Decarbonizing Energy Supply: Corporate Strategies of Renewable Energy and Fossil Firms

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National and corporate leaders have pledged to act to limit global temperature rise to 2^0C, and achieve net zero emissions (NZE) primarily through the installation of renewable energies (RE) such as solar and wind. This paper focuses on corporate efforts in the renewable space particularly batteries, hydrogen and hard-to-decarbonize sectors such as steel. However, unless the influence and use of fossil fuels is simultaneously lowered, REs will continue to meet only a fraction of the world's energy needs. The strategies of fossil energy firms to further entrench their dominant position are analyzed and pathways are proposed to scale back their stranglehold.

Keywords: energy supply, renewable energy, batteries, hydrogen, carbon capture, fossil fuel firm strategies, lock-ins

INTRODUCTION

Global temperatures have, on average, risen by nearly 1.2^0C since the start of the industrialization period, half of the increase in the past three decades. The Paris Accord stipulated that the signatories would develop policies and pursue actions to limit the global temperature rise to 1.5^0C or, in the worst case, to 2^0C. Barring the period when output was affected by the Covid pandemic, total emissions have kept rising, casting doubt on whether even the 2^0C limit is realistic and making it likely that the 1.5^0C mark will be exceeded in the 2030s (IPCC, 2023). At the Conference of Parties (COP) held in Glasgow late 2021, participating countries agreed to return a year later with revised plans to slash emissions drastically (Hill and Babin, 2021). Little progress was reported in this regard at COP 27 (WRI, 2022) Concerns over spiking inflation, the war in Ukraine, potential threats to national security, and a variety of domestic pressures have combined to deflect some attention away from climate initiatives. The Net Zero Emission (NZE) target established by major carbon emitting nations are still in place but the pathways to getting there are becoming more tenuous (IPCC, 2022; UN, 2023).

While national leaders negotiate, decide on climate goals and consider policy alternatives on both the supply and demand sides of the energy equation, corporate leaders have been engaged in a similar effort (UNFCCC, 2022; Murray and Warner, 2022). This paper focuses on energy supply and discusses corporate strategies of energy providers within the context of transitioning to a decarbonizing world. The paper is distinctive in its emphasis on corporations being central to combating climate change. In addition to accelerating the use of renewables through innovations in energy storage, the paper also analyzes the strategies of fossil fuel firms that aim to ensure the continued use of coal, oil, and gas.

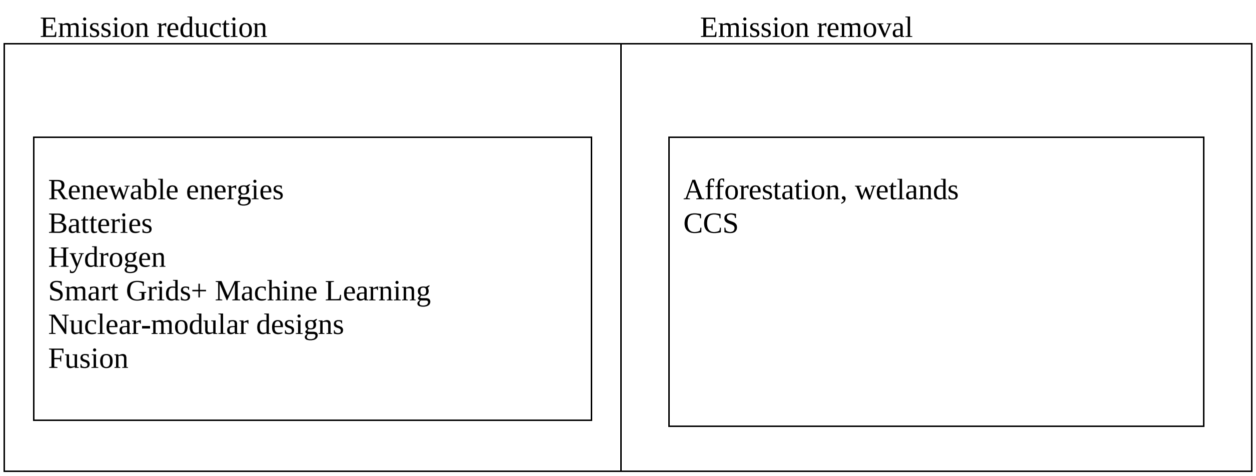
Replacing fossil fuel energies with cleantech is a monumental undertaking that involves installing carbon-free sources while, at the same time, weaning users off existing carbon-emitting energies. The immense investment needed, the scaling up of nascent technologies, and a lack of collaboration between countries are some hurdles to surmount in making the energy transition (Markovitz, Harrison, and Treanor, 2022. Equally daunting is the fact that entrenched fossil fuel firms have shown little inclination to accept a new energy order. By and large, companies in coal, oil, and gas have attempted to create/increase dependence on their products or have developed strategies that give the appearance of joining the cleantech revolution while, in fact, entrenching and enhancing the use of fossil fuels.

