supply:** Division responsible for operating utility-owned power generation units (e.g. natural gas turbines, wind farms), procuring resources from markets or third parties (e.g. merchant generation), and managing short- and long-term energy, financial, and compliance positions.
- **Transmission and Distribution:** Division responsible for planning, designing, constructing, maintaining, and operating power lines or pipeline infrastructure, often segmented into high-voltage (electric) / high-pressure (gas) transmission systems and low-voltage / low-pressure distribution systems with differing operational and regulatory considerations. (**For a diagram of these divisions and more information, please see the diagram 'A Typical Deregulated Electricity Market in the United States' on page 20.*)

Power Supply

For most utilities, Power Supply is responsible for sourcing energy for customer needs, and often includes a mix of utility-owned assets and contracts with third parties. Power Supply resources vary by utility and region, but typically include conventional resources, including nuclear, coal, natural gas, renewable resources (including hydroelectric, solar, wind, and geothermal); storage resources, such as lithium-ion batteries; and customer resources, such as energy efficiency and demand response. In addition to owned and contracted resources, utilities in restructured regions often participate in wholesale markets to trade energy and balance supply and demand in real-time.

Conventional power generation resources — nuclear, coal, gas, and oil — convert their respective fuels to heat, which is transformed into electricity. Typically, these facilities are large, centralized stations that may have potential as host sites for energy-intensive CDR operations or incorporate CDR in the form of green materials (built environment) used for construction and maintenance. A single nuclear power plant requires hundreds of thousands of cubic yards of concrete.[36] Increasingly, utilities are expanding their power fleets to include solar and wind resources, which are typically land-intensive, opening opportunities to integrate a variety of CDR solutions through application of CDR pathways on properties shared with solar and wind, such as application of biochar or enhanced weathering under or around solar arrays.

As discussed further in *Section 2*, whether utilities own or contract for resources is often a function of the utility's regulatory history, and may be a key consideration for CDR developers looking for partnership opportunities. As a generalization, generation assets in regulated regions (Pacific Northwest, Southwest, and Southern US) are

36 Power, Georgia. *Major Concrete Placement Completed for Vogtle Unit 4*. https://www.prnewswire.com/news-releases/major-concrete-placement-completed-for-vogtle-unit-4-300575072.html. Accessed 6 Sept. 2024.

more likely to be utility-owned, while generation assets in restructured regions (California, Texas, Atlantic, and Midwestern states) are more likely to be owned by competitive entities (merchant generators). This distinction may be impactful regarding the generator owner's interests and incentives to incorporate CDR.

Transmission and Distribution

Transmission and distribution, the conveyance and delivery of energy from producers to consumers, is a core business for every energy utility. Transmission and distribution both refer to conveyance networks, including high- and low-voltage power lines, substations to transform voltage, customer-facing infrastructure (e.g. meters), and the teams, fleets, and equipment necessary to build, operate, and maintain them. Transmission and distribution networks are rife with opportunities for CDR integration.

Transmission networks carry high-voltage power from power generation to end-users, such as distribution substations feeding local neighborhoods or directly to large industrial users. Transmission networks also play a key role in balancing power across the utility and trading power with neighboring utilities. After many years of underinvestment, there is a surge in interest and activity towards new transmission projects intended to support integration of new renewable energy resources and improved market integration across utility regions.

Distribution networks carry low-voltage power from substations to customers within a local community and tend to be integrated into the urban landscape — nearly every street has distribution poles and wires or underground services providing energy. Distribution systems, like transmission systems, are seeing significant investment, driven by both the need to replace aging assets and urgent concerns regarding utility wildfire ignition risk.

Transmission and distribution systems are where the majority of utility property lies — there are over 5 million miles of transmission and distribution system in the US and almost 80,000 substations[37]. A significant share of transmission and distribution infrastructure is on utility-owned or utility-managed land, which often require active management of 20-40 feet on either side of power lines[38]. Utility substations are often several acres in size and require active management on and off the property for electrical safety purposes.

Natural and Working Lands

From hydroelectric watersheds to distribution rights of way, utilities own and manage vast tracts of natural, working, and urban lands — a function which is increasingly in focus as utilities grapple with the impacts of climate change on their properties. Carbon removal has the potential to be a major economic driver to support climate initiatives, such as vegetation management, which may already be required as utilities confront rising wildfire risk. In addition to monetizing improved forestry management, utility lands present ample opportunities to explore other pathways, such as enhanced trees with lower-fire risk properties, improved soil carbon management, and application of enhanced weathering or biochar on utility lands where appropriate.

Wildfire Risk and Vegetation Management

Chief among these environmental, operational, and economic concerns is the rising threat of wildfires. Wildfires triggered by utility infrastructure have resulted in mass casualty events[39], bankrupted one major utility (with several others facing ongoing litigation)[40], and led to drastic operational impacts in the form of preventative

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37 Cybersecurity & Infrastructure Security Agency (CISA). *Sector Spotlight: Electricity Substation Physical Security*. CISA, 16 Feb. 2023, https://www.cisa.gov/resources-tools/resources/sector-spotlight-electricity-substation-physical-security.

38 "Transmission System Vegetation Management." *Eversource*, https://www.eversource.com/content/residential/about/reliability/vegetation-management/transmission-system-vegetation-management. Accessed 6 Sept. 2024.

39 "Remembering the Camp Fire." *Cal Fire*, Cal Fire, https://www.fire.ca.gov/our-impact/remembering-the-camp-fire. Accessed 6 Sept. 2024.

