How Industries can be Modified to Achieve Environmental Sustainability?

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Since the inception of the Industrial Revolution, catalysed in part by the steam engine, extensive operations have elevated living standards and offered a plethora of choices beyond the imagination of our ancestors. However, it has also yielded unintended consequences, such as pollution The majority of industries currently rely on fossil fuels for power. To ensure a sustainable future, these industries should transition from fossil fuels to various renewable energy sources. While a complete shift to full electrification may be a significant challenge for many factories, some find hybrid equipment to be a practical step towards achieving long-term financial and environmental goals. Fossil fuels have been indispensable for powering the world's largest factories for over a century. Although a sweeping change won't happen overnight, electrification is gaining momentum. Our recent Global Energy Perspective indicates that by 2035, renewables could account for more than half of the world's electricity production, often at a lower cost than fossil-fuel generation. The decreasing costs of both electrical equipment and renewable electricity generation are expected to drive the electrification of industrial processes The costs of fossil fuels compared to electric power exhibit variability, and there's considerable uncertainty about when electric power will definitively and irreversibly become more cost-effective. Cost-effectiveness hinges not only on the current relative prices of fossil fuels and renewable electricity at a specific industrial site but also on factors like carbon pricing, where an increase could make industrial electrification more viable. Additionally, the long-term energy efficiency of electric equipment compared to conventional equipment plays a crucial role. Given that energy costs can surpass capital-investment costs by more than tenfold over the lifetime of a typical industrial furnace or boiler, the stakes are undeniably high.

Use of Hybrid Equipment

In certain situations, companies can take an initial step towards electrification by opting for a partial switch, incorporating hybrid solutions for specific applications. This involves utilizing equipment capable of running on either electricity or conventional fossil fuel. Another approach is the installation of additional electrical equipment, like electrical boilers, in a "dual"

setup. Such dual or hybrid equipment is readily available for generating low- and medium-temperature heat, particularly in sectors such as chemical, petrochemical, and food industries that heavily rely on steam boilers. While partial electrification may not represent a final solution, hybridization presents substantial benefits for both industrial companies and society.

By incorporating hybrid equipment, businesses gain the flexibility to optimize energy expenses, strategically shifting to electricity during periods of lower costs and seamlessly reverting to fossil fuels when electricity prices surge. This dynamic approach intertwines with an added cost-benefit dimension: industrial companies stand to earn payments through "grid balancing" practices. These practices involve rewarding customers for efficiently utilizing excess electricity generated during peak renewable periods. By receiving such incentives, industrial facilities not only contribute to grid stability but also enhance their own financial prospects. In essence, these grid payments, along with associated fees and connection costs, emerge as pivotal elements that can either make or break a business case, often necessitating contractual adjustments or regulatory interventions. In addition, hybrid equipment can enable direct use of electricity from a nearby intermittent renewable-production site, such as a solar or wind farm. Such an off-grid setup could lower electricity costs for industrial companies significantly, as grid-connection costs, taxes, and other levies are mitigated or avoided. Industry could even be considered as a cheap battery, using electricity when available and switching back to fossil-fuel power when required, serving to help stabilize an entire grid.

Investing in hybrid equipment proves most pragmatic when a company is either retiring outdated machinery or embarking on the creation of a new facility. In the context of greenfield plants, a forward-thinking strategy leans heavily towards embracing full electric setups for future-proofing. However, in the immediate future, the installation of hybrid equipment during equipment replacements or new construction phases could render electrification more cost-effective than opting for conventional equipment now and transitioning to electric alternatives later on. As renewable-electricity prices witness a decline in various regions, the feasibility of hybridization as a near-term option gains momentum across a broader spectrum of industrial sites.

Switching can bring about positive, downstream effects. If industrial players ramp up their electricity usage due to falling prices compared to conventional fuel, the reduced price could

establish a baseline in the power market. This might boost the energy transition by making investments in renewable-energy production more appealing.

