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REVIEW ARTICLE

CURBING CORPORATE DEMAND-SIDE EMISSIONS: A CRITICAL PATHWAY TO NET ZERO

Bernard Arogyaswamy*

Strategic Management Madden School of BusinessLe Moyne College Syracuse, NY 13214 USA.
Corresponding Author Email: arogyas@lemoyne.edu

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ABSTRACT

One of the pathways pursued to achieve Net Zero Emissions (NZE) has been through a sharp rise in renewable energy (RE) installations, which has not proved adequate. Corporate innovation could help slash demand-side emissions. Using the Avoid-Shift-Improve (A-S-I) methodology originally developed for policymakers, we address demand side emissions in four sectors-electricity, transportation, industry, and buildings. Increasing digitalization by corporations helps address areas where *electricity* is wasted, combine REs with their existing energy mix, and optimize the cost-risk-emission mix. In *transportation*, challenges faced by companies transitioning to EVs are discussed particularly with reference to battery production, charging, and recycling, public transit, remote work, and reconfiguring future city design. *Industry* includes consumer and industrial goods. Scope 3 emissions, circularity, and hard-to-decarbonize areas are analyzed. Emission reduction arising from *building* heating and cooling, and construction, are discussed particularly for steel and concrete. Though the investments needed to implement these A-S-I strategies are massive, the returns to business and society, even if not immediate, would be sufficient to justify the initial outlays.

KEYWORDS

Net zero emissions; corporate demand-side emissions; energy efficiency; transportation emissions; industry emissions; decarbonizing cement; avoid-shift-improve; digitalizing emissions.

1. Introduction

Much of the attention in limiting the worldwide temperature rise to 1.5^{0}C, or at worst to 2^{0}C, has been focused on decarbonization by replacing fossil fuels (FFs) with renewable sources of energy (REs). Setting a target of net zero emissions (NZEs) by mid-century has helped focus efforts on how the rise in temperature and the destructive effects of climate change can be attenuated. The planned pathway to NZE looks something like this: Increase Res $\rightarrow$ Electrify $\rightarrow$ FF use decreases $\rightarrow$ NZE.

However, the data on the impact REs have had on lowering carbon emissions bears out the hypothesis that increases in RE capacity are not correlated with lowered fossil fuel use and emissions. The installed capacity of REs rose to 3800 GW in 2020, maintaining a growth rate of 15% over the preceding five years (Ritchie and Roser, 2020). In 2022, 90% of renewable energy capacity added was in solar and wind, the former increasing by 22% and the latter by 9% (IRENA, 2023). Despite the spurt in RE capacity, the proportion of electric power supplied by these two REs amounted to under 15% of the total. The share of FFs in the energy mix hovers around 80% despite the commitments made and policies pursued at the international, national, and local government levels. We contend that corporations, being responsible for the bulk of energy-related emissions, are central to the effort to reach NZE. Governments make commitments, policy makers steer their societies toward fulfilling the promises made, but corporations are typically responsible for implementation. Their impact derives both from how rapidly they can increase their *uptake of REs*, and their ability to address and curb *demand-side emissions*. The first part of this paper addresses specific ways in which clean energy use could be accelerated while the second (and major) part focuses on curbing demand side emissions by corporations. A distinctive aspect of this work is that business firms are viewed as potentially becoming a significant force in mitigating emissions and climate change.

2. Increasing Renewable Energy Uptake

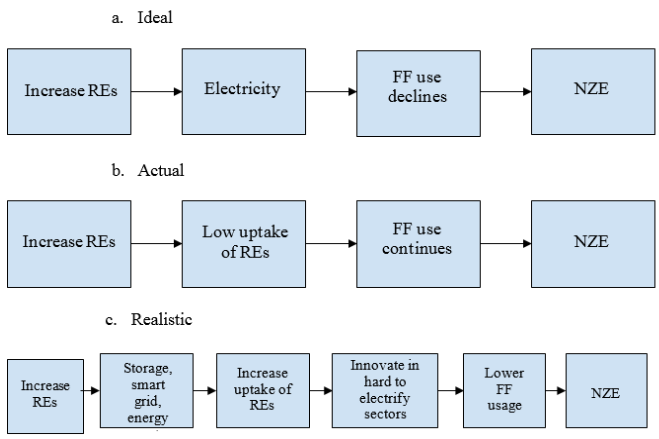

Figure 1: Decarbonization Pathways

The process of decarbonization has been slowed if not stymied by the relatively low utilization of REs due, in part, to their intermittency and distance from demand centers. The "ideal" route shown in Figure 1 has not led to significantly lower emissions thus far. Consequently, fossil fuels still provide almost the same proportion of energy consumed worldwide as they did a decade ago, making NZE almost as distant now as it was a decade

