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Research article

Technology diffusion and green transition support in the brick sector of Bangladesh: Why transformational change is still elusive

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ABSTRACT

The government of Bangladesh keeps using the policy instrument of technology mandate to achieve technology substitution in the brick industry. The target of achieving 100% technology substitution by 2013 is yet to be achieved. Using historical data this paper models diffusion trajectory of the substitute technologies and found that 100% substitution is unlikely by 2035 although the action is prioritized in the updated Nationally Determined Contribution (NDC). Several development agencies have implemented projects aimed at cleaner technology diffusion in the sector over the last twenty years. Using established definitions of functions from innovation system literature, actions of all development partners in the sector were mapped against the functions. Donor projects were found to be more involved under *Guidance of Search* and *Creation of Legitimacy* functions. The implications of this research can inform design of future donor supported projects piloting climate technologies with insights from diffusion theories and innovation system.

1. Introduction

On 23rd March 2022, newspapers in Bangladesh had a common headline of the country ranking top in having the most polluted air according to the 2021 World Air Quality Report. Brick kilns have been a major contributor to this bad air quality, although their attribution rate has varied over the years. In 2013, 40% of fine particulate matter ($PM_{2.5}$) pollution load in Dhaka's air was due to 1200 brick kilns in the vicinity, which rose to 58% pollution load by 2017 (ICIMOD, 2019). However, in recent years, this contribution of brick sector for the degraded air quality of Dhaka city have been replaced by urban infrastructure construction projects and transportation (Mahmud, 2022). Considering air pollution load based on employment and gross output among major industries, brick kilns under structural clay product industry ranks top as the most polluting industry (Karmaker et al., 2022). Thus, there is considerable interest in greening the brick sector not only to reduce this sector's contribution to air pollution but to also achieve other co-benefits and global climate goals.

The government of Bangladesh have attempted green transition for the brick industry for the last fifteen years mainly using the policy instrument of technology mandate (Haque, 2016). Identifying the sector as the major contributor of air pollution twenty years ago, a few development partners such as the World Bank, United Nations Development Program (UNDP) and others have implemented projects aimed at cleaner technology diffusion (Lehmann et al., 2014). These projects under technical & financial assistance of development agencies, as well as two carbon finance projects under the Clean Development Mechanism (CDM), have laid the ground

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for technology transfer in the brick sector of Bangladesh (Alam, 2019). While these projects appear impactful in their internal reports, the reality on the ground in terms of cleaner technology diffusion resulting in improved air quality remains grim. These external interventions implemented demonstration projects of cleaner brick making technologies increasing stakeholder awareness on the financial and environmental benefits of efficient technologies. Other governance related factors such as improving regulatory framework for achieving cleaner air were not adequately addressed. This paper offers a narrative review of the diffusion trajectory of cleaner brick making technology, development cooperation for brick sector of Bangladesh and presents a systems-wide diagnosis of the institutional and conceptual problems plaguing the sector, which are often addressed in isolation.

2. Overview of brick sector in Bangladesh

Bangladesh relies mostly on clay bricks as the country lacks stones and other alternative building materials at comparable cost (Sharmin et al., 2018). The country produces around 32.4 billion bricks annually, using 3350 million cubic feet of clay (ICIMOD, 2019) burning 7.4 million tons of coal and in the process emitting 22.4 million tons of carbon dioxide (Alam and Barman, 2019). More than one million people are employed in this sector including 110,000 children (ILO, Brooke, and Donkey Sanctuary, 2017). Currently, the brick sector is the largest consumer of coal in Bangladesh which is mostly coming from India as undocumented flows (Roy et al., 2023). The predominant brick making technology in the country was the Fixed Chimney Kilns (FCK), which is now being replaced gradually by Zig Zag Kilns (ZZK). Following an ineffective ban of FCKs from 2013, existing kiln owners upgraded to traditional zig-zag kilns, which required investment of around 4.5 to 6 million taka (Khaliquzzaman et al., 2020; Sharmin et al., 2018). Other technologies prevalent in Bangladesh in the order of efficiency are Improved Zig Zag Kiln (IZZK), Hybrid Hoffman Kiln (HHK) and Tunnel Kiln (TK). Fig. 1 shows the features of these technologies in a continuum, but detailed information on kiln technologies are summarized in Khaliquzzaman et al. (2020) and Eil et al. (2020).

To operate a brick kiln, mandatory environmental clearance certificate must be obtained from the regulatory authority Department of Environment (DoE), followed by a license from the district commissioners office (ICIMOD, 2019). Although license and clearance certificates are mandatory for operating kilns and producing fired bricks, hundreds of illegal kilns operate without them reflecting poor governance in this sector (Amin, 2018; Rahman and Pieal, 2023; Sarker and Abir, 2019). Irrespective of technology or location, there is a uniform stack emission standard for particulate matter from brick kilns which was 1000 mg/Nm^3 since 2002 (ICIMOD, 2019) but later revised down to 250 mg/Nm^3 under the Air Pollution (Control) Rules, 2022. However, the DoE does not have the resources to monitor and measure emissions, and a reliable geocoded inventory of existing kilns and their location was only developed recently. As most of the brick kilns in the country are unregulated and out of government purview due to its informal nature, industry-wide enforcement of regulations exists more on paper than in reality (Eil et al., 2020).

The bricks produced in Bangladesh are purchased in bulk by construction companies and individuals building houses whose primary interest is to buy good quality bricks at a low price (Luby et al., 2015). Citing the low cost of bricks as construction materials, buyers acknowledge the environmental damage of bricks but considers mitigating them solely the government's responsibility. Most brick manufacturers prefer FCKs as they can be constructed easily on leased land or floodplains which ultimately ensures quick return of their investments (Cullen, 2020; Luby et al., 2015). Moreover, due to seasonal operations of kilns during the dry season, the cost of producing bricks with seasonal labor is substantially less with FCK compared to efficient kilns which need fixed assets of land in higher grounds (Luby et al., 2015). In the rainy season, traditional kilns cannot operate due to their inability to dry unfired clay bricks under sunlight. Thus the price of brick increases during monsoon months while in the dry season kiln owners and wholesalers stockpile bricks

Fig. 1. Brick Kiln Continuum in Bangladesh (adapted from ILO et al. (2017)).

when prices are low (Cullen, 2020). The kiln owners are locally powerful economic agents with political connections which has developed into a nexus of kiln owners and government officials making brick related laws powerless (Luby et al., 2015; Rahman and Pieal, 2023). On the other hand, brick kilns are dependent on internal migrants who arrive at the beginning of the dry season when there is limited agricultural work and returns to their villages when monsoon season arrives (Cullen, 2020). Kiln workers often suffer from dehydration, heat stroke, skin and eye diseases due to their continuous exposure to high heat and dust (Cullen, 2020).

