Journal of Scientific Reports 2026, 15(1), 146-165
ISSN: 2708-7085 (Online) & 3079-9317 (Print)
Journal: ijsab.com/jsr

Europe's Climate Demand and Bangladesh's Energy Constraints: Attainable Alignment Theory of Transmitted Carbon Lock-In

Kazy Mohammad Iqbal Hossain [1]

[1] Centre for Higher Studies and Research (CHSR), Bangladesh University of Professionals (BUP), Mirpur Cantonment, Dhaka-1216, Bangladesh.
Email: iqbalwrdbuet@gmail.com

Abstract

Bangladeshi garment exporters face growing climate demands from European buyers, although the most important conditions shaping their emissions remain outside factory control. Existing theories do not adequately explain why substantial factory-level efforts may produce only limited market-recognised climate alignment. This article develops Attainable Alignment Theory, formalised through the Attainable Alignment Framework. The theory separates the carbon footprint of an exported garment into four necessary abatement levers: energy efficiency, electricity carbon intensity, thermal fuel carbon intensity, and embedded material carbon. It also introduces verification as a market-access gate. The core theoretical claim is that climate alignment is conjunctive: it is constrained by the least attainable lever, while reductions without credible verification have no recognised market value. The article develops five falsifiable propositions and evaluates them using peer-reviewed evidence, European Union law as of August 2026, Bangladesh's Nationally Determined Contribution 3.0, and an analytical bounding model. The findings show that factory-level efficiency can reduce operational emissions by approximately 4 to 10 per cent. However, fossil fuels supply about 98 per cent of national electricity generation, while rooftop solar remains limited by technical coverage and financing conditions. Even under favourable assumptions, the firm-controlled reduction envelope reaches only about 15 to 19 per cent, compared with buyer pathways requiring reductions of around 45 to 50 per cent by 2030. The 2026 regulatory amendments further weakened buyer obligations without removing product-data requirements or private emission targets. The theory extends carbon lock-in, environmental upgrading, and the Brussels Effect by explaining how system constraints, verification requirements, and unequal control over abatement levers shape supplier transition and exclusion.

ARTICLE INFO

Research paper
Received: 13 July 2026
Accepted: 15 September 2026
Published: 28 September 2026
DOI: 10.58970/JSR.1244

CITATION

Hossain, K. M. I. (2026). Europe's Climate Demand and Bangladesh's Energy Constraints: Attainable Alignment Theory of Transmitted Carbon Lock-In, *Journal of Scientific Reports*, 15(1), 146-165.

COPYRIGHT

*Copyright © **2026** by author(s)*
Papers published by IJSAB International are licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

Keywords: *Ready-made garments, European Union, industrial decarbonization, Scope 2 emissions, Digital Product Passport, carbon lock-in.*

1. Introduction

Bangladesh's garment export model was built on scale, low unit labour cost and preferential market access. Europe remains its anchor. EU-Bangladesh goods trade reached EUR 23.3 billion in 2025, textiles made up close to 94 per cent of EU imports from Bangladesh, and Bangladesh is the largest single user of the Everything But Arms (EBA) arrangement, with EUR 19 billion of exports drawing on those preferences in 2024 at a utilisation rate of 96 per cent (European Commission, 2026). Concentration of this order turns European regulatory choices into investment signals inside Bangladeshi factories, because in buyer-driven chains lead firms set the parameters that suppliers must meet (Gereffi et al., 2005; Ponte, 2020). A change in product rules, disclosure duties or sourcing risk management reshapes technology, financing and firm survival far beyond Europe's borders. The energy base of that export model has barely moved. Fossil fuels supplied about 98 per cent of Bangladesh's electricity generation in 2024 (Worldometer, 2026), and renewables accounted for less than 6 per cent of installed capacity in 2025 (Government of Bangladesh, 2025). Wet processing, the carbon-heavy core of the chain, still runs on gas-fired steam (M. M. Hasan et al., 2024). Measurements from fifteen dyeing mills reported average energy use of 2.58 kWh per kilogram of dyed fabric (Al Mamun et al., 2022), and a composite factory audit found that the full technically available package of boiler, motor, pump, generator and lighting improvements would cut greenhouse gas emissions by 9.78 per cent (Khan et al., 2022). That is a material gain. It is also an order of magnitude short of the trajectories European buyers now write into supplier contracts (United Nations Framework Convention on Climate Change [UNFCCC], 2021). Public debate has mostly asked whether Bangladesh "can meet the EU climate target." The question misattributes a legal obligation that does not exist and treats as a single threshold what is in fact a plural and moving set of instruments. Its most consequential flaw is that it places the problem at the level of the firm when the binding constraints sit in the national energy system (Rahman et al., 2025; Seto et al., 2016). Policy discourse built on that framing rewards factory-level effort and leaves the limiting factors untouched.

Three bodies of research speak to this situation, and each stops short of it. Environmental upgrading research shows that suppliers improve environmental performance under lead-firm pressure and asks who captures the value (De Marchi et al., 2013; Khattak et al., 2015; Krishnan et al., 2023), yet it treats upgrading as a firm capability and does not model constraints that sit in national grids or fuel systems. Carbon lock-in research explains why fossil systems persist (Seto et al., 2016; Unruh, 2000), but it is framed at national or technological scale and says little about how lock-in is passed to an exporting firm through a foreign buyer's targets. Work on the Brussels Effect explains why EU rules travel (Bastos Lima & Schilling-Vacaflor, 2024; Bradford, 2020), but it assumes that public rules and private buyer demands move together, an assumption the 2026 EU amendments have broken. Studies of Bangladesh's garment sector document buyer pressure, weak finance and thin renewable adoption (Chen & Akter, 2026; Rabbani et al., 2025; Rahman et al., 2025). None of this work links specific abatement levers to the verification standard that decides whether a reduction is recognised in the EU market. The gap is therefore specific: no framework connects abatement levers, distinguished by who controls them, to verification, and none explains why firm effort and market-recognised alignment diverge. This article addresses that gap with one question: under what conditions can Bangladeshi garment exporters achieve EU-market climate alignment, and why does factory-level effort translate so weakly into recognised alignment? It makes three contributions. The first is a theory. The article develops a theory of attainable alignment, formalised as the Attainable Alignment Framework (AAF), which holds that alignment is conjunctive: it is limited by the lever furthest from its required contribution and multiplied by a binary verification gate. Five propositions are derived, each stated with the evidence that would refute it (Jaakkola, 2020; Whetten, 1989). The second contribution extends three established concepts. The theory recasts carbon lock-in as a property that can be transmitted across borders through value-chain accounting, adds verification to environmental upgrading as the condition under which upgrading earns a market return, and identifies a privatised variant of the Brussels Effect in which public obligations on buyers soften while product rules and private demands persist. The third contribution is empirical positioning. The article specifies which EU instruments bind as of August 2026 and confronts each proposition with the best available evidence, including an analytical bounding model of what firms can achieve on their own.

2. Literature review and theoretical background

Global value chain research holds that in buyer-driven chains lead firms set product and process parameters, environmental ones included, that suppliers must meet without controlling the terms on which they are set (Gereffi et al., 2005). Standards are a main tool of this coordination, and they tend to favour suppliers that already have the capacity to comply, which can push smaller producers out of chains altogether (Nadvi, 2008). Environmental upgrading research builds on this base. De Marchi et al. (2013) show that suppliers can improve environmental performance but that the return depends on whether lead firms reward it. Evidence from Sri Lankan apparel shows buyers using environmental standards to coordinate their chains and suppliers upgrading to stay competitive (Khattak et al., 2015). Ponte (2020) goes further and argues that lead firms turn sustainability into green capital accumulation, capturing value from supplier improvements while passing on the cost. Krishnan et al. (2023) separate the process of environmental upgrading from its outcomes and show that upgrading demanded by buyers can coincide with environmental downgrading for producers, a distinction that matters when a supplier's physical improvement goes unrecognised. Bangladeshi evidence fits this governance logic. Rahman et al. (2025), drawing on 34 stakeholder interviews and factory observation, identify buyer pressure as the main driver of low-carbon action and name limited investment, technical capability and asymmetric bargaining power as the main constraints. Anner (2020) documents how purchasing practices in the Bangladesh garment sector compress prices and lead times, which limits the capital suppliers can commit to improvement. Chen and Akter (2026), using survey data from 503 Bangladeshi garment firms, find that market pressure, resource support and internal commitment operate as interdependent conditions within a single mechanism. What this literature does not do is model constraints that no supplier controls. Upgrading is treated as a firm-level capability even where the carbon content of the firm's electricity and heat is set by the national system. Regulatory diffusion theory explains why EU rules travel. Where the EU market is large and production cannot easily be split by destination, multinationals find it rational to apply the strictest standard across their operations, a mechanism Bradford (2020) calls the Brussels Effect. Recent work qualifies the mechanism. Bastos Lima and Schilling-Vacaflor (2024) show that exporters can segment supply chains by destination and so escape EU due-diligence rules where Europe's market share is small. For Bangladeshi apparel, where the EU takes a large share of exports, that escape route is narrow and the rules bite. Diffusion can also exclude. Jabotinsky and Sarel (2026) argue that when buyers cannot verify supplier conduct cheaply, due-diligence duties can lead them to avoid whole supplier countries, a form of statistical discrimination that harms the producers the rules aim to protect. Wilhelm (2024) notes that mandatory due diligence reallocates governance costs along value chains, and Stadler et al. (2025) trace the pathways through which the Ecodesign for Sustainable Products Regulation (ESPR) and the Corporate Sustainability Due Diligence Directive (CSDDD) reach textile suppliers. This literature largely assumes that public rules and private buyer demands point in the same direction. It has not yet considered what happens when public duties on buyers are withdrawn while product-data rules and private targets remain. Carbon lock-in theory explains why the response is slow. Technologies and institutions co-evolve into a techno-institutional complex that resists change even when better alternatives exist (Unruh, 2000). Seto et al. (2016) distinguish infrastructural, technological, institutional and behavioural lock-in and show that the forms reinforce each other. In both accounts lock-in is a property of a national or sectoral system. A Bangladeshi exporter experiences it second-hand: the carbon intensity of the grid and the gas supply is fixed outside the factory, yet a buyer abroad charges it to the factory's product footprint. Two further mechanisms shape how firms respond. Rebound effects mean that efficiency gains are partly offset by output growth, so intensity gains do not translate one-for-one into absolute reductions (Sorrell, 2009). Decoupling theory predicts that firms facing legitimacy pressure without capacity will produce compliant appearances instead of compliant substance (Bromley & Powell, 2012). Bangladeshi evidence is consistent with this. Rashid and Haque (2024) find that effluent treatment plant adoption is predicted by access to green finance and by regulator staffing but not by the size of fines, and they describe part of the observed compliance

