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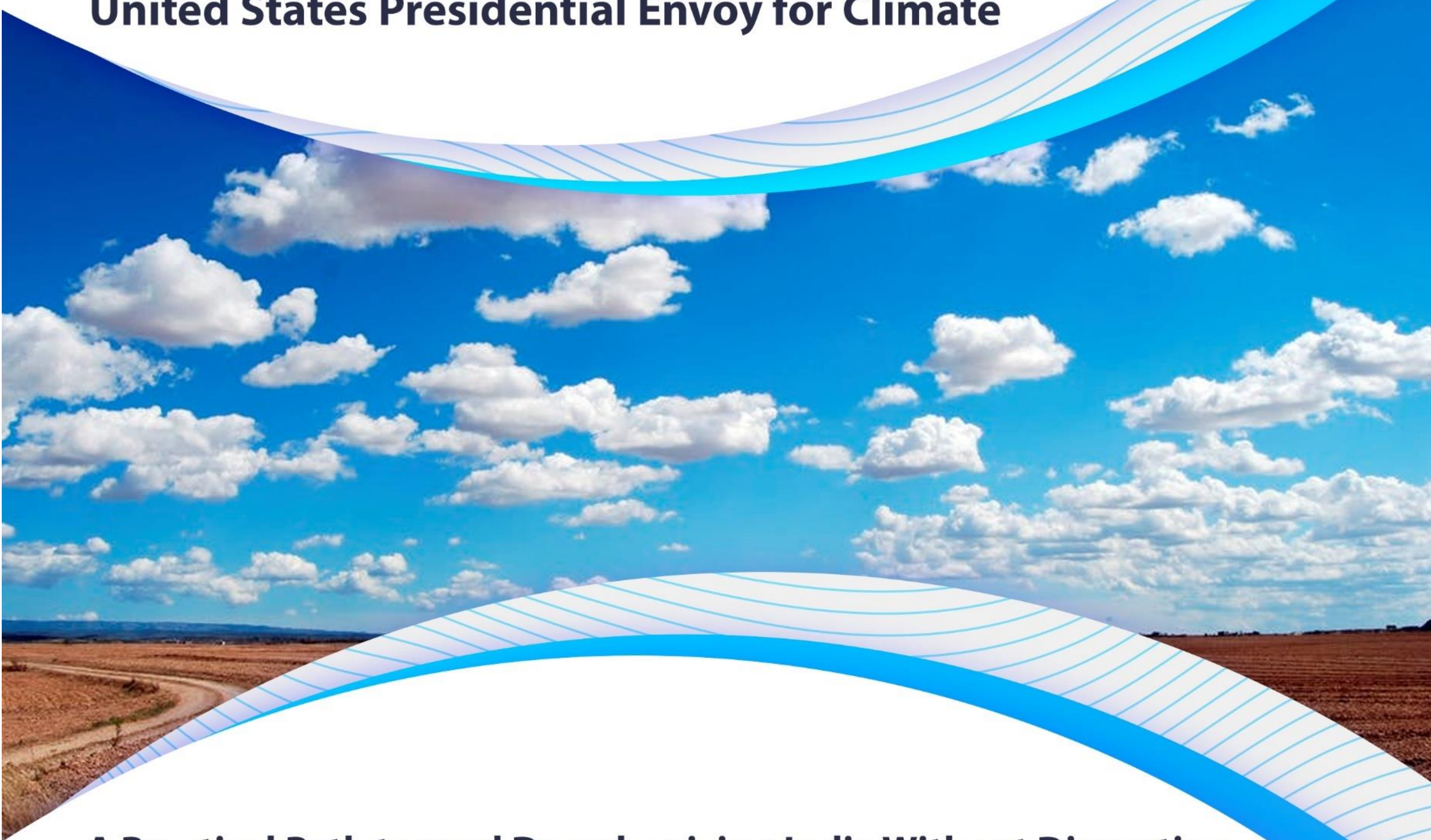
U.S. – INDIA DECARBONIZATION POLICY PROPOSAL

Prepared for Hon. John Kerry

United States Presidential Envoy for Climate



A Practical Path toward Decarbonizing India Without Disrupting Economic Growth

How the U.S. May Participate Through Policy Alignment and Public/Private Partnerships