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ago (the "actual" case in figure 1). In the absence of concerted action to increase the uptake of REs, ongoing acceleration in their installed capacity is unlikely to make significant inroads into emissions. The steps needed to make NZE a reality in the next few decades ("Realistic") are outlined in Figure 1(c).

3. Demand Side Action

In addition to ramping up RE capacity, energy storage and management, and the development of a smart grid would be among the actions which could stimulate an increase in RE uptake. Innovations in hard-to-decarbonize areas which resist electrification (e.g., cement, steel, chemicals) are also critical and need to be complemented by policies to actively curb FF use (Wolf, 2023). In addition to making the supply of REs more reliable and versatile, action on the energy demand front is vital to achieve NZE within a reasonable timeframe. Demand-side mitigation consists mainly of lowering energy intensity (energy used per unit of output) and/or emission intensity (emissions per unit of energy used). Considerable attention has recently been devoted to demand-side mitigation from a policy perspective (IPCC, 2022). The President of COP 28, who heads one of the largest oil and natural gas producers in the world, conceded that, in the absence of demand side reductions, NZE targets were unrealistic (The Guardian, 2024a).

Corporations are central to carbon neutrality since they play a dominant role in both supplying and using energy. Since climate change and biodiversity loss are rated the direst risks to business by the World Economic Forum (Leimbach, 2024). Corporations have much to lose if action to mitigate these risks is not pursued vigorously.

We now examine each of the main emitting sectors and the ways in which businesses are attempting/could attempt to Avoid (A), Shift (S), or Improve (I) aspects of their operations to minimize emissions (Creutzig, et. al, 2022). We start with electrical energy, followed by transportation, industry, and buildings.

3.1 Electricity

Electric power generation is responsible for around 35% of emissions worldwide. This includes the electricity used in industrial, commercial, and residential establishments, transport, and buildings. The transition to a net zero emission scenario depends on a rapid growth of renewable energy (RE), and perhaps nuclear, installations to replace fossil fuel generation. However, the capacity factor of REs is low (ranging between 15 and 25% for solar) compared with power from coal (70% or more), varying with location, sun-tracking ability, and inverter capacity (IEA, 2022; Solarsena, 2021). Storing excess energy in batteries and in the form of hydrogen produced by electrolysis could raise the capacity factor (EIA, 2024a). Demand side energy management is equally vital, as exemplified in Table 1.

Table 1: A-S-I Framework for Electricity

Avoid	Shift	Improve
Energy efficiency Digitalize/use of Machine Learning Smart grids SMRs	REs on site Energy storage Green PPAs Green hydrogen	Customized energy solutions Rooftop solar RE connections to grid

Users ranging from households to large industrial establishments could benefit from energy deployment expertise. Considering the range of electricity sources, variations in price and reliability, and diverse emission goals of users, optimizing the cost-risk-emission combination could accelerate the uptake of energy from clean sources (Motyka, 2023). Increasing energy efficiency and minimizing emission intensity are expected to contribute to *avoiding* 30% of emissions which would otherwise have occurred by 2050 (IEA, 2022). It has also been noted that the ROI from these demand side measures is likely to be realized much earlier than from supply side investments (Reuters, 2023). While few users, not even large firms, possess the knowledge and experience to address these and other demand side needs, companies like Enel, Schneider Electric, Iberdrola and GE are among the companies attempting to fill this gap. We briefly outline the efforts of Enel and Schneider Electric which facilitate the A-S-I approach.

