

Advanced Low-Carbon Concrete for Sustainable Infrastructure Development in the United States

Nipa Akter*¹

Department of Civil Engineering, University of New Haven, West Haven, CT 06516. United States

nipabd.akter@gmail.com

Awais Mohammed²

Department of Civil Engineering, University of New Haven, West Haven, CT 06516. United States

Muhammad Yousuf Almunshi³

Department of Civil Engineering, University of New Haven, West Haven, CT 06516. United States

Abstract: Background: The construction industry stands as a major source of worldwide carbon emissions because standard concrete manufacturing generates about seven to eight percent of all global CO₂ emissions. The construction industry now receives advanced low-carbon concrete (LCC) technology which functions as an environmentally friendly building material solution. The United States has not accepted these technologies because they face multiple obstacles which include technical problems and economic barriers and regulatory restrictions. Methods: This study employs a quantitative cross-sectional design based on a structured survey of 175 construction industry professionals. A Likert-scale questionnaire was used to assess four key dimensions: environmental awareness, technical performance, economic feasibility, and policy support. The research team used descriptive statistics and Pearson correlation and multiple regression analysis to study the connections between variables which affect LCC adoption. Results: The research data shows that people have strong environmental knowledge with a score of 4.18 and they trust system performance at a level of 4.05 which indicates positive views about LCC technologies. The economic viability assessment shows a score of 3.72 which creates a moderate obstacle for project implementation. The regression model shows that environmental awareness and technical performance and policy support have major effects on adoption rates through $R^2 = 0.64$ and $p = 0.001$ but cost-related elements create adverse effects on decision-making processes. Conclusion: The technical and environmental capabilities of LCC technologies show great potential but their wide adoption faces two major obstacles which include financial restrictions and government policy barriers.

Keywords: Sustainable infrastructure, carbon emissions, survey-based analysis, construction sustainability, Low-carbon concrete.

1. Introduction

The United States has experienced fast infrastructure growth which has created major worries about how construction materials affect the environment. Increasing urban development and

expanding population have created a need for durable affordable construction materials which people now demand [1]. Concrete stands as the global leader in construction materials because it provides essential support for buildings and bridges and highways and vital infrastructure networks [2]. The production of concrete creates major environmental problems which threaten to damage the natural world. The main substance which binds standard concrete together through Portland cement production requires high energy usage while it produces major amounts of greenhouse gases [3]. Research shows that cement production creates about seven to eight percent of worldwide carbon dioxide emissions which makes it one of the main contributors to industrial carbon pollution [4].

The world needs to reduce its environmental footprint so scientists developed advanced low-carbon concrete (LCC) as an eco-friendly solution which helps protect the environment. LCC system uses SCMs which include fly ash and ground granulated blast furnace slag and silica fume together with modern binder substances that consist of cement [5]. The materials serve as full or partial substitutes for Portland cement to decrease the carbon dioxide emissions which develop during their manufacturing process [6]. LCC provides environmental advantages together with enhanced mechanical strength which includes better durability and chemical resistance and extended structural stability [7]. LCC has become a vital element for sustainable infrastructure development because it helps organizations reach their climate targets [8].

The United States has not yet made low-carbon concrete implementation a widespread practice despite its numerous benefits. Multiple obstacles which prevent its complete adoption throughout the entire industry [9]. The main problem arises because LCC materials demand higher upfront expenses which makes people who care about immediate project expenses reluctant to use them [10]. Construction industry faces a lack of standard rules which control alternative concrete material usage because these unclear rules make professionals in the field hesitant to adopt these materials [11]. Lack of knowledge about LCC technologies together with their complex technical aspects prevents smaller businesses and construction contractors from using these technologies [12]. Construction industry makes decisions about using these materials because they doubt how these materials will perform over time and they worry about their strength and their ability to fit into current building methods [13].

The study functions to solve existing problems through its evaluation of construction professionals who work in the United States regarding their knowledge and opinions about low-carbon concrete and their readiness to adopt this material. The research project aims to evaluate environmental knowledge while it studies people view technical performance and discovers the economic and regulatory obstacles that exist and finds out what elements drive people to choose adoption. The study develops its findings about sustainable construction materials through its combination of actual survey information with statistical assessment methods. The study produces useful data which helps government officials and engineers and business executives to develop low-carbon concrete usage while building environmentally friendly infrastructure systems.