as environmental grandstanding. Locke (2013) shows more generally that private compliance regimes improve measurable, low-cost outcomes far more reliably than capital-intensive ones.
A final strand concerns how separate inputs combine. Where an outcome requires several inputs that cannot substitute for each other, the weakest input sets the outcome. Hirshleifer (1983) formalised this weakest-link logic for public goods, and necessary condition analysis gives it an empirical test: a condition is necessary if the outcome cannot occur without it, whatever the level of other inputs (Dul, 2016). None of the literatures reviewed above applies this logic to supplier decarbonisation, although buyer pathways set separate requirements for electricity, heat and materials (UNFCCC, 2021). Taken together, these strands locate the gap stated in Section 1. Upgrading research explains the pressure on suppliers, diffusion research explains its reach, and lock-in research explains the inertia. None explains why maximum effort on the levers a supplier controls can leave market-recognised alignment almost unchanged.

3. The regulatory context: what "meeting the EU climate requirement" means?

The EU's climate-neutrality objective governs the European economy. It does not turn Bangladesh's Nationally Determined Contribution into an EU obligation. Exposure runs instead through importers, brands and retailers, who must collect product information, manage risk and account for value-chain emissions. Suppliers therefore face contractual conditions that can be stricter and faster than Bangladesh's own mitigation pathway (Government of Bangladesh, 2025; Stadler et al., 2025). Two errors follow when this is missed. The first treats the Carbon Border Adjustment Mechanism (CBAM) as a carbon tariff on garments. Regulation (EU) 2023/956 covers cement, iron and steel, aluminium, fertilisers, electricity and hydrogen, and it entered its definitive phase on 1 January 2026 (European Parliament and Council of the European Union, 2023). The Commission's December 2025 proposal would extend coverage to about 180 steel- and aluminium-intensive downstream goods from 2028, and the Council agreed its general approach on 12 June 2026 (Council of the European Union, 2026a; European Commission, 2025b). Apparel is not among them. The second error infers from this absence that the sector faces no carbon-related market risk. The regulation requires the Commission to assess extension to further goods, including organic chemicals and polymers, which is where synthetic fibre precursors sit (European Parliament and Council of the European Union, 2023). The textile track runs through the EU Strategy for Sustainable and Circular Textiles (European Commission, 2022) and the ESPR, Regulation (EU) 2024/1781, which sets product-specific requirements and creates the Digital Product Passport (European Parliament and Council of the European Union, 2024). The 2025 to 2030 working plan lists textiles, with a focus on apparel, as a priority group, with an indicative delegated act in 2027 and a transition period of at least eighteen months (European Commission, 2025a). The ban on destroying unsold apparel, accessories and footwear applies to large enterprises from 19 July 2026 and to medium-sized enterprises from 19 July 2030 (European Parliament and Council of the European Union, 2024). The reporting and due-diligence pillar changed in 2026. Directive (EU) 2025/794 first deferred application (European Parliament and Council of the European Union, 2025), and Directive (EU) 2026/47, published on 26 February 2026, amended the substance (European Parliament and Council of the European Union, 2026a). Sustainability reporting now applies only to undertakings with more than 1,000 employees that meet turnover or balance-sheet thresholds, which removes about 80 per cent of previously covered companies. Due diligence applies only above 5,000 employees and EUR 1.5 billion net worldwide turnover, from 2029. The duty to adopt and implement a climate transition plan was deleted, and a value-chain cap lets undertakings below 1,000 employees refuse information requests that exceed a voluntary standard (Jabotinsky & Sarel, 2026). Trade preferences changed as well. Regulation (EU) 2026/1395 replaces the previous scheme from 1 January 2027 for ten years, and EBA continues without expiry for least developed countries (European Parliament and Council of the European Union, 2026b). The Council's own assessment is that the special incentive arrangement cannot fully compensate for the loss of EBA status after graduation, because stricter safeguards and rules of origin reduce the preferences that can actually be claimed, by an estimated 80 per cent (Council of the European Union, 2026b). Bangladesh's graduation, scheduled for 24 November 2026, remains unresolved, since the

Economic and Social Council referred an extension request to the General Assembly for decision (United Nations Economic and Social Council, 2026). Table 1 maps the resulting exposure.

Table 1: EU instruments, legal status as of August 2026, and transmission to Bangladeshi suppliers

Instrument	Status (Aug 2026)	Direct obligation on BD supplier?	Transmission mechanism	Exposure intensity
CBAM, Reg. (EU) 2023/956	Definitive phase since 1 Jan 2026; downstream extension proposed for 2028 (COM(2025) 989)	No; apparel out of scope	None currently; possible via future chemical/polymer coverage	Low now, uncertain post-2028
ESPR, Reg. (EU) 2024/1781	In force; textile delegated act indicative 2027, application c. 2028-2029	No, but product cannot be placed on market without compliant data	Importer must hold product-level data; supplier is the only source	High and rising
Digital Product Passport	Data fields to be fixed by textile delegated act	No	Chain-of-custody and primary data demands flow to tier 2 and tier 3	High and rising
Unsold goods destruction ban	Applies to large enterprises from 19 Jul 2026	No	Buyer order discipline, smaller and later buys	Moderate
CSRD as amended by Dir. (EU) 2026/47	Scope narrowed to >1,000 employees; c. 80% of firms removed	No	Buyer data requests, now legally capped for small EU intermediaries	Moderate, reduced from 2024 baseline
CSDDD as amended by Dir. (EU) 2026/47	Scope >5,000 employees and >EUR 1.5bn turnover; applies 2029; transition-plan duty removed	No	Contractual assurances from a smaller set of very large buyers	Reduced but concentrated
GSP, Reg. (EU) 2026/1395	Applies 1 Jan 2027 for ten years; EBA without expiry	No	Tariff exposure conditional on LDC status and post-graduation arrangement	Potentially decisive post-2029
Buyer value-chain targets	Private, contractual, unaffected by Omnibus	Yes, contractually	Purchase orders, supplier scorecards, audit protocols	High and immediate

Source: *Author, based on European Parliament and Council of the European Union (2023, 2024, 2025, 2026a, 2026b), European Commission (2025a, 2025b) and Council of the European Union (2026a, 2026b).*

The pattern in Table 1 is plain. The instruments softened in 2026 are the public ones that placed duties on buyers, while the product-data rules and private contracts were left intact. Pressure on suppliers has moved from public law to private contract (Jabotinsky & Sarel, 2026; Stadler et al., 2025).