FCKs were banned through the promulgation of the Brick Manufacturing and Brick Kilns Establishment (Control) Act 2013. However, enforcement of the ban were fraught with difficulties including court injunctions which were vacated in 2016 (Khaliquzzaman et al., 2020). The quick uptake of ZZKs was a direct result of this Act as many existing kiln owners simply found it as the easiest and most cost-effective way to come into compliance. Land requirement for FCK or a Zigzag Kiln is about 2.5 acres whereas that for HHK or TK (Fig. 1) is about 10 acres mainly due to the latter's higher production capacity (DoE, 2017). In their annual reports, DoE used to report the number of FCKs that have converted to efficient kilns as an annual performance target, but in the last two years DoE has ceased monitoring the conversion rates stating that recently converted zig-zag kilns are not meeting pollution standards (DoE, 2021). DoE regulations only required substitution to cleaner production technology without quantitative standards for fuel efficiency and emission for new kilns (Khaliquzzaman et al., 2020). This issue of standardization was addressed by a World Bank project discussed later in section 4.2.1.b. In 2017, DoE with the support of Asian Development Bank (ADB) drafted the *National Strategy for Sustainable Brick Production in Bangladesh.* The recommendations in this strategy paper have already been addressed by other donor driven projects.

The brick sector is identified as a priority in both first and second versions of the Nationally Determined Contribution (NDC) of Bangladesh for the Paris Agreement. Kuylenstierna et al. (2020) found that the most effective measure in the first NDC is 100% conversion of FCKs to traditional ZZKs which can substantially reduce carbon dioxide emissions by 1177 kilotonnes, Black Carbon (BC) by 11 kilotonnes and $PM_{2.5}$ load by 13 kilotonnes relative to the baseline in 2030. According to the latest NDC report of Bangladesh, brick kilns emitted 11.73 million ton CO_2e in 2012 which is 6.94% of total country emissions, and this emission level is expected to grow to 23.98 million ton CO_2e by 2030 under business as usual (BAU) scenario (MoEFCC, 2021). The government of Bangladesh has pledged 11.9% reduction of greenhouse gas emissions from this sector, which can go up to 12.73% contingent upon receiving financial and technological support (conditional contribution). While the difference between the mitigation targets of unconditional and conditional contribution is small, the action outlined for achieving both are the same which involves banning FCK and encouraging advanced technology and non-fired brick use. Interestingly this same activity will lead to 14% emissions reduction in unconditional contribution and 47% reductions with conditional support (MoEFCC, 2021).

Technology mandate remains the policy of choice for the government of Bangladesh despite its shortcomings and missing compliance targets (Haque, 2016). Thus, it is necessary to forecast when 100% conversion of FCKs can be seen in the sector aligning with Paris Agreement commitments. This paper maps the diffusion trajectory of cleaner technology substitution in the sector providing insights that can inform future policy decisions focusing on substitution targets. Despite the involvement of multiple development cooperation projects there are lingering issues hampering sustainability transition in the brick sector. This paper also provides a critical evaluation of these projects to better understand their impact & shortcomings and offer guidance that can inform future projects as part of the conditional support mentioned in NDC. This critical evaluation is complemented by applying innovation system framework in order to reorient future project design to incorporate 'innovation cooperation' (Pandey et al., 2021).

3. Methodology

The objectives of this study are two-fold –

i Using historical data of technology substitution from FCK, model the diffusion trajectory of cleaner brick kilns through different stages.
ii Through qualitative review, identifying the innovation system functions that were supported through development cooperation for the green transition in the brick sector.

The study employs two different analytical frameworks suited for each of the objectives and then combines the findings in the results and discussion section.

3.1. Technology diffusion models

Modeling technology diffusion involve measuring the cumulative share of adopters over time, generally resulting in an S-curve pattern. The S-shaped curve represents an initial slower diffusion process, but increasing growth after a point of inflection, followed by a slower trend and finally saturation (Kumar and Sharma, 2021; Rao and Kishore, 2010). There are different diffusion modeling techniques for various applications available in academic literature. However, logistic and Gompertz models are more commonly applied for spread of technology or growth diffusion and forecasting (Anderson et al., 2008; Chow, 1967; Desiraju et al., 2004; Kraja and Braimllari Spaho, 2019; Purohit and Kandpal, 2005). In this study Gompertz model is chosen to estimate the cumulative number of brick kiln substituted at different time periods.

3.1.1. Gompertz model

According to the Gompertz model, the cumulative number, N(t), of the technology diffusion up to the t^{th} year can be expressed as -

$$N(t) = ce^{-a*(e^{t-t_0})}$$

where c is the maximum diffusion rate; a is the speed of diffusion. This curve gives a non-symmetrical S-shaped growth pattern with an inflection point occurring at 0.367 of c. So, t_0 is the moment of time when technology diffusion achieved the share $1/e \approx 36.8\%$ of its maximum level. The values of a, c and t_0 can be estimated using the prior information on diffusion rate. The Gompertz process is asymmetric as diffusion goes faster at the beginning but becomes slower over time (Franses, 1994).

3.1.2. Data and forecast performance test

Annual data of cumulative proportion of transformation from FCK to efficient kilns is applied in this paper, which is sourced from the annual reports of DoE. This information from 2012 to 2020 is used to model the diffusion process and to predict future trends. The out-of-sample forecast covers the period 2021–2033. Given that diffusion is estimated using a small number of observations, evaluation of the fit and forecast performance of the model is crucial. This paper employs two different tests to examine forecast performance of the model: mean absolute deviation (MAD) and root mean square error (RMSE) as recommended by literature (Kraja and Braimllari Spaho, 2019; Meade and Islam, 1998).

3.2. Qualitative review of project documents

This paper also maps the activities of donor projects in the brick sector with the analytic framework of technological innovation systems, where it is well-established that successful technological diffusion depends on seven functions of an innovation system. The actions and results of the projects are assigned to the respective innovation system functions. Mapping the functions of innovation system within the diffusion trajectory can influence the direction of future projects that can better address lingering issues and speed up transformational change.

3.2.1. Technological innovation systems (TIS) framework

The concept of Technological Innovation Systems (TIS) maps the societal subsystems, actors, and institutions contributing to adoption and diffusion of that technology as well as the interactions in between. An effective TIS fulfills crucial functions that build up innovation capability of firms and other agents, and thereby influence the development, diffusion and use of new technologies. Hekkert et al. (2007) refers to these functions as activities taking place in an innovation system resulting in technological change. The strength and weaknesses of the functions and their internal interactions can provide an effective description of a system's capacity to achieve specific goals (de et al., 2022; Haque, 2022). Evidence for innovation system functions may be quantitative (e.g., demonstration projects, training, size of budgets) or qualitative (number of awareness events, existence of business networks), but there is no consensus among researchers about a scheme involving a comprehensive set of innovation system indicators (Haque, 2022). Nonetheless, innovation system framework is useful in understanding mechanisms enabling diffusion and analyzing systemic problems hampering that process (Haque, 2020; Negro et al., 2012). Table 1 provides a summary of the functions from Hekkert et al. (2007).

Modifications of the TIS framework for developing country context have been attempted by multiple authors (de et al., 2022) to contextualize its relevance for an informal sector in a developing country (Egbetokun et al., 2017). This paper maps out the project outcomes as functions at various stages of cleaner kiln diffusion, using innovation system as an analytical tool or a 'focusing device' (Egbetokun et al., 2017).

4. Results

4.1. Insights from diffusion modeling

To identify the required timeframe to achieve government mandate of full substitution of brick kiln technology, analysis of transformation rates and diffusion processes is essential. Using the conversion rate of FCK to efficient kilns reported by the DoE in their

Table 1
Summary of innovation system functions.