Originally an electric utility supplying fossil fuel-based power, Enel gradually added REs to its portfolio, and is now in the business of custom designing energy systems for large clients. Machine learning helps Enel refine and customize its forecasts of users' energy needs, which are then matched to the sources to which it has access. As Enel expands its client list, their diverse demand patterns reduce the likelihood of peaks exceeding the firm's available capacity (Enel, 2023). Enel navigates the clean energy landscape to provide its clients with the best sources. It has signed Power Purchase Agreements (PPAs) to the tune of over 2,000GW, which includes green PPAs. Auctions help the firm procure clean energy at the best prices (Enelx, 2023). It offers solar power with storage, while separately offering energy storage at customers' facilities, enabling the purchase of power when prices are low. The company's demand response contracts pay large buyers of power who are willing to use less electricity when the grid is stressed.

From its beginnings in steel and armaments, Schneider Electric morphed into an electrical product and service business and is now in the business of devising customized solutions for buildings, Data Centers, Industry, and Infrastructure. Some of its areas of specialization are: energy management for buildings while maximizing efficiency and comfort; monitoring and managing grid connection to increase reliability, lower wastage, and keep costs low; enhancing machine reliability in manufacturing, minimize energy costs, and ensure the use of environmentally friendly materials; mitigating energy used in data centers as the latter consume ever-rising amounts of energy (SE, 2023a). Schneider is focused on combining the optimal Operations Technology with cutting-edge digitalization. Whether in buildings, mining operations for cleantech materials, IT firms' scope 3 emissions (from outsourced work), or emissions from the refining and production of oil and gas, Schneider's energy management expertise, as is the case with Enel, seeks to fill the gap between national policies and corporate strategies to decarbonize, on the one hand, and implementation of the transition through digitalization, on the other (SE, 2023b).

Avoiding emissions could be further accelerated by the implementation of Small Modular Reactors which have the potential to provide nuclear power with plants which can be installed in lower capacities at a fraction of the cost to meet localized demand. The *Shift* can also be accomplished by corporations installing their own RE and storage capacities. A major step in the Included in the *improve* category would be the development of smart grids, thus increasing the grid's uptake of REs (Ebmgen, 2023; Wolf, 2024). While expanding grid coverage and creating smart capabilities calls for public-private collaboration, business firms are central to developing the technologies critical to the effort. Additions to municipal and community RE supplies and to rooftop solar are some of the other ways in which firms can help reduce emissions.

3.2 Transportation

Overall, transportation is responsible for a little under 25% of worldwide emissions, with personal transport (cars and buses) accounting for over two-thirds of the amount. Trucking contributes about 20% and air travel over 10% of transportation emissions (UNEP, 2024; Ritchie, 2020). Focusing on personal travel and trucking could help alleviate the bulk of the emissions in this sector. Table 2 summarizes some of the possible means to achieving this reduction.

Table 2: A-S-I Framework for Transportation

Avoid	Shift	Improve
Modernize public transport. Select locations to reduce travel distances. Lower emissions in manufacture of EVs. Increase hybrid/remote work.	Increased sale of EVs. Direct messaging to consumers. EV batteries to provide power for homes. Increase use of fuel cells for trucking. Alternative fuels (e.g., ammonia) for shipping.	Supply chain for battery materials and production. Expand charging infrastructure. Use only REs for charging; use of Life Cycle Emissions. Battery recycling; alternative battery materials. Lower cost of production.

Strategies to help *avoid* emissions include minimizing the need for travel through means such as working from home where possible and encouraging the use of mass transit. Disincentives like levying fees for car use in city centers would complement the effort to avoid the use of personal transportation. Cities which are being built or expanding in developing nations could be designed to lower travel distances to work, school, stores, and the like.