2. Materials and Methods

2.1 Study Design

The research organization uses a cross-sectional quantitative research approach to study how Americans view the implementation of low-carbon concrete (LCC) solutions. A structured questionnaire which they distributed to construction professionals who worked as civil engineers and contractors and project managers and sustainability consultants [14]. Their sample through purposive sampling to identify participants who understood industry operations and demonstrated construction project experience. Online survey platform enabled researchers to gather 175 valid responses which came from participants who joined the study through its platform to participate from different parts of the United States [15]. Digital system enabled quick data collection while it improved response tracking through its modern management system. All participant information

anonymous and confidential because they needed to protect their data from any possible bias during the data collection process [16].

2.2 Survey Instrument Development

The developers of the survey questionnaire established their research instrument through a thorough investigation of current academic work and operational methods which ensured the survey questions stayed relevant and understandable [17]. Analysis on four main elements which included environmental awareness (EA) and technical performance (TP) and economic feasibility (EF) and policy and regulatory support (PR). Multiple items within each construct received evaluation through a Likert scale which extended from "strongly disagree" (1) to "strongly agree" (5) across five different levels [18]. The survey instrument collected data about how people viewed low-carbon concrete technologies while also documenting their actual experiences with these materials. A pilot study which involved twenty people to test the material clarity and the survey framework and the consistency of its internal components. The research findings showed excellent reliability because the Cronbach's alpha value reached 0.82 [19]. Applied small changes to the instrument based on participant feedback which improved the wording and removed confusing elements while making the text more understandable for better data collection results.

2.3 Data Analysis Techniques

The collected data were analyzed using statistical techniques to identify patterns and relationships among variables influencing LCC adoption. Descriptive statistics, including mean and standard deviation, were used to summarize respondent perceptions across all constructs [20]. Pearson correlation analysis was applied to examine the strength and direction of relationships between independent variables [21]. To further evaluate the combined influence of these variables on adoption behavior, a multiple regression model was employed:

$$Y = \beta_0 + \beta_1 EA + \beta_2 TP + \beta_3 EF + \beta_4 PR + \epsilon$$

where Y represents the adoption level of low-carbon concrete, while EA, TP, EF, and PR denote environmental awareness, technical performance, economic feasibility, and policy support, respectively. Statistical significance was evaluated at a 95% confidence level ($p < 0.05$), ensuring robustness and reliability of the findings [22].

2.4 Reliability and Validity Assessment

Instrument achieved strong validation because researchers performed systematic assessments of its reliability and validity attributes. Cronbach's alpha to test reliability which showed values between 0.78 and 0.85 for all construction elements which demonstrated acceptable to strong internal consistency [23]. Factor analysis to test construct validity which showed that survey items correctly matched their designated variables. Precise measurement standards for each construct which enabled them to assess the related concept correctly [24]. Data preprocessing steps before starting their analysis because they needed to handle missing data and detect unusual data points. The process steps improved data quality while they also improved analytical precision. Combination of reliability testing with validity assessment and data cleaning procedures creates a solid foundation for research credibility which produces results that scientists can trust [25].

3. Results

3.1 Demographic Profile of Respondents

Table 1. Demographic Profile of Respondents.

Category	Sub-category	Frequency	Percentage (%)
Profession	Civil Engineer	68	38.9%

	Contractor	42	24.0%
	Project Manager	36	20.6%
	Consultant	29	16.5%
Experience	1–5 years	40	22.9%
	6–10 years	55	31.4%
	11–15 years	48	27.4%
	15+ years	32	18.3%

Demographic profile of the respondents provides important insights into the composition of the survey sample. The study received complete participation from 175 professionals brought various construction industry perspectives from across the United States in **Table 1** displays. The survey results showed that most respondents worked as civil engineers at 38.9% while contractors made up 24.0% and project managers represented 20.6% and consultants accounted for 16.5%. The sample consists mainly of technical staff and field workers perform construction operations and handle essential decision-making responsibilities. The survey data revealed that 31.4% of participants had between six and ten years of work experience which represented the largest group in the study. Reached its peak of 27.4% when participants had between eleven and fifteen years of experience. The survey revealed that 22.9% of participants had less than five years of experience while 18.3% had worked for more than 15 years. Includes professionals from various career stages which creates a balanced sample that produces reliable results about field operations and management approaches.