4. Theory development: attainable alignment

4.1 Constructs and the conjunctive logic

Attainable Alignment Theory explains when a supplier can achieve climate alignment under buyer-defined requirements despite having limited control over several sources of product-level emissions. Its central proposition is that market-recognised alignment depends on the simultaneous attainment of all necessary abatement conditions and the credible verification of the resulting reductions. Strong performance in one area cannot compensate for a binding constraint in another. The theory begins with an accounting identity. The cradle-to-gate carbon footprint of an exported garment is the sum, across process stages such as spinning, weaving or knitting, wet processing, and cut-make-trim, of electricity use multiplied by the emission factor of delivered electricity and thermal energy use multiplied by the emission factor of process fuel, together with embedded material carbon and logistics emissions (Hasanbeigi & Price, 2012; Niinimäki et al., 2020). This identity identifies four principal abatement levers. Attainable Alignment Theory distinguishes these levers according to their locus of control. The efficiency lever (L1) represents energy intensity and includes motors, drives, compressed-air systems, steam systems, low-liquor dyeing, and energy management. This lever is largely controlled by the firm (Hasanbeigi & Price, 2012). The electricity lever (L2) represents the carbon intensity of delivered electricity. It is mainly determined by the national generation mix, although a firm may influence it through on-site solar generation or credible off-site renewable electricity procurement. The thermal lever (L3) represents the carbon intensity of process heat. It depends on fuel infrastructure and access to technologies such as heat pumps, electric boilers, solar thermal systems, and energy storage (Arpagaus et al., 2018; Madeddu et al., 2020). The material lever (L4) represents fibre-related and upstream carbon. For a cut-make-trim exporter, this lever is largely determined by the sourcing and material choices of the buyer. A fifth construct operates across all four levers. Verification (V) is not an additional abatement lever but a market-access gate. It determines whether a reduction can be demonstrated at the product level through metered, invoiced, calibrated, and chain-of-custody data that an importer can use when placing a product on the EU market. This construct draws on the product-data architecture of the ESPR and on accounting research showing that reported reductions may differ from physical emission reductions (Bjørn et al., 2022; Brander et al., 2018). The theory distinguishes between emissions arithmetic and market alignment. Emissions reductions are additive because reductions achieved across different production stages can be summed. Alignment, however, is conjunctive because buyer pathways often establish separate requirements for electricity, thermal energy, operational efficiency, materials, and reporting. The Fashion Industry Charter for Climate Action, for example, commits signatories to halve emissions by 2030 or adopt science-based targets, source all electricity from renewable sources by 2030, and phase out coal from tier 1 and tier 2 supplier sites by 2030 (UNFCCC, 2021). A supplier may exceed its energy-efficiency requirement but still fail to align if it cannot decarbonise its electricity supply. Surplus performance in one domain therefore cannot be exchanged for a shortfall in another. Following the weakest-link logic of Hirshleifer (1983) and the logic of necessary conditions developed by Dul (2016), attainable alignment is expressed as:

$$\boldsymbol{A = \min(L_1, L_2, L_3, L_4) \times V} \qquad \textbf{(1)}$$

In Equation (1), each lever represents the share of its required contribution to a buyer-defined pathway that is attainable under prevailing exogenous constraints. Each lever is measured from zero to one. Verification equals one when the claimed reduction meets the applicable evidentiary requirements and zero when it does not. The functional form has two important implications. First, maximum effort on a lever controlled by the firm cannot compensate for a binding constraint on a lever controlled by the state, energy system, technology market, or buyer (Hirshleifer, 1983). Second, because verification is multiplicative and binary, an unverified reduction has no recognised market value. In EU market terms, a supplier with a verified 20 per cent reduction may therefore outperform a supplier claiming an unverified 40 per cent reduction. The binary form is a deliberate simplification because verification may be partial when primary data are available for some stages but not for others. It is retained because a product-data regime ultimately treats each required data point as either admissible or inadmissible. This functional form is also consistent with available empirical evidence. Chen and Akter (2026) combined partial least squares structural equation modelling with necessary condition analysis using data from 503 Bangladeshi and 358 Chinese manufacturers. They found that the drivers of sustainability capability function as interdependent conditions within a common mechanism. This pattern is consistent with conjunctive logic because it cannot be fully explained through an additive model. The core statement of Attainable Alignment Theory is therefore: Market-recognised climate alignment is achieved only when every necessary abatement lever reaches an acceptable level and the resulting reductions pass a credible verification gate. The least attainable lever constrains the level of alignment, while absent verification reduces recognised alignment to zero. When lead firms raise performance requirements faster than suppliers can influence system-level levers, the likely outcome shifts from broad environmental upgrading towards selective upgrading, symbolic compliance, or supplier exclusion.

Figure 1: Summarizes the principal constructs and relationships of Attainable Alignment Theory.

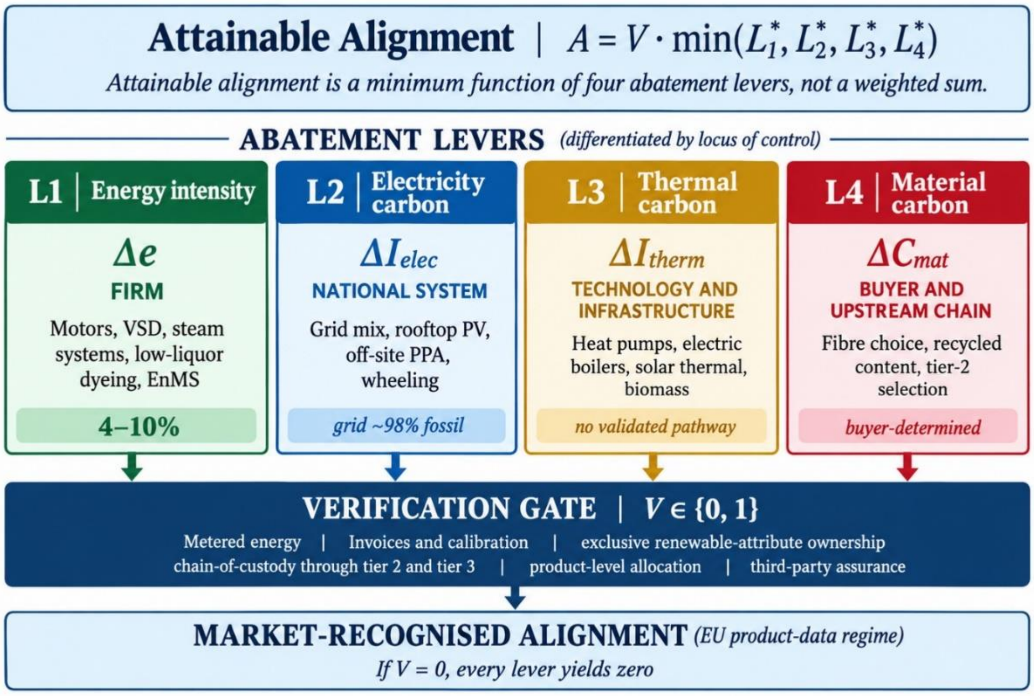

Figure 1. The Attainable Alignment Framework. Four abatement levers are differentiated by locus of control and combine through a minimum function. The verification gate is multiplicative and binary: an unverified reduction has no market value under the EU product-data regime. Source: Author.

4.2 How the theory extends existing concepts

The theory advances three established concepts. First, it extends carbon lock-in from a national property to a transmitted one. Unruh (2000) and Seto et al. (2016) locate lock-in in the system that owns the infrastructure. The AAT shows how a foreign buyer's footprint rules charge that lock-in to a supplier that owns none of it, so the supplier carries the cost of lock-in without holding the levers that could break it. This condition can be called transmitted lock-in. Second, the theory adds verification to environmental upgrading. De Marchi et al. (2013) and Krishnan et al. (2023) tie the return on upgrading to lead-firm recognition. The AAF specifies how recognition happens: upgrading earns a market return only when it passes an evidentiary standard, and physical upgrading that fails the standard counts, in market terms, for nothing. Third, the theory identifies a privatised Brussels Effect. Bradford (2020) describes diffusion through public rules that firms choose to generalise. After the 2026 amendments, the reach of EU demands on Bangladeshi suppliers depends increasingly on product-data rules and private buyer contracts, while the public duties that obliged buyers to act on their value chains have been cut back. The standard still travels. The obligation to share its cost does not.

4.3 Propositions

Five propositions follow from the theory. Each is stated with the evidence that would refute it, so that the theory can be tested and not merely illustrated (Whetten, 1989).

Proposition 1 (efficiency ceiling) holds that factory-level energy efficiency alone cannot deliver more than roughly a tenth of operational emissions reduction in the Bangladeshi textile and garment chain. It rests on rebound (Sorrell, 2009) and on the arithmetic of the identity, in which efficiency changes the quantity of energy while grid and fuel emission factors stay fixed. A representative multi-facility panel showing operational reductions above 25 per cent from efficiency alone, with production volume held constant, would refute it.

Proposition 2 (Scope 2 lock) holds that market-based Scope 2 reduction for the sector is bounded by the availability of additional renewable generation and by the cost of capital, not by roof area. It rests on lock-in theory and on accounting research showing that unbundled certificates do not change physical generation (Bjørn et al., 2022; Brander et al., 2018). Evidence that sector rooftop generation can meet sector demand at temporally matched resolution, or that adoption does not respond to financing cost, would refute it.

Proposition 3 (thermal residual) holds that wet-processing heat is the binding residual, so that without low-carbon heat deep reduction is arithmetically out of reach whatever happens to electricity. It rests on engineering evidence that process heat dominates wet-processing energy (Hasanbeigi & Price, 2012) and that heat pumps and direct electrification face temperature and grid-carbon limits (Arpagaus et al., 2018; Madeddu et al., 2020). A validated wet-processing pathway achieving more than 50 per cent direct-fuel reduction at commercial scale in Bangladesh would refute it.

Proposition 4 (verification gate) holds that the immediate EU-facing constraint is verifiability and not abatement. It rests on the product-data architecture of the ESPR (Stadler et al., 2025) and on decoupling theory (Bromley & Powell, 2012). Evidence that importers or ESPR delegated rules accept unverified supplier declarations on a par with assured primary data would refute it.

Proposition 5 (redistribution, not relief) holds that the 2026 Omnibus amendments moved compliance pressure from public regulation to private contract while removing the reciprocal duties that would have obliged buyers to co-invest, which raises the probability of supplier exclusion relative to supplier transition. It rests on standards-driven exclusion (Nadvi, 2008), price squeeze (Anner, 2020) and statistical discrimination in due-diligence regimes (Jabotinsky & Sarel, 2026). Evidence that buyers relaxed supplier-emission requirements, or that supplier consolidation slowed after February 2026, would refute it.