Prepared By

Ravi Krishnan

Krishnan & Associates, Inc

1516 Bedford Street, Stamford, CT, USA

E: rk@krishnaninc.com | T: +1 203.257.9232

www.krishnaninc.com

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Policy Proposal

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Executive Summary

Radically reducing the carbon footprint of many countries cannot follow a one-size-fits-all tactic, such as the capture, transport, and geologic sequestration (CCUS) approach favored in the U.S. Many developing countries have adopted Net Zero carbon reduction goals but lack the industrial infrastructure, the economic means, or suitable subsurface geology to follow this CCUS development path. This paper presents India as the exemplar of this dilemma. India's red-hot, coal-based economy and dedication to reducing carbon emissions by increasing significant amounts of renewables[1] must be balanced against the availability of indigenous fuels and fuel security, robust community development through electrification, and limited government policy support and economic resources dedicated to the task. Further, India lacks significant experience with constructing and operating long gas pipelines and lacks suitable geologic resources for subsurface storage of CO_2.

A path to decarbonizing the Indian economy is possible by carbon capture coupled with electrolysis to produce green hydrogen for power generation (particularly to fuel new fast-acting turbines necessary to backstop intermittent wind and solar resources for grid stability) and other industrial fuel needs and green ammonia that may be co-fired in coal plants to reduce CO_2 emissions. India also features a world-class cement production infrastructure dedicated to producing building materials for its growing economy. Using green hydrogen to produce polymers that facilitate sequestering carbon in building materials is an essential pathway to decarbonization.

This white paper proposes an international public-private partnership to address decarbonization in developing countries, starting in India. In sum, U.S. policymakers must provide funding and support for U.S. industries to develop CCS technologies directly related to carbon sequestration in concrete and associated products. In return, Indian policymakers must ensure a certain percentage of government construction projects will use green cement and green fuels for power generation, aviation, and allied industries. Such policies could economically benefit U.S. technology providers by opening new markets and empowering LDCs to achieve decarbonization goals.

In India, an economically viable development path away from fossil fuels is believed to be possible when the production of green hydrogen reaches USD 1/kg. As the cost of decarbonizing infrastructure and suitable fuel stocks are reduced, adoption by other developing countries becomes more economically feasible.

[1] According to Government of India's Ministry of Power statistics, renewable generation grew 7.96% in fiscal 2021-2022 and are projected to grow 9.74% in fiscal 2022-2023.

Introduction

Perhaps the most debatable aspect of the global energy transition is the pace that decarbonization must sustain, enabled by cutting-edge regulatory schemes and technological advances. For example, the International Energy Agency (IEA) has proposed a decarbonization plan in its Net Zero by 2050: A Road map for the Global Energy Sector.[2] The IEA suggests that nothing less than a "complete transformation of how we produce, transport, and consume energy" is necessary to reduce global carbon dioxide emissions to zero by 2050." The IEA plan envisions massive additions of renewables (solar PV and wind) each year through 2030. Every country has unique economic, social, and energy use patterns, so contextual solutions for decarbonization must be respected.

The proposed Net Zero by 2050 plan assumes advances in three critical technology areas: carbon capture and storage, advanced batteries, and hydrogen electrolyzers, as well as the pipeline infrastructure to transfer hydrogen and carbon dioxide from source to users or direct to storage facilities. The plan estimates that global "annual investment in transmission and distribution grids expands from USD 260 billion today to USD 820 billion in 2030." However, adopting renewables or constructing CO_2 pipelines and storage facilities does not address less developed countries" (LDC) specific infrastructure, economic, and social development needs. The cost and ability of LDCs to invest in evolving carbon capture, pipelines, and sequestration technologies are not addressed. Thus, the Net Zero by 2050 plan does not adequately consider the ability of LDCs to contribute meaningfully to the goal of Net Zero by 2050.

Case Study: India

An excellent case study to illustrate these concerns is the energy transition that is now underway in India. India is the third largest consumer of energy in the world after China and the U.S. (EIA data for 2021). India has announced that it aims to reach net zero emissions by 2070 and to meet the goal of producing 50% of its electricity needs by 2030 with non-fossil-fueled generation.