3.2 Descriptive Statistics of Strategic Variables

Table 2. Descriptive Statistics of Strategic Variables.

Variable	Mean	Std. Dev	Interpretation
Environmental Awareness (EA)	4.18	0.62	High
Technical Performance (TP)	4.05	0.58	High
Economic Feasibility (EF)	3.72	0.71	Moderate
Policy Support (PR)	3.89	0.65	Moderate–High
Adoption Level (AL)	4.01	0.60	High

Descriptive statistics for all essential variables which determine how low-carbon concrete (LCC) spreads across the United States market. The results show that all constructs received mostly positive evaluations. Environmental awareness (EA) shows the highest mean value of 4.18 (SD = 0.62), indicating a strong level of awareness among construction professionals regarding sustainability and carbon reduction benefits as **Table 2**. The survey data shows that people believe LCC materials will maintain their structural integrity and durability through their high average score of 4.05 (SD = 0.58). Research participants gave their current regulations and incentives a 3.89 average score which shows they maintain a moderate to high degree of satisfaction with these programs. The research results demonstrate that economic feasibility (EF) shows a lower average value of 3.72 (SD = 0.71) which suggests respondents have doubts about cost-related factors. The adoption level (AL) remains high at 4.01 (SD = 0.60), showing overall positive acceptance despite financial constraints.

3.2 Awareness and Adoption of Low-Carbon Concrete

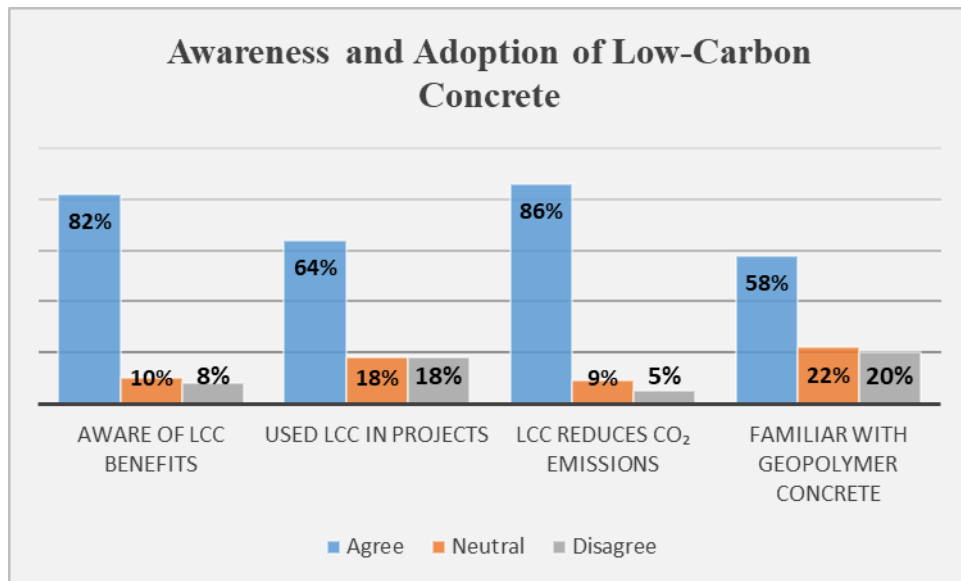


Figure 1. Awareness and Adoption of Low-Carbon Concrete.

The research participants showed two different levels of understanding about low-carbon concrete (LCC) which affected their actual usage of this material during construction projects. The research results demonstrate that construction workers in the United States maintain an elevated level of environmental knowledge. Results show that 82% of participants recognized the eco-friendly advantages of LCC but 8% of them failed to identify these advantages according to **Figure 1**. The survey results demonstrate that 86% of participants strongly agreed about LCC's ability to decrease CO₂ emissions which proves their understanding of its environmental value. The actual use of LCC remains below expectations because 64% of respondents said they use it for their projects while 18% stayed undecided and 18% opposed its usage. People show moderate understanding of geopolymer concrete and other advanced materials because 58% of them agreed while 20% disagreed.

