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Assessment of the Decarbonization Pathways of the Cement Industry in Uzbekistan †

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Abstract: Cement production is one of the key industries responsible for emissions of greenhouse gases; especially carbon dioxide (CO_2); which influence climate change. In order to reach zero carbon cement industry; various deep decarbonization pathways involving carbon capture; storage; and utilization (CCSU); using low-carbon material and fuel; optimal process control; and waste heat utilization techniques must be implemented. As for the example of Uzbekistan; approximately 30 facilities generate more than 15 Mt of cement annually and are responsible for 11.3% of the country's total CO_2 emissions. In this study; decarbonization pathways for cement plants in Uzbekistan including CCSU; use of alternative fuels; electrification; and waste heat integration techniques are compared based on existing challenges and opportunities. The availability of alternative fuel and material resources suitable for the total production capacity; the comparison of post-combustion; pre-combustion; and oxyfuel combustion CCSU methods for the cement plant; and the use of energy-efficient technologies are discussed.

Keywords: decarbonization; cement industry; Uzbekistan; CO_2 capture; energy efficiency

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1. Introduction

The growth of cities and the upgrading of infrastructure around the world are increasing the demand for cement, which is widely regarded as the most important binding material for a construction site. However, cement production is one of the key industries responsible for emissions of greenhouse gases, especially carbon dioxide (CO_2), which influence climate change. In 2022, it was estimated that global CO_2 emissions reached around 36.6 Gt [1], of which the cement industry was responsible for more than 7% of total emissions. In this industry, CO_2 emission occurs mainly in two ways: combustion of fuel and decomposition of raw materials at high temperatures. In order to reach zero emission cement industry, various decarbonization pathways must be implemented. Deep decarbonization of the cement industry is one of the main directions of the current power and industrial sector's decarbonization trend [2]. Following this concept, it can be accomplished not only by the implementation of carbon capture, storage, and utilization (CCSU) techniques, but also through the enhancement of process control, the use of alternative fuels and materials, and improved energy efficiency. CO_2 emissions are considerable in comparison to the amount of cement produced in Ordinary Portland cement production facilities. This is owing to the high proportion of carbonate minerals in the raw materials as well as the high temperature required for pre-heating, calcination, and clinker formation. Improving this process, using cement substitutes, minimizing energy losses and converting it into useful energy are the first steps of decarbonization.

As for the example of Uzbekistan, there are approximately 30 cement plants. Together, these facilities are responsible for 11.3% of the country's total CO_2 emissions. Before 2015, there were a total of 4 large cement plants, and in the following years, their number is increasing according to the consumption demand. As of 2022, roughly 15 million tons of cement are produced [3] annually by 30 cement plants with varying production capabilities across the country. Cement consumption per capita is equal to 422 kg, which is 33% less than the world average [4]. This value is considered too low for a country that is renewing its infrastructure, and it is necessary to build new cement plants to cover the full need.

In this study, decarbonization pathways of cement plants in Uzbekistan, existing challenges, and opportunities are analyzed. The availability of alternative fuel and material resources suitable for the total production capacity, the comparison of carbon capture, storage, and utilization methods for the cement plant, and the use of energy-efficient technologies are given. In addition, our estimated "deep decarbonization" scenario is compared with the business as usual (BAU) scenario. To best of author's knowledge, this analysis and discussion about the decarbonization of cement industry in Uzbekistan is the first open access publicly available data collection in the international scientific database.

2. Methodology

In this work, the annual total production capacity of the cement industry in Uzbekistan is estimated based on local statistical data and information from local publications. The amount of CO_2 emissions in the cement industry is calculated based on the Intergovernmental Panel on Climate Change guidelines (2006 IPCC) [5], the type of fuel used, the geological location, the process type, and the annual production capacity of each cement plant. Since cement production in Uzbekistan developed rapidly after 2015, studies are divided into two periods including 2015–2022 and 2023–2050 years. The current policy changes in Uzbekistan and the scientific advances in CO_2 capture led to the prediction that the country will eventually implement methods for the decarbonization of its cement industry. In addition, a business as usual (BAU) scenario is formulated by drawing upon the reports that emphasize the industry development plan and the anticipated future demand for cement in Uzbekistan.

