Beyond Sustainability: Carbon Negative

Investment Ideas for Renewables and Emerging Opportunities

- Global investment in climate-change mitigation and adaptation strategies has grown almost 60% over the past decade, with almost half of climate finance provided by the private sector. Yet the world is not on track to reach globally agreed goals.
- Renewable energy investments such as solar, wind, and hydropower have been the core elements of current efforts to reduce reliance on carbon-based fuels. More recently, both public and private sector investors are broadening their focus, advocating an "all hands on deck" approach to climate solutions that encompasses renewable energy, non-renewable zero-carbon energy (e.g., nuclear), and "carbon-negative" solutions – ways to *remove* carbon emissions from the atmosphere.
- In this report, we highlight less well known zero-carbon or carbon-negative solutions. We provide a brief recap of the science, key current net-zero approaches, and the growing (albeit still small) opportunity set for carbon-negative investments. We also look at some of the more early-stage or "edge" ideas as well as examples of innovative products and services targeting a zero-carbon future.
- Lastly, many investment managers are positioned to take advantage of the opportunities in this mega-trend. We offer selected examples of such strategies at the end of the report.

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Introduction

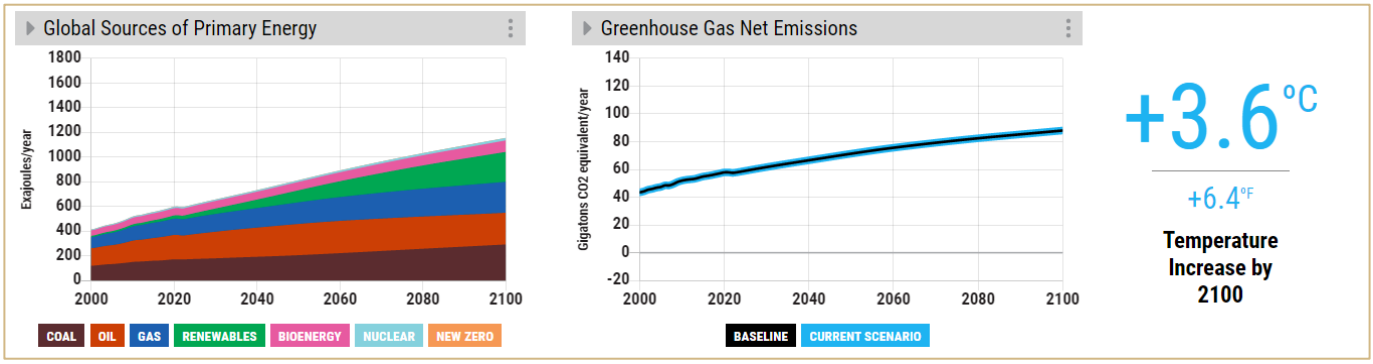
Recent years have seen substantial growth in both public and private sector commitments to achieving carbon neutrality, or "net zero," as a core strategy to combat climate change. At a high level, achieving net-zero greenhouse gas emissions can be achieved by 1) balancing the production of emissions with their removal, or 2) eliminating emissions altogether – i.e., by transitioning to zero-carbon energy. Both of these paths, and the variety of technologies and tactics underpinning them, are key areas of current focus for both public and private sector participants.

According to Climate Policy Initiative (CPI), a nongovernmental analysis and advisory organization, total climate finance has increased approximately 58% over the past decade, reaching $632 billion in 2019/20. The public sector (primarily development finance organizations) accounted for 51% of that investment. Private investment in climate solutions, particularly from commercial financial institutions, has grown in recent years to $310 billion in the 2019/20 period.[1]

Despite growing investment and stated commitments, however, the world is not on track to achieve net-zero emissions (carbon neutrality) by 2050. This is the target year laid out by the Paris Climate Agreement as necessary to limit global temperature increases to approximately 1.5°C by the end of the century, thereby averting the most severe forecasted impacts. Not only are global emissions still rising, CPI estimates that current levels of investment in renewable energy would need to triple from 2020 levels in order to meet that target by 2050.[2]

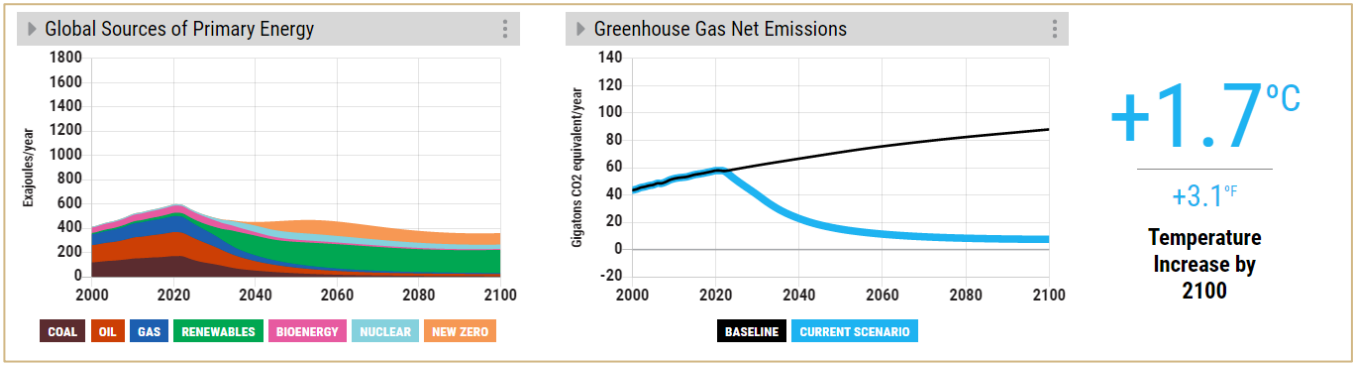
As illustrated by the En-ROADS global climate simulator, a "baseline" scenario in which no further climate action is taken (i.e., no government incentives, no investments in new technology) would yield a 3.6°C temperature increase by 2100 (Exhibit 1). Conversely, to approach a 1.5°C limit, all carbon-based energy use would need to cease immediately – an obviously impossible scenario, and one that the En-ROADS simulator suggests might not even be enough (Exhibit 2).