India has expressed its desire to reduce CO_2 emissions. Prime Minister Narendra Modi has announced two independent goals. First is the construction of 500GW of renewable energy capacity by 2030. The second is to create a sink of CO_2 emissions by a billion tonnes of CO_2 annually. Still, coal remains the nation's fastest-growing fuel, at 8.1% above its pre-pandemic level. Renewables (excluding hydro) reached 10% for the first time in 2021.

However, India's GDP growth has been among the highest globally over the past 20 years, jumping 8.9% in 2021 post-COVID-19 alone. Coal and oil remain the dominant fuel powering electrification and lifting millions of people out of poverty. Electricity was provided to 50 million people each year for the first time over the past decade. CO_2 emissions have likewise grown in tandem with electrification and economic growth, with India now ranking third highest in the world. However, per capita emissions place the country near the bottom of world emitters.

India, the world's second most populous country with a population of 1.39 billion (2021), is growing at approximately 1 %/year and is expected to surpass China by 2023 reaching 1.43 billion. India's electricity appetite is also staggering. According to government data, India's power consumption reached double digits in November 2022 at 13.6% over the past year. Government sources predict electricity usage will grow an average of 7.2% annually through 2027. Thus, the EIA projects that coal-fired generation will continue to expand, peaking around 2030.[3]

[2] https://iea.blob.core.windows.net/assets/7ebafc81-74ed-412b-9c60-5cc32c8396e4/NetZeroby2050-ARoadmapfortheGlobalEnergySector-SummaryforPolicyMakers_CORR.pdf

Further, oil imports will double between 2021 and 2050 because of limited local resources. Natural gas will fall to less than 5% of electricity generation due to high LNG prices. Government sources estimate coal demand will rise by 25% by 2030 to support the country's strong economic growth, expected to expand by 90% between 2021 and 2030 for producing electricity, iron and steel, and cement. India became the world's second-largest coal producer in 2021 (in energy terms), overtaking Australia and Indonesia, and it plans to continue to increase domestic production each year through 2025.

Much like many LDC economies, India has relied on inexpensive fossil fuels for many years to energize their economies. Coal use grew 8.1% in 2021, above its pre-pandemic level, closely mirroring GDP growth. However, this transition presents what has been termed the classic energy trilemma. How does a country balance the security of supply (which includes the electricity supply chain—starting with indigenous fuel resources through the transmission and distribution of electricity), with the consumer electricity price sensitivity (of particular concern in India and other LDCs) and with environmental protection and sustainable energy practices? How India is attempting to balance these contradicting requirements is instructive.

Even if one looks at electricity generation, green hydrogen could play a vital role as India balances its need for affordable baseload power and net-zero transition. India does not have abundant natural gas, and electricity generation from imported LNG for baseload power is not economically feasible. While nuclear will play a role, high upfront capital expenditure, long-lead times for commissioning, and reliance on imported uranium could be constraints. Hydropower is one of the few indigenous clean sources of baseload electricity, but any significant expansion has to consider the ecological impact and community displacement. Hence, thermal power from coal will remain a part of India's energy mix for some time.

The Indian government is also grappling with many energy transition challenges. In the near term, rising commodity prices and the lessening ability to secure energy supplies have made electricity less affordable, placing downward pressure on future social and industrial economic development. At the heart of any nation's sustainability journey lies the principle of equitable growth. A Net Zero goal unaligned with the nation's development priorities may create greater inequality.

Balancing Conflicting Priorities

Meeting this growing energy demand, continued electrification, securing affordable energy supplies, and maintaining energy security while pursuing decarbonization summarizes the principal challenge facing the Indian government. When considering alternative solutions to India's energy dilemma, several economic and technological concerns must be considered.

- Growth in electricity supply is vital for India's red-hot economy. The use of coal will continue because coal is an indigenous, affordable fuel that affords the country energy security.
- India must continue to secure investment for future electricity production facilities and transmission projects, which is threatened by international financial entities intent on reducing their investment in coal-related projects.
- India does not have access to fuels other than coal for baseload electricity production. Indigenous natural gas production is approximately one-half that in 2010. In 2021, 6.1%of electricity was produced from natural gas.[4]

[3] India increased coal-fired electricity production in 2022 over 2021 while natural gas-powered generation dropped nearly 40% as the rise in the price of LNG made operation of many plants uneconomical. In 2022, solar generation was approximately four times that of natural gas generation.

