Low-Carbon Thermal Energy Roadmap for the Textile Industry

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Low Carbon Thermal Roadmap for Textile Industry

This roadmap focuses on transitioning to low-carbon thermal energy.

Five key countries were studied: China, India, Vietnam, Bangladesh, and Indonesia.

About the Report

- This is the second of two reports on low-carbon thermal energy for the textile industry.
- The first report evaluated and compared low-carbon thermal energy technologies and sources, assessing readiness for adoption in 20 major textile-producing countries.

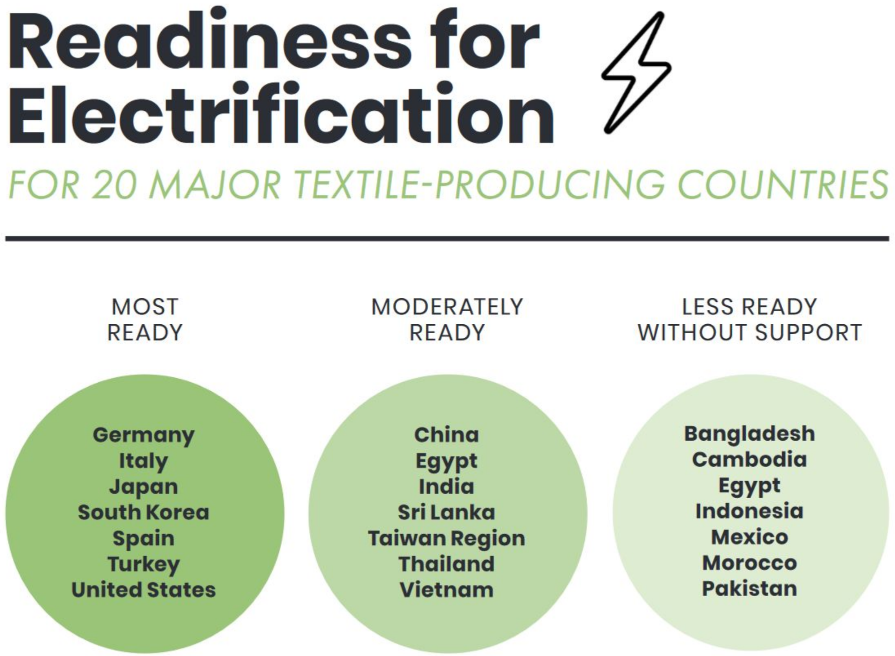


FIGURE: READINESS FOR ADOPTING ELECTRIFICATION TECHNOLOGIES IN THE 20 MAJOR TEXTILE PRODUCING COUNTRIES
Source: Hasanbeigi, Springer, and Wei 2024

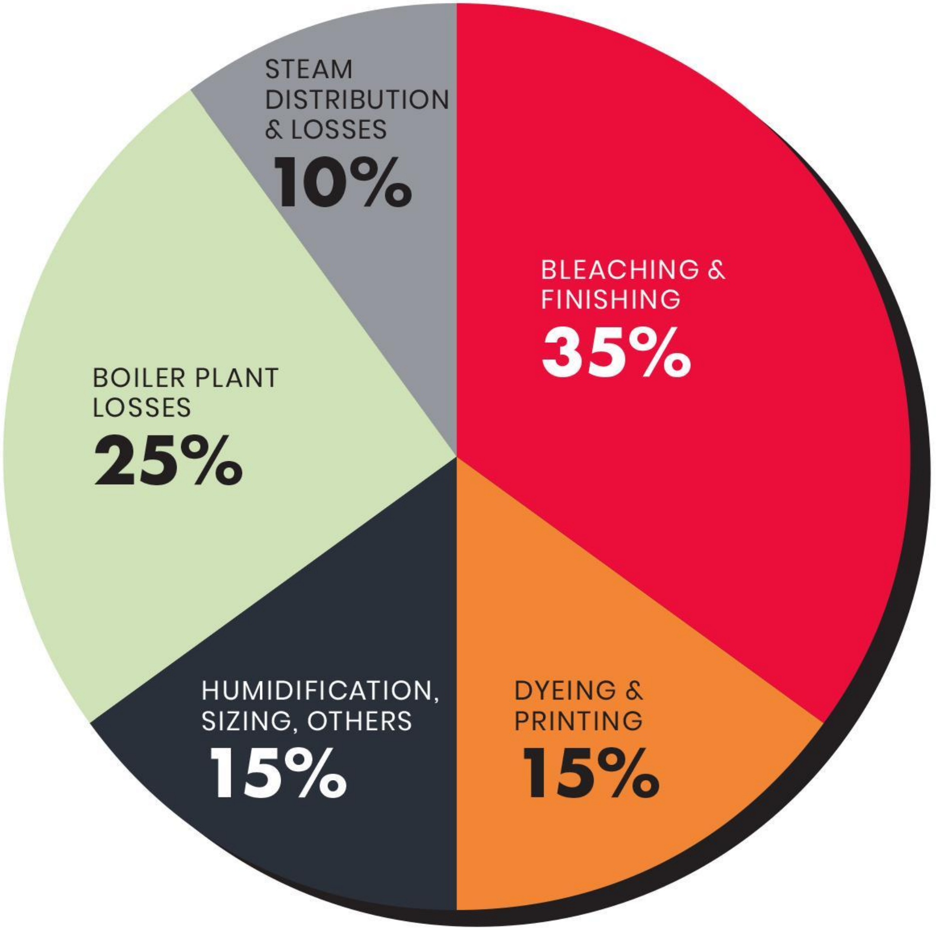
Introduction & Approach

Introduction

- Heating accounts for more than two-thirds of global industry energy demand, with only a small fraction provided by renewable energy sources.
- Lower-carbon energy sources and high-efficiency technologies to electrify heating have significant potential to reduce GHG emissions in the textile industry.

FIGURE:
BREAKDOWN OF TYPICAL THERMAL ENERGY USED IN A TEXTILE PLANT

Source: Hasanbeigi and Zuberi 2022



Decarbonization Levers for the Textile Industry

- **Near term**: Fully commercial and ready for adoption now.
- **Mid term**: Fully commercial but low adoption by 2030.
- **Long term**: Mostly emerging techs with adoption after 2030.

Note: CCUS is another industrial decarbonization lever, but it is not applicable to the textile industry.

Covered in this analysis: Electrification of Industrial Heat; Low-carbon Fuels, Feedstocks, and Energy Sources (LCFFES)

Material Efficiency and Circular Economy near to mid term	Energy Efficiency near term	Electrification of Industrial Heat near to mid term	Low-carbon Fuels, Feedstocks, and Energy Sources (LCFFES) near to mid term
• Sustainable sourcing of raw materials • Using recycled fibers • By-product synergy/ waste reduction	• High-efficiency motor systems • Energy management and control systems • Improved insulation and waste heat recovery • Systems optimization	• Electric boilers • Heat pumps • Thermal energy storage • Electric heaters and dryers	• Sustainable biofuels and bio-feedstocks • Solar thermal • Renewable electricity • Natural gas

Study Scope

- **Electric boilers** and **industrial heat pumps** ranked highly in the first report's technology comparison.
- Decarbonization via electrification relies on clean electricity grids or a procured supply of clean RE.
- Sustainable **biomass** can be a near-term solution, but limited supply will hinder industry scaling.
- A textile facility's ability to switch to **natural gas** boilers is highly dependent on the local natural gas infrastructure.