Electric Vehicles (EVs) appear to be the pathway chosen by policy makers and corporations to mitigate emissions by *shifting* away from fossil fuel usage (IEA, 2023). Most of the world's largest car manufacturers envision an increasing proportion of their output will consist of EVs, some projecting that they will phase out internal combustion engines (ICE) by 2035 (Motavalli, 2023). Nearly 15% of cars sold in 2022 in the U.S. were EVs, a percentage which keeps rising every year. EV sales are rising in most markets, taking some share away from ICEs. However, considering that nearly 70 million new cars are sold on average globally, more than 55 million ICE cars are still entering service every year. China is the world's largest market (selling more EVs than the rest of the world combined), followed by the EU, and the U.S. Tesla and BYD lead in worldwide sales, but companies like GM, Ford, BMW, VW, Daimler, Toyota, Honda, Hyundai, and Volvo are among the brands which are slated to invest over $800 billion in the EV value chain by 2030 (Gabriel, 2023). Most of these companies are engaged in manufacturing (or have formed alliances for this purpose) batteries, establishing supply chains stretching back to mining, and forward to developing or expanding a charging network, and are involved in a variety of activities needed to make EVs attractive to customers. The recent alliance among seven manufacturers to build a charging infrastructure is an instance of *coopetition* to grow the EV market.

Several other challenges remain offering considerable scope for *improvement*. Materials needed for batteries are available in relatively limited locations, Chinese firms' (e.g. CATL) dominance in manufacturing know how will take years to overcome, battery recycling technology is in the nascent stage, production of EVs generates over 50% more GHGs than that of ICEs, the appetite for SUVs in the U.S. increases the use of scarce materials, and the price differential with ICEs remains a deterrent to higher sales (Mayoral, 2023). While the price gap is gradually declining, other problems need to be addressed simultaneously if a significant dent in GHG emissions in personal transport is to materialize (Tabuchi and Plumer, 2023). The ascendancy of Chinese firms in battery manufacturing could give them an edge lasting well into the next decade especially when one considers that demand for EVs is projected to quadruple by 2035. This makes recycling vital to replacing ICEs with EVs. Companies like Northvolt, LG, and Panasonic are investing heavily in recycling technology (Weiss and Rillaud, 2022). Efforts are also underway to find alternatives to lithium and to reduce the use of cobalt and nickel. Sodium batteries show some promise since sodium is available in relatively plentiful quantities, though more work is needed to resolve problems such as reducing their weight. Chinese companies are first movers in this field but research efforts in countries such as the U.S. are ratcheting up. As the number of EVs and hybrids on the roads increases, the search for alternative battery materials and for recycling at scale appears to be picking up pace (Afdc, 2023).

Even if all the pieces of the EV puzzle fall into place, reliable sources of REs for charging are essential. Some authors contend that even if electricity from natural gas is used for recharging batteries, it would constitute a net reduction in emissions. The life cycle emissions (LCEs) for a sedan EV charged from a grid drawing on a mixture of power would be about 150gm.per mile, an ICE sedan averaging about double that amount. Taking emissions in manufacturing into consideration, EVs have LCEs which are about 25 % lower than their ICE counterparts. The gap widens significantly when REs are used for battery recharging (Oguz, 2023; Scott, 2023).

For companies dueling one another for a rising share of a growing EV market, and policy makers focused on greening the transportation sector, the lessons are clear. While auto firms view higher EV sales (and profits) as an opportunity to improve corporate performance, an increasing proportion of EVs in the output mix does not necessarily lower emissions. To lower life cycle emissions (LCEs) from transportation, the policy regimen may need to be altered to offer subsidies and incentives tied to LCEs (computed along the entire value chain to encompass mining, shipping, manufacture, charging, and marketing of smaller vehicles) rather than to "face-value" emission reductions. While the Avoid approach depends mainly on policy decisions, actions to Shift and Improve are typically within the ambit of corporations, though some (e.g. charging infrastructure) need public-private collaboration or policy support (Totty, 2023).

3.3 Industry

Firms which are consumers of energy are critical to emission lowering efforts. Of the 2000 top emitting firms in the world, over 600 have made some form of net zero commitment, some as early as by 2030 (Accenture, 2022). Only about 7% of the firms studied have been able to attain their targeted decline in emissions. We investigate the emissions attributable to consumer goods firms separately from those in heavy industry (Table 3) with a view to understanding the challenges involved and the causes underlying the failure to live up to commitments made.