- India lacks the infrastructure or financial means to construct a system of interconnected CO_2 pipelines. Further, there are no geologic options for the sub-surface sequestration of CO_2. Using the U.S. pipeline infrastructure and geology as a template for LDC decarbonization projects merely siphons funds from other vital infrastructure projects. The U.S. currently operates 8,500 km of CO_2 pipelines, the most extensive infrastructure in the world. There is modest CO_2 pipeline infrastructure outside of the U.S.
- Adding large amounts of renewables in the coming years will merely reduce the rate of India's CO_2 emission growth up to a point. India does not have a candidate fuel, such as natural gas in the U.S., that can be relied upon for powering fast-acting generators to replace renewable power during a system emergency when the sun doesn't shine or the wind doesn't blow.
- Renewable growth in India is limited by the ability of existing transmission infrastructure to move regionally-produced renewable power. Further, the use of renewables is determined by the response time of existing coal plants to respond to system emergencies.

A Practical Path to Decarbonization

Carbon capture must remain the centerpiece of decarbonization technology, although the efficacy and capital cost of the technology options is prohibitively expensive at this time. LDCs cannot be expected to make a studied selection of carbon removal technologies until the technology options have been placed into commercial service and thoroughly tested for some time.

Many recent studies have concluded that CCUS technologies in the U.S. are marginally economic unless carbon capture takes place near or adjacent to existing CO_2 pipelines, the geologic sequestration well is near a CO_2 pipeline, and there is significant governmental policy and economic support (e.g., 45Q, IRA, DOE Loan Program Office, and other state and regional incentives). Further, other recent studies have concluded that a successful rollout of CCUS requires interstate transport and storage infrastructure are essential parallel activities with the construction of carbon capture infrastructure. If one portion of the triad fails, the entire CCUS system fails. The financial burden on LDCs would be significant for this development path, particularly in India, where no government or state incentives or policy support are available for CCUS development.

Support for this path to decarbonization is found in the commitment of the Adani Group to improve the operational emission efficiency of their businesses and, where possible, via electrification of operations and the use of biofuels to reduce Scope 1 emissions.[5] The Group's formidable renewable portfolio allows businesses to progressively source renewable power to lower their Scope 2 emissions. However, it is also the case that for many sectors, green hydrogen will be critical for decarbonization, the last mile in their net-zero journey.[6]

The culmination of Adani's strategy of progressively moving into adjacent sectors and the vision of an India that is a net exporter of clean energy has positioned the Khavda-Mundra corridor to become a globally leading green hydrogen hub. There can be no better statement of the seriousness of this intent than the establishment of Adani New Industries Limited (ANIL) to spearhead the development of the green hydrogen value chain with a planned investment of USD 70 billion over the next decade.

[4] Natural gas consumption has been relatively flat since 2011. In 2021, approximately 48% was for industrial use (principally fertilizer plants), 25% for electricity production, and the remainder in transportation, residential, and services sectors. Enerdata at www.enerdata.net/estore/entergy-marketing/india/

While the scale of this investment presents a great business opportunity that will contribute to India's energy independence, it also positions the Group uniquely to provide a credible decarbonization roadmap for its businesses, as, for many sectors, there is no Net Zero without green hydrogen.

New U.S. – India Decarbonization Policy Proposal

CCUS can be expensive, risky, and technologically challenging for many developing countries. India is well-positioned to follow a different development path. Large-scale renewable development now underway in the country coupled with electrolysis produces green hydrogen. When economically justified, green hydrogen can be used for power generation directly (e.g., combustion turbines to backup renewables) or as an energy storage option.

A more carbon-conscious development path is to use green hydrogen produced by electrolysis, renewable electricity, and nitrogen separated from the air to produce carbon-free green ammonia. Ammonia is easily stored in bulk as a liquid at modest pressures (10-15 bar) or refrigerated to -33C for transportation by pipeline, tanker trucks, and ships. Ammonia is also less flammable than hydrogen. Green ammonia can be burned as a zero-carbon power generation fuel by an engine or fuel cell. Electrification and battery electric vehicles will undoubtedly figure prominently in the decarbonization of the transportation industry, and fuel cells operating on green hydrogen will be critical for heavy-duty trucking and mining operations.