3. Results and Discussion

In recent years, due to the increase of new production capacities in the cement industry of Uzbekistan, CO_2 emissions have increased by an average of 7% per year, reaching 12 Mt in 2022. No significant steps have been taken in existing and under-construction cement plants to transition to the zero-carbon cement industry. Deep decarbonization of the cement industry in Uzbekistan has several opportunities and challenges depending on regional location, economic situation, fuel sources, and government policies. The following subsections highlight the opportunities and challenges for each pathway of decarbonization techniques. Furthermore, all decarbonization pathways are compared under BAU and zero-carbon cement industry scenarios.

3.1. Implementation of Energy-Efficiency Methods, Alternative Fuels, and Materials

In Uzbekistan, activities related to the use of energy-efficiency methods in the cement industry began in 2016 with the replacement of the production type in the existing plants from the wet method to the dry method. In 2015, the average energy consumption for the production of 1 ton of cement in all cement plants was 7.56 GJ, and by 2022, these points have decreased to 3.96 GJ (see Figure 1) [6,7]. The reasons for the decrease in average energy consumption are the increased production capacity of dry cement plants compared to wet cement plants and the use of improved clinker cooling, rotary kiln, and preheating processes in newly built cement plants. After the modernization of all cement plants, energy consumption can be brought closer to the best available technology (BAT) indicators [8].

As for the implementation of waste heat recovery (WHR) in the cement plants, none of the cement plants have heat recovery equipment installed owing to the low price of electricity ($0.053/kWh for manufacturers and $0.026/kWh for the households) and fuel (mainly, natural gas) ($0.06/m^3 for manufacturers and $0.034/m^3 for households) [9]. Due to the energy collapse observed in the winter season 2023 [10], it is expected that government decisions will be taken on the liberalization of prices of energy and the recovery of waste heat in production enterprises. Beginning in 2023, the government required that all enterprises use renewable energy sources to support a portion of their electricity consumption [11]. Due to this reason, energy consumption related to carbon emissions will be reduced and significant progress will be made in sustainable cement production.

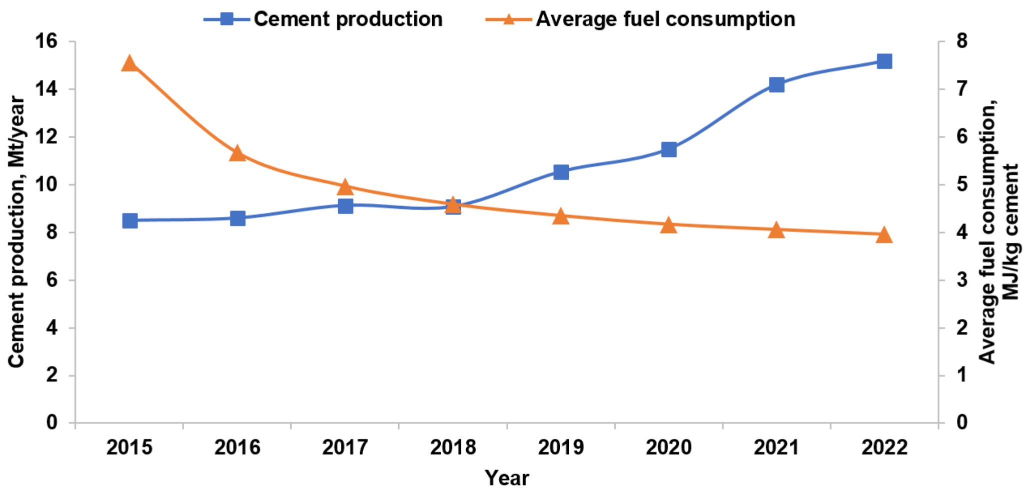

Figure 1. Cement production and its average fuel consumption in Uzbekistan based on BAU scenario (2015–2022).