Emission of Green House Gases

The industry's fuel consumption alone contributes to a third of all greenhouse gases (GHG), and oil and gas operations directly emit another 9 percent of GHG. This 42 percent total is the largest share attributed to any single industry. Consequently, the pressure on oil and gas producers to change is substantial and steadily increasing. Investors are demanding stronger emissions-reduction plans or are divesting from fossil fuels altogether. Meanwhile, wind and solar energy are becoming more effective and affordable. For fossil-fuel providers, the long-term implications of these trends are significant, even existential. To meet the Intergovernmental Panel on Climate Change's (IPCC) goal of keeping temperatures below the 1.5-degree threshold, the industry would need to cut its direct emissions by 90 percent by 2050, relative to today's levels. Achieving this target could be more feasible if the use of oil and gas declined. However, even if demand doesn't decrease significantly, the sector can still substantially reduce its direct emissions now, and more cost-effectively than companies might realize.

Hazardous by-products

Oil and gas companies' production-related activities contribute to 9 percent of global greenhouse gas (GHG) emissions. The major GHG contributor, linked to over 60 percent of the industry's emissions, is natural gas. Despite being primarily methane, this gas is often burned off during oil discoveries due to its lower value compared to oil. The intentional burning, known as flaring, transforms methane into CO2 and constitutes 14 percent of the industry's direct emissions. Unburned gas, whether released intentionally or accidentally, stands as the largest single source of the industry's direct GHG emissions, making up 48 percent. The release of methane into the atmosphere is concerning, given its potency—86 times more effective than carbon dioxide at trapping heat during the first 20 years of its release. The annual amount of methane released through oil and gas operations is substantial, equivalent to 6 percent of the global energy sector's total GHG emissions in 2017. Emissions sources within the oil and gas industry are scattered across its value chain, with downstream production activities contributing about 30 percent of the industry's direct greenhouse gas (GHG) emissions. An effective solution involves replacing on-site generators with a solar photovoltaic

and battery setup, as demonstrated by one oil and gas company that significantly reduced emissions, breaking even on the investment within five years. Tackling such complex challenges will test the leadership of oil and gas executives, providing them with opportunities to signal the industry's commitment to decarbonization and pave the way for a new future. While acknowledging that the more significant challenge lies in the combustion of the industry's products, every improvement counts. The speed at which operational opportunities are implemented could generate valuable momentum for the demanding work ahead. The industrial sector, being a top energy consumer and responsible for over one-quarter of global CO2 emissions, faces the imperative of reducing its carbon footprint. Process optimization and increased energy efficiency are pivotal in achieving emission reductions, with digital technology playing a significant role in this transformation. The industries which are contributing mainly to the environmental pollution and trying to become more environmentally friendly are discussed below.

Mining Industries

The global mining industry confronts escalating physical risks due to a changing climate and is under growing pressure to decarbonize, making the creation of a climate strategy both challenging and increasingly urgent. Mining operations are accustomed to harsh climates, often operating in inhospitable conditions. However, forecasts predict more frequent and intense effects such as heavy precipitation, droughts, and heat, introducing new physical risks to mining operations. Simultaneously, the industry grapples with a significant decarbonization challenge. Mining operations directly contribute to 4 to 7 percent of global greenhouse gas (GHG) emissions, with at least three-quarters attributed to methane emissions from coal mining. Mounting pressure from climate change, governments, and investors is beginning to spur additional action within the industry. Further efforts are necessary, and as they unfold, they should enable mining companies to seize emerging opportunities in providing raw materials for new technologies while working towards a more sustainable future. The decarbonization challenge remains a central focus amidst these evolving dynamics.

Every industry holds a crucial role in the collective effort to limit global warming to 1.5 degrees Celsius above preindustrial levels—an objective deemed essential by the Intergovernmental Panel on Climate Change to mitigate the most severe risks of climate change. While the potential for decarbonization varies across mines, influenced by factors like commodity, type,

and power source, our research indicates that mines could fully decarbonize their direct CO2 emissions, constituting approximately one-quarter of the industry's direct greenhouse gas (GHG) emissions. Achieving this involves a strategic combination of operational efficiency improvements, electrification, and the adoption of renewable energy. While capital investments are necessary to unlock most of this potential, certain measures are already economically viable for many mines today.