Exhibit 1: Projected emissions/temperatures if no further climate action is taken



Source: https://www.climateinteractive.org/en-roads/. The En-ROADS climate simulation tool is a publicly available online model developed by Climate Interactive, the MIT Sloan Sustainability Initiative, and Ventana Systems. It allows users to adjust variables related to greenhouse gas emissions to see their project impacted on global temperatures.

Exhibit 2: Projected emissions/temperatures if all carbon-based energy use ceased



These simulator results reinforce a growing interest on the part of scientists and policymakers to taking an "all hands on deck" approach to climate solutions, one that encompasses renewable energy, non-renewable yet zero-carbon energy (e.g., nuclear), and "carbon-negative" solutions – ways to *remove* carbon emissions from the atmosphere.

Renewable energy investments such as solar, wind, and hydropower are core elements of current efforts to reduce reliance on carbon-based fuels. In this report, we highlight less well known zero-carbon or carbon-negative solutions. We provide a brief recap of the science, key current net-zero approaches, and the growing (albeit still small) opportunity set for carbon-negative investments. We also look at some of the more early-stage or "edge" ideas as well as examples of innovative products and services targeting a zero-carbon future.

Lastly, many investment managers are positioned to take advantage of the opportunities in this mega-trend. We offer selected examples, indicating those available through Pathstone.

The Science in Brief

Carbon dioxide equivalent (CO_2e)[1] circulates through Earth's ecosphere. It naturally cycles from the atmosphere to the earth, water, plants and other living beings, then back into the atmosphere through various natural processes.[3]

This natural carbon cycle, billions of years old, has been thrown out of balance in a strikingly short period of time by the burning of fossil fuels, changing land use, and other human activities (Exhibits 3 & 4). CO_2 levels increased 34% between 1950 and 2021, from 310.7 parts per million (ppm) to 419 ppm, exceeding 400 ppm for the first time in over 800,000 years. Changes of this magnitude in CO_2 concentrations historically have occurred over thousands of years, not decades.[4]

Exhibit 3: World CO_2 Concentrations Over 800,000 Years

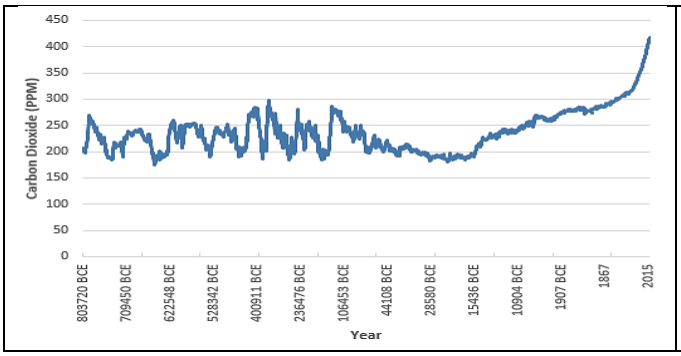
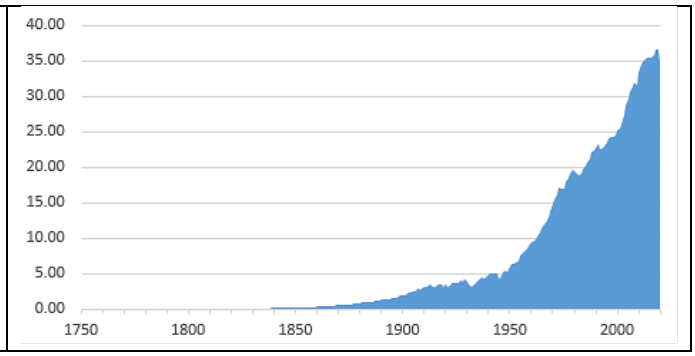


Exhibit 4: Global Annual CO_2 Emissions (Billion Metric Tons)



Source: https://ourworldindata.org/atmospheric-concentrations

The disruption to the carbon cycle has created unintended consequences for Earth's climate, such as increasingly common temperature anomalies and rising sea levels (Exhibits 5 & 6). During 2022 alone, polar temperatures hit a staggering 50°F to 90°F above normal,[5] India experienced its hottest April in 122 years, and temperatures in Pakistan reached as high as 120.2°F.[6]

Exhibit 5: Temperature Anomalies, 1900 – 2020
(Deviation from average temperature over 1951-80 period)

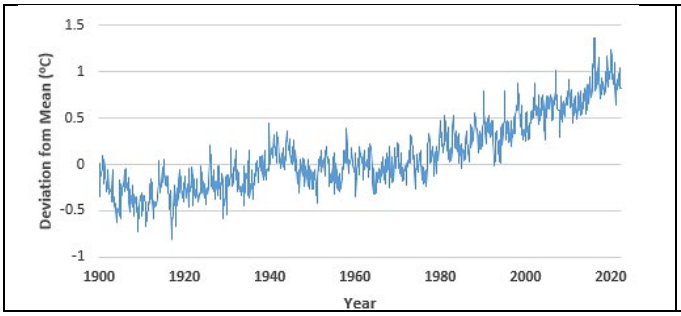
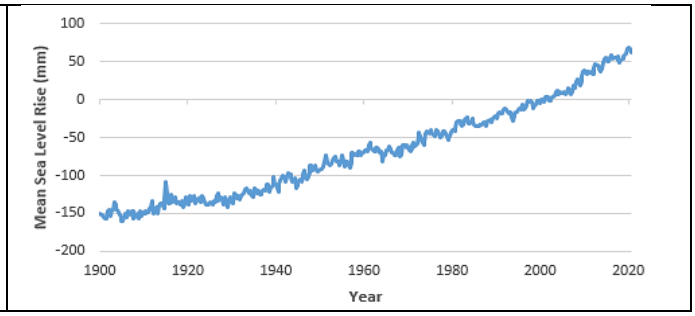


Exhibit 6: Global Average Sea Level Rise
(Relative to 1993 - 2008 world average sea level)



Source: https://ourworldindata.org/explorers/climate-change

The consequences are proving severe and widespread, from diminishing water supply to declining yields from crops. As a result of sea-level rise primarily due to melting polar ice, it is estimated that by 2100 as many as 2 billion people could be displaced from their homes from rising waters, effectively becoming climate refugees.[7]

The financial impacts of climate change are jarring as well – the London School of Economics estimates that $3-24 trillion in global financial assets is at risk by the end of the century. This is a theme we at Pathstone have explored in the past: See No Place to Hide: Climate Change and Systemic Financial Risk for our analysis.[8]

[*] CO_2e is a measure used to compare emissions from different greenhouse gases on the basis of their contribution to global warming. It converts amounts of other gases to the equivalent amount of carbon dioxide.