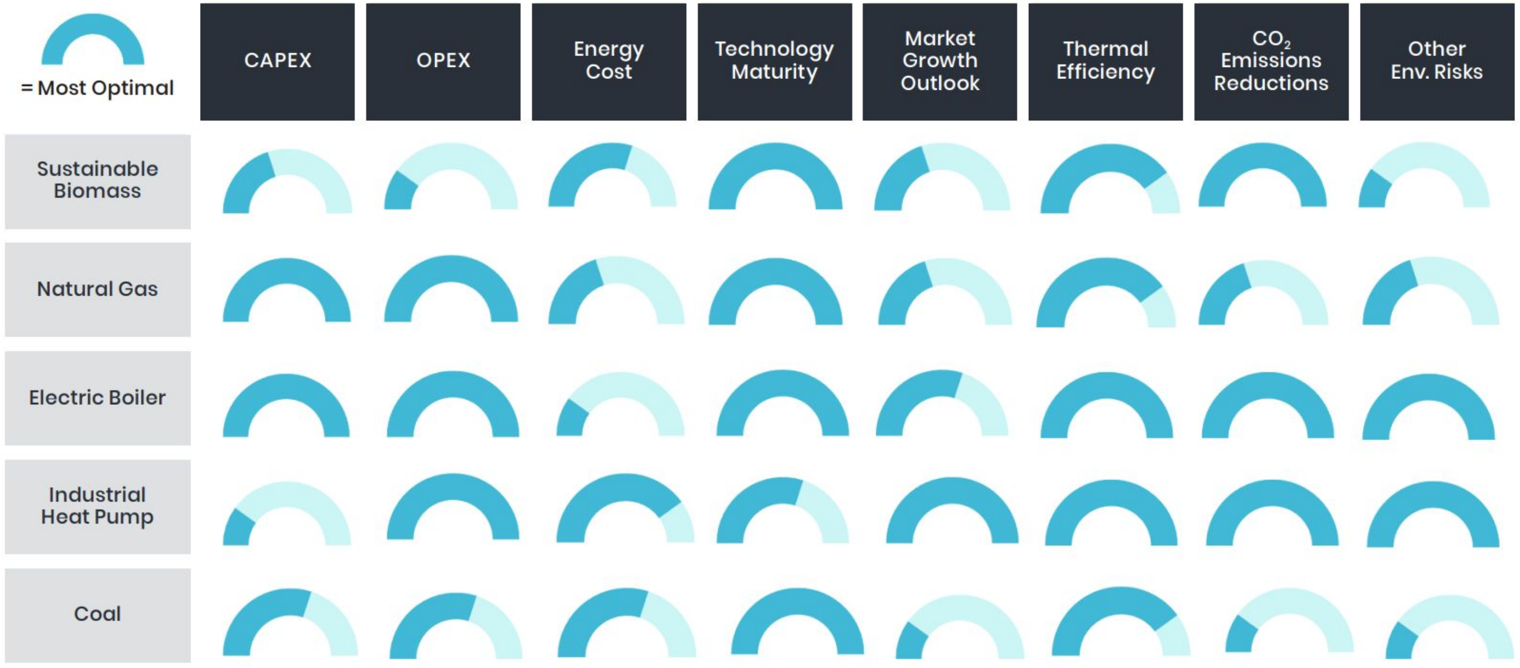


FIGURE: CROSS-TECHNOLOGY COMPARISON MATRIX FOR THE LOW-CARBON THERMAL TECHNOLOGIES AND ALTERNATIVE FUELS ANALYZED
Source: Hasanbeigi, Springer, and Wei 2024

Study Scope

- We analyzed low-carbon thermal energy adoption in five of the top textile-producing countries.
- We assessed conversion to two electrification technologies (electric boilers and heat pumps) and two alternative fuels (biomass and natural gas).
- We assessed these options for steam generation and thermal oil heating.

TABLE: TEXTILE INDUSTRY ECONOMIC DATA FOR COUNTRIES ANALYZED

Source: Hasanbeigi, Springer, and Wei 2024

Country	Textile Export Value, 2021 (billion USD)	Textile Share of Value Added in Manufacturing
China	478	10%
India	48.1	9%
Vietnam	83.4	15%
Bangladesh	49.1	57%
Indonesia	24.2	11%

FIGURE: LOW CARBON THERMAL ENERGY SOURCES ANALYZED IN THIS STUDY

Electric Boilers (Steam and Thermal Oil)

Heat Pumps (Steam)

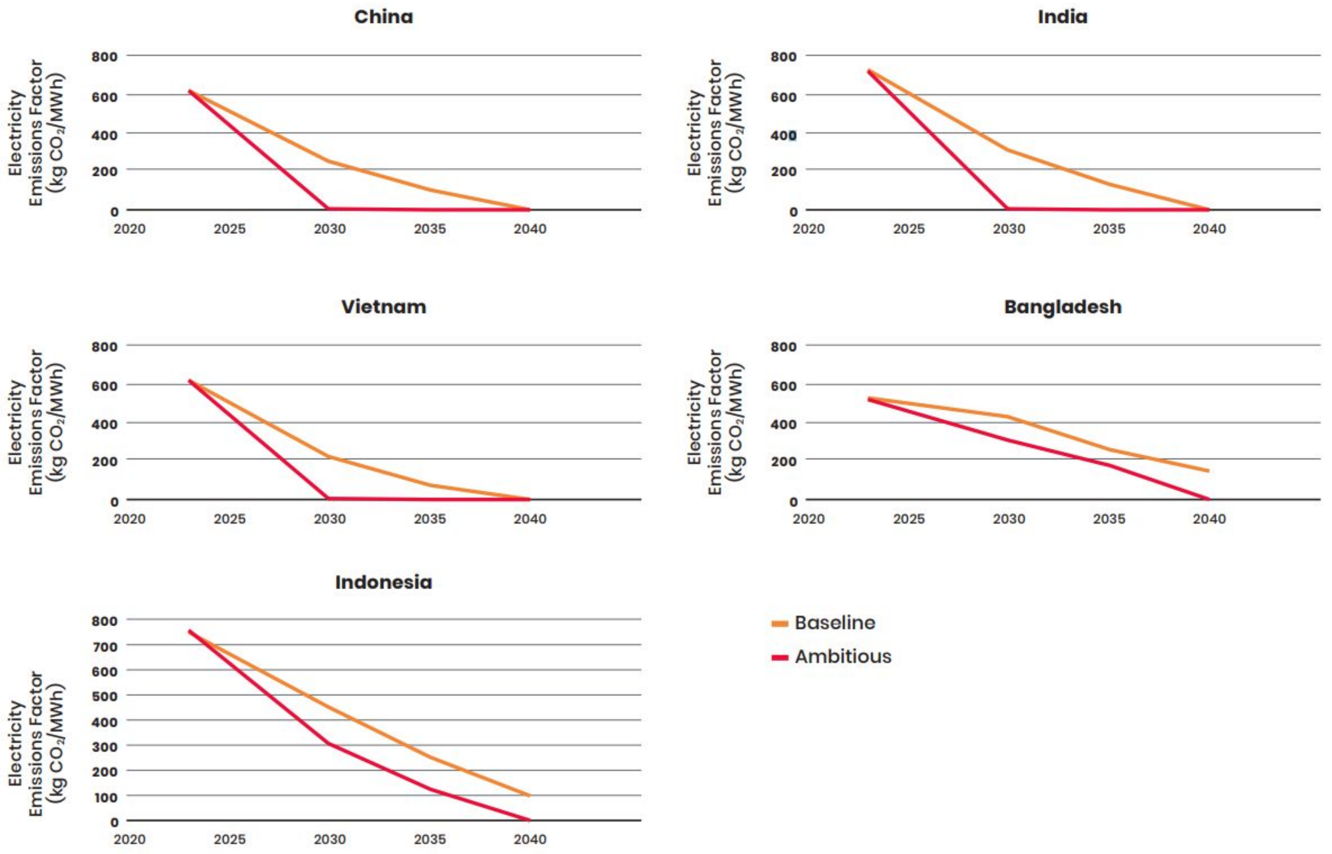
Biomass Boilers (Steam and Thermal Oil)