Functions	Description
Entrepreneurial Activities	Entrepreneurs reduce uncertainty of a new practice or technology by experimenting, thereby generating knowledge, networks and markets. Entrepreneurship is essential for a well-functioning innovation system.
Knowledge Development	Mechanisms of learning encompassing 'learning by searching' and 'learning by doing' & imitation.
Knowledge Diffusion	A precondition for learning to occur on a system level is knowledge diffusion, which often takes place through various learning networks.
Guidance of Search	Refers to those activities that can positively affect the visibility and clarity of specific demands among technology users.
Market Formation	Activities of nursing, bridging & mass marketing that can help price or performance of new technology and generate greater demand for it.
Resource Mobilization	Resources are needed for functioning of activities within a system. This function maps the extent to which innovation system can mobilize human capital, financial capital and complementary assets.
Creation of Legitimacy	Social acceptance of a new technology is formed through conscious actions of individuals & institutions to counteract resistance for the new technology.

annual reports during 2012 to 2020, Fig. 2 displays an approximate S-pattern. Gompertz model is applied to understand the diffusion process and the speed of convergence to the saturation. Table 2 shows the estimation results of Gompertz diffusion model. Results indicate a maximum level of efficient kiln diffusion of 74.596%, the speed of diffusion is 0.468 and half of its maximum level was achieved in 2012.

Fig. 3 shows the projected time variation of the cumulative rate of adoption of cleaner brick kiln technology diffusion models. In Fig. 3, logistic model results are also added to compare forecast results using the same small dataset. Fig. 3 illustrates Gompertz model projecting quicker substitution of clean technology whereas logistic model shows a slower rate of technology diffusion. Furthermore, by comparing the AIC, BIC, RMSE, and MAD values of logistic model (79.93; 81.63; 4.157; and 3.224 respectively) Gompertz model is found to be better at predicting the diffusion rate of cleaner technology in brick kiln industry of Bangladesh using low data points.

Table 3 presents the time variation of the projected cumulative adoption rate of energy efficient kilns in the two models. Results of both models indicate that with the current speed of diffusion it is unlikely to reach the government targeted goal of 100% substitution from FCK in the next 10 years although it was pledged in the revised NDC. Although the government announced banning FCK and 100% substitution to cleaner kiln technology by 2013, the rate of conversion was only 30% at that period. The substitution rate reached “early majority” phase by 2015 and does not complete the “late majority” phase which ends at 84% of cumulative conversion (Fig. 3).

4.2. Donor interventions in the brick sector of Bangladesh

The following sub-sections provide a brief overview of the projects that supported the brick sector. Each project description summarizes the brick related objectives, results and lessons learned from the project documents as well as peer-reviewed and gray literature. A summary of the results and lessons learned is provided in Table 4.

4.2.1. Air quality management project (AQMP)

This is the very first project funded by World Bank designed to generate consistent & reliable data and develop institutional capacity for air quality management. Through multiple technical studies, the project established that brick kilns around northern cluster of Dhaka city contribute to 30% of the total emissions of the city (World Bank, 2008). At the end of the project in 2008, it laid the foundations for the next World Bank project designed to encourage the brick manufacturers to adopt energy efficient technology.

4.2.2. Clean air and sustainable environment (CASE)

The World Bank supported the DoE with a combination of technical assistance and brick kiln demonstration projects, which are found to be 30% more energy efficient compared to FCKs (Alam, 2019). The project had a specific aim of decreasing particulate emissions by 20% greenhouse gas emissions by 20% by end of project period, thereby improving air quality. However, the project evaluation report noted serious attribution gaps in how kiln based demonstration projects will affect ambient air quality, which was not even measured by the project (IEG Review Team, 2020). In the last two years, the project received negative press coverage following critical observations made by the parliamentary committee on environment, forest & climate change. The committee was critical of the project highlighting half of project cost went into foreign training of 296 government officials, fees for consultants, purchasing cars and construction of a new building for the DoE (Mahmud and Karim, 2019). Considering project fund management,

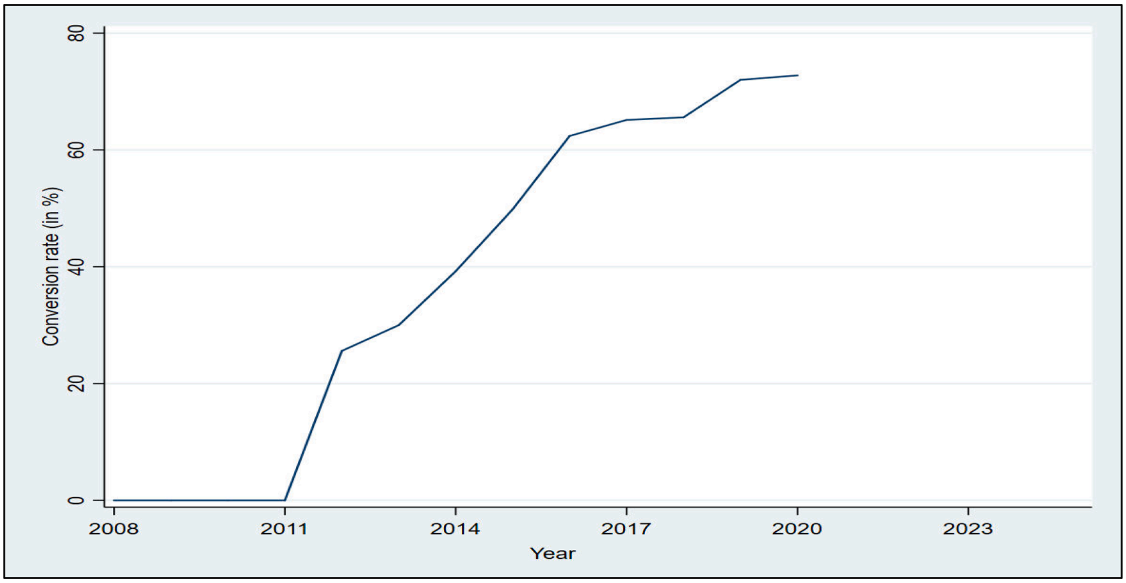

Fig. 2. Annual rate of conversion from FCK to energy efficient kilns as reported by the DoE.

Table 2
Estimation of parameters of Gompertz Model.

Parameter	Gompertz Model
c (maximum diffusion rate)	74.5967***
a (diffusion speed)	0.46875***
t_0 (moment of time when diffusion reached 1/e)	2012.811***
R^2	0.9946
Adj R^2	0.9929
AIC	75.1312
BIC	76.8261
RMSE (in sample)	3.455
MAD (in sample)	2.3574
N	13

Note: ***$p < 0.01$.