The Journey to Net Zero

Given the body of scientific evidence, virtually all countries accept the need to transition to net-zero carbon emissions.[9] Governments and corporations are reviewing their practices and establishing roadmaps to net zero carbon operations. Momentum toward energy generation from zero-carbon sources is building: According to the U.S Energy Information Agency, the percentage of U.S. energy sourced from zero-carbon resources such as wind and solar has steadily increased over the past three decades (Exhibit 7) and zero-carbon sources accounted for 40% of total energy generated during 2020 (Exhibit 8).[10]

Exhibit 7: U.S. Electricity Generation by Source 1990 - 2020

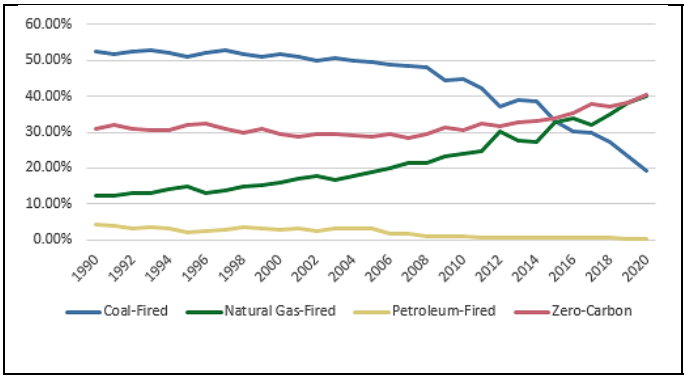
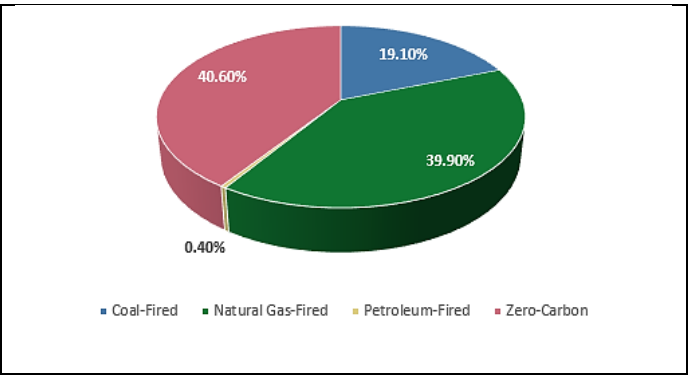


Exhibit 8: U.S. Electricity Generation by Source, 2020



Source: https://www.eia.gov/environment/emissions/carbon/

Both public and private initiatives are spurring the development of infrastructure to support net-zero goals. For example:

- The U.S. passed the $1 trillion Infrastructure Investment and Jobs Act in November 2021. Among other provisions, the law authorized funding for transit and clean energy transition; $7.5 billion of this amount is allocated to building out electric vehicle charging networks with a goal of 500,000 EV chargers across the country.[11] This move was followed in August 2022 by the Inflation Reduction Act, which is primarily focused on climate-related investments. (Please see our recent report Inflation Reduction Act of 2022 – Key Investment Implications for an assessment of its potential impact climate-related investment.)
- Automobile manufacturers are starting to openly pledge commitments to full electric vehicle fleets. General Motors is investing $35 billion between 2020 and 2025 towards their ambitions of an "all-electric future".[12] Honda plans to phase out all gas- and diesel-powered cars by 2040. Volvo aims to sell only EVs by 2030.

Applying Circular Economy Concepts to the Electric Energy Supply Chain

Redwood Materials has ambitions to create a domestic U.S. circular economy of recycled materials to power electric vehicles. Creating a sustainable supply chain by collecting and recycling materials with elements of lithium, cobalt, nickel and more, Redwood Materials recovers value from scraps of products such as cell phones, smart watches, laptops and other battery-powered items and returns recycled elements to the U.S. battery production supply chain. For example, in a partnership with Panasonic, Redwood will supply Panasonic with recycled materials to produce lithium-ion cells. Not only will this drive down the cost of batteries, but it will also reduce carbon emissions related to international transportation of materials.

Beyond Renewables: Other Net-Zero and Carbon-Negative Ideas

The latest report by the Intergovernmental Panel on Climate Change (IPCC), Global Warming of 1.5°C, shows that in every scenario the IPCC assessed, limiting global temperature rise to 1.5°C (the threshold beyond which economic and social impacts may be catastrophic) will require the world's economies to adopt carbon dioxide *removal*. [13]

This conclusion is not surprising given annual expected carbon emissions of about 42 gigatons per year and a remaining budget of only 420 gigatons of CO_2 before 1.5°C is reached. The world, in particular developing economies, will not achieve net-zero emissions in the next ten years. Therefore, the remaining carbon budget will be more than depleted, requiring carbon removal – i.e., carbon negative solutions – as soon as possible and on a large scale within the coming decades. According to IPCC models, 5-16 gigatons per year of carbon removal is necessary to achieve net zero emissions.

Some companies have already recognized and are acting upon this imperative. For example, in 2020 Microsoft announced its commitment to becoming carbon negative by 2030 and to removing from the atmosphere all the carbon it has emitted since its 1975 founding. In 2020 Microsoft purchased the removal of 1.3 million metric tons of carbon across 26 projects around the world.[14] To account for historical emissions, Microsoft must remove 24 million tons of carbon between 2030 and 2050 plus 6 million tons of residual carbon emissions annually by 2030 and onward.[15] To sustain and accelerate progress toward carbon removal, Microsoft founded a $1 billion Climate Innovation Fund investing in climate technologies such as direct air capture. [16]

Below we discuss carbon removal strategies, zero carbon energy alternatives, as well as theoretical/early-stage solutions.