Natural Gas Boilers (Steam and Thermal Oil)

Methodology and Assumptions

- Conducted a techno-economic analysis of heating-related energy use and emissions at a typical textile wet-processing facility in the five countries.
- Gathered country-specific data on fuel and electricity prices, grid emissions factors, and other key local data.
- Developed two electricity pathways to analyze the effects of electrification over time: **Baseline** and **Ambitious Grid Plus RE Procurement**
- Key assumptions: procured RE costs less than grid electricity and electricity costs decrease over time.

FIGURE: ELECTRICITY EMISSIONS FACTORS BY PATHWAY AND COUNTRY ASSUMED IN THIS STUDY



The Energy Systems Landscape

- For each studied country, we assessed key context for low-carbon thermal energy adoption, including:

  - Alternative fuel availability for natural gas and biomass.

  - The state of the electricity grid.

  - Corporate renewable electricity procurement markets.

- This information was used to inform scenario development.

TABLE: RE PROCUREMENT PATHWAYS ASSUMED BY COUNTRY IN THIS STUDY

China, India, and Vietnam		
Year	Baseline Grid Plus RE Procurement Scenario	Ambitious RE Procurement Scenario
2030	50%	100%
2035	75%	100%
2040	100%	100%

Indonesia		
Year	Baseline Grid Plus RE Procurement Scenario	Ambitious RE Procurement Scenario
2030	25%	50%
2035	50%	75%
2040	75%	100%

Bangladesh		
Year	Baseline Grid Plus RE Procurement Scenario	Ambitious RE Procurement Scenario
2030	0%	30%
2035	30%	50%
2040	50%	100%

Energy Systems Pinch Points Per Country

Country	Natural Gas Boilers	Sustainable Biomass Boilers	Electric Boilers	Heat Pumps
China	• Natural gas supply is largely imported, making scale-up challenging • Competing priorities for the limited supply of natural gas	• Regional variation in biomass availability and costs • Competing demands for sustainable biomass sources from other industries and the electric power sector • Industrial clusters too large to supply sustainable biomass • Ban on biomass boilers in some provinces	• High energy costs in the near term based on the electricity-to-fuel price ratio • High grid emissions factor • Moderate supply of RE for corporate procurement, but not yet ready for scaling across the entire textile industry	• Technology availability in the Chinese market for high-temperature industrial heat pumps is currently limited
India	• Natural gas supply is largely imported and relatively expensive • Natural gas distribution infrastructure limited	• Logistical and storage challenges for biomass for large industrial users in textile-producing regions	• High grid emissions factor • Corporate RE procurement increasingly available, but 24/7 supply is limited	• Capital costs are very high • Technology availability still emerging in the Indian market
Vietnam	• Competing demand for limited natural gas supply • Growing reliance on imported natural gas	• Competing demand for agricultural residues from local communities, exports, and the electric power sector	• High grid emissions factor • Nascent corporate RE procurement mechanisms just established in 2024 face regulatory and scale-up challenges	• Capital costs are very high • Heat pump suppliers have not yet entered the Vietnamese market
Bangladesh	• NA – reference fuel	• Limited industrial biomass market due to household and small-scale uses • Limited infrastructure for large-scale biomass adoption	• Grid reliability issues • Lack of corporate RE procurement framework at present • Limited RE supply	• Grid reliability issues • Lack of corporate RE procurement framework at present • Limited RE supply • Limited technology availability
Indonesia	• Natural gas distribution infrastructure is challenging and expensive to scale up across diverse island geographies	• High risk of biomass scale-up contributing to tropical deforestation issues • Competing demand for limited biomass supply	• High grid emissions factor • Limited RE supply • Very limited mechanisms for corporate RE procurement	• Limited RE supply • Very limited mechanisms for corporate RE procurement • Limited technology availability

Analysis & Results

Biomass and Natural Gas for Steam Generation: CO_2 emissions

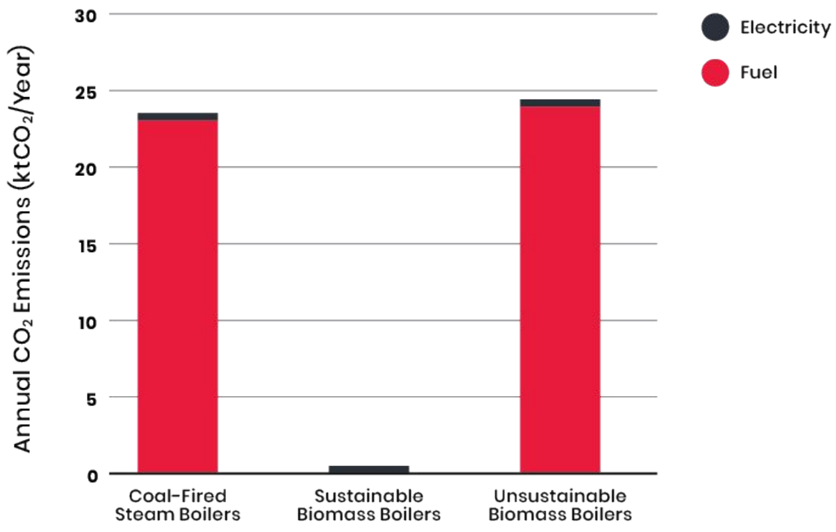


FIGURE: ANNUAL CO_2 EMISSIONS FROM COAL-FIRED STEAM BOILERS VS. BIOMASS STEAM BOILERS IN A TYPICAL TEXTILE WET-PROCESSING PLANT

- The direct combustion emissions factor of biomass is slightly higher than that of coal, underscoring that sustainable sourcing (namely agricultural residues) is essential.
- Switching to natural gas steam boilers may increase the annual CO2 emissions compared to coal-fired boilers if upstream methane emissions are considered.