Shifting towards renewable electricity sources is expected to become more viable, even in off-grid environments, thanks to a projected 50 percent decline in the cost of battery packs by 2030. Remarkably, battery electric vehicles, in some cases, boast a 20 percent lower total cost of ownership compared to traditional internal-combustion-engine vehicles. However, the electrification of mining equipment, including diesel trucks and gas-consuming appliances, is only just becoming economically feasible, with only 0.5 percent of mining equipment fully electric at present. Addressing the remaining three-quarters of GHG emissions in the mining industry poses a more formidable challenge. These emissions stem from coal mining, particularly the release of naturally occurring methane found in many coal beds. While solutions exist for capturing this fugitive methane and converting it into power, these solutions are not universally applicable across all types of mines, and the required investment is often uneconomical in many cases.

Cement Industries

The cement industry stands out as a significant emitter, holding a prominent position in the sources of emissions. Cement, a crucial component of concrete and an integral part of our daily lives, is also a major contributor to global CO2 emissions. Specifically, two-thirds of the industry's emissions stem from the calcination process, involving the chemical decomposition of raw materials like limestone. Decarbonizing this process proves to be particularly challenging, given that carbon emissions are inherent to the calcination process itself.

Operational advances

Building on decades of efforts to enhance efficiency, traditional abatement strategies have the potential to reduce emissions by approximately one-fifth by 2050. The production of clinker, the essential component of cement, in cement kilns requires a substantial amount of heat. Alongside increasing the use of clinker substitutes, the industry could decrease energy intensity

by improving plant utilization and enhancing equipment effectiveness. The recovery of waste heat also presents an opportunity to generate carbon-free electricity. Future cement plants could gain a competitive edge by integrating digital technologies into their operations, fostering both efficiency and sustainability.

Additionally, incorporating alternative fuels like waste and biomass, a trend in the industry spanning multiple decades, could contribute to a nearly 10 percent reduction in emissions by 2050. However, these endeavors come with challenges. Biomass availability varies by region, and competition from other industries adds complexity. Clinker substitutes face limitations, with natural pozzolans, such as volcanic rock and ash, not yet being extensively evaluated at scale. Furthermore, industrial byproducts serving as clinker alternatives, like fly ash from coal-fired power plants and slag from steel blast furnaces, may become scarcer as the power and steel industries decarbonize and produce less waste. Overcoming these challenges is integral to achieving sustainable and impactful emission reductions in the cement industry.

Technological innovation

Innovation is crucial for realizing the sustainability and performance potential of the cement industry, and promising avenues are already emerging. An intriguing development involves adding CO2 to concrete, which not only strengthens the material but also reduces the amount of cement required. Carbon-cured concrete presents another innovative solution by utilizing CO2 captured during cement production. While current methods can sequester up to 5 percent of the CO2 produced during production, newer technologies hold the promise of achieving much higher levels, ranging from 25 to 30 percent. Products like carbon-cured concrete, strategically positioned, could command a "green premium," providing companies with a competitive advantage among environmentally conscious buyers and potentially enhancing pricing power.

Realizing the full potential of technology and innovation in the cement industry will necessitate increased investment and a shift in mindset for companies that have grown accustomed to the status quo. Many players in the cement industry are not accustomed to relying on partnerships or operating within the ecosystems that are second nature in other industries. Breaking away from the comfort of familiarity is a crucial step toward achieving lasting change and sustainability in the sector.

New growth horizons

Sustainability may serve as the catalyst propelling the cement industry towards seeking growth through new business models, partnerships, and construction approaches. Cement-based concrete is likely to remain the global construction material of choice, but the emergence of "sustainable construction" value chains on regional and local levels is expected to prompt a reorientation of many corporate portfolios.

The decarbonization of the cement industry is poised to involve alternative building materials and other approaches, although the extent of emissions reduction remains uncertain. Opportunities for innovation extend beyond cement and concrete, and the industry is at a crucial juncture, facing challenges like decarbonization, ongoing value-chain disruption, and competition within the broader construction ecosystem.

Cement makers are approaching a moment of truth where the convergence of decarbonization and reinvention becomes imperative. Just as automakers redefine their role as providers of mobility rather than just manufacturers of cars, cement companies could similarly position themselves as providers of comprehensive construction solutions. As climate pressures intensify and traditional cement and concrete sales encounter threats, a combination of new thinking, innovation, and novel business models will be critical for ensuring a profitable and environmentally friendly future.

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