Table 3: A-S-I for Industry

Avoid	Shift	Improve
Consumer goods. Install renewables. Tackle Scope 3- design for sustainability. Work with/monitor suppliers. Reduce consumer energy usage. Circularity-recycle, reuse, refurbish. Heavy industry. Develop lightweight steel with similar strength. Lower carbon footprint of concrete. Reduce methane leakage in oil and gas extraction.	Direct messaging to consumers. Industry standards; co-opetition. Replace coal with hydrogen in blast furnaces. Steel production in electric arc furnaces powered by REs. Use of less carbon-intensive clinker.	Reduce material waste. Increase recycled inputs. Minimize use of fossil fuel-based inputs (e.g., plastics, synthetic fibers) Carbon capture and storage (CCS)

3.3.1 Consumer goods

A closer look reveals that most consumer goods firms (as is true of all the firms in the Accenture in 2022 report have targeted only Scope 1 and Scope 2 emissions (those resulting from their internal operations and attributable to energy from external sources) (Accenture, 2022). Scope 3 emissions (along the supply chain or after production/sale) are, on average, 70% of a firm's carbon emissions and are excluded from many firms' net zero commitments (Deloitte, 2024). For instance, consumer goods giant P&G has committed to lowering its emissions by 50% in a decade. However, Planet Tracker notes that P&G is on course for a 3 deg (Planet Tracker, 2023). C rise by 2030. Other companies in similar lines of business, such as Kimberly Clark, have made similar commitments which exclude Scope 3 pollution, suggesting that corporate undertakings to sharply scale back pollution are probably vastly exaggerated. In general, there is a wide gap between net zero commitments by firms and their integration into corporate strategies and cultures (Weirens, et. al., 2024; Geradts and Bocken, 2018). Considering that Scope 3 emissions on average comprise a significant proportion of all corporate emissions, net zero commitments by businesses in their present form will limit progress toward carbon neutrality to a minimal, highly insufficient degree. The manufacture and use of consumer goods such as clothing, appliances, electronics and the like contribute to nearly 20% of demand side emissions quite apart from the electric power and transportation involved in their production. The manufacture, retailing, shipping, and use of consumer durables and nondurables holds enormous potential for reducing demand side emissions. Consumer goods businesses are influenced by user behavior and mindsets, though an argument can be made that firms could play a role in "selling" sustainability to their customers as well. This is further explored in a later section.

3.3.2 Circularity

One of the ways in which firms can reduce emissions is by breaking free of the extraction-manufacture-use-discard paradigm and hewing closer to the concept of strong sustainability, an ideal which may be impossible to realize but is worth striving for. Circular businesses attempt to minimize wastage of natural resources and energy through various initiatives. The use of REs to minimize scope 1,2&3 emissions helps lower emissions attributable to energy. Products may be designed for sustainability by minimizing use of energy and materials used in production. Suppliers are an integral part of this effort to *avoid* emissions. Recycling is among the best known and most widely used methods for material conservation while also addressing emissions caused by discarding end-of-life items (Lacy, Long, and Spindler, 2020). There are numerous ways to ensure that recycling is accomplished with minimum waste. Design for recycling, whether applied to cell phones, carpets, or sneakers, ensures that products are made in a way that recycling is efficient and that any changes made to the product are accompanied by assessing the impact on recycling (Atasu et al., 2021). Remanufacturing of products is an effective way to market to a price-conscious segment while competing against lower-priced rivals. Collection of used and/or end of life products is critical to achieve greater circularity in recycling. HP's collection of plastic waste in Haiti, Patagonia's ability to acquire used fishing nets in the Philippines, and H&M's collection boxes at retail stores speak to these firms' commitment to recycling (Young and Gerard, 2021). The clothing industry, responsible for over 10% of all CO^2 emissions, is also engaged in product life extension by being involved in the used clothing industry as well as finding other uses for used clothes such as donations to less developed nations and repurposing unusable clothing as rags for use in repair shops. Platforms such as the Textile Exchange enable indirect collaboration among competitors by sharing best practices and sustainability strategies across supply chains, in an effort to make the industry as a whole more circular (Four Source, 2024). The embedded value in a product, ease of access to the used product, and level of difficulty involved in processing it determines the effort required for, and effectiveness of, recycling, refurbishing, or remanufacturing (Dumas and Wassenhove, 2020). In general high embedded value products which are easy to access and to process (e.g Patagonia's clothing or Herman Miller metal furniture) are ideal targets for circularity. On the other hand, low embedded values, combined with difficulty in recycling and elaborate initiatives needed to collect used materials (e.g sneakers, T-shirts) require far more effort.