40 Post, et al. "Wildfires Pushed PG&E into Bankruptcy. Should Other Utilities Be Worried?" *Utility Dive*, https://www.utilitydive.com/news/wildfires-pushed-pge-into-bankruptcy-should-other-utilities-be-worried/588435/. Accessed 6 Sept. 2024.

service outages[41] and, in at least one case, a reallocation of utility capital from clean energy investments to wildfire damages and prevention.[42]

Forest thinning is a regular component of land management for many utilities clearing rights of way and maintaining forest health. The resulting biomass can be burned or simply left to decompose, releasing most of the stored carbon back into the atmosphere and further contributing to warming from greenhouse gases. Mechanical tree thinning in the Western US produces millions of tons of waste biomass[43], which creates opportunities for CDR. These opportunities can look like biomass burial (above or below ground)[44], biochar carbon removal (via pyrolysis of biomass feedstock; can also generate electricity),[45] or even reuse in utility operations as a power generation fuel as bioenergy with carbon capture and storage (BECCS).[46] Today, a significant share of this biomass is burned on-site or trucked off-site for disposal, but little if any of it is permanently removed from the atmosphere. The examples provided for biomass into carbon-negative approaches are just a few of the many forms of innovation that intersect with utility opportunities.

While wildfire risks were initially perceived as a regional problem, wildfire concerns have spread rapidly, with serious events across the western US, Texas, Hawaii and beyond[47]. While not all utilities own large forest assets, every utility manages extensive easements and rights-of-way under utility infrastructure. These long strips of often clear-cut vegetation provide ample opportunity for land-intensive CDR, such as enhanced weathering, as the utility land typically cannot be built under or used for other purposes.

Managing Hazard Vegetation with Biomass Carbon Removal and Storage (BiCRS)

Wildfire risk has led to a dramatic escalation in the pace and magnitude of vegetation management programs. These programs produce vast quantities of biomass that often needs to be removed to manage fire risk, and are often sited in remote, difficult terrain. As one reference point, Pacific Gas and Electric (PG&E), a Northern California utility that escalated vegetation management programs following devastating utility-triggered wildfires in recent years, prunes or cuts down over a million trees per year[48].

Removed trees are woodchipped, burned, or left to decay, resulting in methane emissions. While some trees are burned for power generation in biomass energy plants, these plants are typically located in agricultural rather than forested regions, and the cost of transporting trees to these plants and associated air quality concerns with their combustion results makes this a rare outcome. Additionally, many legacy biomass facilities are aging and have poor efficiencies and high criteria pollutant impacts for neighboring communities. More often, downed trees are burned without recovering either the energy or carbon.

Moving forward, utilities should explore opportunities to better utilize forest wastes that integrate CDR and offset vegetation management costs with new revenue sources. Using forest residuals for power generation is discussed further in this chapter. Given the remoteness of many vegetation management programs, utilities could explore opportunities to bury and sequester biomass, a CDR biomass with carbon removal and storage (BiCRS) pathway known as terrestrial biomass storage. Some BiCRS pathways include conversion of biomass residuals to biochar

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41 "Public Safety Power Shutoffs." *California Public Utilities Commission* (CPUC), CPUC, https://www.cpuc.ca.gov/psps/. Accessed 6 Sept. 2024.

42 Mason, Greg. "PacifiCorp Suspends 2022 RFP, Citing Uncertain Federal Regulations." *NewsData, LLC*, 6 Oct. 2023, https://www.newsdata.com/clearing_up/supply_and_demand/pacificorp-suspends-2022-rfp-citing-uncertain-federal-regulations/article_b1860e38-646e-11ee-b0ec-a750e88fc2b8.html.

43 *2016 Billion-Ton Report.* U.S. Department of Energy (DOE), July 2016, https://www.energy.gov/eere/bioenergy/articles/2016-billion-ton-report-advancing-domestic-resources-thriving-bioeconomy.

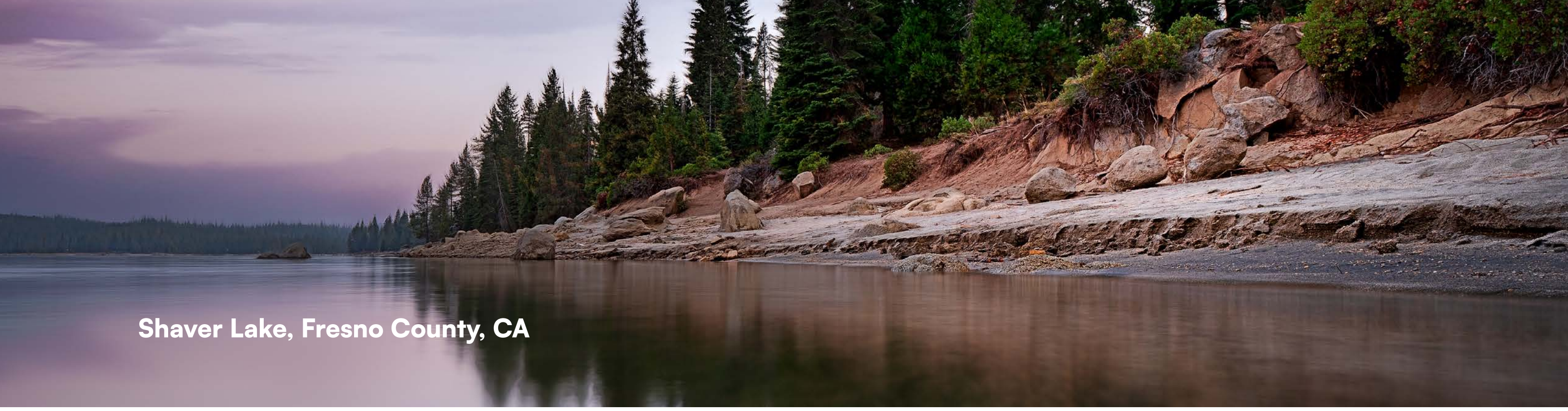
44 Denvir, Audrey, and Haley Leslie-Bole. "Biomass Can Fight Climate Change, but Only If You Do It Right." *World Resources Institute*, 16 Jan. 2024, www.wri.org/insights/sustainable-biomass-carbon-removal. Accessed 6 Sept. 2024.