Another way to deeply decarbonize the cement industry is to use alternative materials and fuels. Many cement plants around the world use materials that replace clinker. In the example of Uzbekistan, the natural pozzolans, artificial pozzolans, and artificial non-pozzolans used in the cement industry for obtaining blended cement cannot meet the needs of all cement plants due to the lack of the resources of fillers, supplementary cementitious (SCMs), and other substitute materials. In terms of alternative fuels, a few cement plants are capable of totally switching over to using alternative fuels. So far, there is a problem with there being insufficient resources for large cement plants that are located a significant distance from industrial zones.

3.2. Implementation of CCSU

Cement production is one of the most advantageous industrial sectors for the implementation of CCSU projects. First, the carbon footprint of cement production is disproportionately high compared to that of produced cement products. Second, since the concentration of CO_2 in cement plant flue gases is greater than that of power plants, the cost of CO_2 capture is cheaper. Post-combustion amine-based absorption as a first-generation capture technology is being used in a cement plant in Norway with good results [12], but from the economic situation of the cement plant, there is a need to develop new methods that are technically and economically competitive. Second and near-term-generation oxy-fuel and pre-combustion CCSU technologies, including chilled ammonia, membrane systems, bio-fixation, and CO_2 mineralization are still in the developing and testing stage

[13]. Therefore, even if the fastest scenario is introduced, the CCSU can be implemented in Uzbekistan after several years.

3.4. Comparison of the Business-as-Usual (BAU) and Zero Carbon Cement Industry Scenarios

Past, current and forthcoming economic trends in the country, demand for cement, and transition to low carbon cement strategies are analyzed to compare all decarbonization pathways. Table 1 provides a comparison of the BAU and zero-carbon cement industry scenarios. Based on the current economic situation, the period of transition to zero carbon cement industry has been divided into two parts, including the years 2015–2029 and 2030–2050.

Table 1. Comparison of BAU and zero-carbon cement scenarios in the case of Uzbekistan.

Decarbonization Pathway	**BAU**		**Zero-Carbon Industry**	
	2015–2029	**2030–2050**	**2015–2029**	**2030–2050**
Material switch	Not considered	Not considered	Only several cement plants	Increase the share of alternative materials in all cement plants
Wet kiln replacement	Increase the share of dry cement kilns	Completely replace all wet kilns	Completely replace all wet kilns	
Fuel switch	Not considered	Not considered	Only several cement plants	Increase the share of waste and biomass fuels in all cement plants
Power/steam generation	Not considered	Only several cement plants	Only several cement plants	For all cement plants
Modernization of electrical appliances	Considered	Considered	Considered	Considered
Renewable energy	Only several cement plants after 2023	For all cement plants	Only several cement plants after 2023	For all cement plants
CCSU	Not considered	Not considered	Not considered	Increase share of the CCSU

It is expected that the wet kilns in the three large cement plants that are currently operating will be gradually replaced by dry ones in the business case. To speed up the transition to a zero-carbon cement industry, it should be completely replaced with dry until 2025. As for the fuel/material switch, cement manufacturers do not intend to use SCMs as materials, biomass and waste as fuel. As a result of restricted reserves, some cement plants are unable to make use of biomasses, industrial and municipal solid wastes, tyres, SCMs, and fillers in their production. As a consequence of this, the potential of this approach is extremely limited in Uzbekistan.

In order to partially cover the plant's need for electricity, it is expected to begin reforms on the production of power from waste heat and the use of renewable energy sources. Cement manufacturers may apply the WHR project to some plants after 2030 at the request of the government [14]. Due to the rapid development of the transition to renewable energy throughout the country, in a few years all cement plants will start using almost entirely solar and wind energy. Over nearly the whole region of Uzbekistan, solar irradiation ((1400 to 1800 kWh/m^2 per year [15]) is considerable, which leads to a significant solar energy potential.

In light of the findings presented above, an analysis of the potential of each method of decarbonization for the cement industry is carried out for the 2015–2050 years (see Figure 2). Areas in Figure 2 show when energy-efficiency techniques, material and fuel replacement, and CCSU methods are used and how much CO_2 emissions are reduced.