Direct Air Capture: What Is It? How Does It Work?

Direct air capture (DAC) is a process in which carbon dioxide is extracted from the air through chemical reactions. Once extracted, the carbon dioxide can be sequestered or repurposed. With continued improvements, direct air capture has the potential to play a significant role in decarbonization. Solutions are needed to address long-term sequestration, storage, resource limitations, and scaling to unlock the full potential of direct air capture.

Currently, the sector is small, with fewer than 20 plants globally, and the technology is still expensive to operate. Currently, the cost of direct air capture can range from $250-600/metric ton; by our calculation, Microsoft would pay $6-14 billion to remove their targeted emissions through DAC alone.

It is not a new technology, however. Carbon Engineering and Climeworks, two companies that provide direct air capture services, were both founded in 2009:

- **Carbon Engineering** and its partners are actively deploying their direct air capture capabilities to capture more than one million tons of carbon dioxide per year.[17] In 2020 Carbon Engineering launched construction on the Innovation Centre, a permanent research and development facility to advance and develop their Air to Fuels technology. In August 2022, Occidental and its subsidiary 1PointFive announced the launch of a plan to build the world's largest DAC plant, in Texas, following work done in collaboration with the Innovation Centre. The plant will begin to capture 500,000 metric tons of CO_2 when launched and is expected to scale up to 1 million metric tons per year. [18]
- **Climeworks** promotes a permanent, efficient, measurable and safe direct air capture option by utilizing CO_2e collectors to draw in air with a fan to filter for absorption. Once the collector is filled, its temperature is raised to 80° – 100°C, enabling the release of CO_2e for redistribution into climate-friendly products or storage. In 2021 Climeworks launched Orca, the world's largest direct air capture and storage plant. In November 2011, Square Inc. agree to purchase 2,000 tons of carbon removal over a nine-year period.[19]

The Role of Afforestation and Reforestation in Decarbonization

Afforestation and reforestation play a key role in reducing carbon levels. They provide a complementary – and to date much less costly – solution to direct air capture.[20]

For well over a decade, the companies highlighted below have had an impactful presence in sustainable forest management. They continue to sequester many metric tons of CO_2e and improve carbon sequestration across the U.S. and Canada.

- The **Lyme Timber Company**, founded in 1976, invests in forest-related assets in the U.S. and Canada. The company focuses on land conservation, sustainable forest management, and ecosystem services to drive environmental and societal benefits while generating risk-adjusted returns for investors. Their portfolio includes over 1 million acres of working forest across the U.S. that use conservation and forestry strategies to sequester carbon.[21] In 2021 the company finalized their five-year plan and metrics. Their environmental goals include increasing forest-related carbon sequestration and reducing the carbon footprint of their corporate and portfolio company operations.22 To meet a goal of ensuring more than 40 years of carbon storage capacity, Lyme Timber seeks to enroll 300,000 new acres of forestland in carbon protocols. Through modified management plans and harvest reductions, the company aims to sequester 30,000 additional tons of carbon per year than was sequestered during 2020.
- **EFM Investments & Advisory (EFM)** Invests in forestry-based solutions across the Americas to create long term financial value and lasting environmental and social impact. EFM manages 130,000 acres of forestland in California, Nevada, Oregon, and Washington. These lands serve as a carbon sink, storing 6.6 million tons of CO_2. Certified by the Forest Stewardship council, EFM uses practices such as rotation, retention, and creating reserves around rivers to increase carbon storage efficiency. Improved carbon sequestration and removal of emissions is achieved by extending rotation ages and allowing trees to grow into more mature age classes. As an illustration of EFM's impact, Nike has partnered with EFM to offset emissions associated with shipments from their website through two projects in Oregon. This partnership will aid Nike's commitment to reduce their greenhouse gas emissions by 65% in their owned or operating spaces and by 30% across their global supply chain.[23] The carbon offset project will include 28,000 acres across two properties in Oregon.
- Founded in 1995 by Tom Massengale and Chris Zinkhan, the **Forestland Group** provides forest-based carbon solutions. They prioritize conservation, sustainable timber harvesting operations, and restoration of working forests. In 2020 the organization sequestered 6.9m metric tons of CO_2 and generated 1.25m carbon credits.[24] Their sustainable management plans cover 2.3m acres, including the largest private forest carbon offset project regulated by the California Air Resources Board.

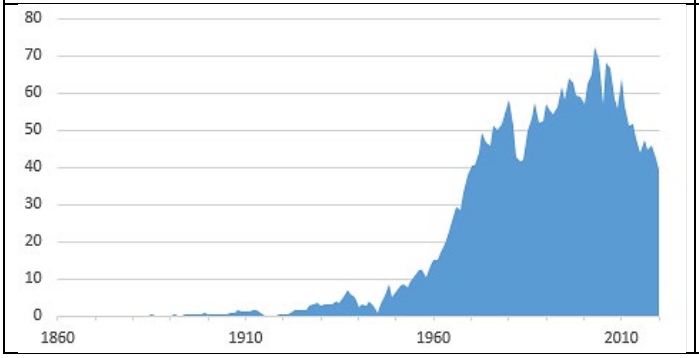
Despite these companies' efforts, some sobering context is warranted: their impact on carbon removal pales in comparison to that of the Amazon, at an estimated 3,279,649 km2 forest cover that absorbs 1.5bn tons of CO2 – which, in turn, represents removal of a mere 4% of global emissions.[25]

Nuclear Energy

Nuclear energy offers a zero-carbon energy alternative, albeit historically a controversial one. Concerns around nuclear energy persists due to the disasters of Chernobyl and Fukushima as well as the challenges of nuclear waste management. During July, however, the European Union labeled investments in nuclear energy as green and climate friendly.[26]