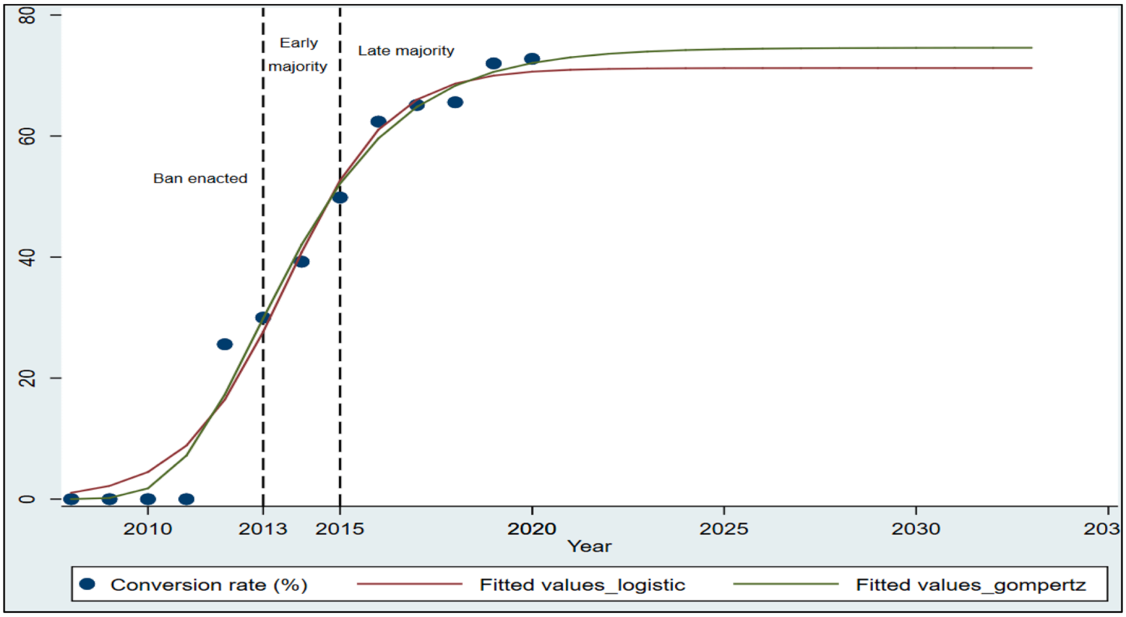

Fig. 3. Time variation of cumulative rate of diffusion of energy efficient kilns in Bangladesh.

Table 3
Projected time variation of the cumulative substitution to energy efficient kilns.

Year	Projected cumulative diffusion rate in (%)	
	Logistic model	Gompertz model
2022	71.096	73.599
2023	71.166	73.971
2024	71.199	74.204
2025	71.214	74.351
2026	71.222	74.443
2027	71.225	74.500
2028	71.227	74.536
2029	71.228	74.559
2030	71.228	74.573
2031	71.228	74.582
2032	71.228	74.587
2033	71.228	74.591

the committee observed that such hefty spending did not yield any visible air quality benefits (Rahman, 2022). The criticism from the parliamentary committee in hindsight is partially valid since it is the state policy actors from the ministries who agreed with the financial agreements and terms & conditions of the implementation arrangement before commencing the project (Rahman et al., 2021). Despite the criticisms, the knowledge products coming out of the project are commendable which includes brick kiln emission assessment studies, and a comprehensive geo-tagged emission inventory for brick kilns and vehicles (Clean Air and Sustainable

Environment (CASE) Project, 2019).

4.2.3. Improving kiln efficiency in the brick making industry (IKEBMI)

This Global Environment Facility (GEF) funded project was implemented by the United Nations Development Program (UNDP) to remove barriers for widespread adoption of energy efficient kilns. It aimed to implement 15 demonstration Hybrid Hoffman kilns (HHK) in a five-year period. The project evaluation report mentions that this overemphasis on technological aspects made this project ambitious, underestimating delays in permitting process for setting up large brick making units including acquiring large areas of land and equipment imports (UNDP, 2016). The failure rate of HHKs dampened the success of the project in later years, with three HHKs out the 15 implemented in the project being abandoned later (Alam, 2019; Khaliquzzaman et al., 2020). This project invested resources for raising awareness of the community and stakeholders in the brick sector. The project received good coverage in local and international media, which secured additional financial support beyond those committed at the time of approval (UNDP, 2016).

4.2.4. Financing brick kiln efficiency improvement project (FBKEI)

This project by the ADB provided direct financing to brick kiln owners to promote energy efficiency in the brick sector (Eil et al., 2020). The project had two separate tracks (i) upgrade existing polluting FCKs to Improved Zigzag Kilns, and (ii) promote the most advanced brick kiln technologies such as HHKs and Tunnel Kilns. Weakness in the demand analysis during project preparation affected the implementation of the project. It was observed that seasonal FCK and zigzag kilns were not eligible for long-term financing from the banks as most of these have no fixed assets such as land and machinery. Most FCK conversions were covered by the owners themselves and through retained earnings (ADB, 2022). As a result, this project had to reallocate funds earmarked for FCKs and zigzag kilns to the construction of HHK and TK (ADB, 2022). According to the project completion report, only twelve TKs and seven HHKs were built using ADB loan, out of which nine are in operation while the rest either shut down or slowed down production (Rahman and Pieal, 2023). The impact of COVID-19 pandemic delayed project goals of the banking sector as well as the small and medium entrepreneurs that secured funding. It was recommended that brick kiln owners or sub-borrowers need more support from financial sector for procurement, contract management, business and technology planning (ADB, 2022). While the project objective states that it will lead to improved environmental conditions with specific reduction on certain air pollution parameters, the growth of the brick sector negated the gains for energy efficient kilns constructed with the support of this project (ADB, 2022) demonstrating macro rebound effects. Rahman and Pieal (2023) reports that number of brick kilns in the country increased from 5000 in 2011 to 8500 currently.

4.2.5. Supporting brick sector development program (SBSD)

A technical assistance (TA) project complemented the lending facility discussed above. The TA project was scheduled to close on 31st December 2014 but was extended twice ending on 30th June 2018. Apart from the loan implementation tied with the financing project performing sub-optimally, the project was successful in delivering a brick sector policy, strategy, and action plan which was adopted by DoE in May 2017. With support from the project, DoE opened a one-stop service center in its new building and published a brochure where detailed application process for environmental clearance for brick kilns (ADB, 2021). The project also provided emissions monitoring devices to the DOE, and organized several training and awareness raising workshops with stakeholders including brick manufacturers, banks and financial institutions (Alam and Barman, 2019). Findings of commissioned studies also positively contributed to the awareness of existing technologies in the brick sector (ADB, 2021).

4.2.6. Knowledge partnership program (KPP)

This program supported by UK Department for International Development (DFID), and managed by IPE Global Limited, was an initiative to explore and showcase India's success in meeting development challenges in terms of policy and practice. One of the sub-projects under this program, initiated in partnership with the DoE and the Bangladesh Brick Manufacturers Owners Association (BBMOA), was to introduce and scale up FaL-G (Fly ash-Lime-Gypsum) technology in Bangladesh, which was invented and patented in India (IPE Global, 2019). Although FaL-G bricks had superior qualities, it faced barriers among users who are not used to the gray colored bricks and are more accustomed to cheaper local clay bricks for which bright red color signifies higher quality (Luby et al., 2015). The presence of ash in the bricks also created unfounded negative perception on the quality of the product (IPE Global, 2019). The project was successful in lobbying the government to include this technology as alternative construction material to be promoted through development of policy briefs and official field visits to India.