Green ammonia can also be co-fired with coal to reduce plant CO_2 emissions. Adani Power Limited is currently undertaking a feasibility study with Japan's IHI and KOWA for blending 20% ammonia with coal at its Mundra plant.

Methanol is an important raw material for the chemical, construction, and plastics industries and is also used as a sustainable fuel or fuel additive. Green methanol can be produced from green ammonia, captured CO_2, and renewable energy. Suppose the CO_2 captured by DAC technologies using renewable energy is used to produce methanol. In that case, combusting that methanol to produce electricity will be carbon neutral or perhaps a carbon sink (if the methanol produced is converted into long-lived polymers). A portion of the captured CO_2 and green hydrogen can be used to make PVC, effectively acting as a form of sequestration.

For ports and shipping, green ammonia is the most probable path for decarbonizing those industries. In the steel industry, CCUS will be required for blast furnaces. The production of direct reduced iron (DRI, commonly called "sponge" iron in India) with green hydrogen and using renewable electricity and sponge iron in electric arc furnaces will significantly reduce the industry's carbon footprint. The key enabling technology is the availability of green hydrogen. Steel produced from this process is called "green steel."

Investment in developing and commercializing the technologies mentioned above significantly reduces the technology and financial risk and reflects India's economic and political realities.[7]

Scaling of India's infrastructure will require a multiple-fold increase in cement production – a very carbon-intensive business. Carbon capture and storage, especially in concrete, will play an important role; however, in India's absence of significant known sequestration reserves, using carbon with green hydrogen to produce polymers for building materials could be another possible pathway for decarbonization.

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[5] Scope 1 emissions are those directly produced from company-owned and controlled resources. Scope 2 emissions are indirect emission from the generation of purchased energy (e.g., from a utility or other energy provider).
[6] The Adani ESG Report 2021-22 describes the sustainability journey of the Adani companies. The report is available at https://www.adani.com/-/media//Project/Adani/Sustainability/Adani%20ESG%20Report.

Bottom line: India will require gap funding in some fashion as it cannot afford a large-scale investment in CCUS without the support of the U.S. In addition, the expected growth in electricity demand through economic development and continuing electrification represent an immense market opportunity for U.S. companies, contingent on formulating acceptable policies. Consider the following:

1. Infrastructure growth alone will increase demand for cement by 45% by 2050.[8]
2. Partnerships with conglomerates (e.g., Adani Group, Reliance Industries, etc.) will accelerate advancements in the upscaling and efficacy of electrolysis technologies for converting CO_2 into green fuels, such as hydrogen and green ammonia. Electrolysis is the critical enabling technology for the future decarbonization of India as it enables the production of green ammonia and green methanol, thus touching virtually every industry.
3. External investment to reduce the R&D and CAPEX of Carbon capture technologies and green hydrogen will be critical to decarbonizing hard-to-abate sectors in India, such as cement and steel. Further, investment in advancing DRI technologies in the steel industry is also required.
4. Demonstration of efficacy and cost of the combination of these technologies may be a demonstration in a practical fashion by decarbonizing India's substantial cement industry. Further, this development path would demonstrate that decarbonization does not suppress economic development.
5. Economic development within India and the rapid growth of urban centers will require significantly increased quantities of building materials in the future. Cement plants currently produce 6% of global anthropogenic CO_2 emissions, according to carbonclean.com.[9] Further, cement is the second most consumed product in the world after water and the largest emitter of CO_2 in the built environment. The U.S. currently has 120 cement plants. There are 210 cement plants in India.[10]
6. A partnership is proposed, with the U.S. developing the enabling technology and India providing the enabling political and economic policies promises to accelerate carbon capture within candidate industries. Further, the partnership will accelerate the commercializing and transfer of enabling technologies with LDCs.
7. The enormous demand for cement for construction represents an ideal opportunity for the sequestration of large amounts of CO_2 potentially using U.S.-developed technologies.[11] Development work is already underway with a demonstration project.[12] Further, the global cement industry is already pushing decarbonization using cement products.[13]
8. U.S. policymakers must provide funding and support for U.S. industries to develop CCS technologies directly related to carbon sequestration in concrete and associated products. Indian policymakers must ensure that a certain percentage of government construction projects will use green cement and fuels, such as hydrogen and ammonia, in allied industries.