5. Research approach

This is a conceptual, theory-building article. It follows the model-building design described by Jaakkola (2020), in which a theory is assembled from established concepts, stated as testable propositions and then confronted with the best available evidence. Three elements support the propositions. The first is a structured evidence assessment. Scopus, Web of Science, ScienceDirect and Google Scholar were searched for January 2019 to August 2026 using combinations of (“Bangladesh” OR “ready-made garment” OR “RMG” OR “textile”) AND (“energy efficiency” OR “greenhouse gas” OR “decarbonisation” OR “rooftop solar” OR “Scope 2” OR “process heat”). Legal instruments were taken from EUR-Lex and the Official Journal, and national data from the UNFCCC registry and Government of Bangladesh sources. Studies were included if they reported measurement, modelling or survey evidence on at least one lever or on verification, and if a DOI, ISBN or stable institutional URL allowed checking. Commentary without a stated method was used only for attributed market facts. Sources were not treated as interchangeable. Legal claims rest on the instruments themselves, national commitments on the NDC as submitted, factory findings on peer-reviewed studies, and sector capacity figures on named institutional studies, such as the Centre for Policy Dialogue (CPD, 2026) rooftop mapping, reported with their sampling frames. Each study was appraised for transparency of sampling frame, representativeness relative to the sector's size distribution, whether measurement was metered or self-reported, and whether a counterfactual was stated (Table 2). Where sources conflict, both are reported and the conflict is treated as a finding. The second element is an analytical bounding model. Using the identity in Section 4.1, it calculates the largest operational reduction a supplier can reach with the levers it controls, holding grid and fuel emission factors at current values. Because no representative inventory reports how operational emissions split between electricity and heat, the electricity share is varied between 40 and 70 per cent instead of being fixed. The third element compares the national pathway in NDC 3.0 with buyer pathways to locate the gap the theory predicts. The main limitation of the design deserves mention here, with others discussed in Section 9.3. No recent representative facility-level emissions inventory exists across the sector's subsectors and size classes. Regression, structural equation or time-series testing of the propositions therefore requires a primary panel that does not yet exist, and the evidence establishes direction and technical potential, not a complete statistical baseline. That absence matters for the theory itself, because EU-facing compliance depends on exactly the auditable primary data the sector cannot yet produce.

Table 2: Core evidence base and appraisal

Source	Design and scale	Lever informed	Key quantity	Principal limitation
Khan et al. (2022)	Engineering audit, one composite RMG factory	L1	9.78% GHG reduction from full measure package	Single case; no counterfactual production path
Habib et al. (2026)	Detailed energy assessment, one textile plant, VSD and HEM modelling	L1	Modelled savings by speed reduction increment	Modelled not metered savings; one plant
Hasan et al. (2019)	Survey of large textile mills; drivers and barriers	L1	3 to 4% gain from energy management practice	Self-reported; large firms only
Al Mamun et al. (2022)	Measurement across 15 dyeing mills	L1, L3	2.58 kWh and 97.27 L per kg dyed fabric	Wet processing only
Sayam et al. (2025)	Measurement across 14 factories, five districts, April 2025	L1, L2	Solar use 5-11,000 kWh/month against electricity to 866,692 kWh	Cross-sectional single month
Hasan et al. (2024)	Sectoral energy and GHG accounts, Savar, 2019-2021	L2, L3	Gas dominant; emissions rising; solar minimal	One cluster; three years
Talut et al. (2022)	GIS and techno-economic modelling, 6,045 industrial plants	L2	7.4 GWp national industrial rooftop potential; 11 TWh/yr	All industry, not RMG-specific; 2022 prices
CPD (2026)	Satellite rooftop mapping, 3,320 factories, 9.73 million m^2	L2	1,768 MWp potential; 509 investment-ready at 9.8%, zero at 10.5%	Institutional study; financing assumptions decisive
Rabbani et al. (2025)	Survey of 661 factories, Gazipur and Savar	L2	31% adoption; half of installations not serving production	Two districts; binary adoption indicator
Mapped in Bangladesh (2026)	Survey of 878 export-oriented factories	L2, G	Solar 3% of consumption; potential 14% of demand; 80% below 1% renewable	Self-reported energy shares
Government of Bangladesh (2025)	National mitigation accounts and targets	All	BAU and target trajectories by subsector to 2035	Government projection, not independent

Source: *Author's appraisal of the studies listed.*

6. Confronting the propositions with evidence

6.1 The layered energy architecture

The chain is not energy-homogeneous. Cut-make-trim assembly uses electricity for sewing, compressed air, lighting, ventilation and ironing. Spinning needs continuous electrical power for frames, humidification and compressed air. Dyeing and finishing combine electricity with large volumes of steam and process heat, and washing plants consume hot water, dryers and boilers (Hasanbeigi & Price, 2012). The carbon intensity of an exported garment therefore depends mainly on where its fabric was made and wet-processed, much less on the sewing floor. In Savar, natural gas was the dominant source across garments, textiles and dyeing, emissions rose between 2019 and 2021, and solar use was negligible (M. M. Hasan et al., 2024). Across fourteen factories in Gazipur, Savar, Dhamrai, Narayanganj and Chittagong in April 2025, monthly electricity use ranged from 100 to 866,692 kWh against solar generation of 5 to 11,000 kWh, a ratio of roughly 79 to 1 at the upper bound (Sayam et al., 2025). Figure 2 assembles the evidence on the first two levers.

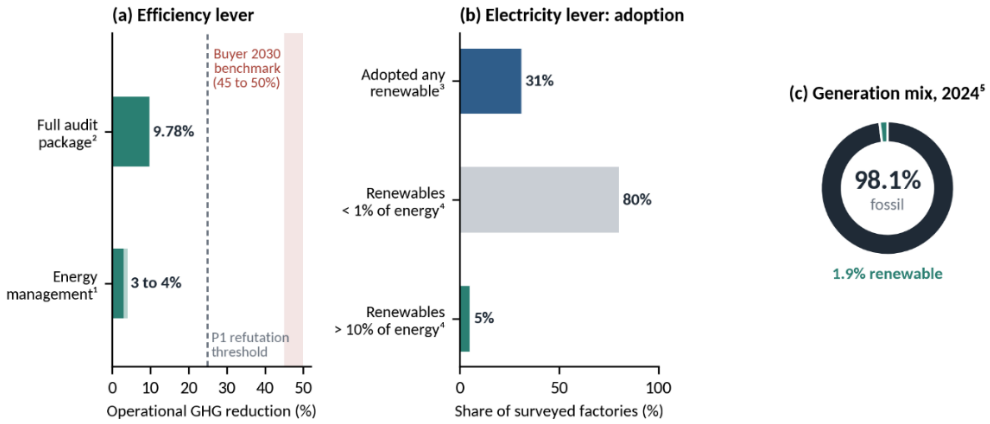

Figure 2: Evidence on the first two levers. (a) Documented operational greenhouse gas reductions attributable to factory-level efficiency measures, against the refutation threshold specified for Proposition 1. (b) Renewable technology adoption across surveyed export-oriented factories. (c) National electricity generation mix, 2024. Source: Author, based on Khan et al. (2022), A. S. M. M. Hasan et al. (2019), Rabbani et al. (2025), Mapped in Bangladesh (2026) and Worldometer (2026).

6.2 The efficiency lever and its ceiling

A composite factory audit estimated that boiler modification, efficient pumps, gas generators, motors and lighting together would cut greenhouse gas emissions by 9.78 per cent (Khan et al., 2022). Survey work across large textile mills found that energy management practice alone yields 3 to 4 per cent (A. S. M. M. Hasan et al., 2019). Plant-level assessment shows sizeable technical savings from variable-speed drives and high-efficiency motors, with financial results that depend on loading, motor size, operating hours and achievable speed reduction (Habib et al., 2026), and earlier work on a garment building found high-efficiency motors more cost-effective than drives at typical loadings (Habib et al., 2016). Water efficiency adds to these gains, since less water pumped is less water heated, treated and discharged (Al Mamun et al., 2022). These measures deserve priority. Paybacks are short to moderate, they improve energy security in a supply-constrained system, and they need no outside permission. Three ceilings still bind. Rebound absorbs part of the gain as output grows (Sorrell, 2009). The remaining energy still carries the grid or fuel emission factor, so the efficiency lever reduces quantity while the electricity and thermal levers fix carbon content. And in wet processing, efficient steam systems reduce but cannot remove a fossil heat demand. Across independent studies the documented range is about 4 to 10 per cent, well inside the refutation threshold of 25 per cent. Proposition 1 is supported.