4.2.7. Promoting sustainable building project (SUSBUILD)

This European Union SWITCH-Asia funded project aimed to bring about transformative change in the brick industry in Bangladesh by promoting alternative building materials & practices under an enabling policy environment. The project's theory of change identified existing policies as the entry point to initiate market transformation by changing demand for bricks (Van Hemelrijck, 2020). The project successfully lobbied the government to announce procurement schedule for brick alternatives and made amendments to the 2013 Brick Control Act to enable the government to command and regulate the market transition to alternative building materials. The new amendment prohibits unsustainable brick production and consumption, use of agricultural topsoil, and promotes the use of alternative technologies (SWITCH-Asia, 2019). The amendment also permitted issuance of auxiliary circular to make use of hollow brick compulsory in public building construction by 2025 (Rahman and Pieal, 2023). The transition was mandated despite the absence of a secured supply of alternative bricks. For hollow brick adoption, the target was 60% for 2020 but only 5% has been achieved so far (Rahman and Pieal, 2023). The project evaluation report offers frank assessment of how three years' time was too short to mobilize political will and the resources for resolving supply chain linking and capacity issues that prevent small and large producers from

Table 4
Donor interventions in the brick sector of Bangladesh.

Period	Name	Project ID	Agency	Implementing Partners	Project Objectives (for brick)	Results	Agency rating of projects	Lessons learned *(from project evaluation reports)*
2001–2007	Air Quality Management Project	PE57833	World Bank	DoE	Preparing an emission inventory including brickmaking	• Emission Inventory on brick kilns on the northern clusters of Dhaka were developed by BUET. • New national air quality standard was promulgated in July 2005.	Satisfactory	• Brick kilns in the north cluster of Dhaka contribute to 30% of the total city emissions. • Project management capacity within DoE was weak. • Addressing only one pollution source will only resolve part of the problem.
2009–2019	Clean Air and Sustainable Environment (CASE)	P098151	World Bank	DoE	• Provide technical support to the Brick Advisory Committee. • Adoption of cleaner technologies and promotion of practices among the brick enterprises from demonstration projects	• Brick Manufacturing and Kiln Construction Control Act was adopted by parliament on November 20, 2013. Establishment of a Brick Technology Information center (BTIC). • Inventory was developed mapping all brick kilns in Dhaka	Modest	• The project indicators only estimate reduced emissions from 12 brick kilns adopting cleaner technology. • While it is plausible that this might lead to improved air quality, the project's Results Framework does not include any indicators that measures improved air quality, resulting in significant attribution gap. • Appropriate data collection and proper project design is necessary.
2010–2016	Improving Kiln Efficiency in the Brick Making Industry in Bangladesh (IKEBMI)	1901	GEF	UNDP, Clean Energy Alternatives, Xian Institute of Wall Building Materials	Removal of barriers inhibiting adoption of cleaner and efficient kiln technologies	• 23 HHK brick kilns were operational and another 16 HHK units were under various stages of construction. • The project seeded the HHK technology, as it was considered most suited to address the air-quality issue according to a World Bank study.	Satisfactory	• The project design placed more emphasis on the technology aspects of energy efficient kilns, since three out of the six components were related to demonstrate and build local capacity to use HHK technology. • Implementation of technology solutions is more complex due to delays in approvals and permits required in setting up a brick making unit, including large area of land. • Periodic meeting between the World Bank, ADB and UNDP for information exchange would have benefitted the project
2012–2019	Financing Brick Kiln Efficiency Improvement Project	45,273–001	ADB	Bangladesh Bank; participating financial intermediaries	Replacement of polluting FCKs with more energy-efficient kilns in the brick sector. • a 10% reduction in annual GHG emissions in the brick sector by	• Credit facility was fully operational. • Brick sector finance was more than $100 million as of 2019. • ADB financing of $50 million in financing 7 HHKs	Satisfactory	• The project has achieved significant results through direct impact and demonstration effect. • The subprojects constructed under the project reduced CO_2 and small particulate emission by 55% and 23%, respectively.

(*continued on next page*)

Table 4 (*continued*)

Period	Name	Project ID	Agency	Implementing Partners	Project Objectives (for brick)	Results	Agency rating of projects	Lessons learned *(from project evaluation reports)*
					2018. • a 20% reduction in annual pollution from the sector for particulate matter by 2018.	and 12 tunnel kilns fully utilized. • FCKs were converted to zigzag kilns by the owners without ADB financing following ban of the government on FCKs.		• However, the rapid growth of the sector still led to nationwide increase in CO_2 emission and fine particulate pollution.
2012–2019	Supporting Brick Sector Development (SBSD) Program	45,273–002	ADB	DoE	Government delivers a long-term brick sector policy, strategy, and action plan for adoption	• Brick sector policy, strategy, and action plan adopted in May 2017. • DOE opened a one-stop service center in its new building. DoE published a brochure detailing application process for environmental clearance for brick kilns. • Total 120 brick entrepreneurs trained on financing modern brick technology.		• For a Technical Assistance (TA) project which closely relates to loan project (above), it is important to harmonize the schedules to the extent possible. • The project could have focused on knowledge building at the grassroots level for brick kiln entrepreneurs in the different districts of Bangladesh. • Could have included HBRI, and Public Works Division which is responsible for government building construction, and promotion of energy efficient green bricks in government construction.
2012–2017	Knowledge Partnership Programme (KPP)	GB-1–202,765	UKAID	IPE Global; Institute for Industrial Productivity (IIP)	Promoting FAL–G Brick Technology for Bangladesh	• Inclusion of fly ash in country environmental policies. • Sector assessment & development of policy briefs. • Policymakers' India field visit.	Program Score: A	• Burnt clay bricks remains popular due to cost and history. • gray color of FaL-G products (imparted by the color of fly ash) has low consumer acceptance. • Fly ash sourcing issues need to be resolved.
2016–2019	Promoting Sustainable Building in Bangladesh (SusBuild)	GB-CHC-202,918-BGDC50	EU SWITCH Asia; UKAID; Oxfam	Housing and Building Research Institute (HBRI); Jagorani Chakra Foundation (JCF); Bangladesh Environmental Lawyers Association (BELA)	Promoting sustainable and eco-friendly building practices in Bangladesh within an enabling policy environment.	• With direct contribution from the project, amendments to the Brick Control Act were passed by parliament in February 2019 promoting alternative building materials. • Government procurement schedules now mandates inclusion of alternative bricks.		• No single solution to the use of traditional bricks exists. • Without sufficient direct financial support, fluctuating market demand and supply deters small and medium scale investors to invest in clean technologies. • Apart from weak market signals, other constraints arising when importing machineries, high taxes, lack of raw materials, and weak regulatory framework were also identified as key challenges during project implementation. • Project's contributions were insufficient in transforming the market.

(*continued on next page*)

Table 4 (*continued*)

Period	Name	Project ID	Agency	Implementing Partners	Project Objectives (for brick)	Results	Agency rating of projects	Lessons learned *(from project evaluation reports)*
Ongoing and Upcoming projects								
2022-	Bangladesh Environmental Sustainability and Transformation (BEST)	P172817	World Bank	DoE	**Project Objectives** A pilot green credit risk guarantee scheme will be able to support ten tunnel kilns, eight hybrid Hoffman kilns (HHK), and three autoclaved aerated concrete (AAC) facilities during project implementation.			
Proposal under development	Catalyzing Emissions Reduction in Brick Manufacturing in Bangladesh	Woods Institute for the Environment - Stanford University		Stanford University, BRAC, Greentech Knowledge Solutions	**Project Proposal** • Piloting a practical strategy to reduce emissions and improve working conditions among brick manufacturers in Bangladesh. • Phase I involves demonstration projects in 10 kilns. • Phase II will expand the intervention to additional 30–45 kilns. • Phase III to progressively scale to nearby 200–300 kilns.			

adopting the new alternative brick (AB) technologies (Van Hemelrijck, 2020). The planned piloting of the AB technologies with 15 targeted entrepreneurs to develop business models did not take place due to delays in the technology research, national elections in 2018, and traditional clay brick industry lobby's resistance to change (Van Hemelrijck, 2020).