The first part of the paper discusses corporate strategies and initiatives directed toward increasing the supply of clean energy (i.e., free of carbon emissions). Some of the hurdles to maximizing clean energy use are also discussed. However, as we note in this section, even as the installed capacity of clean energies has risen sharply, the supply and use of fossil fuels (coal, oil, and natural gas) continues to expand. The factors underlying the almost unabated demand for fossil energies and the strategies adopted by their suppliers are explored in the second part of the paper. Technological, social, political, and cultural lock ins must be overcome, and the strategies of fossil fuel firms countered if NZE by 2050 is to become a reality.

CLEAN ENERGY INSTALLATIONS

Fig. 1 encapsulates the strategies being deployed by firms engaged in the effort to increase the availability of clean energies.

FIGURE 1
CLEAN ENERGY SUPPLY FOR NZE



Sources and Capacities

Mitigation efforts primarily focus on electrification using renewable energies while removing a portion of existing and future GHG emissions (IPCC, 2022; Fawzy, Osman, and Rooney, 2020). Though solar and wind power generation capacity has grown at a remarkably high rate of nearly 15% per year over the period 2015-2020, they still constitute only about 10 % of total electrical capacity, with hydro adding another 15%. Nuclear contributes about 10%, with coal and natural gas comprising the rest (Ritchie and Roser, 2021; IEA, 2020). The rapid growth of solar and wind has been driven by falling costs, the former plummeting by over 80% since 2010, while wind power costs have halved in that period. Policies (incentives and subsidies, government support of R&D, feed-in tariffs, and competitive auctions) have spurred the exponential expansion of REs in the EU, the US, and more recently, in India (Jaeger, 2021). China's policy support and governmental investment in renewables have resulted in its domination of solar manufacturing, which the EU, US, and India are trying to counter by supporting local firms. The availability of cheaper financing, the industry's growing political power, and a better appreciation of the risks of fossil energy have also contributed to a meteoric expansion in the installation of renewables.

Large firms such as Apple, Google, and Walmart have added solar arrays to bring down their scope 1 (internal) and 2 (energy from external sources) emissions (Murray. 2020). The top five solar firms generated revenues in excess of $15 billion in 2022 (Smith, 2022), and the industry is poised to expand fast enough to supply at least 20% of electricity needs by 2030 in the US and EU (SolarPower, 2023; DNV, 2019). Wind power is also expected to grow rapidly. Companies like Siemens, Vestas, Goldwings, and GE have ambitious growth plans for the coming decade (Blackridge, 2022). The intermittent nature of REs, the growing demand for energy, the likelihood that electric vehicles will need 5-10% more clean energy for charging, and the need to electrify heating and cooling make energy storage a critical element in decarbonization.

Storage: Mechanical and Heat Energy

While electrical power cannot be stored, it could be converted into some other form of storable energy, which can be transformed into electricity when needed. The most widely used method so far has been pumped storage. Water is pumped to a storage reservoir at a higher level when excess power is generated and released through turbines to generate electricity when peak demand arises. Almost 90% of the energy stored for grid connection is of this type (Hydropower, 2022). Other methods of converting excess electricity into potential or kinetic energy involve the use of springs (which coil and uncoil when power is in excess and when needed respectively), pumping water underground under pressure and releasing it when demand for electricity rises, transferring energy to and from spinning flywheels, lifting and lowering massive weights in special chambers, and so on. Other techniques involving using the heat from compressing air, storing energy in molten salt and, more recently, in other metals in the liquid state (Valentine, 2018; Geuss, 2017). Mechanical and heat storage are seen as the best bets for storing energy at levels needed by grids to smooth out electricity supply when variable renewables get to around 50% of available capacity (Gibson, 2020). In fact, the capacity of thermal storage is expected to triple to 800 GwH by 2030 (Masterson, 2021). For quick synchronization to the grid, flywheel systems seem ideal. Other gravity systems will likely be of great value in regional and microgrids (Hutson, 2022; Holbrook, 2022).