6.3 The electricity lever and the Scope 2 lock

Installed capacity of 31,389 MW in late December 2025 carried a renewable share of 5.4 per cent (The Business Standard, 2026), and generation is more fossil-heavy still, with fossil fuels supplying about 98.1 per cent of electricity in 2024 (Worldometer, 2026). The NDC records demand growth averaging 6.91 per cent a year over the preceding decade (Government of Bangladesh, 2025). A factory can therefore improve its electricity intensity while its location-based Scope 2 footprint barely moves. On-site solar is the obvious response, and the evidence on its limits is unusually precise. National industrial rooftop potential was estimated at 7.4 GWp across 6,045 plants, or 11 TWh a year (Talut et al., 2022). Satellite mapping of 9.73 million square metres of usable roof across 3,320 garment factories yields 1,768 MWp of technical potential requiring USD 188.2 million (CPD, 2026). Survey evidence puts the ceiling at up to 14 per cent of sector electricity demand, against a current solar contribution of about 3 per cent, with roughly 80 per cent of factories drawing less than 1 per cent of their energy from renewables (Mapped in Bangladesh, 2026). A survey of 661 factories in Gazipur and Savar found that 31 per cent had adopted any renewable technology, mostly rooftop solar at low capacity, and that half of the installed systems did not serve production processes (Rabbani et al., 2025). The decisive quantity is the cost of finance. In the CPD (2026) mapping, 509 factories are investment-ready at a blended financing rate of 9.8 per cent and none at a commercial rate of 10.5 per cent, so a movement of 70 basis points removes the investable pipeline altogether. Roof area is not the binding constraint: fully exploited, it covers about 14 per cent of demand, on a daytime profile poorly matched to continuous spinning and dyeing loads. Scaling needs off-site procurement through corporate power purchase agreements, wheeling, green tariffs and a registry with additionality rules. Without these, claims of renewable supply will rest on unbundled certificates that leave the national generation mix unchanged, the integrity problem that accounting research has flagged for corporate science-based targets (Bjørn et al., 2022; Brander et al., 2018). Bangladesh has moved in this direction. The National Renewable Energy Development Strategy 2026 to 2030, released in draft in June 2026 and approved in July, targets 20 per cent renewable electricity by 2030, including 5,500 MW of rooftop solar, and proposes a dedicated fund and payment guarantees (Power Division, 2026). Proposition 2 is supported. Figure 3 sets the financing discontinuity against the coverage ceiling.

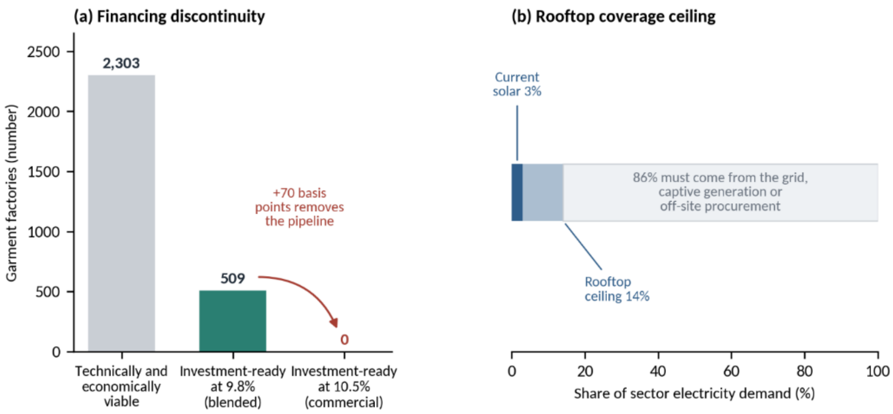

Figure 3: The two bounds on the electricity lever. (a) Investment-ready factories fall from 509 to zero across a 70 basis point movement in the cost of capital. (b) Even fully exploited, rooftop generation is bounded at about 14 per cent of sector electricity demand. Source: Author, based on CPD (2026) and Mapped in Bangladesh (2026).

6.4 The thermal lever

Dyeing, washing, drying and finishing need steam and heat that electricity decarbonisation does not touch. Steam-system efficiency, condensate recovery, economisers, heat recovery and low-liquor-ratio dyeing reduce the quantity of fossil heat but not its carbon content (Hasanbeigi & Price, 2012). Each substitute comes with a qualification. Industrial heat pumps serve low- and medium-temperature loads where process design permits, but high-temperature units remained at an early market stage when last reviewed (Arpagaus et al., 2018). Direct electrification of heat cuts emissions substantially only where the electricity is low-carbon (Madeddu et al., 2020), so with a grid that is about 98 per cent fossil an electric boiler in Bangladesh moves emissions from the thermal lever to the electricity lever without removing them. Solar thermal can preheat process water and storage can shift demand, but neither displaces base load. Biomass can lower fossil-carbon accounting, but weak feedstock safeguards can erase the benefit. Bangladesh's policy framework acknowledges the gap without closing it. NDC 3.0 lists cogeneration in textiles and the gradual replacement of diesel and oil-fired boilers with electric boilers and induction systems, but it sets no thermal-specific target and no financing instrument (Government of Bangladesh, 2025). This is lock-in in Unruh's (2000) sense, with sunk capital, fuel infrastructure and institutional routine reinforcing each other. No candidate refutation exists in the Bangladeshi literature, and Proposition 3 is supported.

6.5 The verification gate

Under the ESPR, textile Digital Product Passport duties will bind only after the delegated act is adopted (European Commission, 2025a). Once they apply, compliant product data become a condition of EU market placement, and suppliers become the main source of process and chain-of-custody evidence (European Parliament and Council of the European Union, 2024; Stadler et al., 2025). The Joint Research Centre's May 2026 study on passport content for apparel proposes structured mandatory data elements, with the production batch as the minimum level of granularity and differentiated access rights (Joint Research Centre, 2026). These data must exist and be verifiable whether or not they are made public. Bangladeshi capacity to produce such data is weak in a specific way. There is no common facility-level protocol, submetering is uneven, allocation from organisation to product is largely absent, and multi-tier chain-of-custody is fragmented by subcontracting (Rahman et al., 2025). A footprint built on generic emission factors may be inadmissible under a product-data regime. A factory that has installed rooftop solar but cannot show exclusive ownership of the renewable attribute, or that has cut steam demand but cannot allocate the saving to a product, has produced physical abatement with no market value. The finding that half of the installed solar systems in the Gazipur and Savar survey do not serve production (Rabbani et al., 2025) shows the gap clearly: the physical capacity exists, the recognised abatement does not. Proposition 4 is supported, with the caveat that the delegated act is still pending. Table 3 summarises the levers and the gate.

Table 3: The four levers and the gate

Levers	L1 Energy intensity	L2 Electricity carbon	L3 Thermal carbon	L4 Material carbon	G Verification
Locus of control	Firm	National system + firm procurement	Technology and infrastructure	Buyer and upstream chain	Firm, but requires common protocol
Documented magnitude	c. 4 to 10% of operational emissions	Grid c. 98% fossil; rooftop ceiling c. 14% of sector demand	No validated pathway at scale	Not measurable without tier-2 traceability	Binary
Binding constraint	Rebound; residual carries grid or fuel factor	Additional generation; cost of capital above c. 9.8%	Temperature range; grid carbon; feedstock safeguards	Buyer sourcing decisions	Metering, allocation, chain-of-custody, assurance
Time to effect	6-24 months	3-7 years	5-12 years	2-5 years	12-30 months
Effect if unresolved	Ceiling on all downstream gains	Caps market-based Scope 2	Caps total reduction arithmetically	Caps cradle-to-gate footprint	Nullifies all four levers

Source: *Author, synthesised from Tables 1 and 2 and Section 6.*

6.6 What a supplier can reach alone: a bounding model

The bounding model makes the conjunctive claim concrete. Let s be the share of a supplier's operational emissions that comes from electricity. If an efficiency gain e applies to all energy and rooftop solar covers a share r of electricity at zero carbon, remaining emissions are $(1 - e)(1 - r{\cdot}s)$ of the baseline. At the documented upper values ($e = 0.10$ and $r = 0.14$), the attainable reduction is 15.0 per cent when $s = 0.40$, 16.9 per cent when $s = 0.55$ and 18.8 per cent when $s = 0.70$. At current adoption ($e = 0.04$, $r = 0.03$, $s = 0.55$) it is about 5.6 per cent. The buyer benchmark is 45 to 50 per cent by 2030 (Intergovernmental Panel on Climate Change [IPCC], 2018; UNFCCC, 2021). Solving the same expression for a 45 per cent reduction, with efficiency at its ceiling and heat left as it is, shows that between about 56 per cent ($s = 0.70$) and 97 per cent ($s = 0.40$) of electricity would need to be zero-carbon. That lies far beyond the rooftop ceiling of 14 per cent and can come only from off-site additional generation (Bjørn et al., 2022). The binding lever is therefore electricity for electricity-heavy spinning and assembly units, and heat for wet processors, whose thermal load stays fossil at every point in the range (Hasanbeigi & Price, 2012). The model is deliberately generous. It ignores rebound, assumes rooftop generation is fully verified, and applies a buyer target that covers Scopes 1 to 3 to supplier operations alone. Even so, the envelope that firms control reaches less than half of what buyers ask.

7. The national pathway and the ambition wedge

Bangladesh's Third Nationally Determined Contribution, submitted on 29 September 2025, reframes the arithmetic. Base-year 2022 emissions were 252.04 MtCO2eq, of which energy contributed 123.01 Mt. Business-as-usual emissions for 2035 are projected at 418.40 MtCO2eq, and the economy-wide targets are 6.39 per cent unconditional and 13.92 per cent conditional, a combined 20.31 per cent at a stated cost of USD 116.18 billion, of which USD 90.23 billion depends on international support (Government of Bangladesh, 2025).