The potential economic impact could be $ 4 trillion or higher in terms of savings, reduced waste, shortened supply chains, increased revenues, and employment generated (McGinty, 2021). Increased circularity creates challenges which need to be addressed. For instance, refurbished products could affect sales of new products (unless a separate market segment is targeted) and suppliers are likely to see their order books reduced. On the other hand, policies to stimulate reuse and refurbishing of products (e.g abolition of sales tax, incentives to firms and suppliers to adopt circular initiatives) could make circularity an attractive option.

Increased efficiency by reducing material waste, minimizing energy used, transportation distances along the supply chain, etc. can help improve ongoing sustainability efforts. Plastics used in production and for packaging are a serious source of pollution both in terms of post-consumer waste and the damage caused to ecosystems, as well as for the fossil energies expended in their manufacture.

The sharp rise in RE capacity over the past ten years, and its expected rapid growth over the next few decades could itself create massive material challenges to circularity. The equipment affected include solar panels, wind turbines, batteries used in EVs and grid connection, and electrolysers used in producing hydrogen (Baldi et al., 2014). The very process of decarbonization calls for innovations to achieve circularity and avoid replicating the extraction-production-consumption-discard sequence of the industrial age.

3.4 Heavy industry

Much of the foregoing discussion relates to consumer and intermediate goods. It may be noted that a significant portion of demand side emissions arises from industrial applications which are difficult to electrify. Steel, cement, and chemicals are foremost among these carbon-dependent businesses. Steel production accounts for about 10% of energy-related emissions. Coking coal is used in the integrated steel mills and improvements in efficiency could lower emissions but still be far from carbon neutral. The use of biomass could make a dent in emissions but is only feasible in regions (such as parts of South America) where the residue is more easily available (IEA, 2024). The use of electric arc furnaces would result in almost green steel but would need a significant boost in REs at low prices. The use of hydrogen as reductant would help produce green steel but would need about 75,000T of hydrogen for which 500MW of RE power would need to be used. Most of Europe's major steel companies are working on a process to manufacture green steel using hydrogen but unless carbon prices are raised (or substantial subsidies/ incentives established) and hydrogen prices drop by around 75%, the cost would remain too high to justify hydrogen-based steel (McKinsey, 2020). It appears, however, that some large steel companies are investing considerable sums to develop a viable solution (CarbonCredits, 2023; Carpenter, 2023). Another critical force which could accelerate the shift to decarbonizing steel is demand from customers at a premium price. The appetite for spending on green steel seems to be lacking in the U.S., while demand for it appears higher in Europe (Fastmarkets, 2021). About 40% of the steel output is used in construction, and innovations in making steel and other construction materials stronger and more durable without increasing their mass is a vital part of decarbonizing hard-to-electrify sectors in industry.

Cement production is another major source of CO_2 emissions. Fossil fuels are used in the calcination process, and CO_2 is also emitted as a result of the process. Efforts are being made by firms such as LaFarge to substitute biomass for fossil fuels, but this is still in the experimental stage) (Skinner and Lalit, 2023). The potential exists to use hydrogen as a fuel but this technology is too energy intensive and expensive at the moment. CO_2 is also generated as a result of calcination, and carbon capture could be a solution here, though one that might take many years to bear fruit (Fennell et al., 2021).

3.5 Buildings

Almost half the energy-related emissions attributed to buildings arises during the construction phase, and focusing on production of the materials needed is central to mitigating these emissions. One could generalize the preceding discussion on steel to other materials such as concrete and chemicals as well. Table 4 lays out some A-S-I strategies for Buildings.

Table 4: A-S-I for Buildings

Avoid	Shift	Improve
Innovations in construction e.g. concrete with a lower carbon footprint, use of wood, etc. Alter design of new buildings to adapt to new materials, minimize energy needed for heating and cooling. Change thermostat settings.	Replace FF energy with rooftop and/or community/utility scale solar. Local and/or grid-level energy storage. EVs supply power at peak load periods. Heat pumps.	Digitization to enhance operational efficiency. Implement PPAs.