Batteries

A predominant portion of personal and public transportation is dependent on petroleum for fuel despite the gradual inroads being made by electric vehicles (EVs). Though the market for EVs is booming is China, and their sales in the EU are rising at the expense of internal combustion engine (ICE) cars, the demand for the latter is likely to take at least about 15 years to plateau. The fact that EVs comprise less than 10% of new car sales in the U.S. and have a minuscule market share in the rest of the world (apart from China and the EU), means that peak oil may arrive no earlier than 2040 under an optimistic scenario. Among the challenges to be overcome are maintaining the supplies of vital materials such as lithium, nickel, and cobalt, establishing sufficient charging stations in the largest markets, and establishing the supply chains necessary for EVs while dismantling the existing ones for ICE vehicles. The major manufacturers such as CATL of China, LG and Samsung, and Panasonic (some in alliances with EV firms) have ramped up output. Some are establishing production in major EV markets, in part to be closer to their major buyers and to avoid being caught up in a version of "eco-nationalism" (locating cleantech production within a country's borders), which seems to be rising (Margulies, 2021; The Economist, 2023a). Technological developments such as increases in energy density and recycling to conserve vital metals and minerals, which are concentrated in relatively few parts of the world, are also picking up the pace (DeLaGarza, 2022).

The use of batteries for storage at grid levels is inching up, reaching up to 5X by 2050, and may stabilize the electricity supply, from solar in particular (NREL, 2021). In 2022-'23, solar capacity in the US is expected to grow by over 50 % and battery storage capacity by over 10GW, 60% of which will be coupled to utility-scale solar (EIA, 2022). The near 80% decline in the price of lithium-ion batteries over the past five years makes this storage method increasingly viable (Chandler, 2021). Among the hurdles to be overcome is the development of battery systems that can store electricity at the scale of a few gigawatts (at present, the capacity is limited to about 10MW), for at least four hours EIA, 2022). Though lithium-ion cells have dominated the market so far and hold a distinct price advantage, their ability to store energy at grid-levels is a work in progress. Newer types are being investigated, including solid state batteries and iron batteries (Gitlin, 2022; Stover, 2022). Flow batteries which involve liquids transferring electrons through a membrane also show promise since their capacity can be increased by adding more liquid, but their energy density is low. Reduction-oxidation batteries are also expected to significantly contribute to rapidly escalating grid-level storage needs as renewable energies are ramped up (Posch, 2022). Most of the buzz in the use of batteries is around Lithium ion, but that is mainly due to the widespread deployment of such batteries in electronics and electric vehicles. Investments in battery development and mechanical storage systems suggest that the potential for growth in these two areas is immense. The storage capacity needed by 2050 would amount to 6TWh of energy at a cost of over $ 2 trillion (Weaver, 2022).

Hydrogen

Though batteries hold great promise for energy storage, it is by no means certain that the challenge of gigawatt-level storage for over eight hours can be met by batteries alone. Decarbonizing hard-to-electrify areas, which include steel manufacture, long-distance trucking, air transport, and shipping, remains a problem.

Hydrogen could help by acting as a buffer between REs and the grid. Power generated by REs when the load is light could be used to produce hydrogen, typically by electrolysis of water, which is stored, preferably in underground caverns, to be used at times of peak demand (Brandon and Kurban, 2017). Fuel cells could provide grid backup for longer than batteries and be grid-connected almost as fast. Long-haul trucking, shipping using methanol produced from hydrogen, and steel production appear to be the most promising initial applications in addition to grid stabilization (Collins, 2022; Edson, 2021). One of the challenges is increasing supply while generating demand simultaneously (IEA, 2019).

Ramping up the hydrogen supply calls for a sharp increase in electrolyzer capacity. At present, China produces the bulk of electrolyzers and possesses a high proportion of the materials needed to make them. The proposed investment of over $ 2 billion in electrolyser capacity in France to produce hydrogen for making green steel is one such project (Collins, 2022). Another "gigafactory" for electrolyzers is being planned by a Norwegian firm (Nel, 2022) in the US. In fact, the planned investment in electrolyzers worldwide is expected to exceed demand by 2027, though the growth of electrolyzer availability could fuel demand for hydrogen, making the latter a viable option for the most immediate applications mentioned earlier.