4.2.8. Bangladesh environmental sustainability and transformation (BEST)

In December 2022, the World Bank launched this $250 million project[1] for the Ministry of Environment, Forests & Climate Change (MoEFCC). Component 2 of the project involves green financing for air pollution control, which will support the Bangladesh Bank (BB) to develop a green credit risk guarantee (GCGS) scheme to invest in green technologies. Project document states that the direct beneficiaries will include 20–30 brick kiln owners who will receive grants and/or credit enhancements to adopt new technology (World Bank, 2021).

4.2.9. Catalyzing emissions reduction in brick manufacturing (CERB)

This proposed project plans to work with existing brick kiln owners offering them loans to be repaid from improved profits generated by reduced costs mimicking an Energy Service Company (ESCO) model. Channeling catalytic philanthropic funding, the initial phase of project will support 10 kilns which will gradually increase to 45 kilns in phase 2 and 200 kilns in phase 3. Other lines of funding will come from social impact investors who will provide capital to BRAC Bank, and global climate mitigation funding based on the documented reduction in black carbon (Luby, 2019).

4.3. Categorizing donor interventions into innovation system functions

Over the last twenty years, the support received from multiple development partners as transition intermediaries (Kivimaa et al., 2019) have been instrumental in policy development and capacity building, but these are just two factors that can change the technology trajectory. Table 5 outlines the project outcomes corresponding to the innovation system functions presented in Table 1, and these may not be mutually exclusive as an action or result can fit under more than one functions. Table 5 shows that most of the donor interventions for the brick sector fulfilled the functions of *Guidance of Search* and *Creation of Legitimacy. Market formation* and *Entrepreneurial Activities* and *Resource Mobilization* are also common functions these donor projects fulfilled. The less prioritized functions during 2001–2020 were *Knowledge Development* and *Knowledge Diffusion*.

Fig. 4 illustrates the innovation system functions supported by these projects at different stages of cleaner kiln diffusion trajectory resulting from the Gompertz model. FBKEI and SBSD projects are shown together in Fig. 4 as they both originate from the same multilateral organization in the form of technical assistance and financing facility. SUSBUILD is highlighted in color as it worked to undermine the existing innovation system in favor of alternative building materials which is a different set of technology & products. There is no normative guideline suggesting which functions need to be prioritized at different stages of technology diffusion. As seen in Fig. 4, five projects were active during the early majority stage of diffusion resulting in 8.1% FCK conversion on average per year. This does not suggest that greater number of projects were needed for accelerated conversion. It is difficult to establish their influence since the conversion may have happened anyway to comply with the government mandate that went into effect in 2013. Nonetheless, this mapping offers unique perspective that can offer lessons for future projects aiming to scale up rapid substitution of existing kilns to efficient ones. Future projects can place more emphasis on the functions of *Resource Mobilization, Entrepreneurial Activities* and *Market formation* as part of an innovation cooperation (Pandey et al., 2021) instead of picking preferred brick-making technologies like the IKEBMI, KPP, SUSBUILD projects have done.

5. Discussion

This section synthesizes findings of the two analysis that made up the objectives of the paper outlined in section 3. It first discusses the theoretical enrichment this empirically novel case-study offers for the innovation system literature as academic research impact (Sovacool et al., 2018). As for non-academic research impact (Sovacool et al., 2018), this paper presents findings of the diffusion models along with recent peer-reviewed and gray literature to offer lessons of development impacts and identify specific areas where targeted intervention can support transformational change.

5.1. Utility of innovation system framework for donor driven transition research

Production technology substitution in the informal brick sector of Bangladesh offers an interesting case study for the innovation system literature where major transition intermediaries are development partners such as World Bank, ADB and UNDP, whereas the government plays a reactive role by monitoring a technology mandate and letting regulated entities figure out how to comply. Despite similarity with the approach taken by Tigabu et al. (2015), this paper uses conversion rate for modeling diffusion trajectory of all cleaner kilns instead of technology adoption figures, and does not assess how accumulation of functions influence diffusion rates, which is novel but comes with criticism (de et al., 2022). The role of donors in sustainability transition of developing countries are critical but downplayed in the literature (Wieczorek, 2018). In the Bangladesh brick sector, the preferential treatment that some

[1] https://projects.worldbank.org/en/projects-operations/project-detail/P172817

Table 5
Connecting project outcomes with innovation system functions.

Project Abbreviation	Active in Years	Project Outcomes	Innovation System functions
AQMP	2001–2007	Emission Inventory	Knowledge Development
		Air Quality Standards	Creation of Legitimacy
CASE	2009–2019	Updated kiln location inventory	Knowledge Development
		Brick Act	Creation of Legitimacy
		Demonstration projects	Guidance of Search
		Brick Center	Market Formation
IKEBMI	2010–2016	Awareness Campaign	Knowledge Diffusion
		Demonstration projects	Guidance of Search
		Association & Network building	Market Formation
FBKEI	2012–2019	Credit Facility	Entrepreneurial Activities
		Loan Disbursement	Resource Mobilization
		Technology support	Guidance of Search
SBSD	2012–2019	Brick Strategy 2017	Creation of Legitimacy
		Brochures & training programs	Knowledge Diffusion
		Brick Information Center	Guidance of Search
KPP	2012–2017	Policy Amendments & Briefs	Creation of Legitimacy
		Field Visits	Guidance of Search
SUSBUILD	2016–2019	Brick Kiln Act amendment	Creation of Legitimacy
		Govt. procurement schedule	Market Formation
BEST	2022 -	Scaling larger kilns	Resource Mobilization
		Credit Facility	Entrepreneurial Activities
CERB	2021 -	Funding support	Resource Mobilization
		Scaling up in existing kilns	Entrepreneurial Activities
		Piloting efficiency measures	Knowledge Development

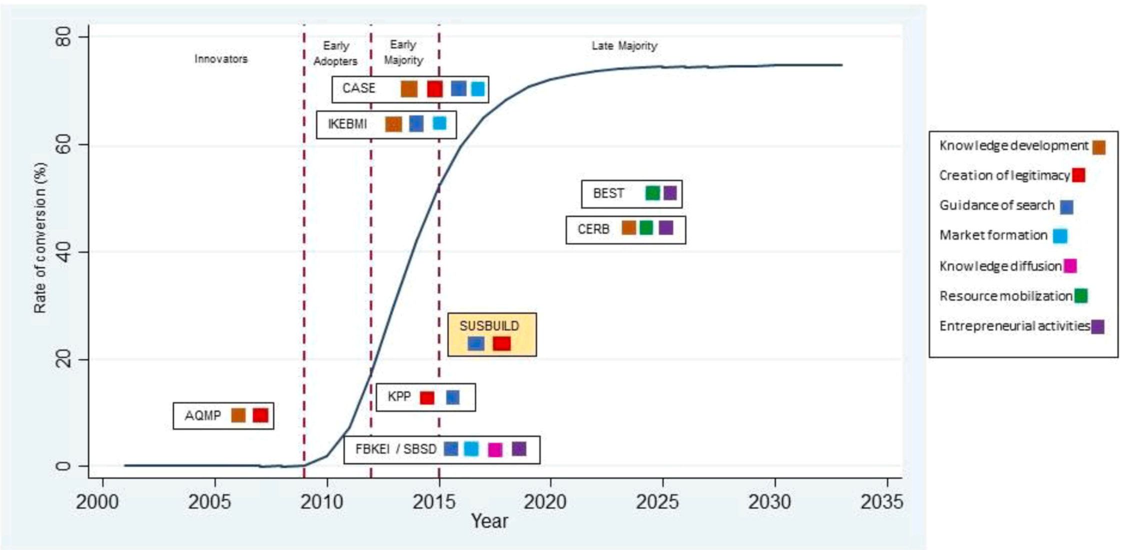

Fig. 4. Functions supported by projects at different stages of cleaner kilns diffusion.