45 Fact Sheet: Biochar." American University, Institute for Responsible Carbon Removal, www.american.edu/sis/centers/carbon-removal/fact-sheet-biochar.cfm. Accessed 6 Sept. 2024.

46 "Fact Sheet: Bioenergy with Carbon Capture and Storage (BECCS)." American University, Institute for Responsible Carbon Removal, www.american.edu/sis/centers/carbon-removal/fact-sheet-bioenergy-with-carbon-capture-and-storage-beccs.cfm. Accessed 6 Sept. 2024.

47 Penn, Ivan. "Utility-Caused Wildfires Are Becoming a National Problem." *The New York Times*, 22 Mar. 2024. NYTimes.com, https://www.nytimes.com/2024/03/22/business/energy-environment/electric-utilities-wildfires-climate-change.html.

48 "Trees and Powerlines." *PG&E*, Pacific Gas & Electric (PG&E), https://www.pge.com/en/outages-and-safety/safety/vegetation-management.html. Accessed 6 Sept. 2024.



carbon removal or bio-oil via pyrolysis. The formation of biochar, for example, can generate electricity during the process, and the produced biochar could be used in utility lands as a soil amendment for forest management. Some aspects of biochar are even being considered to be applied as an alternative within lithium-ion batteries. BiCRS is experiencing rapid growth, and it is likely that new technologies and pathways will continue to emerge.[49]

Carbon Removal for Soils and Forests

Many utilities own and maintain forest properties, often surrounding hydroelectric dams or other remote utility assets. These forests can themselves present CDR pathways through improved forest management, reforestation, and soil carbon management. Additionally, some utility properties may be suitable for afforestation — developing new forests on properties without prior tree cover.

Southern California Edison (SCE), a major electric utility with operations across metropolitan Los Angeles and the Sierra Nevada mountains, has identified improved forest stewardship as one element of its plan to help California meet its 2045 carbon neutrality goals. SCE's 20,000 acre forest property in Shaver Lake forest was once heavily logged. Prescribed burns, selective logging, and planting up to 30,000 native trees annually have helped restore the forest to its historic composition[50]. The result is a forest that is more resistant to disease and catastrophic forest fires. Beyond creating a healthy, safe forest, such tree planting efforts also remove carbon from the atmosphere.

While SCE's forest management practices initially focused on fire mitigation, its management plan has expanded to assess best practices in soil carbon management. As part of this plan, SCE explored the potential benefits of formal participation in a CDR program to monetize carbon savings, but has cited regulatory hurdles which prevent it from making extended commitments which may limit future flexibility in how the land is used to maximize benefits for ratepayers and recreational users.

Utilities with large tracts of natural lands should explore methods to integrate improved forestry management, and, where appropriate, seek to incorporate CDR projects into existing vegetation management processes. Considering the active management already applied to many utility forests — and increasing interest where active management has not yet been implemented due to wildfires — the marginal cost of implementing CDR is likely to be low and may be offset by potential for CDR revenue.

Leveraging Acreage with Enhanced Weathering

Enhanced weathering represents the natural process of rock erosion which releases minerals that can remove carbon dioxide from the atmosphere and trap it in places like the ocean as bicarbonate. While this process works in

49 Denvir, Audrey, and Haley Leslie-Bole. *Biomass Can Fight Climate Change, But Only If You Do It Right*. Jan. 2024. www.wri.org, https://www.wri.org/insights/sustainable-biomass-carbon-removal.
50 Milbourn, Mary Ann. "A 100-Year-Old Map to a Healthy Forest." *Energized by Edison*, http://energized.edison.com/stories/a-100-year-old-map-to-a-healthy-forest. Accessed 6 Sept. 2024.


Grand Coulee, the largest dam in the United States, contains 12 million cubic yards of concrete.

geological time, it needs to be accelerated to be meaningful in the context of the rapid pace of emissions produced by human activities in recent centuries.[51]

Pulverized rocks, particularly basalt and olivine, can be applied to certain landscapes to accelerate the uptake of carbon dioxide from the atmosphere, which can eventually via runoff make their way to the ocean and help to combat ocean acidification. Utility properties, many of which have gravel or other aggregate applied, could incorporate these materials to leverage expansive un- or under-utilized utility properties for enhanced weathering, where applicable. This can include application at substations and under power lines, which often have gravel or other materials to prevent vegetation in clearance zones, or under solar and wind farms, which may have extensive land areas under and between resources.

Built Environment

Fundamentally, utilities are infrastructure developers and managers. They have decades of experience building and maintaining transmissions and distribution lines, substations, and power generating stations, including the construction of many dams which were, at the time of their construction, among the largest man-made structures on the planet.

With these capital budgets, utilities have immense purchasing power. Utilities are expected to develop hundreds of billions in transmission and distribution investments in coming years,[52] reflecting massive investments in concrete, aggregate, steel, glass, and other raw materials necessary for construction projects. Each of these resources represents an opportunity for the utility and regulator to drive demand for lower-carbon materials.

While it may be cost-prohibitive to fully replace a large infrastructure project's raw material inputs with low-carbon alternatives, incorporating procurement targets can be a major driver to kickstart the new industry. For example, requiring 5% of the cement used to construct a power plant to be carbon-negative may have a marginal impact on the total cost of the plant, but would be a massive source of demand for the emissions-free and carbon-negative cement industry. The same could be said for usage of enhanced wood products that sequester greater amounts of carbon, for internal construction and more at sites.

Clean Foundations: Carbon Negative Cement for the Power Sector

Cement is the foundation of the built environment — it is one of the most commonly used materials and also represents a significant fraction of global CO_2 emissions. Cement plays a key role in construction in the power

51 "Enhanced Rock Weathering." *Climate Portal*, Massachusetts Institute of Technology (MIT), 9 Nov. 2023, https://climate.mit.edu/explainers/enhanced-rock-weathering.
52 "2024 Power and Utilities Industry Outlook." Deloitte Insights, https://www2.deloitte.com/us/en/insights/industry/power-and-utilities/power-and-utilities-industry-outlook.html. Accessed 6 Sept. 2024.

sector as the main ingredient in hydroelectric dams and nuclear power plants as well as the building foundation for other power generation technologies. It is also essential in constructing substations and power lines.