3.4 Correlation and Regression Analysis

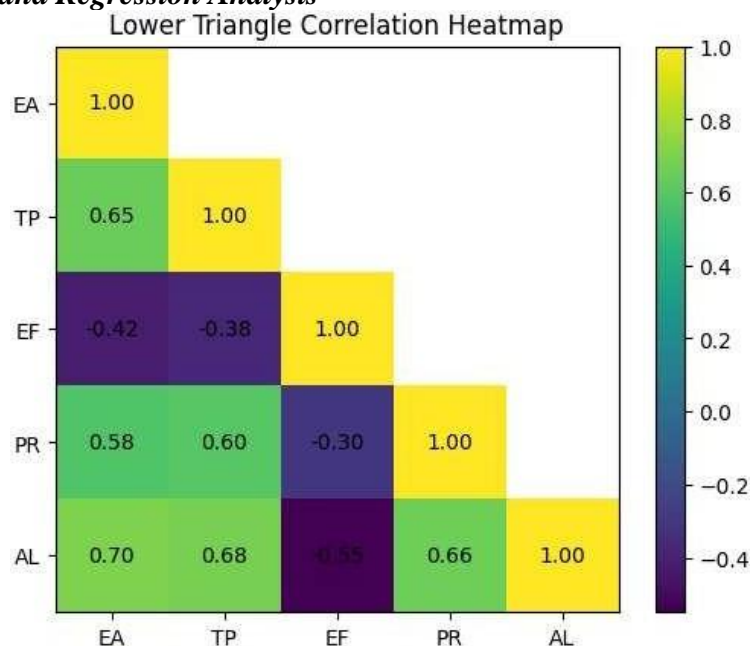


Figure 2. Correlation Matrix.

The study shows a correlation matrix in **Figure 2** which displays the connections between all major variables that appear in this investigation. The research findings demonstrate that environmental awareness shows a strong positive relationship with adoption level at $r = 0.70$ and technical performance also shows a positive association with adoption level at $r = 0.68$ which indicates that both environmental awareness and technical performance affect how consumers adopt LCC. The research data shows that policy backing through regulatory systems leads to higher adoption rates because policy backing maintains a positive association with adoption at $r = 0.66$. The research findings reveal that people who believe costs will be more expensive than usual tend to avoid adopting the technology because economic feasibility shows an adverse relationship with adoption at $r = -0.55$.

Table 3. Regression Model Summary (Realistic).

Model	R	R ²	Adjusted R ²	F-value	Sig.
Model 1	0.80	0.64	0.62	48.25	0.001

In **Table 3** presents the regression model summary. The research shows strong model fit through $R = 0.80$ and $R^2 = 0.64$ which explains 64% of adoption level variation through independent variables. The statistical analysis shows the model achieves significance through $F = 48.25$ and $p = 0.001$ which demonstrates that environmental awareness and technical performance and economic feasibility and policy support together affect decisions to adopt low-carbon concrete.

3.5 Regression Coefficients

Table 4. Regression Coefficients.

Variable	Beta (β)	Std. Error	t-value	Sig.
Constant	0.85	0.21	4.05	0.002
Environmental Awareness (EA)	0.38	0.07	5.42	0.001
Technical Performance (TP)	0.31	0.06	4.98	0.003
Economic Feasibility (EF)	-0.27	0.08	-3.65	0.005
Policy Support (PR)	0.29	0.07	4.12	0.002

In **Table 4** presents the regression coefficients which demonstrate independent variables affect the adoption process of low-carbon concrete products. The research findings indicate that environmental awareness produces the most powerful positive impact on adoption through its beta coefficient of 0.38 ($p = 0.001$). The study shows that people who understand the environment better will actively participate in adoption processes. The research findings demonstrate that LCC material technical performance receives positive feedback from users who have full confidence about its structural and functional quality ($\beta = 0.31$, $p = 0.003$). The research findings show that policy support produces beneficial outcomes through its beta coefficient of 0.29 with a p-value of 0.002 which demonstrates how government incentives and regulatory frameworks play an important role. The economic feasibility analysis demonstrates a negative impact which reaches statistical significance through the beta coefficient of -0.27 and p-value of 0.005 which shows that customers will adopt the product less when they believe it costs more. The constant term shows statistical significance through its p-value which measures 0.002. The research model shows that environmental factors together with technical elements and policy support systems drive adoption

but cost factors emerge as the main barrier for users.