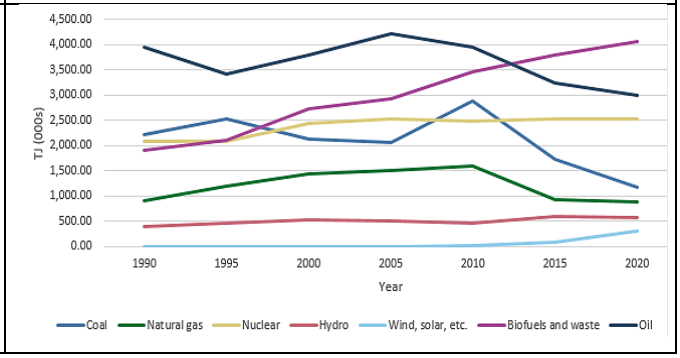
Finland, a top five greenhouse gas emitter on a per capita basis during 2001, has found success reducing its reliance on fossil fuels while increasing energy generated from nuclear, wind, solar, and biofuel sources. Through the use of carbon sinks, public policy, and efforts to phase out coal, Finland has been able to reduce its annual CO_2 emissions from their peak by over 30% (Exhibit 9). Finland has five nuclear reactors with plans for a sixth. These nuclear reactors could account for around 60% of the country's electricity if all proposed projects are completed.[27] The nuclear waste is entombed and buried 430 meters below the ground in a repository at Onkalo.[28]

Exhibit 9: Finland Annual CO2 Emissions (Million Metric Tons)



Source: https://ourworldindata.org/co2-emissions

Exhibit 10: Finland Total Energy Supply by Source



Source: https://www.iea.org/countries/finland

Nuclear reactor designs have progressed, and there are now more diverse designs in development.[29] For example, TerraPower, cofounded by Bill Gates, is promoting a nuclear technology that uses liquid sodium rather than water as a cooling agent and does not require outside energy to operate, thus reducing risk.[30]

Furthermore, exploration of nuclear fusion has garnered interest for its potential to unlock limitless clean energy, although it remains far from being a commercial opportunity. Nuclear fusion occurs when two nuclei merge to form a single nucleus. This process requires extreme temperatures in order for the reaction to occur, which will release large amounts of energy. Tae Technologies, a nuclear fusion company, has raised $1.2b. Commonwealth Fusion Systems has raised more than $1.8b for the endeavor. Lockheed Martin aspires to develop compact fusion reactors to harness nuclear energy. Potential applications include powering a city up to 100,000 people, delivering energy to the developing world, and speeding up space travel.[31]

Establishing Markets Through Climate Tech

The Frontier Fund uses advance market commitments to fuel innovation in climate tech. Advance market commitments, historically used for vaccines, ensure a market for products with high development costs. Using this vehicle, Frontier Fund has pledged $925 million in commitments over nine years from Alphabet, Meta, Shopify, Stripe and McKinsey for carbon removal. The commitments are not an investment in early-stage carbon tech startups, but rather a commitment to accelerate carbon removal as early adopters and customers. Frontier Fund is seeking solutions that can store carbon for at least 1,000 years, drive prices to less than $100/metric ton, and remove more than 0.5 gigaton of carbon a year. Establishing a market for these solutions further solidifies the demand and need for climate solutions.

"Edgier" Solutions

Given the magnitude of the challenge, scientists are looking at a range of solutions. Among these are early-stage concepts, some of which may seem far-fetched — today. Below are just a few representative approaches.

Solar Geoengineering

There are several methods under investigation to basically limit the effect of solar radiation on the earth.

Aerosol injection and marine cloud brightening are two forms of solar radiation management methodologies. Mimicking cloud ashes from volcanic eruptions to reflect sunlight, aerosol injection can theoretically cool the planet by spraying aerosols into the atmosphere. Marine cloud brightening entails using ships to spray saltwater into the clouds, making them appear brighter and thus able to deflect more sunlight from reaching the earth. Although these two strategies may theoretically cool the planet, they will not remove CO_2e from the atmosphere. Further, each brings a risk of creating new harmful impacts on the ecosphere. [32]

Therefore, it is critical to study the efficacy of solar geoengineering solutions. One such initiative, the Keutsch Group at Harvard University, is conducting a Stratospheric Controlled Perturbation Experiment (SCoPEx), a project exploring the impact of aerosols with air mass. Flying a balloon 20km into the atmosphere, SCoPEx studies the interaction between air mass and gases as well as particles. The experiment analyzes the air mass for changes in the density, chemistry, and light scattering.[33]

"Space Bubbles"

A team of MIT scientists is working on a space-based solar geoengineering solution that could reverse global warming by deflecting just 1.8% of solar radiation from reaching Earth. [34] The team intends to manufacture "bubbles" – thin reflective films – between the Earth and Sun at the point where their gravitational pulls are roughly equal. These bubbles would deflect solar radiation without affecting ecosystems on Earth, according to their research.

Ocean De-Acidification

Canadian firm Planetary Technologies is seeking to effect permanent carbon removal using the oceans. Decreasing the ocean's acidity by lowering its CO_2 content would boost the ocean's capacity to absorb more CO_2 from the air. Planetary's technology (still in the research and development phases) would add alkalinity to seawater. The firm plans to start open-ocean trials in 2022 by adding its "antacid" to wastewater treatment facilities.[35]

Decarbonizing Real Estate Finance

Amalgamated Bank aims to achieve net zero emissions in their financing and operations by 2045.[1] Acknowledging the challenges of measuring emissions within the financial sector, the bank has sought guidance from organizations such as the Science Based Target Initiative, Net Zero Banking Alliance, and Glasgow Financial Alliance for Net Zero. Amalgamated intends to encourage electrification and decarbonization through public policy advocacy and engagement with clients to meet reduction targets for their financed emissions. They will apply their approach across, commercial real estate, multi-family housing, mortgages, and business loans. By 2030 their goal is to reduce finance emissions from commercial real estate and multi-family housing by 50% and from mortgages by 47%. In addition to reducing scope 1 and 2 emissions, Amalgamated is investing in solar energy and efficiency programs.