Significant efforts are underway to develop low carbon and carbon-negative cement — cement processes that avoid or manage the carbon-intensive process of baking limestone which produces approximately 1 kilogram of carbon for each kilogram of cement.[53] As cement is between 10 and 15% of the final concrete product, this can have a major impact on the total lifecycle emissions of a large infrastructure project. Biochar for example can be embedded into cement processes, simultaneously helping with carbon storage, improved strength, and other properties.[54] Incorporating carbon-negative cement into a large utility infrastructure project can have meaningful emissions reductions, which can be monetized by the utility — and can help jumpstart a greener built environment industry with relatively modest cost impacts for an individual project. This vision can take different forms, such as concrete that has biochar stored in it, solutions that mineralize carbon dioxide in demolished concrete aggregate and later recycle it, and other methods for portland cement with limestone alternatives.

Green Steel for the Renewable Macrogrid

Like cement, steel is a critical construction input for the power sector. A typical steel lattice transmission tower may use 40,000-60,000 pounds of steel, while high-voltage transmission lines contain approximately 270 pounds of steel per thousand feet of wire[55]. Utilities are currently undergoing significant re-investment, with thousands of miles of annual replacements anticipated in coming years, as well as construction of new lines necessary for integration of new renewables and market expansions.[56] As steel continues to be part of the hard-to-abate portfolio, carbon removal can be implemented at different stages down the value chain. For example, steel slag — an alkaline material — can be used in mineralization processes for carbon storage. A utility could also use carbon removal to meet the final 10% of its hard-to-abate residual emissions goals where steel is involved.[57]

Fuels and Operations

Utilities have extensive energy demand for their trucks, buildings, and other operations that could align with emerging CDR pathways for bioenergy with carbon capture, some of which could come from improved utility land management.

Bioenergy with Carbon Capture and Storage

Stockholm Exergi has developed a model for cost-effective BECCS[58,59] at a cogeneration plant used for district heating. Upon completion, the 150MWe/400MWth facility will be able to capture 800,000 tons of carbon dioxide every year — more than the carbon dioxide emissions of Stockholm's road traffic over the course of one year. However, Exergi has found that project costs are high, and therefore "updated regulations and new economic instruments are needed to enable the creation of large carbon sinks." Exergi's project will provide decarbonized heating for much of the city of Stockholm, and will continue to generate electricity for sale to the regional system operator. While the capture and sequestration process will consume slightly less than half of the electricity production, the associated thermal energy will be recovered for the district heating system. In 2024, Microsoft announced that it had agreed to a 10-year deal with Exergi for a cumulative 3.3 million tonnes of removal.

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53 Srubar, Mark Fischetti, Nick Bockelman, Wil V. "Solving Cement's Massive Carbon Problem." *Scientific American*, 1 Feb. 2023, https://www.scientificamerican.com/article/solving-cements-massive-carbon-problem/.

54 Barbhuiya, Salim, et al. "Biochar-concrete: A comprehensive review of properties, production and Sustainability." *Case Studies in Construction Materials, vol. 20*, July 2024, https://doi.org/10.1016/j.cscm.2024.e02859.

55 "Energy." *American Iron and Steel Institute*, https://www.steel.org/steel-markets/energy/. Accessed 6 Sept. 2024.

56 *Transmission Investment Needs and Challenges*. Brattle, 1 June 2021, https://www.brattle.com/wp-content/uploads/2021/10/Transmission-Investment-Needs-and-Challenges.pdf.

57 "The Net-Zero Standard." *Science Based Targets Initiative*, https://sciencebasedtargets.org/net-zero. Accessed 6 Sept. 2024.

58 Wretborn, Sara. "BECCS – Negative emissions." *Stockholm Exergi*, https://www.stockholmexergi.se/en/bio-ccs/. Accessed 6 Sept. 2024.

59 Löfstedt, Daniel. *Stockholm Exergi announces permanent carbon removal agreement with Microsoft, world's largest to date — Beccs Stockholm*. https://beccs.se/news/stockholm-exergi-announces-permanent-carbon-removal-agreement-with-microsoft-worlds-largest-to-date/. Accessed 6 Sept. 2024.

Waste Heat and Water

Thermal power plants generate tremendous amounts of heat that must be actively managed by plant operators. This process typically involves air-cooling or water-cooling, both of which may create opportunities for CDR. First, this waste-heat may be used directly in CDR pathways — direct air capture, enhanced weathering, and ocean alkalinity pathways all involve heat either in application or in the upstream input development. Waste heat from power plants may present opportunities to reduce input costs for these CDR processes while also finding a beneficial use for heat that would otherwise be released into the atmosphere or nearby bodies of water, reducing the carbon intensity of both processes.

Additionally, some thermal plants may present opportunities for ocean alkalinization resulting from their water-cooling processes. Many large plants process large quantities of ocean water through their cooling systems which are returned to ocean ecosystems. While this process is itself controversial and environmentally detrimental, it is likely to remain in use for years to come given challenges and costs associated with reconfiguring these facilities to be air-cooled. This water flow process may create a cost-effective way to deliver soluble minerals into the ocean that facilitate additional carbon removals.

Utility x CDR Vision: Integrating CDR

What could a future vision of a CDR-integrated utility look like? In this chapter, we identified several key opportunities for utilities to integrate CDR into their existing assets and operations — integrating CDR into forestry and vegetation management operations, using utility lands for enhanced tree growth or enhanced weathering, incorporating carbon negative cement and low carbon steel into infrastructure projects, the use of bioenergy with carbon capture to displace coal consumption at existing power plants, and more.