The focus in addressing building emissions has typically been on operations rather than materials and construction (As Zhong et al., 2021). The authors note that, over the next two decades, there is likely to be a boom in new construction in parts of Asia and Africa, while developed nations will see a decline. Developing materials with lower environmental impact and modifying building design to use such materials is vital to lower/ avoid the expected additional emissions of up to 4 Gt CO_2eq. (Sisson, 2023).

Over 10% of all energy-related emissions are caused by building heating and cooling. In developed nations, electrification offers a pathway to net zero provided RE capacity and reliability are ensured. Companies such as Enel, Schneider, and other energy management firms could accelerate the process of using energy more efficiently through digitalization, as well as by avoiding, shifting, and improving building operations to minimize energy use and emissions. Regional and community RE projects, municipal grids, rooftop installations, PPAs, using EVs as power supply during peak demand periods, and other such approaches could help enhance operational energy efficiency in developed and developing nations. Lowering thermostat settings in winter by 1^0C could result in a 6% drop in energy used for heating. However, there is little willingness on the part of the public to adopt this approach.

4. Market Preferences

Corporate strategies to lower carbon footprints would need to increasingly focus on influencing customers' values and behaviors towards more sustainable products. As is the case with transportation, and building heating and cooling, the ability to persuade end users that more environmentally friendly products promote both individual and collective wellbeing, is critical if sustainability is to be 'pulled' through the system. The challenge for corporations is to develop sustainable products which are competitive on price and quality, persuade customers to buy them, and, as customer expectations rise, to be able to ramp up efforts to meet or exceed customer expectations. Far more people would like to purchase sustainably made goods than the number who actually do (White et al., 2019). Circularity in durable and fast-moving goods is highly dependent on the cooperation of consumers. Addressing reluctance on the part of individual and industrial customers to invest in products with lower carbon and other harmful emissions involves overcoming behavioral, social, and cultural lock-ins, and are vital to corporate efforts to curb demand-side emissions. Disruptive external factors such as rising inflation, unemployment, and social and political turbulence could further dampen customers' willingness to pay more for environmentally friendly products and services. The fossil fuel industry wields both hard and soft power. Its hard power stems from its entrenched position in the energy supplied to the four segments discussed in this paper, its ability to use pricing and supply variation to ensure continued use of, and dependence on, coal, oil, and natural gas, and the ongoing investment in technologies such as CCS and hydrogen produced using natural gas toward the same end. Soft power derives from its considerable lobbying abilities, influence over policy makers even at climate conferences such as the COPs, efforts at misinformation, and support for climate-skeptic scientists. Demand side actions jointly undertaken by governments and corporations with support from large investors could play a big part in loosening the stranglehold of the fossil fuel industry in energy supply.

5. Discussion and Conclusion

If corporations are to play a prominent role in diminishing demand side emissions, some challenges and hurdles need to be overcome. For one, if pursuing emission reductions placed firms at a competitive disadvantage (increased costs, longer lead times, etc.), they would be reluctant to take that route unless standards were imposed on, or organically arrived at by, the industry as a whole, or the emission lowering strategy yielded a quick payback. Governments in the EU, China, and the US have enacted regulations to enable phasing out fossil fuel powered vehicles over the next two decades. This could be a tall order given the daunting challenges that lie ahead as the transition proceeds. These include the need for hundreds of millions of batteries, a proliferation in the number of charging stations and the clean energy to power them, methods of disposing of/recycling batteries, and finding ways to employ displaced workers in the manufacturing and repair of traditional vehicles. In regard to electricity generation, additions to the stock of REs are proceeding apace but in order to better utilize the power generated, as noted earlier, storage and smart grids are vital, which call for direct government assistance (as being offered in the Inflation Reduction Act (EPA, 2023). Incentives in the form of tax breaks, speeding up the approval/due diligence process, and so on. Such initiatives and policies are being formulated but delays in their implementation make the large-scale substitution of clean for fossil fuel electricity seem rather distant.