donors provided for selected technologies resulted in a diffusion path that is different from diffusion patterns of niche technologies in the European context (Hansen et al., 2018). It also shows that classical technology transfer through individual demonstration projects of international organization is not always effective due to creation of unconnected niches that are not viable beyond their official duration. Thus, this case-study further contributes to the stream of sustainability transitions research that critically analyze how foreign donors can engender transitions in the developing world (Hansen et al., 2018).

Another difference in experience of innovation system application in developing countries is the governance of informal sector which this case study also highlighted. According to Hekkert et al. (2007), the technology mandate for 100% brick kiln substitution falls under *Guidance of Search.* However, unlike the target set for the Dutch renewable energy portfolio standard example discussed by Hekkert et al. (2007), there are major differences in the Bangladesh in the form of lack of legitimacy and informality. In developing countries, regulatory frameworks partially exist and often lacky legitimacy (Ramos-Mejía et al., 2018). In Bangladesh, the lack of legitimacy is exposed by the DoE's unitary decision to set deadline for production technology mandate rather than setting it through conscious actions by brick kiln associations and owners in a socio-political process (Negro et al., 2012). The mandated transition from bricks to alternative blocks is another sign of lack of legitimacy where landscape pressure for an undeveloped innovation system of alternative bricks is generating strong regime resistance from clay brick industry which the relevant donor project failed to counter (Section 4.2.7). The informal brick industry is operating within these pressures in the absence of formalized and enforced regulation. Deeper understanding of the institutional settings underlying *Guidance of Search* in developing countries will enrich the application of innovation system function framework as well as refine the scope for external resources to support this function traditionally associated with government interventions (Ramos-Mejía et al., 2018; Walrave and Raven, 2016).

5.2. Policy implications

Apart from the recommendation for prioritizing some innovation system functions for future projects, this paper also consolidates lessons learned from development cooperation projects in the brick sector of Bangladesh. Combining them with results of the diffusion models and recent peer-reviewed and gray literature, some recommendations are presented which can be used to design targeted interventions through future projects.

5.2.1. Building regulatory and enforcement capacity

The transition to sustainable brickmaking requires significant changes in the way regulatory agency manages brick-making industry. The DoE should be provided with more effective methods, equipment, and capacities for "state management" functions such as: emissions measurement, environmental monitoring, clay resource management, planning, and promotion of development in the brick-making industry (DoE, 2017). This recommendation is especially applicable for the CERB project (discussed in Section 4.2.9) which should refrain from joining the bandwagon of piloting technological solutions and instead focus more on *Knowledge Development* and *Knowledge Diffusion* functions of the innovation system. They have developed data and scalable methodology using machine-learning approach on satellite images for identifying brick kilns that can be effective in identifying illegal kilns and governing the sector (Lee et al., 2021). Nazir et al. (2020) have also developed a semi-automated method of dataset generation from satellite images that can be used to understand brick sector's pollution and climate impacts and address other short-lived climate pollutant emissions. Donor projects can be instrumental in building capacity of regulatory agency to use these tools. Future projects can support DoE on revamping the permitting process to assign each kiln an emission standard to comply with based on their airshed location instead of the current system of issuing permits with uniform emission standard. These processes and tools are themselves innovations for the regulatory agency, for which development cooperation can support the functions of *Knowledge Development and Diffusion, Guidance of Search* and most importantly *Resource Mobilization*.

5.2.2. Focusing on priority locations for air pollution benefits

Several donor projects were initiated specifically targeting air pollution and environmental conditions surrounding Dhaka (Begum and Hopke, 2018). This is true for the World Bank projects (AQMP, CASE and BEST discussed in Section 4.2) which were designed to improve urban air quality with components addressing issues in the brick sector. Urban air quality improvement should be prioritized, but technology mandate for brick kilns do not need to be extended to kilns that do not contribute to degrading urban airsheds. In making these non-contributing kilns comply to the technology mandate, it exerts unnecessary cost burden to kilns that are more than content in supplying to a sub-urban or rural market. The 2017 brick kiln strategy developed by ADB support also echoed this observation citing massive social cost involved in total substitution of FCKs (DoE, 2017). There is also no guarantee that a reduced emission profile from converted kilns will lead to improved ambient air quality, as observed by the evaluation of CASE project citing attribution gaps (IEG Review Team, 2020). Clustering of brick kilns remain a huge problem as the sum of the emissions from all the kilns in a cluster could impact greatly on the nearby settlements even if individual kilns within the cluster adopts efficient technology and complies with new emission standards (Clean Air and Sustainable Environment (CASE) Project, 2019). Khaliquzzaman et al. (2020) proposed closing or relocating brick kilns within 20 km of Dhaka city's boundary initially and progressively implementing such measures for other major urban centers with large population. Such policy innovations discussed in the academic literature can be supported by future projects. Irrespective of production technology, permitting new kilns needs to account for airshed carrying capacity determined using pollution dispersion models. Perhaps the price of permits within 20 kms of urban areas can be set higher increasing the kilns' regulatory costs, which is a variable known for affecting diffusion speed (Blackman, 2001) but could also hasten relocation from polluted airsheds.

5.2.3. Monitoring macro rebound effects from efficient kilns

According to Alam and Barman (2019), 7.1 million tons of coal were consumed by the brick sector in 2018, which increased from 3.4 million tons in 2006. During this period, six projects were active in the brick sector with at least three explicitly stating that reduction of emissions is the success metric. None of the project measured the sector's coal usage during project period in their evaluation reports. During this same period of 2006–2018, number of brick kilns increased from 4200 to 6877 (Sarker and Abir, 2019) and the number is currently estimated to be around 8000 (Khaliquzzaman et al., 2020; Rahman and Pieal, 2023). This demonstrates that substitution of FCK is a partial solution to reducing emissions from brick kilns (Haque et al., 2018) and that macro rebound effect of efficiency is being observed in the sector. Only ADB (2022) offered the frank confession that despite technology improvements, the rapid growth of the sector led to increased CO_2 emissions and particulate pollution. To replicate China's success in curbing pollution using command and control, a nationwide cap on coal use as well as sectoral caps are recommended (Economist, 2017). Future projects must measure decoupling of coal consumption from brick sector's growth. Furthermore, supporting government agencies to track undocumented coal import from India (Roy et al., 2023) can also enhance reporting for NDC progress complementing with the number of efficient kilns adopted. As a policy prescription, both NDC goals and diffusion speed in the brick sector can be achieved by increasing the price of coal as price of inputs and their supply limitations are known for driving diffusion (Blackman, 2001).