Each of these pathways has specific considerations that will impact the viability for any given utility. For a utility in a forested region facing increased wildfire risk, it is likely that forestry-related processes, including the burial of vegetative matter removed as part of a wildfire management strategy, or enhancing soil carbon sequestration to help tree health, may be a compelling opportunity to offset some of the program's costs through CDR credit generation. For a utility considering large investments in cement-intensive nuclear power stations or initiating a transmission re-investment program, the utility may be well-suited to incorporate alternative materials for the built environment into their construction efforts.

How a utility identifies and executes a CDR program will require careful consideration — and buy-in from local and state policymakers. The utility regulatory process in which those decisions are made is the subject of the subsequent chapter.

When should utilities invest in CDR?

As discussed in Chapter 1, the primary focus for utility decarbonization should be on direct emissions reductions. Notwithstanding, there may be compelling reasons for a utility to pursue an integrated CDR project in parallel with ongoing emissions reductions. First and foremost, it may be interesting from an economic or technical standpoint, for instance, if a project which reduces utility costs associated with vegetation management and disposal of woody biomass may both reduce operational expenditures and generate revenue as a carbon project. In other cases, a CDR project may have useful community benefits associated with wildfire risk mitigation or protection of natural lands. More so, it may be a strategic investment in support of commercialization of a new technology pathway aligned with utility and regulator interests.

Operational Opportunities

Key Takeaways

Overview: In addition to providing energy, utilities spend a significant share of their budgets on assets, operations, and infrastructure, areas that are rife with opportunities for CDR investments. Key examples of these synergies include utility-managed forests and rights-of-way which generate significant quantities of flammable biomass waste, opportunities to utilize bioenergy with carbon capture at utility facilities, and opportunities to use utility purchasing power for bulk commodities, especially cement and steel, to spur investments in low-carbon and carbon negative materials.

Integrating vegetation management with CDR practices and accounting can significantly reduce methane emissions while opening a new revenue stream to support wildfire mitigation.

- Wildfire mitigation is emerging as a key area of concern for utilities across the country, a reality that is stretching utility budgets and competing for scarce investment dollars.
- Integrating CDR methods into forest management practices can improve carbon outcomes, reducing the share of forest residues left to decompose, while improving the forest thinning economics.
- Forest residues may be a good fit as a feedstock for bioenergy, which can be used by utility assets to offset operational costs of biomass and wooden pole disposal.
- Beyond forests, extensive CDR pathways exist on grassy rights-of-way and on coastal properties.

Bioenergy with Carbon Capture and Storage (BECCS) can be a useful drop-in alternative in coal power stations, enabling substantial emissions reductions while retaining the financial and operational benefits of reusing existing infrastructure.

- BECCS has the potential to substantially reduce fuel-related emissions for existing power generation infrastructure.
- Microsoft recently signed a 3.3 million tonne agreement for carbon removal at an existing bioenergy facility in Sweden, the largest of its kind.

Capital projects represent significant opportunities to integrate carbon negative materials in a manner to spur the industry.

- By allocating even a small share of a large capital budget to emerging carbon negative materials, utilities could jumpstart this evolving industry.

CDR developers will need to work creatively with utilities and policymakers to establish workable policy structures and rates to serve the needs of the carbon removal and wider community.

CHAPTER 4

Utility Regulation: Policymakers and Stakeholders

WHY THE UTILITY REGULATORY FRAMEWORK ALIGNS WITH CARBON REMOVAL

Utilities have a unique and compelling business structure for CDR — as regulated monopolies, utility investments are overseen and approved by policymakers and have strong engagement and input from the stakeholder community. This enables utilities to pursue strategic investments in CDR that meet the intersecting environmental, social, economic, and energy reliability goals that are beneficial to the community as a whole.

There are four elements of alignment between the utility regulatory environment and CDR. First, many utilities increasingly have strong carbon reduction policies that align well with the CDR value proposition, which is explored in Chapters 1 and 2. Second, utilities have a long history of 'market transformation' — i.e., early investments in critical technologies that enable cost declines and commercialization — supported by regulatory action and facilitated by utilities' unique cost recovery models. Third, utilities have expertise in financing and project development for large capital projects that will be necessary to 'launch' large CDR projects. Finally, the utility regulatory process enables critical engagement with CDR pathways from multiple lenses — prior to executing a CDR investment, the proposal would be reviewed by policymakers and stakeholders to ensure its cost-effectiveness, environmental impact, and any specific considerations for electric system reliability or system cost.

There are also many co-benefits that could come with these couplings, such as wildfire mitigation helping the entire region decrease risk and harm, as well as unique jobs that are created from the new carbon removal industry. In some cases, there may be significant revenue opportunities for utilities seeking to integrate CDR, particularly around wildfire mitigation and wooden pole disposal, both of which are significant costs to the utility today. This theme — cost-effectiveness of CDR initiatives — was central in interviews with regulators and utilities supporting this paper, and will likely be at the forefront of discussions of CDR proposals within the utility regulatory context.

Background: Utility Regulation

As 'natural monopolies' in the United States landscape, utilities have a long tradition of economic regulation to ensure they provide quality service at reasonable rates to customers. Over a century and a half of utility regulation has led to a significant expansion in its scope. In the last half-century, many jurisdictions have significantly expanded the role of environmental regulation, beginning with initiatives to mitigate poor local air quality, water pollution, noise, and other concerns from individual facilities.