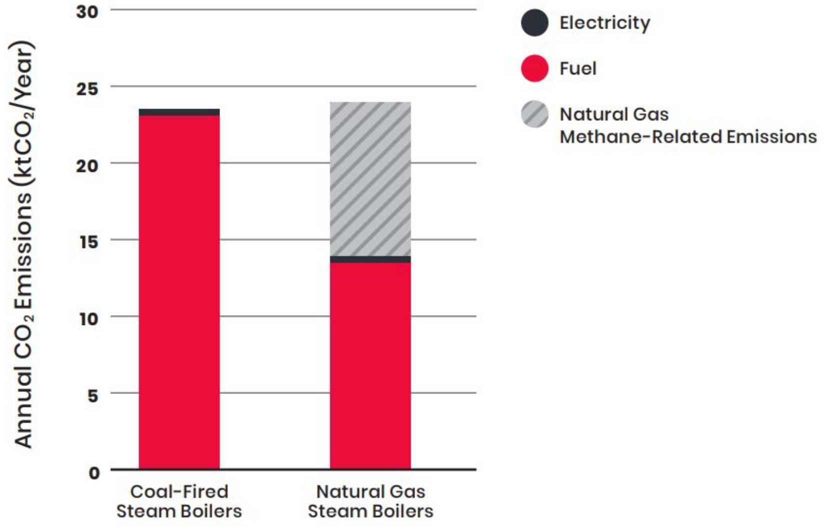
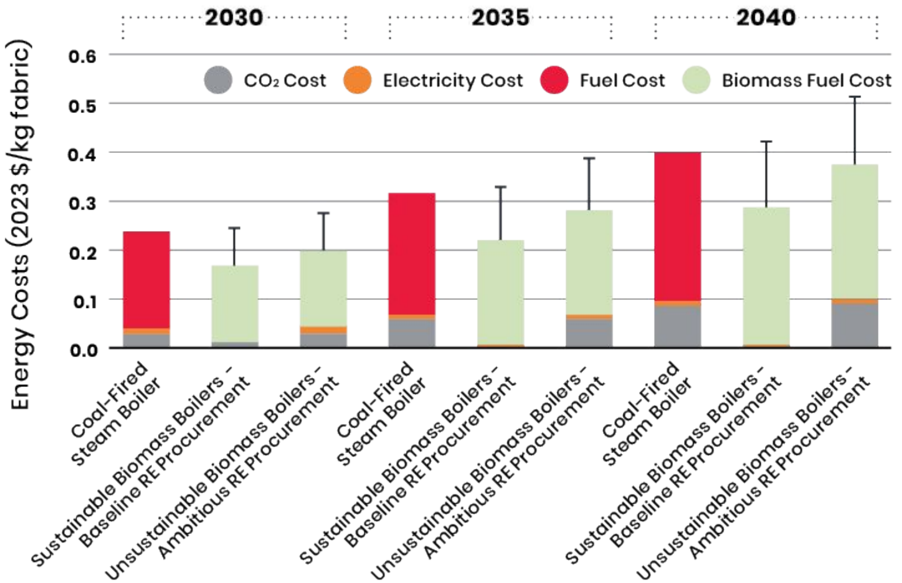


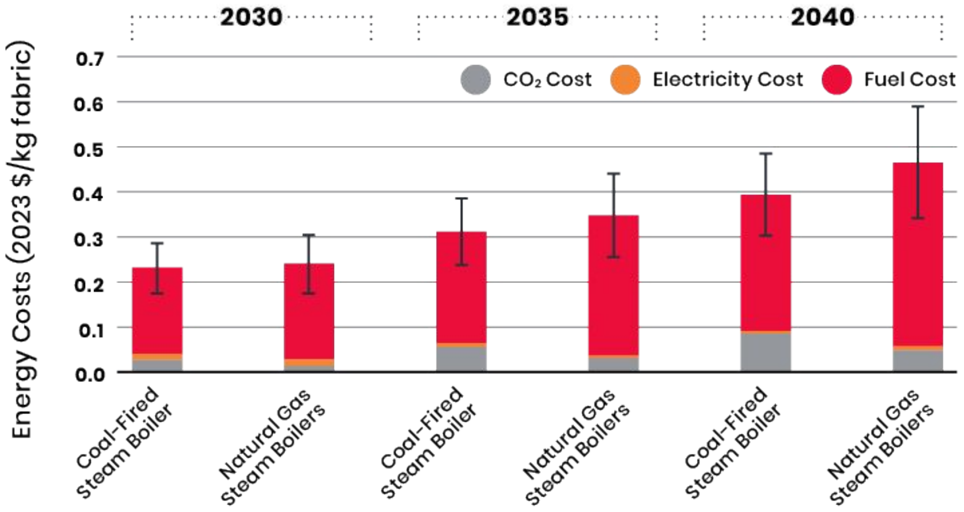
FIGURE: ANNUAL CO_2 EMISSIONS FROM COAL-FIRED STEAM BOILERS VS. NATURAL GAS BOILERS IN A TYPICAL TEXTILE WET-PROCESSING PLANT

Biomass and Natural Gas for Steam Generation: Energy Cost



BIOMASS

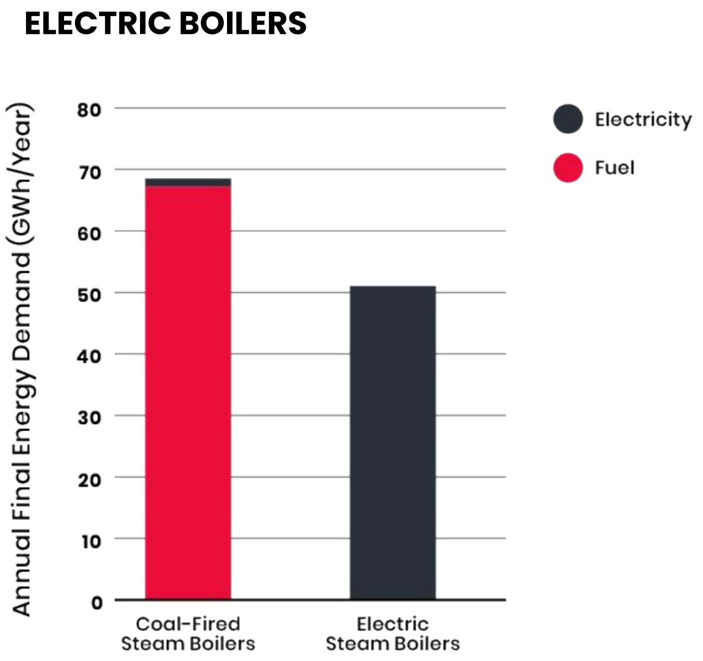
- Low biomass prices are a key driver of its adoption in the textile industry.
- However, biomass prices are expected to rise as the demand for sustainable biomass grows while supply remains limited.
- Natural gas is typically more expensive than coal in China, India, Vietnam, and Indonesia, with prices expected to rise, limiting the financial attractiveness of a transition.