Countries in the EU are planning to expand their use of wind power in slack demand periods to produce hydrogen. It is estimated that almost 50% of the EU's wind power added up to 2030 will go toward generating hydrogen. The North Atlantic appears to be a particularly suitable location with the likelihood that major users (such as the steel industry) will relocate part or all of their operations to the region. Spain and Portugal, with around 3,000 hours of sunshine a year, have ambitious plans to produce hydrogen on a large scale, exporting it via pipelines to France and beyond. The U.S. 'hydrogen shot' (Energy.gov, 2022a) aims to lower the price of green hydrogen to $1/kg by 2030 (using mainly solar as the power source), an 80% reduction from the current price, while plans are underway to establish massive storage (Blain, 2022). The "seed funding", subsidies, and incentives in the Inflation Reduction Act have spawned a variety of initiatives to produce green hydrogen on a sharply escalating scale in the next few years. Startups and large firms are involved in the race to make hydrogen integral to the country's plans to become carbon neutral.

The promise of hydrogen as a fuel in hard-to-electrify sectors (steel, chemicals, and cement, long-distance trucking, aircraft, shipping) and as a way to store energy at grid levels for long periods has attracted a suite of investors ranging from startups to large firms (Pistilli, 2023). Companies such as Arcelor Mittal and Tata's are researching ways green hydrogen can be used to make carbon-neutral steel. A large steel mill in Salzgitter, Germany, plans on using hydrogen for the reduction process in the next few years (The Economist, 2023b). Currently, some steel producers are using hydrogen in blast furnaces with natural gas as a fuel coupled with CCS. However, this steel is far from green with CO2 reductions of less than 10%.

In some cases, emissions actually increase if hydrogen is generated using grid-based power. Sweden's H2 Green Steel has invested over $3 billion to produce 50,000 Mt of carbon neutral steel using RE by 2024. Other large steel firms are likely to do likewise as the price of hydrogen drops to around $3 per kg. At around $2 per kg, the cost differential between green and grey steel could be negligible.

The supply of energy, presently heavily dependent on fossil fuels, has to tilt significantly and rapidly toward clean energies in the coming decade for the global temperature rise to remain with 20C, and for NZE to become a reality by 2050. The pace at which REs can be installed has to match, and be matched by, the speed and magnitude with which battery and hydrogen production are ramped up. Heavy financial investments of $3-5 trillion a year are needed for the green energy revolution to take off.

Nuclear Energy

Nuclear fission provides about 15% of the electricity used globally. Nuclear power stations utilize the heat generated by fission reactions to produce steam which rotates turbines connected to generators. What distinguishes a nuclear station from a coal-fired plant is the heat source. Though they emit no carbon, nuclear power stations, have long been viewed unfavorably mainly due to the potential for the leakage of radioactive material or, worse, for an uncontrolled chain reaction resulting in the core melting down. However, apart from the near accident at Three Mile Island, the Fukushima disaster caused by a tsunami (with inadequate safety precautions in place), and Chernobyl (where the core did melt owing to poor management and negligence), nuclear power's safety record is stellar. In terms of fatalities per unit of energy produced, they are safer than thermal and hydro power. France, which obtains nearly 75% of its electricity from nuclear, has a remarkable record of accident-free operations. Another concern with nuclear energy is with disposal of radioactive waste. Even this turns out to be a manageable issue with waste being stored in deep caverns or lead-lined containers. The space needed is of the order of 6,000 cubic meters to date for all the nuclear stations in the U.S. combined (Energy.gov, 2022a). While environmental activists have long been opposed to the installation of new plants in the U.S. and Europe, Germany going so far as to ban any expansion of its nuclear capacity, there appears to be a growing realization that REs alone are not going to suffice in the transition to clean energy. Firms in China, Russian, and South Korea have raced ahead with R&D and improved manufacturing and installation techniques which have placed firms such as Westinghouse, GE, Siemens, EDF, and others at a distinct disadvantage. These firms aim to recover their lost market positions with better designs, production methods, and construction techniques.