5.2.4. Recalibrate goals for efficient kilns and alternative building materials

It can be argued that the activities of KPP and SUSBUILD projects may not have contributed to the same innovation system as these projects promoted alternatives to clay bricks. In the case of SUSBUILD, by hastening the transition to alternative bricks in the form of government procurement schedule, it may have had a negative impact on all other development cooperation initiatives financing efficient kilns. Brickmakers are already concerned about new bans on existing technology as it leads to stranded assets in the form of already converted kilns (Alam, 2019; Haque, 2016). If bricks are being phased out, existing kiln owners and entrepreneurs will not be interested in building new kilns using financial incentives offered under the BEST project. Acting on concerns of losing agricultural topsoil and lobbying efforts of SUSBUILD partners, government has issued a notification on progressive replacement fired bricks by concrete blocks in public construction starting with 10% clay bricks during 2019–20 in public construction, progressively increasing on yearly basis to 100% replacement in 2024–25 (Khaliquzzaman et al., 2020). The bulk of clay brick demand however lies in private sector construction where lack of familiarity with alternative bricks is preventing widespread usage along with prevailing perceptions that the concrete blocks are heavy, difficult to plaster, have higher water seepage and are difficult to arrange for concealed work for plumbing and wiring conduits (Khaliquzzaman et al., 2020). Insights from innovation literature suggests that the existing technological regime is stronger for burnt clay bricks, and alternative bricks are unfit in this prevailing innovation system (de-Ligny and Erkelens, 2008). The linear rates of substituting bricks with concrete blocks adopted by the government are already missing targets. In the fiscal year of 2020–2021 only 13% of the target for using blocks could be achieved against the target of 20% (Shishir, 2021). It is likely that government will fail to meet 100% target by 2024–2025 (Zaman, 2022) as the Bangladesh Concrete Block Association estimates that at least 10,000 block producing factories are needed across the country for supplying 100% alternative to clay bricks (Shishir, 2021) which is more than existing number of brick kilns in the country. According to DoE's annual report 2021–2022, there are 209 environment-friendly block producing companies in the country. Lehmann et al. (2014) used 80% brick kiln conversion target in their ambitious technology penetration scenario for Bangladesh suggesting that the remaining percentage will be kilns operating in isolated locations, far from government purview but maintaining their business assuring brick availability in remote areas.

The experience of missing deadlines in the brick sector of Bangladesh shows a lack of understanding of technology diffusion process among policymakers. Policies can be effective in significantly influencing the diffusion of cleaner brick making technologies (Zhang et al., 2002). There are a range of instruments that can be deployed at various stages of diffusion instead of just relying on the policy instrument of technology mandate with a deadline. To speed up diffusion, policies can reduce the level of perceived risks inherent in adoption of an innovation (Zhang et al., 2002). Technology adoption will be affected by a lack of information at the early stages (Blackman, 2001). Experience in India shows that the average time taken by a brick kiln entrepreneur to adopt zig zag technology was 5.1 years after their first exposure (Kumar and Sharma, 2021). It is at this stage where innovation functions of *Knowledge Development* and *Knowledge Diffusion* can be more effective in informing stakeholders about the characteristics of the innovation. On the other hand, to replace burnt clay bricks with alternative bricks entails structural shifts in the construction sector which calls for a change in the existing technological regime (de-Ligny and Erkelens, 2008). Policymakers and development partners can benefit from such insights to provide regulated entities time and incentives to transition instead of just a deadline. modeling techniques used in this paper can inform timeline for diffusion of efficient kilns and alternative building materials.

5.2.5. Ensuring alignment with climate action plans

As major raw materials for concrete blocks are Portland cement, stone dust and sand, there are emerging questions on how sourcing of these materials can be sustainable in the country context. There are concerns that illegal sand mining of rivers may intensify for supply of sand for producing alternative building materials (Hossain and Taylor, 2021). Relying on cement to substitute clay bricks may negate the climate benefits of this switch given the enormous carbon footprint of cement (Hossain and Taylor, 2021; Nature Editorial, 2021). There is a huge research gap assessing changes in greenhouse gas emission profile of Bangladesh that will result from total substitution of bricks with concrete blocks and other alternative materials. These research gaps were completely overlooked by the SUSBUILD project discussed in section 4.2.7. Without such critical assessments, SUSBUILD project proponents lobbied the government to embark on phasing out brick use in favor of cement-based blocks, which is solving a local problem of air pollution by contributing to the global problem of climate change. There are no decarbonization targets for cement sector in the latest NDC as well as no description of how emission profile will change from the substitution of bricks with concrete blocks (MoEFCC, 2021). Future NDC revisions must consider this embodied carbon content of buildings materials being promoted and specify targets related to decarbonizing concrete production (Zinecker et al., 2021).

6. Conclusions

The brick sector of Bangladesh is yet to experience transformational change and sustainability transition where interconnected challenges of - localized air pollution, greenhouse gas emissions, top-soil depletion, child labor and brutal working conditions - demands fundamental reconfigurations of cultures, institutions, policies, regulations, funding models, and routines that surround this system (Mintrom and Rogers, 2022). It cannot be expected that a single development cooperation project can achieve all these within a typical project timespan of 3–8 years (Haque and Rashid, 2022). Insights of the innovation diffusion process can be taken into consideration before deciding on a timeframe to substitute existing brick making technologies or phase out bricks in favor of alternative building materials. Future project developers and policymakers need to be cognizant about diffusion theories and innovation system functions to design better interventions within a realistic timeframe. These lessons are applicable beyond this country case-study to other contexts of informal sectors in developing economies where socioeconomic transition is attempted through cleaner technology diffusion.

There is still a lack of shared vision among all stakeholders, and the 2017 *National Strategy for Sustainable Brick Production in Bangladesh* falls short in formulating this vision. This paper has found that donor driven projects are more involved in policy development under *Guidance of Search* and *Creation of Legitimacy* functions, and less invested on the functions of *Knowledge Development, Knowledge Diffusion* and *Resource Mobilization.* This may be due to the ease in recording milestone achievements compared to measuring substitution targets and attribution impact on air quality in the long run. There are criticisms and debates about the extent of donors and non-state actors engagement in the policy decisions in the context of Bangladesh (Rahman et al., 2021). No single solution exists for the use of traditional bricks in Bangladesh. Donor driven non-state actors lobbying for brick phase-out within unrealistic timeframe adds to this debate on how much they should be involved in policy decision as these policy outcomes make current sector visions incoherent. Echoing the lessons learned from donor involvement in forestry initiatives in Bangladesh, donors could be more active in mobilizing appropriate resources and cooperation but reactive in advocating policy preferences (Rahman et al., 2021). For the brick sector, there are ample opportunities for donor driven projects and lending initiatives to continue commercializing new business models and technologies, and providing sustained investment in supply chains, training, and access to capital (Eil et al., 2020). The transition narrative alongside diffusion trajectory provided in this paper will be useful in ensuring all stakeholders learn about what has not worked and remain focused on the vision they all are pursuing.

CRediT authorship contribution statement

Nabil Haque: Conceptualization, Data curation, Writing – original draft, Writing – review & editing. **Sungida Rashid:** Methodology, Software, Formal analysis, Validation, Visualization, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data will be made available on request.

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Code availability

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