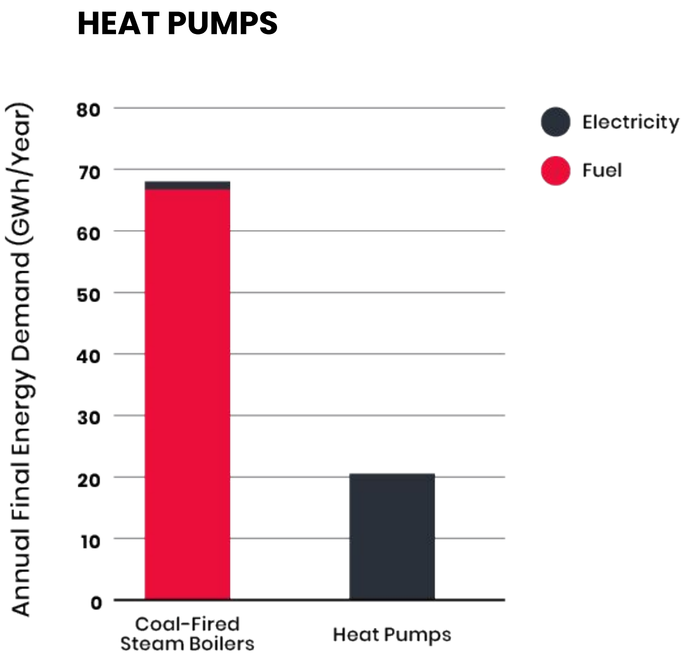


NATURAL GAS

FIGURE: ENERGY COSTS FROM COAL-FIRED STEAM BOILERS VS. ALTERNATIVE FUEL BOILERS IN A TYPICAL TEXTILE WET-PROCESSING PLANT IN CHINA

Electrification of Steam Generation: Energy Saving

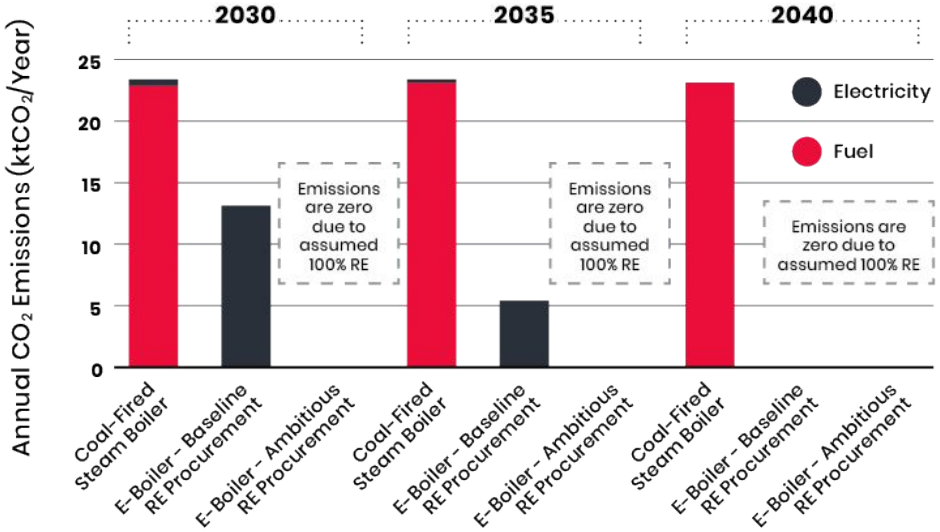




- Electrification with electric boilers and heat pumps can save energy (especially for heat pumps).
- Steam-generating heat pumps are not yet widely implemented in the textile industry, but their adoption is expected to increase significantly by 2030.
- Switching to biomass boilers or natural gas boilers will not lead to significant efficiency gains.

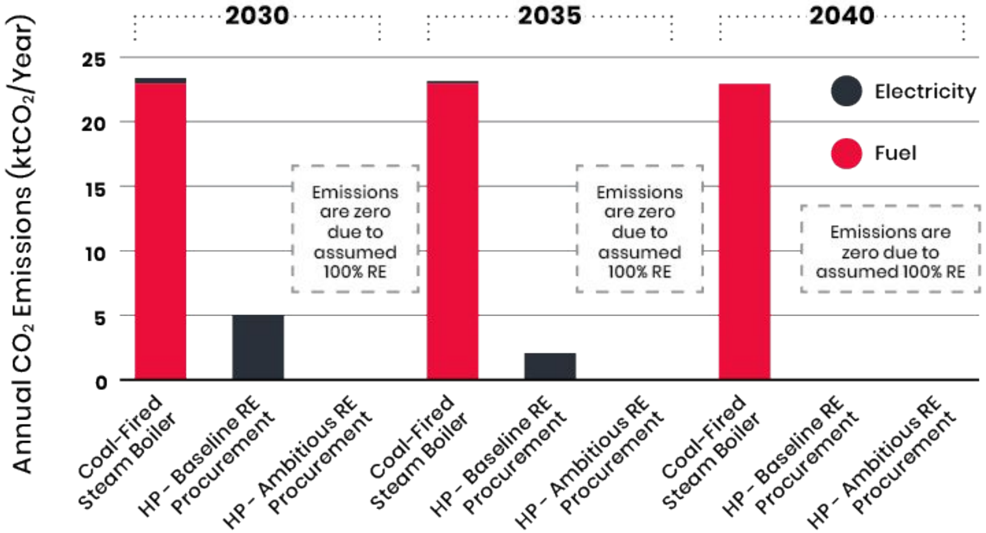
FIGURE: ANNUAL ENERGY DEMAND FROM CONVENTIONAL STEAM BOILERS VS. ELECTRIFIED TECHNOLOGIES AT A TYPICAL TEXTILE WET-PROCESSING FACILITY