Modular designs are becoming more popular since they can be factory-made in smaller sizes and weights, resulting in easier shipping and speedier installation (El Emam and Sabki, 2021). Companies such as Nuscale and Kairos are among the firms which are in the final stages of developing and obtaining regulatory approval for small modular reactors (SMRs). The capacity of these SMRs could be anywhere from one-third to three-quarters that of traditional nuclear, but with a considerably shorter order-to-commissioning time.

Carbon Capture and Storage

Most scientists agree that around 10 Gt per year of CO_2eq has to be removed by 2050 for the world to stay on track to achieve NZE by that date and to limit warming to $<2^0$C (IISD, 2022). Investments to the tune of a few billion dollars are being made in Carbon Capture and Storage (CCS) technology, which is being supported by subsidies in the US, EU, and China among other countries. The most viable version of CCS is to locate the device at the "tailpipe" (e.g chimneys of coal/gas fired power stations), separate out the CO2, and store the trapped gas in sealed caverns. CCS is an energy-intensive technology costing around $600 per ton of CO2 removed. The viability of CCS on a scale beyond a few million tons remains unproven (Wang, et al., 2020) but that has not deterred innovators such as Carbfix and CarbonFree from trying out a variety of techniques to achieve the scale economies needed (Ahmad, 2023). The technology is expected to attract investment of around $ 150 billion this decade, spurred, in part, by government subsidies (The Economist, 2023c)

Rising Use of Renewables and Fossil Fuel Energies

The installed capacity of modern renewables (solar, wind, biofuel, geothermal) has risen by around 30% between 2010 and 2020. However, with the rising demand for energy over this period, the share of fossil fuels in the energy mix has remained nearly constant at just over 80% (c2es, 2022). It can be seen in Table 1 that the use of coal has remained almost steady, while oil demand inched up by around 10% till the pandemic year of 2020. Natural gas usage has shot up by nearly 50% as considerable substitution of coal by natural gas in power generation occurred in the decade in question.

TABLE 1
FOSSIL FUEL CONSUMPTION 2010-2020

Year	Oil[1]	N. Gas[2]	Coal[3]
2010	4104.06	3151	7353
2011	4150.46	3258	7832
2012	4245.08	3326	7935
2013	4265.12	3366	7976
2014	4352.50	3437	7939
2015	4458.38	3511	7968
2016	4516.18	3552	7293
2017	4505.62	3676	7544
2018	4619.32	3852	7827
2019	4617.42	3976	7960
2020	4296.19	43861.	7575

[1] in million Tons. Source: IEA, World oil supply and demand, 1971-2020, IEA, Paris https://www.iea.org/data-and-statistics/charts/world-oil-supply-and-demand-

[2] in billion m^3 . Source: https://www.statista.com/statistics/265344/total-global-natural-gas-production-since-1998/

[3]in million Tons. Source: IEA, World total coal production, 1971-2020, IEA, Paris https://www.iea.org/data-and-statistics/charts/world-total-coal-production-

FOSSIL FUEL ENERGY

The main energy source during the earliest period of industrialization was coal, followed by oil and gas which started playing a dominant role in energy supply over a century ago. Coal is still widely used in power generation (it is used to generate the bulk of the electricity in China and India) and in industries such as steel, cement, and chemicals. Considering how deeply embedded these three fuels are in the fabric of our daily lives, firms involved in the extraction, refining, and delivery of these energy sources are, at best, likely to be reluctant participants in the process of decarbonization.

Ongoing Dependence on Fossil Fuels

Corporations are integral to limiting emissions, both on the supply and demand sides for energy. Over the past three decades, one hundred firms are responsible for over 70 % of all GHGs emitted (CDP, 2017). The top emitters are firms engaged in the extraction, refining, and delivery of fossil fuels particularly those in the coal, and oil and gas industries, which contribute 14, 12, and 8 Gt CO_2e resp. per year (Ritchie and Roser, 2021). Based on the massive investments they have made, the number of people they employ (directly and indirectly), shareholder expectations, political forces, and social dynamics involved, fossil fuel businesses are strongly committed to the existing energy order (Li, Trencher, and Asuka, 2022). China Coal is by far the single largest emitter (14%), while the top ten energy firms together account for over a third of all emissions. (Investments in oil and gas, though down from pre-pandemic levels, stand at around $630 billion (Li, Trencher, and Asuka, 2022), with coal adding another $ 100 billion (IEA, 2020). Profits have soared for fossil fuel firms after the pandemic-induced slow down, making it unlikely that firms in the industry are likely to reduce output in the near term (Sadai2023). Employment in the oil drilling and gas extraction industries in the U.S. alone stands at nearly 350 000, with many multiples of that number employed in the extended value chain and support activities. Worldwide employment in oil and gas is about 6 million (IEA, 2022), with an equal number working in support activities. The coal industry employs about 50,000 people in the U.S. and close to 9 million worldwide, though the number who earn a living from coal-related industries is far higher, amounting to nearly 10 million in China and India alone.