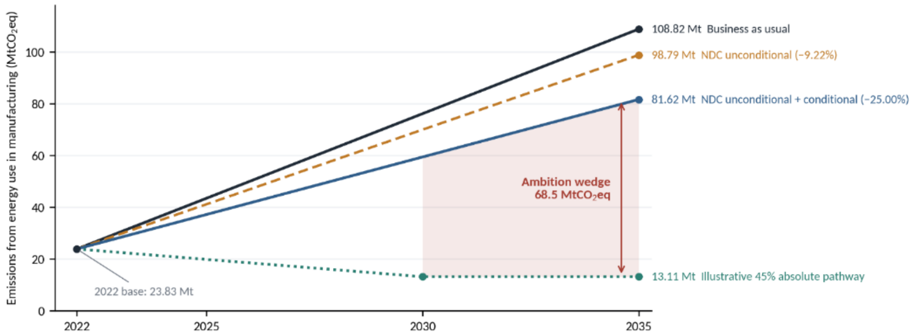

Figure 4: The ambition wedge. Energy use in manufacturing becomes Bangladesh's largest emitting subsector by 2035 under NDC 3.0, and the fullest internationally financed commitment leaves it about 68.5 MtCO2eq above an illustrative absolute 45 per cent pathway. Source: Author, based on Government of Bangladesh (2025), NDC 3.0 Tables 1 to 3.

Energy use in manufacturing is projected to reach 108.82 MtCO2eq by 2035, or 26.01 per cent of national emissions, which makes it the largest emitting subsector, ahead of power generation at 61.66 Mt. For this subsector the NDC commits to a combined reduction of 27.20 Mt, or 25.00 per cent below business as usual by 2035, relying on a 10 per cent efficiency improvement and industrial rooftop solar. Buyer pathways run faster. Fashion Charter signatories commit to halve emissions by 2030 or follow science-based targets and to phase coal out of supplier sites by 2030 (UNFCCC, 2021), in line with the roughly 45 per cent global reduction by 2030 that 1.5 °C pathways require (IPCC, 2018). Bangladesh's most ambitious industrial commitment, if fully financed, is 25 per cent below a rising baseline by 2035, while buyers seek about 45 per cent absolute reduction five years earlier. This article calls the gap the ambition wedge. A supplier can comply fully with the national pathway and still fail a buyer's science-based target, and a leading factory can cut its operational emissions while its location-based Scope 2 position worsens under expanded coal and gas dispatch. The NDC recognises the sector's exposure to stricter buyer standards but provides no sector target, thermal instrument or financing facility (Government of Bangladesh, 2025). Figure 4 presents the wedge.

8. Rival explanations

A theory has to be judged against its rivals, and two are prominent. The first is a frontier-firm reading, and it has substance. Bangladesh's garment industry is geographically concentrated, which supports shared infrastructure and aggregated procurement. Exporters have two decades of audit experience and an unusually large stock of certified green buildings (Rashid & Haque, 2024). Machinery turns over quickly and the policy framework has moved (Power Division, 2026). On this reading a cohort of large integrated exporters meets buyer pathways before 2030 and gains share. The AAF agrees that such firms can pass the gate; it disputes that their success generalises. The second is a structural reading, which is stronger at sector level. Grid decarbonisation is outside any factory's control, wet processing remains gas-dependent, and access to finance is unequal, to the point that the investment-ready set is empty at a 10.5 per cent commercial rate (CPD, 2026). Fragmented subcontracting defeats chain-of-custody, and purchasing practices continue to reward low prices and short lead times (Anner, 2020). Eurostat data show Bangladeshi apparel unit values in the EU falling 3.25 per cent in January to November 2025 while export value rose 7.65 per cent, a pattern of volume-led growth underprice compression (The Financial Express, 2026a). Suppliers are being asked to finance a capital-intensive transition out of contracting margins. Rahman et al. (2025) reach a similar conclusion: buyer pressure starts environmental upgrading but does not resolve the financing and power asymmetries that decide whether suppliers can invest. The theory supports a third reading and treats it as the more probable one. The 2026 Omnibus amendments are widely read in Dhaka as relief. The AAF reads them as a redistribution of obligation that leaves suppliers worse placed. The deleted transition-plan duty was the provision most likely to make buyers fund supplier abatement, because a credible transition plan for an apparel brand is mostly a Scope 3 plan and therefore a supplier-investment plan. Raising the due-diligence threshold to 5,000 employees and deferring it to 2029 removes the legal duty to address value-chain impacts from most buyers, and the information cap protects intermediaries below 1,000 employees, which covers many European importers but essentially no Bangladeshi exporters (European Parliament and Council of the European Union, 2026a).

Table 4: Propositions, verdict and discriminating evidence

Proposition	Verdict	Discriminating evidence	Strength
P1 Efficiency ceiling	Supported	9.78% (Khan et al., 2022); 3 to 4% (A. S. M. M. Hasan et al., 2019); modelled VSD gains (Habib et al., 2026)	Strong; three independent designs converge
P2 Scope 2 lock	Supported	98.1% fossil generation; 14% rooftop demand ceiling; 509 to 0 investment-ready across 70 bp	Strong; discontinuity is directly measured
P3 Thermal residual	Supported	Gas dominance (M. M. Hasan et al., 2024); no validated substitution pathway; no NDC thermal target	Moderate; supported by absence of counter-evidence
P4 Verification gate	Supported	ESPR data architecture; half of solar not serving production (Rabbani et al., 2025); no common protocol	Moderate to strong; delegated act still pending
P5 Redistribution not relief	Supported	Dir. (EU) 2026/47 removals versus unchanged ESPR and private targets	Provisional; requires post-2026 longitudinal test

Source: *Author, based on the evidence reported in Sections 6 and 8.*

Nothing that creates cost for suppliers was softened. The ESPR and the passport are unaffected, the destruction ban took effect in July 2026, and private buyer targets were never in scope.

Demand for supplier data and performance therefore persists, while the countervailing duty that would have made buyers partners in meeting it has gone. Under these conditions the rational buyer response to verification cost is consolidation: fewer suppliers, retained because they can already evidence performance. This matches the exclusion mechanism of standards-based governance (Nadvi, 2008) and the statistical discrimination predicted for due-diligence regimes (Jabotinsky & Sarel, 2026). Early 2026 trade data are consistent with rising pressure: Bangladeshi apparel exports to the EU fell 19.33 per cent in value in January to April 2026, with unit prices down 10.45 per cent (The Financial Express, 2026b). Weak demand and trade diversion contribute to this, and the data cannot isolate an Omnibus effect. Combined with the graduation uncertainty set out in Section 3, the evidence makes exclusion the likely outcome for smaller and thermally intensive suppliers. Proposition 5 is supported on current evidence, but it is the proposition most in need of longitudinal testing. Table 4 summarises the verdicts.

9. Discussion

9.1 Theoretical implications

The findings carry four implications for theory. First, they support treating decarbonisation alignment in supplier economies as a conjunctive outcome. Much of the upgrading literature implicitly treats supplier effort as additive, so that more effort yields more recognised improvement (De Marchi et al., 2013; Khattak et al., 2015). The evidence here suggests that the weakest lever sets recognition, which explains why diligent suppliers can record little progress. Second, lock-in theory gains a transmission channel. The grid and gas lock-in that Unruh (2000) and Seto et al. (2016) analyse at national level reappears as a firm-level liability once a buyer's accounting rules charge it to a product. Lock-in studies should therefore add the value chain to the national system as a unit of analysis. Third, verification is a construct in its own right. The distinction between upgrading and downgrading drawn by Krishnan et al. (2023) can be read through the gate: physical upgrading that fails verification behaves in market terms like no upgrading, and verification capacity can become a new basis for stratifying suppliers, in line with the exclusionary potential of standards identified by Nadvi (2008). Fourth, the Brussels Effect has a privatised variant. When public duties on lead firms are narrowed but product rules and private targets remain, EU standards keep travelling while the cost-sharing obligations that accompanied them do not. This condition sharpens the concern of Bastos Lima and Schilling-Vacaflor (2024) and Jabotinsky and Sarel (2026) that diffusion can exclude as readily as it upgrades.

9.2 Managerial and policy implications

For supplier managers, the theory reorders priorities. Verification comes first, because without metered, allocated and assured data every later investment is unbankable in EU market terms. A common national protocol covering fuel by type, grid and captive electricity, on-site renewables, steam, refrigerants and production volume, with allocation rules that follow actual processes instead of revenue, would let suppliers share the fixed cost of passing the gate. Efficiency remains worth pursuing for its payback and energy security, but managers should not expect it to deliver alignment on its own (A. S. M. M. Hasan et al., 2019; Khan et al., 2022). For buyers, pressure without co-investment produces exclusion. Longer contracts, minimum volume commitments, shared savings, advance purchase agreements for low-carbon product and credit enhancement change the supplier's investment calculus, because factories will not take long-term debt against short-term orders at falling prices (Anner, 2020; Rahman et al., 2025). Buyers that intend to meet Scope 3 targets have a direct interest in funding the electricity and thermal levers their suppliers cannot move alone, and in accepting renewable instruments only when they are traceable, exclusive and additional (Bjørn et al., 2022). For policymakers, the most actionable single quantity is the financing discontinuity. A facility that delivers blended finance at or below 9.8 per cent would turn an empty pipeline into 509 investment-ready factories (CPD, 2026), and tying disbursement to measured savings would reduce the grandstanding risk documented by Rashid and Haque (2024). Off-site procurement needs transparent wheeling charges, standard power purchase contracts, settlement rules and a national attribute registry that prevents double counting. Heat needs its own plan, built on a process heat map by temperature band, pilots of heat pumps and of electric boilers tied to contracted renewables, and safeguards on biomass. A dedicated transition facility for smaller suppliers follows from Proposition 5, since without one consolidation is the default. Throughout, a just transition matters: automation and consolidation carry employment costs, and skills for electricians, boiler operators and energy managers are preconditions for every step above.