Electrification of Steam Generation: CO_2 Emissions



ELECTRIC BOILERS

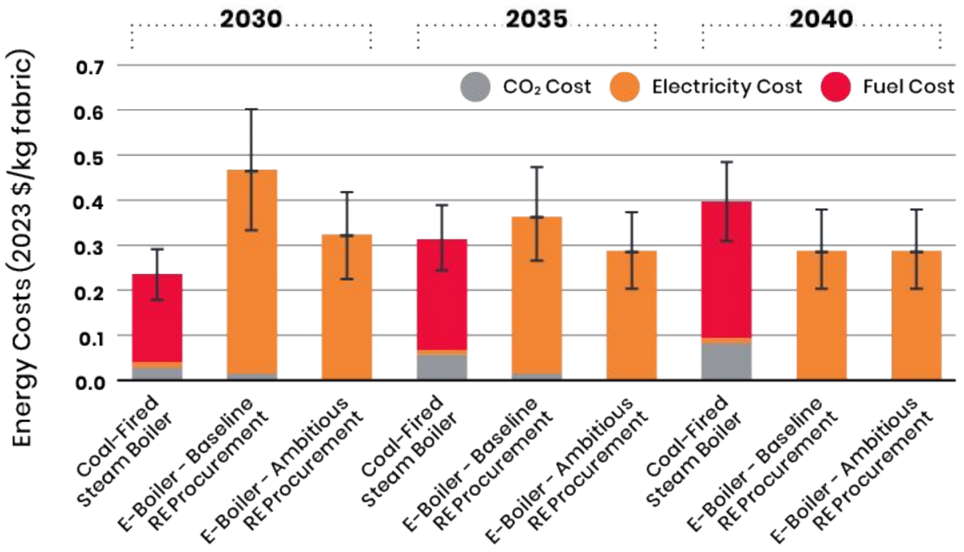
- China has a strongly positive market growth outlook for RE and corporate RE procurement.
- Even under baseline scenario, we project that a typical textile plant would be able to reduce emissions from electrification (especially with heat pumps).



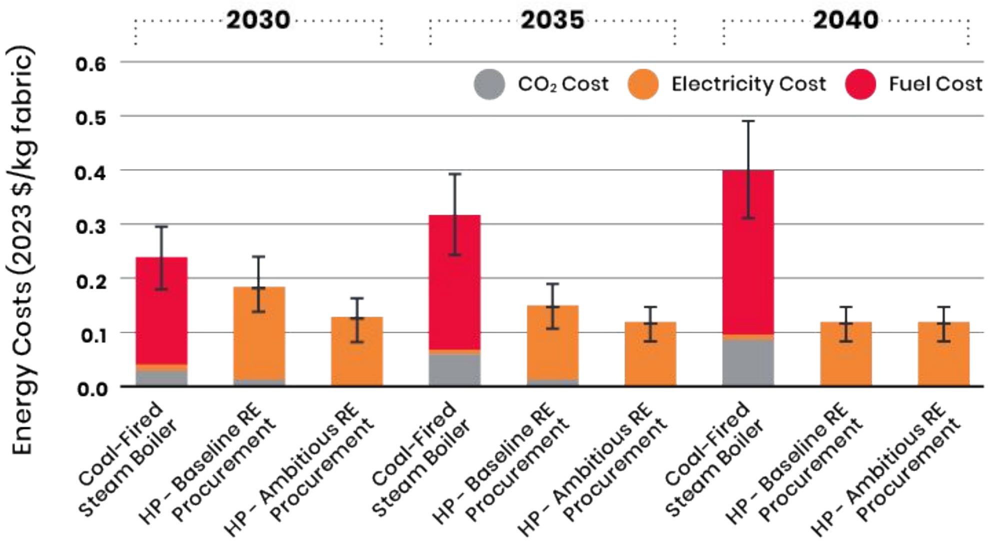
HEAT PUMPS

FIGURE: ANNUAL CO_2 EMISSIONS FROM COAL-FIRED STEAM BOILERS VS. ELECTRIFIED TECHNOLOGIES IN A TYPICAL TEXTILE WET-PROCESSING PLANT IN CHINA BY ELECTRICITY PATHWAY

Electrification of Steam Generation: Energy Cost



ELECTRIC BOILERS



HEAT PUMPS

- While electric steam boilers reduce emissions from 2030, even in the Baseline Grid Plus RE Procurement pathway, the cost of RE is not likely to make this an attractive option until 2035-2040.
- Heat pumps' efficiency enables emissions and energy cost reductions by 2030.

FIGURE: ENERGY COSTS FROM COAL-FIRED STEAM BOILERS VS. ELECTRIFIED TECHNOLOGIES IN A TYPICAL TEXTILE WET-PROCESSING PLANT IN CHINA BY ELECTRICITY PATHWAY

Low-Carbon Technologies for Steam Generation:
Levelized Cost of Heating (LCOH)