Some of the strategies being pursued by firms in the fossil fuel industry are laid out in Fig. 2. The strategic intent appears to maintain or expand the industry's dominance in the supply of energy. We start with a set of initiatives aimed at explicating how this is done and follow with strategies that could ameliorate the carbon intensity in the energy supply. These strategies are rarely if ever, adopted unless they help advance the goal of selling more oil and gas.

FIGURE 2
STRATEGIES OF FOSSIL FUEL FIRMS

Emission reductions	Emission removals
Strategies	
Lobbying governments; COPs	CCS-subsidies/incentives
Subsidies	CCS-barriers to entry?
Reinforcing lock in	
Scope 1-Methane?	
Scope 3?	
Renewable energies?	
Grey Hydrogen-subsidies/incentives	
Grey Hydrogen with CCS-subsidies/incentives	

Political Influence of Fossil Fuel Firms

Lobbying and attempts to influence climate policy have become part and parcel of fossil fuel firms' strategies to slow down the transition to clean energy, casting doubt on scientific findings, attending the COP events, and so on. It is estimated that the oil and gas industry dispatched over 500 lobbyists to COP 26 intending to dilute any efforts to accelerate the energy transition and avoid setting specific targets for slashing the use of oil and gas. (Elton, 2022). The combination of corporate lobbyists and government officials from petrostates proved potent: the most prominent resolution affecting oil and gas interests was one calling for the reduction of methane emissions at wellheads, an action that would increase industry-wide profits.

Despite the commitments made by numerous countries to reduce dependence on fossil fuels, the suppliers in the industry are subsidized to the tune of around $500 billion (Nature, 2021). However, when environmental costs and consumer subsidies are factored in, the subsidies amount to a hefty $7 trillion, which far outweighs the subsidies and incentives provided to renewable energies (IMF, 2021). The far-reaching political and geopolitical influence of corporations and countries profiting from the continued use of fossil fuels makes it likely that oil, natural gas, and, perhaps, even coal, will together remain the sources of a significant source of energy supplied well past mid-century. While renewables need to comprise at least 75% of the energy generated by 2050 for the temperature rise to be limited to 2^0C, supply-side forces and strategies have aligned to insulate fossil energies from rapid emission reduction pathways.

Past and Ongoing Lock-ins

The growing use of natural gas for power generation as a substitute for coal and/or as a means to ease the transition to renewables has meant that massive investments have been, and are being, made in natural gas power stations. Carbon emissions undoubtedly diminish in trading gas for coal, but the technological lock-in because of gas-fired turbines with lives of around 30 years must be reckoned with. The increased demand for liquefied natural gas (LNG) in the EU and elsewhere only adds to the lock-in effect as major investments are made in the production, storage, shipping, handling, and use of LNG. When one figure in social and cultural lock-ins (driving habits, thermostat settings), the hold exercised by fossil fuels becomes difficult to shake (Jorgensen, et.al., 2018; Seto, 2016)).

While most countries have committed to using less coal, the use of this fuel continues almost unabated in China, India, Russia, and Indonesia, among other countries. Even in parts of the EU, coal has been used as a backup energy source, while the US, where coal use has declined sharply, has become a coal exporter.

Methane emissions from the production process for oil and gas (O&G) amount to about 80 Mt a year, which is, at a conservative estimate, about 3-5 Gt CO2eq., or 6-10% of all GHG emissions. Though methane reduction by O&G was a goal firms in the industry agreed to at COP 26, methane emissions, in fact, rose in the following year. It appears that, despite the windfall profits earned by O&G firms recently, the will to invest in methane reduction technologies is lacking, even though it would result in savings and more revenues. As more coal mines are shut down all over the world, they are going to be potent sources of methane leakage, which need to be addressed as well. The inability of governments to induce O&G firms to take responsibility for their own (Scope 1) emissions speaks to the gap between national commitments and the will to act in support of their own policies. At COP 27. strenuous efforts on the part of oil-producing nations and corporations succeeded in keeping any reference to phasing out fossil fuels out of the final report.