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[7] A recent report presented at the 2023 World Economic Forum concludes that " green hydrogen and carbon capture and storage will play a critical role or provide alternate pathways for decarbonization. "Here's How to Fund the Decarbonization of Hard-to-abate Sectors in Developing Economies." The focus of the report is to promote the need for "significant up-front capital expenditures" by developed countries. https://www.weforum.org/agenda/2023/01/davos23-decarbonization-developing-economies-steel-cement/

[8] "The Net-zero Industry Tracker." World Economic Forum. The full report is available at https://www.weforum.org/reports/the-net-zero-industry-tracker/in-full.

In the long-term, an economically viable path away from fossil fuels is possible at a price point of under USD 1/kg for green hydrogen, combined with cost-reduction for combined cycle hydrogen turbines or utility-scale fuel cells with energy storage. In the medium term, ammonia produced from green hydrogen can be blended with coal to reduce a thermal power plant's carbon footprint significantly or used directly. Also, green hydrogen is the principal feedstock for producing carbon-free green ammonia that may be used as renewable energy storage and transportation fuel. Green hydrogen is also a necessary precursor to decarbonizing the steel industry. Captured CO_2, such as from the cement industry, combined with green ammonia, forms low-carbon methanol with many industrial uses. If the CO_2 is captured via DAC using renewable energy, methanol as a fuel may be a negative carbon sink (if the methanol produced is converted into long-lived polymers).

In the short term, with the appropriate policy support from the U.S. and Indian governments, a viable decarbonization path for India is possible. Further, U.S. manufacturers would address India's decarbonization market needs through suitable policy formulations. Finally, as the cost of decarbonizing infrastructure is reduced, adoption by other LDCs becomes economically feasible.

Author:
Ravi Krishnan, Krishnan & Associates, Inc.

Acknowledgments:
Arun Kumar Sharma, Ph.D., Group Head for Sustainability & Climate Change, Adani Group

Whitepaper Author Contact:
Ravi Krishnan
Krishnan & Associates, Inc.,
1516 Bedford Street
Stamford. CT 06905, USA
tel: +1 203.257.9232
e: rk@krishnaninc.com
Website: www.krishnaninc.com

[9] Ibid. World Cement "Committing to Carbon Capture" March 2020 suggests 8% of global carbon emissions are from cement plants.

[10] There are 77 cement plants in the states of Andhra Pradesh, Rajasthan, and Tamil Nadu alone.

[11] Estimates suggest that the Spanish cement industry could reduce its specific direct emissions by only 21% between 2010 and 2050 without CCS (García-Gusano, D.; Herrera, I.; Garraín, D.; Lechón, Y.; Cabal, H. Life Cycle Assessment of the Spanish Cement Industry: Implementation of Environmental-Friendly Solutions Clean Technol. Environ. Policy 2015, 17(1) 59– 73 DOI: 10.1007/s10098-014-0757-0). A UK study suggests that CO_2 emissions from cement plants could be reduced with CSS by 81% by 2050 (Industrial Decarbonization and Energy Efficiency Roadmaps to 2050. https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-roadmaps-to-2050.

[12] A project is underway at CEMEX's Victorville plant in California that will demonstrate the potential to significantly reduce carbon capture costs using CycloneCC and analyze new opportunities for CO2 utilization. The project is part-funded by a Department of Energy grant and includes partners RTI and Oak Ridge National Laboratory.

[13] Thomas Guillot, CEO of the Global Cement and Concrete Association, said: "Cement is the vital ingredient in concrete, the world's most-used human-made material. It is the backbone of the modern world. The industry is striving to innovate at every stage of the concrete life cycle. We see carbon capture as a vital lever for the global cement industry to achieve its ambitious goal of net-zero concrete by 2050. "We are starting to see the first CCUS projects already emerge. We have mapped 35 projects announced and underway across the world and up to 100 additional projects are also in the pipeline among our member companies who operate all around the globe."