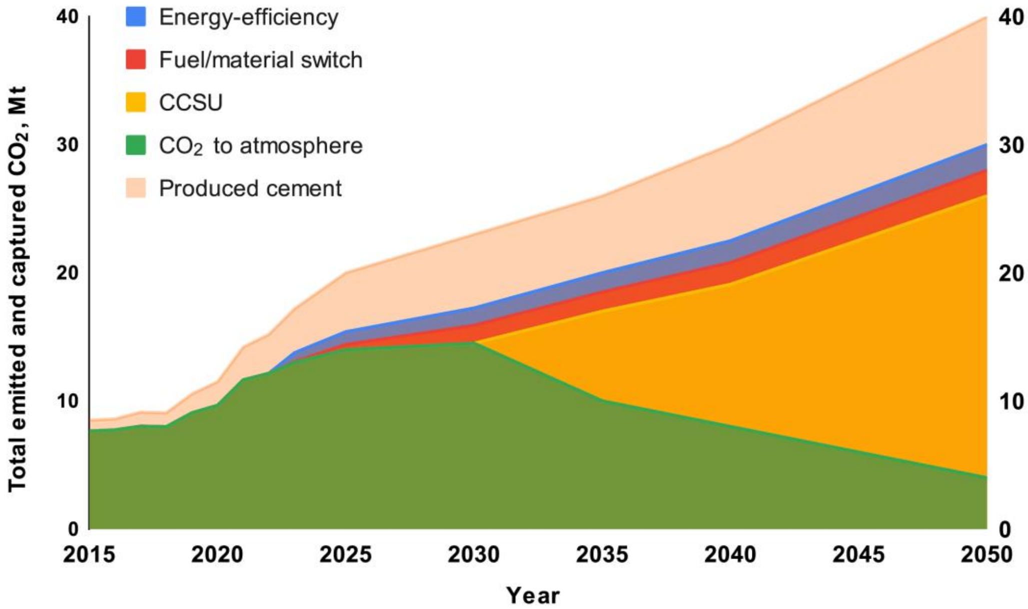

Figure 2. The potentials of decarbonization pathways in the case of Uzbekistan.

Total annually CO_2 emission from the cement plants will continue to increase into the next decade due to the increase of cement production, regardless of wet kiln replacement, energy efficient techniques, electrical equipment modernization, and fuel/material replacement. After CCSU is applied to cement plants, CO_2 emissions begin to decrease, despite the increase in product production. If CO_2 emissions are brought down to 0.63 using the above pathways before the installation of CCSU, then this value can be brought down to less than 0.1 using CCSU. To actualize the above-described zero-carbon cement plant scenario, society, cement manufacturers, and the government should collaborate and not be embarrassed to use technological advances to cement plants.

4. Conclusions

In this study, the various strategies, challenges, and opportunities for decarbonizing the cement industry in the context of Uzbekistan have been discussed. The cement industry's annual total production capacity in Uzbekistan is evaluated according to regional statistical data and information from local publications.

The following key conclusions can be drawn summarizing all the analyzes in this study:

- In recent years, due to the increase of new production capacities in the cement industry of Uzbekistan, CO_2 emissions have increased by an average of 7% per year, reaching 12 Mt in 2022.
- No significant steps have been taken in existing and under-construction cement plants to transition to the zero-carbon cement industry.
- There is a lack of resources of SCMs, fillers, municipal solid and industrial waste fuels, and tryes to replace with fossil fuels and materials. For this reason, the fuel and material replacement pathways have a low potential to decarbonize all cement plants.
- Although some scientific progress in the world has been made on CCSU, the decarbonization initiatives related to CCSU can be done in the next decades in Uzbekistan.
- Due to the development of the transition to renewable energy throughout the country, in a few years all cement plants will start using almost solar and wind energy.

- Despite wet kiln replacement, the use of energy efficiency methods, electrical equipment modernization, and fuel/material replacement, cement production will increase CO_2 emissions throughout the next decade.
- Society, cement manufacturers, and the government should work together to reach environmental friendly cement industry.

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Abbreviations

CCSU	Carbon capture, storage, and utilization
BAU	Business as usual
IPCC	Intergovernmental Panel on Climate Change
BAT	Best available technology
WHR	Waste heat recovery
SCM	Supplementary cementitious material

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