Investment Opportunities

Investing in unique solutions to decarbonize or outright remove carbon, many investment managers' portfolio strategies are aligned to take advantage of the opportunities in this mega-trend. The table below provides a small sample of investment funds and strategies available today to invest in the transition away from carbon.

Investment Fund	Strategy	Strategy Type	Decarbonization? Carbon negative?
Acre Venture Partners	Acre Venture Partners III	Venture capital	Overweight carbon negative investing; pure play sustainable
Boston Trust Walden	Walden Small Cap*	Active public equity	Overweight decarbonization; pure play sustainable
Brown Advisory	Sustainable Large & Small Cap*	Active public equity	Overweight decarbonization; pure play sustainable
Carbon Direct Capital	Fund II	Private growth equity	Pure play decarbonization; overweight carbon negative investing
Change Finance	US Large Cap Fossil Fuel Free	Public equity ETF	Overweight decarbonization; pure play sustainable
Clean Energy Transitions	CLEAN	Long only hedge fund	Carbon negative potential; pure play decarbonization
Ecosystem Integrity Management	Ecosystem Integrity Fund	Venture capital	Overweight decarbonization; pure play sustainable
Energy Impact Partners	Flagship Fund II*	Private equity	Carbon negative potential; pure play decarbonization
Energy Impact Partners	Frontier Fund LP	Private equity	Overweight Carbon Negative Investing
Federated Hermes	SDG Engagement Equity Fund*	Active public equity	Overweight decarbonization; pure play sustainable
Generation IM	Global Equity Fund*	Active public equity	Overweight decarbonization; pure play sustainable
Generation IM	Just Climate	Private equity	Carbon negative potential; pure play decarbonization
New Energy Capital	New Energy Capital Infrastructure	Private credit	Pure play decarbonization
Rockefeller Capital Management	Rockefeller Climate Solutions*	Active public equity	Carbon negative potential; pure play decarbonization
WisdomTree	WisdomTree Recycling Decarbonisation	Public equity ETF	Overweight Carbon Negative Investing

** Available on Pathstone platform.*

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Bibliography

Office of Nuclear Energy. "5 Advanced Reactor Designs to Watch in 2030," March 17, 2021. https://www.energy.gov/ne/articles/5-advanced-reactor-designs-watch-2030.

"2020 Impact Report." Ecotrust Forest Management, July 23, 2021. https://efmi.com/wp-content/uploads/2022/02/EFM_2020-ImpactReport.pdf.

"2020 Impact Report." The Forestland Group, August 27, 2021. https://www.forestlandgroup.com/wp-content/uploads/sites/30/2021/09/TFG-Impact-Report_2020_08-27-2021.pdf.

Abnett, Kate. "EU Parliament Backs Labelling Gas and Nuclear Investments as Green." Reuters, July 6, 2022. https://www.reuters.com/business/sustainable-business/eu-parliament-vote-green-gas-nuclear-rules-2022-07-06/.

Lyme Timber. "About Us," n.d. https://www.lymetimber.com/about/.

Climeworks. "Achieve Net Zero Targets with Climeworks Direct Air Capture," n.d. https://climeworks.com.

Brigham, Katie. "Why Companies like Stripe, Meta and Alphabet Are behind Carbon Removal." CNBC, June 28, 2022. https://www.cnbc.com/2022/06/28/why-companies-like-stripe-meta-and-alphabet-are-behind-carbon-removal.html.

NOAA Research News. "Carbon Dioxide Peaks near 420 Parts per Million at Mauna Loa Observatory," June 7, 2021. https://research.noaa.gov/article/ArtMID/587/ArticleID/2764/Coronavirus-response-barely-slows-rising-carbon-dioxide.

Clifford, Catherine. "Bill Gates' TerraPower Aims to Build Its First Advanced Nuclear Reactor in a Coal Town in Wyoming." CNBC, 2021. https://www.cnbc.com/2021/11/17/bill-gates-terrapower-builds-its-first-nuclear-reactor-in-a-coal-town.html.

Lockheed Martin. "Compact Fusion," n.d. https://www.lockheedmartin.com/en-us/products/compact-fusion.html.

1PointFive. "Construction of World's Largest Direct Air Capture Plant in the Texas Permian Basin," September 26, 2022. https://www.1pointfive.com/worlds-largest-direct-air-capture-plant-in-the-texas-permian-basin.

"Deforestation of the Amazon Rainforest." In *Wikipedia*, September 21, 2022. https://en.wikipedia.org/w/index.php?title=Deforestation_of_the_Amazon_rainforest&oldid=1111537000.

Dietz, Simon, Alex Bowen, Charlie Dixon, and Philip Gradwell. "'Climate Value at Risk' of Global Financial Assets." *Nature Climate Change* 6, no. 7 (July 2016): 676–79. https://doi.org/10.1038/nclimate2972.

Ellis-Petersen, Hannah, and Shah Meer Baloch. "'We Are Living in Hell': Pakistan and India Suffer Extreme Spring Heatwaves." *The Guardian*, May 2, 2022, sec. World news. https://www.theguardian.com/world/2022/may/02/pakistan-india-heatwaves-water-electricity-shortages.

El-Showk, Sedeer. "Final Resting Place: Finland Is Set to Open the World's First Permanent Repository for High-Level Nuclear Waste. How Did It Succeed When Other Countries Stumbled?" Science, February 24, 2022. https://www.science.org/content/article/finland-built-tomb-store-nuclear-waste-can-it-survive-100000-years.

IEA. "Finland - Countries & Regions," 2020. https://www.iea.org/countries/finland.

"Focusing on Scalable, Permanent Solutions," n.d. https://frontierclimate.com/.

Friedlander, Blaine. "Rising Seas Could Result in 2 Billion Refugees by 2100." Cornell Chronicle, June 19, 2014. https://news.cornell.edu/stories/2017/06/rising-seas-could-result-2-billion-refugees-2100.

General Motors. "GM's Path to an All-Electric Future | General Motors," n.d. https://www.gm.com/electric-vehicles.

Karp, Erika. "No Place to Hide, Climate Change and Systemic Financial Risk." Pathstone, September 10, 2019. https://www.pathstone.com/no-place-to-hide-climate-change-and-systemic-financial-risk/.