9.3 Limitations and future research

The theory has limits. Its evidence base relies on case factories and clusters, several capacity estimates come from institutional studies, and the EU position is fixed at August 2026 while the textile delegated act, the graduation decision and the CBAM downstream regulation remain open. The binary gate simplifies a process that may in practice be graded, and the material lever receives less attention than the others because its evidence base is thinnest. These limits define a testing agenda. A stratified facility-level inventory by subsector, size, technology and fuel would allow Propositions 1 to 3 to be tested by regression on metered data. Time-series analysis that separates efficiency from capacity utilisation and product mix would measure rebound directly. Structural equation modelling combined with necessary condition analysis (Dul, 2016), of the kind used by Chen and Akter (2026), could test whether the levers behave as necessary conditions, which is the core claim of Equation (1). Product carbon studies using primary supplier data would test whether the gate can be passed under realistic subcontracting. Longitudinal analysis of buyer sourcing before and after February 2026 would test Proposition 5, and system-dynamics modelling could capture feedbacks such as higher energy prices that shorten efficiency payback while weakening factory cash flow.

10. Conclusion

This article asked why factory effort in Bangladesh's garment sector translates so weakly into EU-recognised climate alignment. Its answer is a theory. Alignment is conjunctive: the lever furthest from its required contribution caps it, and a verification gate multiplies it. The levers Bangladeshi firms control are the smallest ones, and the binding levers of electricity and heat sit in a national system the firms do not own. The evidence supports all five propositions, the fifth provisionally. The scholarly contribution lies in three extensions. Carbon lock-in can be transmitted across borders through value-chain accounting. Environmental upgrading earns a market return only when it passes an evidentiary standard. EU regulatory reach can persist in a privatised form that carries standards without the duties that once shared their cost. Each extension is stated as a refutable proposition, which gives future empirical work, including regression and structural models on facility panels, a clear target. The debate should move from whether Bangladesh can meet a target it was never assigned to the conditions under which alignment becomes attainable. Whether the transition proves broad or regressive will depend less on any single carbon target than on whether the costs of the system are shared as widely as its requirements.

References

Al Mamun, A., Bormon, K. K., Rasu, M. N. S., Talukder, A., Freeman, C., Burch, R., & Chander, H. (2022). An assessment of energy and groundwater consumption of textile dyeing mills in Bangladesh and minimization of environmental impacts via long-term key performance indicators baseline. *Textiles, 2*(4), 511–523. https://doi.org/10.3390/textiles2040029

Anner, M. (2020). Squeezing workers' rights in global supply chains: Purchasing practices in the Bangladesh garment export sector in comparative perspective. *Review of International Political Economy, 27*(2), 320–347. https://doi.org/10.1080/09692290.2019.1625426

Arpagaus, C., Bless, F., Uhlmann, M., Schiffmann, J., & Bertsch, S. S. (2018). High temperature heat pumps: Market overview, state of the art, research status, refrigerants, and application potentials. *Energy, 152*, 985–1010. https://doi.org/10.1016/j.energy.2018.03.166

Bastos Lima, M. G., & Schilling-Vacaflor, A. (2024). Supply chain divergence challenges a 'Brussels effect' from Europe's human rights and environmental due diligence laws. *Global Policy, 15*(2), 260–275. https://doi.org/10.1111/1758-5899.13326

Bjørn, A., Lloyd, S. M., Brander, M., & Matthews, H. D. (2022). Renewable energy certificates threaten the integrity of corporate science-based targets. *Nature Climate Change, 12*(6), 539–546. https://doi.org/10.1038/s41558-022-01379-5

Bradford, A. (2020). *The Brussels effect: How the European Union rules the world*. Oxford University Press. https://doi.org/10.1093/oso/9780190088583.001.0001

Brander, M., Gillenwater, M., & Ascui, F. (2018). Creative accounting: A critical perspective on the market-based method for reporting purchased electricity (scope 2) emissions. *Energy Policy, 112*, 29–33. https://doi.org/10.1016/j.enpol.2017.09.051

Bromley, P., & Powell, W. W. (2012). From smoke and mirrors to walking the talk: Decoupling in the contemporary world. *Academy of Management Annals, 6*(1), 483–530. https://doi.org/10.5465/19416520.2012.684462

Centre for Policy Dialogue. (2026, August 20). *Industrial rooftop solar in the RMG sector: Investment potential under a Chinese FDI lens* [Conference presentation]. Fifth Bangladesh-China Renewable Energy Forum, Dhaka, Bangladesh. https://cpd.org.bd/industrial-rooftop-solar-in-the-rmg-sector/

Chen, P.-K. A., & Akter, M. H. (2026). Building self-reinforcing capability for green supply chain ecosystems: Strategic insights from Bangladesh's RMG industry. *Business Strategy and the Environment*. Advance online publication. https://doi.org/10.1002/bse.70637

Council of the European Union. (2026a, June 12). *Council moves to strengthen the EU's carbon border adjustment mechanism* [Press release]. https://www.consilium.europa.eu/en/press/press-releases/2026/06/12/council-moves-to-strengthen-the-eu-s-carbon-border-adjustment-mechanism/

Council of the European Union. (2026b). *Report on the Generalised Scheme of Preferences covering the period 2023–2025* (ST 12037/26). https://data.consilium.europa.eu/doc/document/ST-12037-2026-INIT/en/pdf

De Marchi, V., Di Maria, E., & Micelli, S. (2013). Environmental strategies, upgrading and competitive advantage in global value chains. *Business Strategy and the Environment, 22*(1), 62–72. https://doi.org/10.1002/bse.1738

Dul, J. (2016). Necessary condition analysis (NCA): Logic and methodology of "necessary but not sufficient" causality. *Organizational Research Methods, 19*(1), 10–52. https://doi.org/10.1177/1094428115584005

European Commission. (2022). *EU strategy for sustainable and circular textiles* (COM(2022) 141 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022DC0141

European Commission. (2025a). *Ecodesign for Sustainable Products Regulation and Energy Labelling working plan 2025–2030* (COM(2025) 187 final). https://green-forum.ec.europa.eu/news/2025-2030-working-plan-2025-07-11_en

European Commission. (2025b). *Proposal for a regulation amending Regulation (EU) 2023/956 as regards the extension of its scope to downstream goods and anti-circumvention measures* (COM(2025) 989 final). https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=COM%3A2025%3A989%3AFIN

European Commission. (2026). *EU trade relations with Bangladesh*. Directorate-General for Trade and Economic Security. https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/countries-and-regions/bangladesh_en

European Parliament and Council of the European Union. (2023). Regulation (EU) 2023/956 of 10 May 2023 establishing a carbon border adjustment mechanism. *Official Journal of the European Union*, L 130, 52–104. https://eur-lex.europa.eu/eli/reg/2023/956/oj

European Parliament and Council of the European Union. (2024). Regulation (EU) 2024/1781 of 13 June 2024 establishing a framework for the setting of ecodesign requirements for sustainable products. *Official Journal of the European Union*, L, 2024/1781. https://eur-lex.europa.eu/eli/reg/2024/1781/oj

European Parliament and Council of the European Union. (2025). Directive (EU) 2025/794 of 14 April 2025 amending Directives (EU) 2022/2464 and (EU) 2024/1760 as regards the dates from which Member States are to apply certain corporate sustainability reporting and due diligence requirements. *Official Journal of the European Union*, L, 2025/794. https://eur-lex.europa.eu/eli/dir/2025/794/oj

European Parliament and Council of the European Union. (2026a). Directive (EU) 2026/47 amending Directives 2006/43/EC, 2013/34/EU, (EU) 2022/2464 and (EU) 2024/1760 as regards certain corporate sustainability reporting and due diligence requirements. *Official Journal of the European Union*, L, 2026/47.