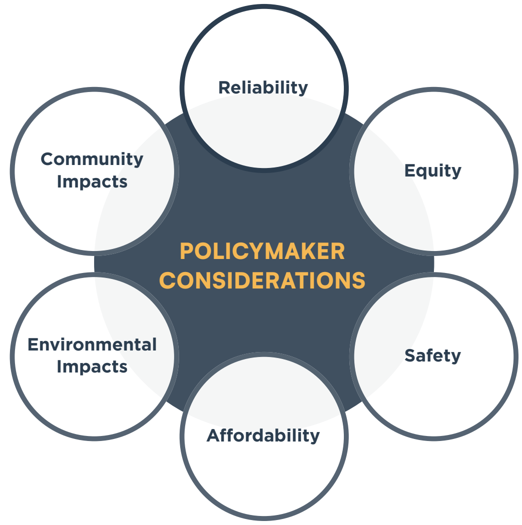
Regulators have traditionally been focused primarily on three pillars: reliability of service (keeping the lights on), affordability of service (keeping the rates low), and safety of service (preventing harm to workers and the public). Increasingly, utility regulators seek to reduce environmental impacts of utilities as a fourth pillar of service, focusing primarily on climate, air quality, land use, and other concerns.

Regulated Investments: Evaluation and Approvals

As regulated entities, utilities must propose and receive approval for investments from regulators to guarantee cost recovery in rates. This process ensures regulated investments are in the best interest of customers and broader policy goals, and gives both policymakers and stakeholders an opportunity to review proposals and weigh in with different perspectives. Utilities have a long legacy of these types of review for utility generation assets and power purchase agreements which could be leveraged for CDR investments.

Specifically, a utility proposing a CDR project would need to convince regulators that the CDR investment is in the best interests of ratepayers and would advance the region's climate ambitions, and would be expected to provide detailed information regarding the project. This would include project costs, sourcing, lifecycle environmental impacts, risks, implications for utility operations (such as energy demand from the grid), areas for community engagement and discussions of co-benefits, and other considerations. Like other proposals, CDR can and should be reviewed by regulators not solely for its cost-effectiveness, but also for holistic benefits and costs, including community co-benefits or community impacts, which some have argued are not effectively captured in current metrics. The utility regulatory ecosystem could be a very effective tool to elicit feedback from stakeholders to determine the total value proposition for customers.

Policymaker Considerations for CDR



In addition to classic resource investment costs, it is likely that regulators will seek to understand specific questions regarding CDR, with emphasis on the investment's emissions integrity and how it interacts with the utility's broader decarbonization planning. Unless or until national standards exist to define CDR integrity — efforts in this direction are underway[60] — it is likely that regulators will seek to understand the following key integrity safeguards:

- **Integrity:** Ensuring the CDR project results in incremental emissions reductions relative to the counterfactual baseline.
- **Permanence:** Ensuring the CDR project results in emissions that are removed for several centuries or more, with safeguards to manage leakage or reversals.
- **Scalability:** Ensuring CDR projects are achievable at scale to the extent they are assumed to be available in future years of a climate plan.

Additionally, policymakers and intervenors are likely to be interested in understanding how CDR fits into the broader portfolio of responses to climate change. Twin targets, the notion of having distinct targets for emissions reductions in tandem with carbon management, is key here to ensure that removals are not pursued at the expense of inaction on direct reductions.

While this level of scrutiny may feel like a barrier for utility CDR investments, it may actually present an important opportunity to wade through these complex issues and arrive at a well-developed, consensus "suite of best practices" for the industry and perhaps even for other industries. A utility investment would inherently have had to pass thorough review from a neutral, critical third-party designed to ensure investments are sound and reasonable while balancing a wide range of outside views — providing an opportunity to surface and address critical perspectives from impacted communities. For a nascent industry working actively to build trust and confidence, this process could build an important record in support of best practices in and beyond the utility sector.

Environmental Regulation: Climate and Clean Energy Policies

The electric utility sector is a leader for decarbonization in both progress and promise. Through investments in clean energy, efficiency, and electrification, electric utilities have been key drivers of emissions reductions, and many face significant statutory or regulatory obligations to achieve lofty clean energy and climate goals in coming years. Statewide policies have ranged from fiscal support for alternative energy, including subsidies and regulations on the competitive landscape, to explicit mandates for renewable energy procurement, to prohibitions on certain resource types, including both near-term prohibitions on coal generation and long-term prohibitions on all oil and gas resources. The magnitude and timing of these policies varies across jurisdictions, but many align on net zero targets between 2040 and 2050.[61]

While CDR may show significant promise for augmenting utility decarbonization efforts, it has yet to play a major role in utility decarbonization plans. This is changing — recent analyses highlight ongoing technical constraints

60 "FACT SHEET: Biden-Harris Administration Announces New Principles for High-Integrity Voluntary Carbon Markets." *The White House*, 28 May 2024, https://www.whitehouse.gov/briefing-room/statements-releases/2024/05/28/fact-sheet-biden-harris-administration-announces-new-principles-for-high-integrity-voluntary-carbon-markets/.
61 Clean Energy States Alliance, Table of 100% Clean Energy States.

with alternative energy sources that are likely to drive a role for CDR[62] — but current policy frameworks have not yet evolved to support utility consideration of CDR within their broader decarbonization plans. Specifically, current policies often focus on the share of energy coming from carbon-free resources rather than the total emissions of the utility portfolio, preventing CDR from being considered within the decarbonization policy framework.

These themes are developed further in Chapter 1, which explores the potential for CDR to play a role in utility decarbonization plans.

Market Transformation: Commercializing New Technologies

Utilities have long played a key role in the commercialization of new technologies, ranging from light emitting diode bulbs to utility-scale solar and storage. Utilities have two characteristics that make them suitable for this task for CDR: they have strong policy incentives to address carbon and face relatively little risk from investments in emerging technologies (despite the challenges listed above). Specifically, utilities — unlike competitive firms — can make a purchase on behalf of all customers, ensuring all customers face equivalent upside potential and downside risk should the investment falter. This has enabled utility regulators to direct investments in emerging technologies that otherwise may struggle to attract the necessary capital to cross the valley of death from concept to commercialization.