Investment in Renewables

Though some oil, gas, and coal majors such as Oxy, BP, Total, and Coal India have indicated their intention to invest in emission-reduction products such as wind farms and solar arrays, such assurances are generally meant to help with public relations (Varadhan, 2022; Braun, 2023). Saudi Arabia is building renewable energy sources, primarily giant solar arrays, to lower its own dependence on oil and gas. Though some firms like Shell have indeed invested in renewables, less than 1% of the amount invested by the industry as a whole has been on clean technologies.

Saudi Aramco's efforts to ramp up the use of fossil fuels have, in the meantime, intensified. Despite protestations to the contrary, fossil fuel firms' commitment to their original lines of business remains unwavering. It will continue to be so unless the world's appetite for their products starts diminishing. Oil demand is expected to peak around 2040, which has prodded oil and gas firms to shift their strategic positioning somewhat. North American firms such as Exxon Mobil (EM) and Chevron seem to be setting their sights mainly on the Americas (to lower risks), while European companies appear to be focusing on untapped sources (e.g., in parts of Africa) closer to home, deploying "cleaner" technologies, while investing in REs as well.

Fossil Fuel Firms Scope 3

An extreme instance of exaggerated claims of making progress toward a net zero carbon world is provided by EM (Energyfactor, 2021). EM and other large oil and gas majors have included only Scope 1 and Scope 2 emissions (which covers internal operations and energy from outside suppliers, respectively) in their reporting. (Even scope 1 methane emissions, as we have seen, have headed in the wrong direction.) Exxon Mobil (EM) concedes that making a dent in Scope 3 emissions, primarily those resulting from the usage of fuel, are not within its control and are hard to even measure (Exxon Mobil, 2021). The firm's estimated Scope 3 GHGs are of the order of 1.8 billion tons (or about 4% of the worldwide total), while the company's efforts have yielded a reduction of around a million tons, that is, a fraction of one percent of its Scope 3 emissions. A few O&G businesses (such as Total and Shell) have started working on Scope 3, which necessitates massive strategic shifts and is an uphill task despite activist investor pressure (Saiyid, 2021). In the wake of the Russian action in Ukraine, the windfall profits generated by fossil fuel firms seem to have dampened concerns over climate change, with shareholder returns taking center stage once again (Reuters, 2023).

Carbon Capture and Storage

Carbon Capture and Storage (CCS) has become one of the technologies most favored by the O&G majors to point to as evidence of their commitment to addressing climate change (IISD, 2022). Companies like Occidental Petroleum and Chevron are investing in Carbon Capture and Storage (CCS), though the scale of their efforts is limited (IHS Markit, 2022; Hook, 2021). Based on this determination, many fossil fuel firms have coalesced around CCS as the pathway to NZE. Their focus on the *net* in net zero offers a pathway to claim to be a part of the solution without addressing the problem of emissions. In fact, companies like EM are eligible for subsidies under the Inflation Reduction Act of 2022, without acting to lower emissions. The fact that subsidies and tax breaks radically lower the risks associated with an unproven technology (Temple, 2021) makes CCS an excellent vehicle for companies to make money on emissions *and* removals at taxpayers' expense while, at the same time, establishing their "green" credentials.

Even if CCS were to become viable enough to remove 5Gt or more carbon a year (at an annual cost of a trillion dollars), could it stimulate greater use of fossil fuels? In other words, will it constitute a moral hazard by encouraging the very behavior it was meant to curb? Researchers are divided on the issue (Fankhauser, et. al.,2022; Shayegh, 2019), but the danger is that technofixes could encourage more emissions which, in turn, could make even more CCS capacity imperative with the passage of time, creating a positive feedback loop of increased removal fostering ever greater demand.