European Parliament and Council of the European Union. (2026b). Regulation (EU) 2026/1395 of 17 June 2026 on applying a generalised scheme of tariff preferences and repealing Regulation (EU) No 978/2012. *Official Journal of the European Union*, L, 2026/1395. https://eur-lex.europa.eu/eli/reg/2026/1395/oj/eng

Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The governance of global value chains. *Review of International Political Economy, 12*(1), 78–104. https://doi.org/10.1080/09692290500049805

Government of Bangladesh. (2025). *Bangladesh's third Nationally Determined Contribution (NDC 3.0)*. Ministry of Environment, Forest and Climate Change. https://unfccc.int/sites/default/files/2025-09/Bangladesh%20Third%20Nationally%20Determined%20Contribution%20(NDC%203.0).pdf

Habib, M. A., Hasanuzzaman, M., Hosenuzzaman, M., Salman, A., & Mehadi, M. R. (2016). Energy consumption, energy saving and emission reduction of a garment industrial building in Bangladesh. *Energy, 112*, 91–100. https://doi.org/10.1016/j.energy.2016.06.062

Habib, M. A., Hasanuzzaman, M., Islam, M. M., Robi, M. R. A., & Sabbir, H. M. (2026). Enhancing energy efficiency and reducing emissions in the textile industry of Bangladesh: A pathway to sustainability. *Energy Science & Engineering, 14*, 1148–1168. https://doi.org/10.1002/ese3.70403

Hasan, A. S. M. M., Rokonuzzaman, M., Tuhin, R. A., Salimullah, S. M., Ullah, M., Sakib, T. H., & Thollander, P. (2019). Drivers and barriers to industrial energy efficiency in textile industries of Bangladesh. *Energies, 12*(9), Article 1775. https://doi.org/10.3390/en12091775

Hasan, M. M., Nobi, F. B., Khan, N. A., Toma, N. I., Islam, M. W., Ali, M. A., & Akram, S. (2024). Greenhouse gas emissions and energy consumption in the garments, textile, and dyeing sectors in Savar, Dhaka (2019–2021). *Asian Journal of Environment & Ecology, 23*(10), 88–95. https://doi.org/10.9734/ajee/2024/v23i10612

Hasanbeigi, A., & Price, L. (2012). A review of energy use and energy efficiency technologies for the textile industry. *Renewable and Sustainable Energy Reviews, 16*(6), 3648–3665. https://doi.org/10.1016/j.rser.2012.03.029

Hirshleifer, J. (1983). From weakest-link to best-shot: The voluntary provision of public goods. *Public Choice, 41*(3), 371–386. https://doi.org/10.1007/BF00141070

Intergovernmental Panel on Climate Change. (2018). Summary for policymakers. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, & T. Waterfield (Eds.), *Global warming of 1.5°C* (pp. 3–24). Cambridge University Press. https://doi.org/10.1017/9781009157940.001

Jaakkola, E. (2020). Designing conceptual articles: Four approaches. *AMS Review, 10*(1–2), 18–26. https://doi.org/10.1007/s13162-020-00161-0

Jabotinsky, H. Y., & Sarel, R. (2026). The corporate sustainability due diligence directive: A law and economics evaluation. *npj Climate Action, 5*, Article 55. https://doi.org/10.1038/s44168-026-00393-z

Joint Research Centre. (2026). *Study on DPP content for textile apparel products under ESPR*. European Commission.

Khan, S. I., Islam, A., & Islam, M. (2022). Auditing and energy efficiency of a ready-made garment factory in Bangladesh: A case study. *Energy and Power Engineering, 14*, 387–403. https://doi.org/10.4236/epe.2022.148020

Khattak, A., Stringer, C., Benson-Rea, M., & Haworth, N. (2015). Environmental upgrading of apparel firms in global value chains: Evidence from Sri Lanka. *Competition & Change, 19*(4), 317–335. https://doi.org/10.1177/1024529415581972

Krishnan, A., De Marchi, V., & Ponte, S. (2023). Environmental upgrading and downgrading in global value chains: A framework for analysis. *Economic Geography, 99*(1), 25–50. https://doi.org/10.1080/00130095.2022.2100340

Locke, R. M. (2013). *The promise and limits of private power: Promoting labor standards in a global economy*. Cambridge University Press. https://doi.org/10.1017/CBO9781139381840

Madeddu, S., Ueckerdt, F., Pehl, M., Peterseim, J., Lord, M., Kumar, K. A., Krüger, C., & Luderer, G. (2020). The CO2 reduction potential for the European industry via direct electrification of heat supply (power-to-heat). *Environmental Research Letters, 15*(12), Article 124004. https://doi.org/10.1088/1748-9326/abbd02

Mapped in Bangladesh. (2026). *Renewable energy adoption in Bangladesh's RMG sector: Survey of 878 export-oriented factories*. Centre for Entrepreneurship Development, BRAC University.

Nadvi, K. (2008). Global standards, global governance and the organization of global value chains. *Journal of Economic Geography, 8*(3), 323–343. https://doi.org/10.1093/jeg/lbn003

Niinimäki, K., Peters, G., Dahlbo, H., Perry, P., Rissanen, T., & Gwilt, A. (2020). The environmental price of fast fashion. *Nature Reviews Earth & Environment, 1*(4), 189–200. https://doi.org/10.1038/s43017-020-0039-9

Ponte, S. (2020). Green capital accumulation: Business and sustainability management in a world of global value chains. *New Political Economy, 25*(1), 72–84. https://doi.org/10.1080/13563467.2019.1581152

Power Division. (2026). *National Renewable Energy Development Strategy 2026–2030*. Ministry of Power, Energy and Mineral Resources, Government of the People's Republic of Bangladesh.

Rabbani, A., Alif, K. M. O., Khan, F. T., Chowdhury, A., Shajahan, S., & Islam, M. F. (2025). *Adoption of renewable energy technology among apparel exporters in Bangladesh: Current state and future pathways* (Working Paper BGD-24144). International Growth Centre. https://www.theigc.org/sites/default/files/2025-12/Rabbani-Alif-Khan-Chowdhury-Shajahan-Islam-Working-Paper-October-2025%20.pdf

Rahman, S., Masud-All-Kamal, M., & Sabastini, P. (2025). Drivers and challenges in green transition: A case of Bangladesh's textile industry. *Circular Economy and Sustainability, 5*(4), 2751–2773. https://doi.org/10.1007/s43615-025-00566-8

Rashid, S., & Haque, N. (2024). Regulatory or market pressures: What promotes environmental grandstanding in Bangladesh? *Journal of Cleaner Production, 457*, Article 142444. https://doi.org/10.1016/j.jclepro.2024.142444

Sayam, S., Das, N., Akter, S., Saha, J., Sarker, A., Sen, A., Habibullah, H., Sajib, G. A., Haque, I., Mia, M. B., Faruk, M. O., Fatema, S., Munshi, M. K., Paul, P. C., & Haider, M. I. (2025). Water and electricity consumption patterns with effluent quality in the textile processing industry of Bangladesh. *RSC Advances, 15*(54). https://doi.org/10.1039/d5ra05917h

Seto, K. C., Davis, S. J., Mitchell, R. B., Stokes, E. C., Unruh, G., & Ürge-Vorsatz, D. (2016). Carbon lock-in: Types, causes, and policy implications. *Annual Review of Environment and Resources, 41*, 425–452. https://doi.org/10.1146/annurev-environ-110615-085934

Sorrell, S. (2009). Jevons' paradox revisited: The evidence for backfire from improved energy efficiency. *Energy Policy, 37*(4), 1456–1469. https://doi.org/10.1016/j.enpol.2008.12.003

Stadler, E., Bonatti, M., & Mithöfer, D. (2025). Unraveling complex impacts pathways of the ecodesign for sustainable products regulation and corporate sustainability due diligence directive in global textile value chains: A European perspective. *Regulation & Governance*. Advance online publication. https://doi.org/10.1111/rego.70064

Talut, M., Bahaj, A. S., & James, P. (2022). Solar power potential from industrial buildings and impact on electricity supply in Bangladesh. *Energies, 15*(11), Article 4037. https://doi.org/10.3390/en15114037

The Business Standard. (2026, January 1). *Bangladesh's electricity generation mix: Renewables at only 5.4%*. https://www.tbsnews.net/infograph/numbers/bangladeshs-electricity-generation-mix-renewables-only-54-1323996

The Financial Express. (2026a, January 17). *Bangladesh's garment exports to Europe exceed €18 billion, growing over 7.5 per cent*. https://thefinancialexpress.com.bd/home/bangladeshs-garment-exports-to-europe-exceed-eur18-billion-growing-over-75-per-cent

The Financial Express. (2026b, June 28). *Apparel exports to EU drop 19.33pc in Jan-Apr amid dual hit to volume, price*. https://thefinancialexpress.com.bd/economy/apparel-exports-to-eu-drop-1933pc-in-jan-apr-amid-dual-hit-to-volume-price

United Nations Economic and Social Council. (2026, July 21). *Decision on requests by Bangladesh and Nepal for extension of the preparatory period before graduation from the least developed country category*.

United Nations Framework Convention on Climate Change. (2021). *Fashion Industry Charter for Climate Action* (Version of 5 November 2021). https://unfccc.int/sites/default/files/resource/Fashion%20Industry%20Carter%20for%20Climate%20Action_2021.pdf

Unruh, G. C. (2000). Understanding carbon lock-in. *Energy Policy, 28*(12), 817–830. https://doi.org/10.1016/S0301-4215(00)00070-7

Whetten, D. A. (1989). What constitutes a theoretical contribution? *Academy of Management Review, 14*(4), 490–495. https://doi.org/10.5465/amr.1989.4308371

Wilhelm, M. (2024). Mandatory due diligence legislation: A paradigm shift for the governance of sustainability in global value chains? *Journal of International Business Policy, 7*, 459–465. https://doi.org/10.1057/s42214-024-00193-4

Worldometer. (2026). *Bangladesh electricity: Generation and installed capacity, 2024*. https://www.worldometers.info/electricity/bangladesh-electricity/

Published by

IJSAB International