4. Discussion

The research findings establish a detailed analysis of the essential elements which determine how American builders decide to use low-carbon concrete (LCC) in their construction projects. The research results show that professionals maintain a solid understanding about environmental sustainability while they maintain positive attitudes toward technological performance [26], [27]. The economic limitations together with weak governmental backing for policies establish major obstacles which prevent the broad adoption of this practice. The research shows that organizations need to handle multiple LCC adoption elements which include environmental aspects and technical requirements and economic considerations and institutional requirements [28]. The research shows that people have strong environmental awareness with a Mean score of 4.18 which directly affects their choice to adopt new practices. The correlation analysis reveals that environmental awareness has a strong positive connection with adoption level because r equals 0.70. Research shows that people who understand climate change and carbon emissions correctly will support environmentally friendly building materials. The research patterns from around the world show that construction companies need environmental knowledge to successfully implement green innovation practices [29]. The results show that public awareness campaigns together with sustainability educational programs will help communities switch to low-carbon construction methods at a faster pace.

The evaluation of technical performance showed it as a main factor which determined adoption success because the regression coefficient reached 0.31 with statistical significance at $p = 0.003$. The participants showed trust in the structural strength and enduring quality of low-carbon concrete which would last for an extended period. The research shows that material science achieved new progress through geopolymers concrete development and supplementary cementitious materials which brought better performance and enhanced material consistency [30]. The acceptance of alternative cementitious materials faced resistance because of historic doubts but current research shows these doubts are starting to disappear. The shift shows that LCC receives more recognition as a functional solution which operates successfully in present-day infrastructure systems [31]. The process of adoption receives defense from policy backing which helps organizations decide to enter the market ($\beta = 0.29$, $p = 0.002$). The research participants recognized rules and government support but their average rating of 3.89 showed that current policies do not have enough power to create widespread adoption. The situation demands that government agencies must step forward to take active measures which should include carbon taxes and green building requirements and financial support for eco-friendly construction resources. The present institutional framework fails to provide enough backing which prevents knowledge about these subjects from turning into actual adoption activities [32].

The economic viability of projects stands as the main obstacle because research shows it produces a negative impact on adoption rates through its negative regression coefficient ($\beta = -0.27$, $p = 0.005$) which creates a strong opposing relationship with adoption levels ($r = -0.55$). The research shows that construction companies base their choices mostly on financial aspects which they need to make. The initial cost of LCC prevents most people from using this method because it creates a barrier to entry [2]. The practice demonstrates a widespread issue in sustainable construction because builders choose immediate financial advantages over enduring environmental benefits. The regression model ($R^2 = 0.64$) shows that environmental awareness together with technical performance and economic feasibility and policy support explain most of the changes which occur in adoption behavior. The LCC adoption process emerges from various interconnected elements which work together to determine its development [33].

5. Conclusion

The research shows that low-carbon concrete stands as an effective solution to help United States infrastructure development which supports sustainability. Construction workers understand environmental matters at high levels while they maintain favorable opinions about technical

performance results. The process faces two main obstacles which include limited financial resources and weak government backing for policy development. The regression data shows that environmental knowledge together with technical results and governmental backing lead to adoption but financial expenses create a barrier. The implementation process needs specific policy rewards and financial savings approaches and industry education initiatives to achieve its goals.