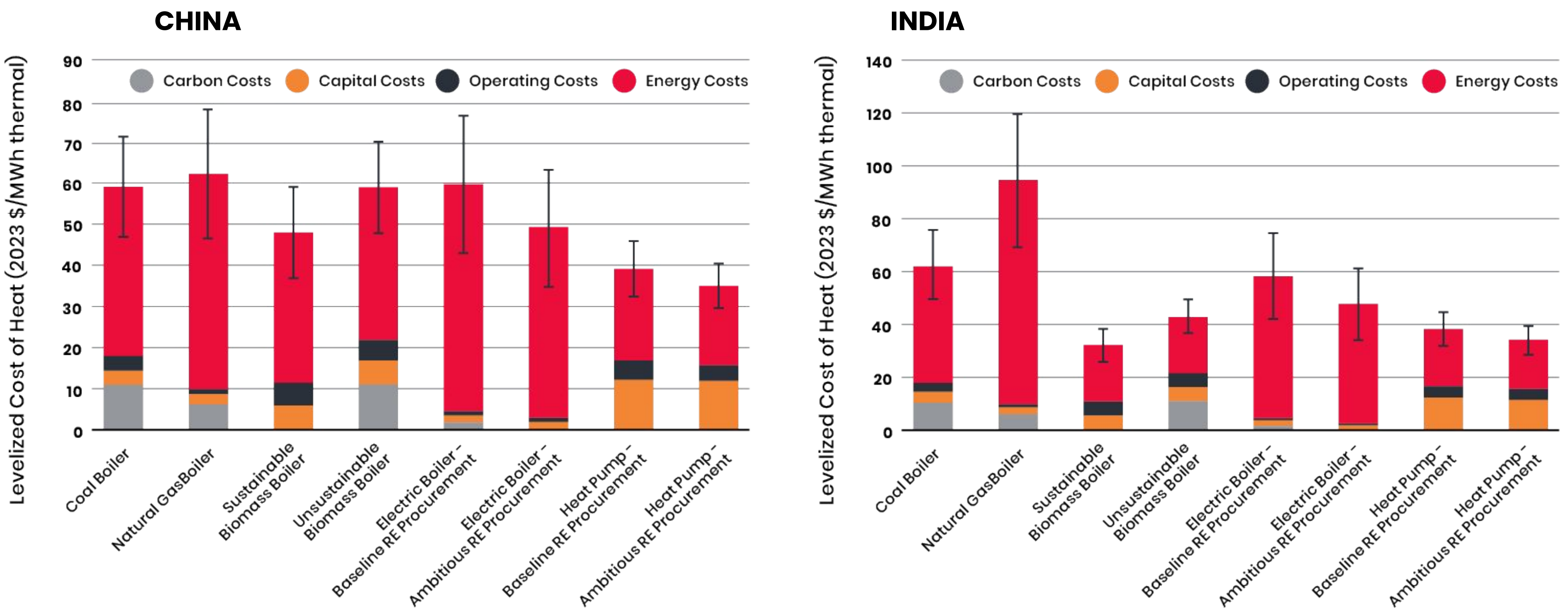


FIGURE: LCOH FOR STEAM GENERATION OF THE ANALYZED TECHNOLOGIES FOR A TYPICAL TEXTILE WET-PROCESSING FACILITY

- LCOH measures lifetime expenses, factoring in CAPEX, OPEX, energy prices, and potential carbon costs.
- Several of the countries studied have or are establishing carbon pricing systems, and exporting countries could be subject to carbon prices in partner countries (CBAM).
- Across countries, heat pumps have the lowest LCOH for steam generation.

Low-Carbon Technologies for Steam Generation:
Levelized Cost of Heating (LCOH)

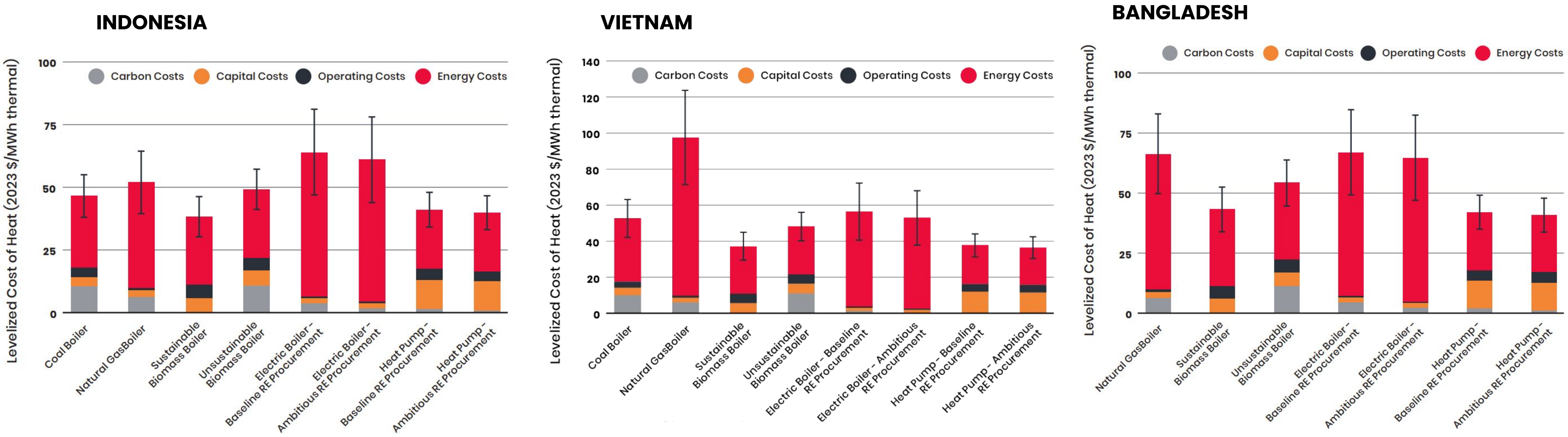


FIGURE: LCOH FOR STEAM GENERATION OF THE ANALYZED TECHNOLOGIES FOR A TYPICAL TEXTILE WET-PROCESSING FACILITY

Low-Carbon Technologies for Thermal Oil Boilers

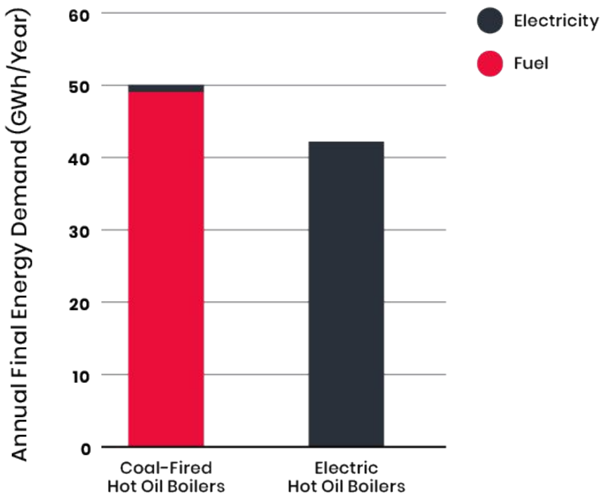
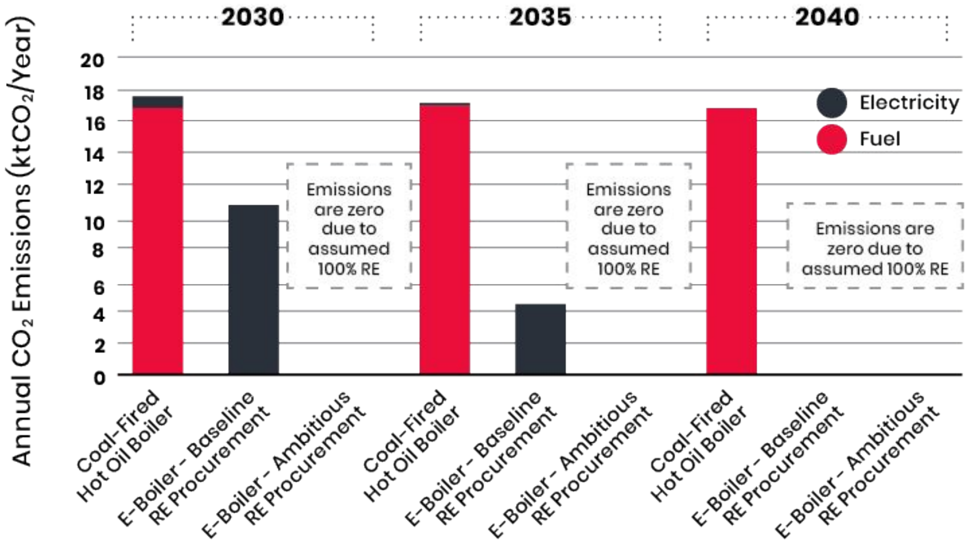


FIGURE: ANNUAL ENERGY DEMAND FROM CONVENTIONAL THERMAL OIL BOILERS VS. ELECTRIC THERMAL OIL BOILERS AT A TYPICAL TEXTILE WET-PROCESSING FACILITY



- Thermal oil heating makes up 30-40% of fuel use in a typical textile wet processing plant.
- Results for thermal oil boilers are similar to results for steam boilers
- For electrification technologies, results for thermal oil boilers are dampened because there are less efficiency gains from electrification of thermal oil boilers (conventional thermal oil boilers are relatively more efficient compared to conventional steam boilers).