Even greater obstacles stand in the way of minimizing emissions in buildings and heavy industry. The bulk of the growth in urbanization and new buildings is projected to be in developing nations in Africa and Asia. The demand for steel and concrete is projected to increase by nearly 50% over current needs (Hansen and Alkousa, 2023). Which could render achieving NZE by 2050 unrealistic unless radical innovations in the production of these materials and in the design, construction, operation and layout of new buildings is undertaken. Germany's decision to invest about $30 billion on developing low-emission construction materials (in addition to another $35 billion on transportation infrastructure and electricity generation and transmission) could, as with the Inflation Reduction Act, jump start a demand side revolution. However, unless the technological advances made by developed nations in all four energy demand areas are shared with countries where the demand spikes are likely to occur, the impact on emissions from energy usage are likely to be minimal. If corporations, with or without governmental support, introduce technologies to reduce emissions on the demand side, mechanisms need to be established by which these radical innovations are made available to users in emerging nations. One way of doing this is by rich countries transferring such technologies on a country-to-country basis as part of the tentative agreement reached at COP 28 to transfer funds to the tune of $500 billion from the developed to the developing world. Sufficient political will has to be summoned in donor nations for this to occur. Despite a fraying international order countries need to acknowledge that global collaboration to address climate change is vital if technology and funds transfer are to become a reality. Financial institutions have a significant role to play in funding new technologies as well as in their dissemination to less prosperous countries as part of a long-term loan agreements. The use of build-operate-transfer contracts might also facilitate the process of sharing emission reduction methods. Public investment and private initiative combining to focus on emissions arising from energy used are indispensable to reach NZE.

Carbon capture and storage (CCS) at the points of carbon emission is increasingly being viewed as central to "mopping up" the residual emissions after all other supply and demand side efforts have been implemented. The technology, though in its nascent stage, is attracting considerable attention and investment. In addition to venture capitalists and tech entrepreneurs, major funders include oil and gas firms. Exxon Mobil, Occidental, and Shell proposing sinking large sums of money into CCS. Though undoubtedly a laudable attempt to increase the "carbon budget" and postpone the day when the planet warms more than 2^0C, or even 1.5^0C, the use of CCS on a large scale could end up serving as a license to continue using fossil fuels. If CCS becomes economically viable at scale, it could subvert work being done to mitigate emissions. Even more problematic is geoengineering which employs techniques such as spraying aerosols to reflect sunlight back into space and spreading iron filings on ocean surfaces to absorb CO2 from sea water. Experiments are being tried out on a small scale to study the extent to which cloud spraying can reduce heat reaching the earth. However, the technology is fraught with danger if tried on a large scale since its impact on weather patterns worldwide remains unpredictable. It appears that despite the inherent risks (in the case of sprinkling chemicals on the ocean's surface, the effect on marine life, for instance, is not yet known), geoengineering is also garnering attention, particularly due to the fact that worldwide emissions show no signs of declining.

At the COP 28 meeting held in late 2023, a commitment was made to 'transition away from fossil fuels', though no timeline or enforcement mechanisms were mentioned. The rather vague commitment was hailed as historic as it was the first time fossil fuels were directly linked to climate change. However, statements by leaders in the oil and gas industry make it clear that they deem their products indispensable to the world's energy needs till at least 2040 (EIA, 2024b; Pringle, 2024), and, in fact, have actively opposed incentives offered for ramping up Res (Niranjan, 2024). In the absence of any appreciable reduction in the supply of fossil fuels and given the prospect of energy demand doubling over the next two decades, staying on track for NZE by 2050 requires tripling RE capacity by 2030, doubling energy efficiency, and ramping up carbon capture, an unlikely trifecta of outcomes. It is apparent that commitments made by national leaders are subject to the constraints imposed by emergent economic, political, national security, and other such considerations. In the absence of an international enforcement mechanism, such commitments are often not adhered to. If corporations, on the other hand, organically undertook to reduce emissions, perceiving it to be in their own interest, considerable headway could be made.

We have argued that rapid increases in the *supply* of clean energy without a concomitant expansion of energy storage and grid optimization have not thus far been effective, nor are they taken alone likely to move the needle on NZE. We have therefore focused on ways in which firms may lower their demand for energy thus *avoiding* emissions, *shifting* to less emissive methods, and *improving* the efficiency of existing technologies. Moderating corporate energy-related emissions by employing the A-S-I methodology is an approach that could yield dividends by diminishing energy used, lowering emissions, and reducing material wastage, potentially increasing profits, and moderating risk in the long run.

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