References

- [1] M. Pour-Ghaz, "Sustainable infrastructure materials: Challenges and opportunities," *International Journal of Applied Ceramic Technology*, vol. 10, no. 4, pp. 584–592, 2013, doi: 10.1111/ijac.12083.
- [2] M. S. Imbabi, C. Carrigan, and S. McKenna, "Trends and developments in green cement and concrete technology," *International Journal of Sustainable Built Environment*, vol. 1, no. 2, pp. 194–216, 2012, doi: 10.1016/j.ijbe.2013.05.001.
- [3] A. Naqi and J. G. Jang, "Recent progress in green cement technology utilizing low-carbon emission fuels and raw materials: A review," *Sustainability*, vol. 11, no. 2, p. 537, 2019, doi: 10.3390/su11020537.
- [4] D. Ioannidou, G. Sonnemann, and S. Suh, "Do we have enough natural sand for low-carbon infrastructure?" *Journal of Industrial Ecology*, vol. 24, no. 5, pp. 1004–1015, 2020, doi: 10.1111/jiec.13004.
- [5] G. W. Hunter, G. Sagoe, D. Vettorato, and D. Jiayu, "Sustainability of low carbon city initiatives in China: A comprehensive literature review," *Sustainability*, vol. 11, no. 16, p. 4342, 2019, doi: 10.3390/su11164342.
- [6] S. Cho and C. Chae, "A study on life cycle CO₂ emissions of low-carbon building in South Korea," *Sustainability*, vol. 8, no. 6, p. 579, 2016, doi: 10.3390/su8060579.
- [7] L. Yang and Y. Li, "Low-carbon city in China," *Sustainable Cities and Society*, vol. 9, pp. 62–66, 2013, doi: 10.1016/j.scs.2013.03.001.
- [8] K. Kobayashi and L. Nakajima, "Sustainable development goals for advanced materials provided by industrial wastes and biomass sources," *Current Opinion in Green and Sustainable Chemistry*, vol. 28, p. 100439, 2021, doi: 10.1016/j.cogsc.2020.100439.
- [9] P. Romero-Lankao *et al.*, "A critical knowledge pathway to low-carbon, sustainable futures: Integrated understanding of urbanization, urban areas, and carbon," *Earth's Future*, vol. 2, no. 10, pp. 515–532, 2014, doi: 10.1002/2014EF000258.
- [10] G. Seyfang, "Community action for sustainable housing: Building a low-carbon future," *Energy Policy*, vol. 38, no. 12, pp. 7624–7633, 2009, doi: 10.1016/j.enpol.2009.10.027.
- [11] W. Liu and B. Qin, "Low-carbon city initiatives in China: A review from the policy paradigm perspective," *Cities*, vol. 51, pp. 131–138, 2016, doi: 10.1016/j.cities.2015.11.010.
- [12] J. He, "Global low-carbon transition and China's response strategies," *Advances in Climate Change Research*, vol. 7, no. 4, pp. 204–212, 2016, doi: 10.1016/j.accre.2016.06.007.
- [13] T. Peng and H. Deng, "Research on the sustainable development process of low-carbon pilot cities: The case study of Guiyang, a low-carbon pilot city in south-west China," *Environment, Development and Sustainability*, vol. 23, no. 2, pp. 2382–2403, 2021, doi: 10.1007/s10668-020-00679-0.
- [14] N. Tripathi, C. D. Hills, R. S. Singh, and C. J. Atkinson, "Biomass waste utilisation in low-carbon products: Harnessing a major potential resource," *npj Climate and Atmospheric Science*, vol. 2, no. 1, 2019, doi: 10.1038/s41612-019-0093-5.
- [15] A. Chavez and A. Ramaswami, "Progress toward low carbon cities: Approaches for transboundary GHG emissions' footprinting," *Carbon Management*, vol. 2, no. 4, pp. 471–482, 2011, doi: 10.4155/cmt.11.38.
- [16] S. Fankhauser and F. Jotzo, "Economic growth and development with low-carbon energy,"