Hydrogen Investments by O & G

Many fossil fuel companies have proposed investing in hydrogen produced from natural gas, using CCS to remove resulting CO2, as a way to moderate emissions (Carleton, 2022). This strategy is likely to result in a net uptick in emissions since CCS technology at scale remains a work in progress. (CO2 can also be pumped into fissures to extract more natural gas, adding to revenues and profits). The increased availability of hydrogen could create the illusion that more green energy is on tap, in effect fostering an increase in demand and emissions. Google searches for terms such as "Carbon Capture" or "hydrogen" yield results in which O&G firms figure prominently. Not only does this create a perception that the industry is assiduously working to address climate change, it could also discourage other companies from investing in these technologies, given the massive advantage in resources that O&G firms enjoy. Ironically, by engaging in strategies that appear to be aimed at reducing and/or removing emissions, O&G companies are even eligible for substantial incentives and subsidies under the Inflation Reduction Act. Though EM, for instance, is investing in "hydrogen hubs", or locations for producing hydrogen which is in proximity to demand centers, the natural gas→hydrogen+CO2→natural gas sequence appears to be a recipe for increased emissions unless CCS can remove all the CO2 generated while maintaining the commercial viability of hydrogen.

CONCLUSION

As the climate crisis intensifies and warnings of worse outcomes to follow become more frequent, radical action to reverse or even stall the rise in global average temperature does not seem likely. The total annual emissions, after a brief dip during 2020, have returned to pre-pandemic levels of around 50+Gt CO2e. The EU, the US, and a few other countries still hope to achieve sharp reductions in emissions by 2030 to meet their commitment to NZE by 2050. The path to a net zero world looks to be increasingly tenuous. While the installed capacity of REs is rising rapidly, the increase is from a low base level, and REs provide only around 10% of the world's power. As battery and hydrogen storage become more easily available and less expensive, REs could become more significant energy sources. Extending the electric grid to include decentralized power sources, using machine learning to predict the demand and outputs of RE sources, and strengthening local grids are all essential to raising the capacity utilization of renewable sources. At a conservative estimate, the cost of expanding RE capacity to supply 75% of the world's electricity needs would cost upward of $ 4 trillion a year. Decarbonizing industry (steel, cement, chemicals), building heating and cooling, and agriculture will add to the investment needed in the coming decades. Incentives and subsidies offered by governments, private investments, and financial backing provided by institutions such as the World Bank are critical if the worldwide temperature rise is to be limited to 2^0C. As outlined earlier, business investment in the various components of a clean energy system is ramping up in tandem with government initiatives in China, the US, India, the EU, and other major emitting regions.

However, unless actions are taken to simultaneously lower the use of fossil fuels, the possibility is real that the increased availability of cleantech alternatives may not be accompanied by a proportionate reduction in emissions. An important step in lowering the attraction of carbon-emitting fuels is to reduce the direct subsidies given to fossil fuels, which amount to around $ 2 trillion annually, the indirect subsidies being of the order of $7 trillion (IMF, 2021). Such an action will be fiercely opposed by the industry and result in an increase in energy costs. However, giving coal, oil, and gas a helping hand places firms in the clean energy business at a distinct disadvantage which may be difficult to overcome. The strategic moves of firms in the fossil fuel industry could speed up or hinder the energy transition. The massive investments flowing to producing hydrogen from natural gas, and commercializing CCS technology could lead to an increased demand for the industry's products. The relatively modest investments made by the industry in renewables clearly signals the underlying strategic intent.

One of the biggest impediments to replacing one form of energy with another is the lock-ins - technological, social, political, cultural-which have an inertial effect on corporate and individual energy users. The stranglehold exerted by fossil fuels can be relaxed, if not broken when users resolve to switch to clean energy and are helped by the energy supply becoming more reliable. The transition is fraught with potential disruptions such as conflicts, financial crises, drops in oil and gas prices, and so on. The corporate efforts to build up renewable energy storage capacity need to be backed by guarantees from governments and financial institutions. If countries and corporations revert to fossil fuel usage whenever there is a systemic shock, the transition will never be complete. National security, economic well-being, social order, and political stability are among the justifications offered for the ongoing reliance on fossil fuels. Still, these will likely be threatened to a greater extent if warming is allowed to continue unchecked. Persuading individuals to alter driving habits, choice of heating and cooling devices, consumption patterns, and dietary preferences is a more onerous undertaking. Still, it must be undertaken in tandem with moderating industrial energy demand if the net zero emission goal is to be realized by mid-century.

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