Lebling, Katie, Haley Leslie-Bole, Zach Byrum, and Liz Bridgwater. "6 Things to Know About Direct Air Capture." World Rescources Institute, May 2, 2022. https://www.wri.org/insights/direct-air-capture-resource-considerations-and-costs-carbon-removal.

Masson-Delmotte, Valérie, Hans-Otto Pörtner, Jim Skea, Panmao Zhai, Debra Roberts, Priyadarshi R Shukla, Anna Pirani, et al. "Global Warming of 1.5°C." The Intergovernmental Panel on Climate Change, 2019.

"Microsoft Carbon Removal: Lessons from an Early Corporate Purchase." Microsoft, 2021. https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE4MDlc.

Nations, United. "The Paris Agreement." United Nations. United Nations. Accessed September 26, 2022. https://www.un.org/en/climatechange/paris-agreement.

"Net Zero Climate Targets Report: Banking on a Climate-Safe Future." Amalgamated Bank, 2021. https://www.amalgamatedbank.com/sites/default/files/Net_Zero_Climate_Targets_Report.pdf.

"Nuclear Power in Finland." In Wikipedia. Wikipedia, August 29, 2022. https://en.wikipedia.org/w/index.php?title=Nuclear_power_in_Finland&oldid=1107297636.

Carbon Engineering. "Our Technology," n.d. https://carbonengineering.com/our-technology/.

Prentice, IC, GD Farquhar, MJR Fasham, ML Goulden, M Heimann, VJ Jaramillo, HS Kheshgi, C Le Quere, RJ Scholes, and DWR Wallace. "The Carbon Cycle and Atmospheric Carbon Dioxide." In Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), edited by JT Houghton, Y Ding, DJ Griggs, M Noguer, PJ van der Linden, X Dai, K Maskell, and CA Johnson. Cambridge: Cambridge University Press, 2001.

The White House. "President Biden's Bipartisan Infrastructure Law," n.d. https://www.whitehouse.gov/bipartisan-infrastructure-law/.

Redwood Materials. "Redwood Materials | Circular Supply Chain for Lithium-Ion Batteries." Accessed September 26, 2022. https://www.redwoodmaterials.com.

Ritchie, Hannah, Max Roser, and Pablo Rosado. "CO_2 and Greenhouse Gas Emissions." Our World in Data, May 11, 2020. https://ourworldindata.org/co2-emissions.

Smith, Brad. "Microsoft Will Be Carbon Negative by 2030." The Official Microsoft Blog, January 16, 2020. https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/.

———. "One Year Later: The Path to Carbon Negative – a Progress Report on Our Climate 'Moonshot.'" The Official Microsoft Blog, January 28, 2021. https://blogs.microsoft.com/blog/2021/01/28/one-year-later-the-path-to-carbon-negative-a-progress-report-on-our-climate-moonshot/.

MIT Senseable City Lab. "Space Bubbles," n.d. https://senseable.mit.edu/space-bubbles/.

Climeworks. "Square, Inc. Partners with Climeworks to Remove 2'000 Tons of CO_2," November 30, 2021. https://climeworks.com/news/square-partners-with-climeworks-to-remove-co2.

The Economist. "The Brazilian Amazon Has Been a Net Carbon Emitter since 2016," May 21, 2022. https://www.economist.com/interactive/graphic-detail/2022/05/21/the-brazilian-amazon-has-been-a-net-carbon-emitter-since-2016.

"The Lyme Timber Company 2021 Annual-Report." The Lyme Timber Company, April 2022. https://www.lymetimber.com/wp/wp-content/uploads/2022/05/The-Lyme-Timber-Company-2021-Annual-Report.pdf.

U.S. Energy Information Administration. "U.S. Energy-Related Carbon Dioxide Emissions, 2020," December 22, 2022. https://www.eia.gov/environment/emissions/carbon/.

Wilkins, Brett. "'Unthinkable': Scientists Shocked as Polar Temperatures Soar 50 to 90 Degrees Above Normal." Common Dreams, March 20, 2022. https://www.commondreams.org/news/2022/03/20/unthinkable-scientists-shocked-polar-temperatures-soar-50-90-degrees-above-normal.

Endnotes

[1] Barbara Buchner, Baysa Naran, Pedro de Aragão Fernandes, Rajashree Padmanabhi, Paul Rosane, Matthew Solomon, Sean Stout, Githungo Wakaba, Yaxin Zhu, Chavi Meattle, Sandra Guzmán and Costanza Strinati. "Global Landscape of Climate Finance 2021," Climate Policy Initiative, December 14, 2021, https://www.climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2021/

[2] Ibid.

[3] Prentice, IC, GD Farquhar, MJR Fasham, ML Goulden, M Heimann, VJ Jaramillo, HS Kheshgi, C Le Quere, RJ Scholes, and DWR Wallace. "The Carbon Cycle and Atmospheric Carbon Dioxide." In *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*, edited by JT Houghton, Y Ding, DJ Griggs, M Noguer, PJ van der Linden, X Dai, K Maskell, and CA Johnson. Cambridge: Cambridge University Press, 2001.

[4] "Carbon Dioxide Peaks near 420 Parts per Million at Mauna Loa Observatory," NOAA Research News, June 7, 2021, https://research.noaa.gov/article/ArtMID/587/ArticleID/2764/Coronavirus-response-barely-slows-rising-carbon-dioxide.

[5] Brett Wilkins, "'Unthinkable': Scientists Shocked as Polar Temperatures Soar 50 to 90 Degrees Above Normal," Common Dreams, March 20, 2022, https://www.commondreams.org/news/2022/03/20/unthinkable-scientists-shocked-polar-temperatures-soar-50-90-degrees-above-normal.

[6] Hannah Ellis-Petersen and Shah Meer Baloch, "'We Are Living in Hell': Pakistan and India Suffer Extreme Spring Heatwaves," *The Guardian*, May 2, 2022, sec. World news, https://www.theguardian.com/world/2022/may/02/pakistan-india-heatwaves-water-electricity-shortages.