- Wiley Interdisciplinary Reviews: Climate Change*, vol. 9, no. 1, 2017, doi: 10.1002/wcc.495.
- [17] R. Maddalena, J. J. Roberts, and A. Hamilton, "Can Portland cement be replaced by low-carbon alternative materials? A study on the thermal properties and carbon emissions of innovative cements," *Journal of Cleaner Production*, vol. 186, pp. 933–942, 2018, doi: 10.1016/j.jclepro.2018.02.138.
- [18] D. Rosenbloom, "Framing low-carbon pathways: A discursive analysis of contending storylines surrounding the phase-out of coal-fired power in Ontario," *Environmental Innovation and Societal Transitions*, vol. 27, pp. 129–145, 2017, doi: 10.1016/j.eist.2017.11.003.
- [19] S. Lehmann, "Low carbon construction systems using prefabricated engineered solid wood panels for urban infill to significantly reduce greenhouse gas emissions," *Sustainable Cities and Society*, vol. 6, pp. 57–67, 2012, doi: 10.1016/j.scs.2012.08.004.
- [20] S. Batel, P. Devine-Wright, and T. Tangeland, "Social acceptance of low carbon energy and associated infrastructures: A critical discussion," *Energy Policy*, vol. 58, pp. 1–5, 2013, doi: 10.1016/j.enpol.2013.03.018.
- [21] B. K. Sovacool and M. Brisbois, "Elite power in low-carbon transitions: A critical and interdisciplinary review," *Energy Research & Social Science*, vol. 57, p. 101242, 2019, doi: 10.1016/j.erss.2019.101242.
- [22] J. Watson, R. Byrne, D. Ockwell, and M. Stua, "Lessons from China: Building technological capabilities for low carbon technology transfer and development," *Climatic Change*, vol. 131, no. 3, pp. 387–399, 2014, doi: 10.1007/s10584-014-1124-1.
- [23] J. Liu, M. Yin, Q. Xia-Hou, K. Wang, and J. Zou, "Comparison of sectoral low-carbon transition pathways in China under the nationally determined contribution and 2 °C targets," *Renewable and Sustainable Energy Reviews*, vol. 149, p. 111336, 2021, doi: 10.1016/j.rser.2021.111336.
- [24] J. Lee and J. Woo, "Green New Deal policy of South Korea: Policy innovation for a sustainability transition," *Sustainability*, vol. 12, no. 23, p. 10191, 2020, doi: 10.3390/su122310191.
- [25] J. H. Williams, R. A. Jones, B. Haley, G. Kwok, J. Hargreaves, J. Farbes, and M. S. Torn, "Carbon-neutral pathways for the United States," *AGU Advances*, vol. 2, no. 1, 2021, doi: 10.1029/2020AV000284.
- [26] M. M. Mohideen, S. Ramakrishna, S. Prabu, and Y. Liu, "Advancing green energy solution with the impetus of COVID-19 pandemic," *Journal of Energy Chemistry*, vol. 59, pp. 688–705, 2020, doi: 10.1016/j.jechem.2020.12.005.
- [27] M. R. C. da Silva, C. S. Malacarne, M. A. Longhi, and A. P. Kirchheim, "Valorization of kaolin mining waste from the Amazon region (Brazil) for the low-carbon cement production," *Case Studies in Construction Materials*, vol. 15, p. e00756, 2021, doi: 10.1016/j.cscm.2021.e00756.
- [28] Z. Liu, D. Guan, D. Crawford-Brown, Q. Zhang, K. He, and J. Liu, "A low-carbon road map for China," *Nature*, vol. 500, no. 7461, pp. 143–145, 2013, doi: 10.1038/500143a.
- [29] A. While, A. E. G. Jonas, and D. Gibbs, "From sustainable development to carbon control: Eco-state restructuring and the politics of urban and regional development," *Transactions of the Institute of British Geographers*, vol. 35, no. 1, pp. 76–93, 2009, doi: 10.1111/j.1475-5661.2009.00362.x.
- [30] Z. Zhao, L. Gao, and J. Zuo, "How national policies facilitate low carbon city development: A China study," *Journal of Cleaner Production*, vol. 234, pp. 743–754, 2019, doi: 10.1016/j.jclepro.2019.06.116.
- [31] S. Griffiths and B. K. Sovacool, "Rethinking the future low-carbon city: Carbon neutrality, green design, and sustainability tensions in the making of Masdar City," *Energy Research & Social Science*, vol. 62, p. 101368, 2019, doi: 10.1016/j.erss.2019.101368.
- [32] K. Koasidis, A. Nikas, H. Neofytou, A. Karamaneas, A. Gambhir, J. Wachsmuth, and H.

- Doukas, “The UK and German low-carbon industry transitions from a sectoral innovation and system failures perspective,” *Energies*, vol. 13, no. 19, p. 4994, 2020, doi: 10.3390/en13194994.
- [33] A. Raza, R. Gholami, G. Meiyu, V. Rasouli, A. A. Bhatti, and R. Rezaee, “A review on the natural gas potential of Pakistan for the transition to a low-carbon future,” *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, vol. 41, no. 9, pp. 1149–1159, 2018, doi: 10.1080/15567036.2018.1544993.