Utilities and their regulators have used various approaches to market transformation. For customer-facing technologies, including light-emitting diodes, high-efficiency appliances, and rooftop solar, utilities have leveraged incentives and programs funding to accelerate adoption by customers. For utility-facing technologies, including utility-scale solar, wind, and batteries, regulators have directed utilities to make investments, often through minimum purchasing quotas or other policy directives. Given the scale and intersection of CDR, it is likely that directing utility investments will be a more effective route than customer incentives.

Because of their tremendous purchasing power, even a relatively small purchase by utilities can be meaningful to incentivizing the CDR market to launch without becoming material for customers. As discussed in Chapter 1, this could include relatively modest purchase orders within planned infrastructure projects — for example, dedicating a small percentage of material sourcing for a new hydroelectric dam or power plant to green materials or adding additional points on a competitive solicitation to a supplier with an improved lifecycle assessment pathway.

Alternatively, it could look as simple as utility advance commitments for CDR as a part of their long-term decarbonization strategies. For example, to date, no utility has made a regulated commitment to participate in Frontier, the consortium of companies making advance market commitments for the CDR market, although many of the consortium participants are large energy users seeking to offset some of the energy emissions.

Whether and how a utility could make such a commitment would be a question for the regulatory process, which would enable policymakers and stakeholders to weigh in on both the overarching merits of utility commitments to CDR as well as merits of the specific project in question.

Community Impacts: Engagement and Equity

Utility regulators are keen to ensure utility projects and investments have positive community benefits while avoiding negative community impacts. Aligning CDR projects with community interests, such as reducing wildfire risk, funding and expanding protected lands, and generating revenue to offset ratepayer costs, will significantly strengthen a CDR project's viability within the regulatory ecosystem. Similarly, a project that is perceived as

62 *2022 Scoping Plan for Achieving Carbon Neutrality.* California Air Resources Board, Dec. 2022, pp. 91-97, https://ww2.arb.ca.gov/sites/default/files/2022-12/2022-sp_1.pdf.

negatively impactful — for instance, one that reduces public access to natural lands or has negative air quality impacts — is likely to face community opposition. Similar dynamics have been escalating in public debates over the development of transmission lines, renewable energy projects, fuel pipelines, and other utility infrastructure.

CDR developers would be well served to engage early with community stakeholders, identifying and seeking to address concerns raised by the community. In addition to the utility's ratepayers, local community members, including Tribes, and environmental organizations should be considered and engaged with as the project is designed and proposed. More broadly, the process of engaging with the public and impacted community members through the utility regulatory process can and should be absorbed as a best practice for CDR developers working beyond the utility regulatory ecosystem.

Carbon Edison: The Utility of the Future?

The concept of carbon removal as a regulated waste management utility has been floated repeatedly over the years[63]. In many ways, carbon dioxide is not dissimilar from other waste streams — trash and sewage, for example — which are addressed through collective action, providing a dedicated funding stream to a mission-oriented entity responsible for the tragedy of the environmental commons.

In this framework, a carbon removal utility would be tasked with removing carbon dioxide from the atmosphere, either directly or indirectly, and then storing or effectively repurposing it. The carbon removal utility would have modeling and planning tools, financial and project development capabilities, a governance structure, and a revenue stream, just like other utility services. This would enable the utility to planfully identify both supply options — compelling removal pathways and storage— and could be structured to facilitate removals for hardest-to-abate sectors while incentivizing or mandating reductions for other sectors.

This standardized, all-encompassing approach may be more efficient at bringing necessary new technologies to scale than today's nascent voluntary market.[64]

At present, the idea of a carbon removal utility is just that — a concept. As the world leans in to addressing historic atmospheric pollution, it will be interesting to see whether it can make the leap from concept to application.

Utility x CDR Vision: Positive Regulatory Engagement

What could a future vision of a well-regulated utility CDR investment look like? In this chapter, we've identified several potential benefits from the utility regulatory ecosystem for early investments in CDR. Utilities have strong climate directives that could drive demand for CDR in tandem with investments in direct reductions through renewables and efficiency. Utilities have a long history of market transformation for climate technologies, ranging from consumer efficiency widgets to large-scale utility resources such as solar, wind and storage — with many lessons and much experience to add to CDR's commercialization curve. Finally, we've identified the potential benefits of utilizing the utility regulatory review process to ensure utility investments are economically and

63 Buck, Holly Jean. "Should Carbon Removal Be Treated as Waste Management? Lessons from the Cultural History of Waste." *Interface Focus*, vol. 10, no. 5, Oct. 2020, p. 20200010. DOI.org (Crossref), https://doi.org/10.1098/rsfs.2020.0010.

64 Geels, Frank W., et al. "Sociotechnical Transitions for Deep Decarbonization." *Science*, vol. 357, no. 6357, Sept. 2017, pp. 1242–44. DOI.org (Crossref), https://doi.org/10.1126/science.aao3760.

environmentally sound while addressing critical perspectives on integrity and community impacts. At a pivotal time for the CDR industry, this level of engagement can build confidence for buyers and local communities and build a public record in support of thoughtful decisions by both regulated utilities and less-regulated industries.

Institutional Synergies

Key Takeaways

Overview: The utility regulatory ecosystem has a number of institutional characteristics that make it well-poised to be a leader in carbon removal.

Utility climate and clean energy policies create a strong incentive for utilities to engage with CDR in tandem with investments in clean energy, efficiency, and electrification.

- Utilities are among the most ambitious sectors in terms of climate progress and climate ambition, with net zero emissions goals and policy requirements in place for much of the industry.
- As utility planning for net zero grows more sophisticated, utilities are likely to identify new constraints which limit their ability to fully decarbonize their power systems and will increasingly look to CDR to fill gaps in their decarbonization trajectories.

Utilities' long history of market transformation in clean energy and consumer products could jumpstart the nascent carbon removal industry.