[7] Blaine Friedlander, "Rising Seas Could Result in 2 Billion Refugees by 2100," Cornell Chronicle, June 19, 2014, https://news.cornell.edu/stories/2017/06/rising-seas-could-result-2-billion-refugees-2100.

[8] Simon Dietz et al., "'Climate Value at Risk' of Global Financial Assets," *Nature Climate Change* 6, no. 7 (July 2016): 676–79, https://doi.org/10.1038/nclimate2972.; Erika Karp, "No Place to Hide, Climate Change and Systemic Financial Risk" (Pathstone, September 10, 2019), https://www.pathstone.com/no-place-to-hide-climate-change-and-systemic-financial-risk/.

[9] Nations, United. "The Paris Agreement." United Nations. United Nations. Accessed September 26, 2022. https://www.un.org/en/climatechange/paris-agreement.

[10] "Environment", U.S. Energy Information Administration, December 22, 2021, https://www.eia.gov/environment/emissions/carbon/

[11] The White House. "President Biden's Bipartisan Infrastructure Law," n.d. https://www.whitehouse.gov/bipartisan-infrastructure-law/.

[12] "GM's Path to an All-Electric Future | General Motors," General Motors, n.d., https://www.gm.com/electric-vehicles.

[13] IPCC, 2018: Global Warming of 1.5°C.An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

[14] Brad Smith, "One Year Later: The Path to Carbon Negative – a Progress Report on Our Climate 'Moonshot,'" The Official Microsoft Blog, January 28, 2021, https://blogs.microsoft.com/blog/2021/01/28/one-year-later-the-path-to-carbon-negative-a-progress-report-on-our-climate-moonshot/.

[15] "Microsoft Carbon Removal: Lessons from an Early Corporate Purchase." Microsoft, 2021. https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE4MDlc.

[16] Brad Smith, "Microsoft Will Be Carbon Negative by 2030," The Official Microsoft Blog, January 16, 2020, https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/.

[17] "Our Technology," Carbon Engineering, n.d., https://carbonengineering.com/our-technology/.

[18] "Construction of World's Largest Direct Air Capture Plant in the Texas Permian Basin," 1PointFive, September 26, 2022, https://www.1pointfive.com/worlds-largest-direct-air-capture-plant-in-the-texas-permian-basin.

[19] "Square, Inc. Partners with Climeworks to Remove 2'000 Tons of CO_2," Climeworks, November 30, 2021, https://climeworks.com/news/square-partners-with-climeworks-to-remove-co2.

[20] Katie Lebling et al., "6 Things to Know About Direct Air Capture," *World Rescources Institute*, May 2, 2022, https://www.wri.org/insights/direct-air-capture-resource-considerations-and-costs-carbon-removal.

[21] "About Us," Lyme Timber, n.d., https://www.lymetimber.com/about/.

[22] "The Lyme Timber Company 2021 Annual-Report" (The Lyme Timber Company, April 2022), https://www.lymetimber.com/wp/wp-content/uploads/2022/05/The-Lyme-Timber-Company-2021-Annual-Report.pdf.

[23] "2020 Impact Report" (Ecotrust Forest Management, July 23, 2021), https://efmi.com/wp-content/uploads/2022/02/EFM_2020-ImpactReport.pdf.

[24] "2020 Impact Report" (The Forestland Group, August 27, 2021), https://www.forestlandgroup.com/wp-content/uploads/sites/30/2021/09/TFG-Impact-Report_2020_08-27-2021.pdf.

[25]"Deforestation of the Amazon Rainforest," in *Wikipedia*, September 21, 2022, https://en.wikipedia.org/w/index.php?title=Deforestation_of_the_Amazon_rainforest&oldid=1111537000; "The Brazilian Amazon Has Been a Net Carbon Emitter since 2016," *The Economist*, May 21, 2022, https://www.economist.com/interactive/graphic-detail/2022/05/21/the-brazilian-amazon-has-been-a-net-carbon-emitter-since-2016.

[26] Kate Abnett, "EU Parliament Backs Labelling Gas and Nuclear Investments as Green | Reuters," Reuters, July 6, 2022, https://www.reuters.com/business/sustainable-business/eu-parliament-vote-green-gas-nuclear-rules-2022-07-06/.

[27] "Nuclear Power in Finland," in *Wikipedia* (Wikipedia, August 29, 2022), https://en.wikipedia.org/w/index.php?title=Nuclear_power_in_Finland&oldid=1107297636.

[28] Sedeer El-Showk, "Final Resting Place: Finland Is Set to Open the World's First Permanent Repository for High-Level Nuclear Waste. How Did It Succeed When Other Countries Stumbled?," Science, February 24, 2022, https://www.science.org/content/article/finland-built-tomb-store-nuclear-waste-can-it-survive-100000-years.

[29] "5 Advanced Reactor Designs to Watch in 2030," Office of Nuclear Energy, March 17, 2021, https://www.energy.gov/ne/articles/5-advanced-reactor-designs-watch-2030.

[30] Catherine Clifford, "Bill Gates' TerraPower Aims to Build Its First Advanced Nuclear Reactor in a Coal Town in Wyoming," CNBC, 2021, https://www.cnbc.com/2021/11/17/bill-gates-terrapower-builds-its-first-nuclear-reactor-in-a-coal-town.html.

[31] "Compact Fusion," Lockheed Martin, n.d., https://www.lockheedmartin.com/en-us/products/compact-fusion.html.

[32] https://www.carbonbrief.org/explainer-six-ideas-to-limit-global-warming-with-solar-geoengineering/

[33] https://www.keutschgroup.com/scopex#h.p_Xru29Emo-OMw

[34] "Space Bubbles," MIT Senseable City Lab, n.d., https://senseable.mit.edu/space-bubbles/.

[35] Katie Brigham, "Why Companies like Stripe, Meta and Alphabet Are Behind Carbon Removal," CNBC, June 28, 2022, https://www.cnbc.com/2022/06/28/why-companies-like-stripe-meta-and-alphabet-are-behind-carbon-removal.html.