- Utilities and policymakers have decades of experience driving market transformation for energy efficient consumer products and clean energy. Utilities are currently playing a key role in the commercialization of solar and wind technologies, battery storage, heat pumps, and electrified transportation.
- As rate-regulated entities, utilities can make investments in early-stage technologies with lower risk than traditional competitive firms — costs and risk are socialized across the entirety of a large customer base with no stranded asset risk to the utility.
- By incorporating CDR into utility carbon policies and resource plans, policymakers and utilities can spur the large, serious financial commitments necessary to commercialize emerging CDR technologies.

The utility regulatory ecosystem is rigorous and will require utilities and CDR developers to make a compelling economic, environmental, and social case to regulators for investment approval.

- Utility investments must be approved by regulators to guarantee cost recovery, requiring utilities proposing CDR to engage with policymakers and stakeholders to develop a record supporting CDR investments from economic, environmental, and social lenses.
- While this may raise the bar for utility CDR interest, it also creates an opportunity for the CDR industry to make a compelling case for the benefits of specific pathways, and allows key implementation and integrity questions to be resolved in public in a manner which can be used as a reference point and best practice for both regulated and non-regulated industries.

Conclusion and Recommendations

Utilities and the CDR industry are on the starting line of a decades-long collaboration to achieve deep economy-wide decarbonization. Each will be necessary for the other, and each will have an outsized role in supporting the decarbonization of other sectors through electrification and removals, respectively. Achieving success in both sectors will require thoughtful engagement on key issues for policymakers.

In this report, we have identified a number of intersectional insights and actions which utilities, the CDR industry, and policymakers can pursue to strive for success across both industries.

- **Utility Decarbonization** – CDR on the Path to Net Zero
  - Utility decarbonization plans increasingly identify the need for emerging technologies — including carbon management strategies — to achieve net zero.
  - Proactive engagement with CDR potential can support utility and policymaker integration of CDR potential into utility planning models for assessment of fit within the utility portfolio.
  - Utilities and policymakers should explore 'twin targets' — distinct procurement targets for reductions (i.e., clean energy) and for carbon management (ie removals) informed by robust technical modeling.
- **Climate Loads** – Powering Energy-Intensive CDR
  - Many CDR pathways are energy-intensive — sourcing low-cost, low-carbon energy will be critical for project success.
  - Navigating the electricity procurement landscape is complex, and must consider economic (rates), technical (engineering limitations), and environmental (emissions attribution) as part of project siting and development.
  - Looking forward, CDR developers and utilities should explore collaborative tariff development to design new rates and programs suitable for emerging climate loads.

- **The Utility-CDR Nexus** – Assets and Operations
  - Beyond the direct energy intersections, opportunities abound for utilities to integrate CDR into their assets and operations, which include extensive land management operations, construction projects via carbon-negative green technologies, operational budgets, and investments.
  - To achieve this potential, utilities and CDR developers should proactively identify synergistic utility-oriented CDR pathways leveraging utility properties, construction projects, and operations, including a specific emphasis on improved management of forest residues and biomass waste generated by wildfire risk mitigation.
- **Utility Regulation** – Policymakers and Stakeholders
  - The utility regulatory ecosystem may hold several benefits for early investments in CDR, recognizing the success and similarities with early utility investments in renewables and storage, utility project management and financing expertise, and the stakeholder-forward process through which utility resource investments are made.
  - To achieve this potential, utilities and CDR developers should lean into the regulatory ecosystem and submit regulatory proposals which identify and articulate the benefits of CDR investments for utilities and ratepayers, developing a pathway and best practices which can be replicated in other industries.

APPENDIX

Utility Regulatory Concepts and Terminology

Several key regulatory concepts which are referenced in this report are provided below for ease of reference:

- **Investor-Owned Utility (IOU) & Publicly-Owned Utility (POU):** Investor-owned utilities (IOUs) are for-profit utility companies and are typically regulated by a state-level commission under state law. Publicly-owned utilities (POUs) are local municipalities operating as utilities and are typically regulated by a local board or commission.
- **Public Utilities Commission (PUC):** Utility commissions are state-level agencies responsible for overseeing and regulating utilities in alignment with state law. State jurisdiction extends to power generation, distribution, operations and maintenance, rate design, customer programs, and other areas.
- **Federal Energy Regulatory Commission (FERC):** The Federal Energy Regulatory Commission (FERC) is a federal agency responsible for overseeing wholesale markets and transmission policy, both of which fall under the interstate commerce clause.
- **Rate Regulation:** Rate regulation is the process of state oversight and approval for proposed utility expenditures to be recovered in utility rates.
- **Integrated Resource Planning:** Integrated resource planning (IRP) is the process to determine which resources a utility will procure on a forward-looking basis, using modeling tools and human intuition to select least-cost, least-risk portfolios intended to comply with policy requirements for reliability and emissions.
- **Renewable Portfolio Standards & Emissions Policies:** Renewable Portfolio Standards (RPS) & Emissions Policies are the two primary decarbonization policies. RPS policies require minimum procurement of clean energy while emissions policies directly target carbon emissions.
- **Deregulation:** Deregulation is the process of removing specific regulatory frameworks, often to facilitate competition; deregulation has been applied differently in different regions but often refers to either deregulation of retail service, whereby customers can select their own provider; deregulation of wholesale markets, whereby generators compete in an open market; or both.
- **Decoupling:** Decoupling refers to bifurcating utility financial incentives from energy sales, shifting sales to a pass-through cost while permitting utilities to recover a fixed return on utility capital expenditures.

Carbon Business Development Council

The Carbon Business Development Council (CBDC) is focused on responsibly reaching gigaton-scale carbon removal by supporting innovators who are leading the charge and educating the general public about carbon removal. We act in the public good to help ensure that carbon removal scales responsibly.

CarbonDevelopmentCouncil.org

Carbon Business Council

The Carbon Business Council (CO2BC), a member-driven and tech-neutral trade association of companies unified to restore the climate, is the preeminent industry voice for carbon management innovators. Together, the nonprofit coalition represents more than 100 companies across six continents with more than $16.5 billion dollars in combined assets.

CarbonBusinessCouncil.org