FIGURE: ANNUAL CO_2 EMISSIONS FROM COAL-FIRED HOT OIL BOILERS VS. ELECTRIC HOT OIL BOILERS IN A TYPICAL TEXTILE WET-PROCESSING PLANT IN CHINA, BASELINE AND AMBITIOUS RE PROCUREMENT PATHWAYS

Country Comparison: China

	Biomass		Natural Gas		Electrification					
Overview	**Biomass Availability**	**Impacts of Biomass Steam/ Hot Oil Boiler Adoption**	**Natural Gas Availability**	**Impacts of Natural Gas Steam/Hot Oil Boiler Adoption**	**Grid Electricity**	**Availability of RE for Procurement**	**Impacts of Adopting Steam-Generating Heat Pumps**	**Impacts of Adopting Electric Steam/Hot Oil Boilers**	**Baseline Scenario RE Procurement**	**Ambitious Scenario RE Procurement**
Status	4% of current total national energy supply, but large volumes unused waste sources.	CO_2 emissions reductions depend on biomass source. Unsustainable biomass increases emissions compared to coal.	8% of total energy supply.	Natural gas has a higher cost than coal; less emissions savings relative to sustainable biomass adoption.	Fastest expanding RE capacity globally.	Corporate RE procurement is growing with emerging policy and market mechanisms.	Leads to greater efficiency gains and energy savings relative to electric boilers. Can already result in substantial emissions and energy cost savings by 2030.	CO_2 emission reductions depend on share of RE procurement, and economic feasibility depends on RE cost.	2030 - 50% 2035 - 75% 2040 - 100%	2030 - 100% 2035 - 100% 2040 - 100%
Future Opportunities & Challenges	Government plans to increase utilization; however, biomass boilers regulations vary by province.	Low biomass prices relative to coal may drive near-term adoption. However, prices will increase if demand grows significantly.	40% of natural gas comes from imports and therefore has price volatility and risks.	Natural gas prices are expected to rise, and switching to natural gas boilers will not lower energy costs.	Challenges with RE integration, including transmission constraints and lack of inter-provincial electricity trading and market structure.	GPT and GECs very promising, growing in scale and suitable for textile manufacturers. PPA attractiveness rates 19/30 in a list of majority mature economies.	Steam generating heat pumps still need to be piloted and proven for the textile industry.	Not energy cost competitive in 2030, but can reduce emissions in the near term. Electric steam boilers have lower energy costs by 2035. By 2040, both types of electric boilers expected to be fully competitive with coal boilers.		
Recommen-dation	Explore certified sustainable biomass as an alternative fuel in regions where cheap and certified sustainable biomass is available. Evaluate on a case-by-case basis due to the large regional differences.		Limited opportunity as alternative fuel - supply and cost challenges; not aligned to net zero as it is still a fossil fuel		The grid is decarbonizing, but this will not be the main source of electricity for facilities in the near future due to volume of RE needed, market flexibility, and price.	Pursue corporate RE procurement to support electrification, improve the enabling environment.	Implement lower temperature hot water heat pumps from 2025 onwards; pilot steam generating heat pumps so scaled deployment can occur by 2030.	Explore transition to electric steam boilers from 2035 and electric hot oil boilers from 2040 onwards.		

Country Comparison: India

	Biomass		Natural Gas		Electrification					
Overview	**Biomass Availability**	**Impacts of Biomass Steam/ Hot Oil Boiler Adoption**	**Natural Gas Availability**	**Impacts of Natural Gas Steam/Hot Oil Boiler Adoption**	**Grid Electricity**	**Availability of RE for Procurement**	**Impacts of Adopting Steam-Generating Heat Pumps**	**Impacts of Adopting Electric Steam/Hot Oil Boilers**	**Baseline Scenario RE Procurement**	**Ambitious Scenario RE Procurement**
Status	22% of energy in India is derived from biomass and waste sources.	Sustainable biomass can deliver energy cost and emissions savings.	6% of total energy supply with 47% coming from imports.	Natural gas has a higher cost than coal and prices are expected to rise.	Rapid expansion of solar energy, becoming one of the lowest-cost sources of energy globally. Despite this, current grid emission factor is still very high.	Most developed corporate RE procurement of all countries studied. India ranks 13/30 on the global PPA index. Third largest generator of solar energy in 2023.	Leads to greater efficiency gains and energy savings relative to electric boilers. Can already result in substantial emissions and energy cost savings by 2030.	CO_2 emission reductions depend on share of RE procurement, and economic feasibility depends on RE cost.	2030 - 50% 2035 - 75% 2040 - 100%	2030 - 100% 2035 - 100% 2040 - 100%
Future Opportunities & Challenges	Large volumes of agricultural waste biomass available and already being used by textile manufacturers.	Not a long-term decarbonization solution as supply is limited. After 2030, focus on phase out as as electrification becomes widely implementable and biomass prices increase.	Reliance on imports results in high price volatility. Ability to switch to natural gas is dependent on local infrastructure.	More expensive than coal in all time horizons, less emissions savings than sustainable biomass.	Grid decarbonizing, but still not fast enough to meet textile industry demand and will have to be coupled with corporate RE procurement mechanisms. Grid infrastructure upgrades needed to deal with this increase in RE and electrification of industry.	PPA market is most favorable of the countries studied and RE can deliver lower-cost electricity relative to the grid. Requires policy stability and improved grid connectivity to maintain this trend.	Steam generating heat pumps still need to be piloted and proven for the textile industry.	Not energy cost competitive in 2030, but can reduce emissions in the near term. Electric steam boilers have lower energy costs by 2035. By 2040, both types of electric boilers expected to be fully competitive with coal boilers.		
Recommen-dation	Textile manufacturers should procure traceable and certifiable sustainable biomass sources. Monitor biomass price compared to corporate RE procurement. Transition away from biomass once the assets retire, sustainable sources of biomass run out, or the economics of electrification with RE procurement becomes economically feasible.		Due to substantially higher costs compared to coal, minimal emissions reductions compared to other sources, and logistical challenges for facilities to access, do not recommend as an alternative fuel in India.		The grid is decarbonizing, but this will not be the main source of electricity for facilities in the near future due to volume of RE needed, market flexibility, and price.	Pursue corporate RE procurement to support electrification, improve the enabling environment.	Implement lower temperature hot water heat pumps from 2025; pilot steam generating heat pumps so that by 2030 scaled deployment can occur.	Explore transition to electric steam boilers from 2035 and electric hot oil boilers from 2040 onwards.		

Country Comparison: Vietnam

	Biomass		Natural Gas		Electrification					
Overview	**Biomass Availability**	**Impacts of Biomass Steam/ Hot Oil Boiler Adoption**	**Natural Gas Availability**	**Impacts of Natural Gas Steam/Hot Oil Boiler Adoption**	**Grid Electricity**	**Availability of RE for Procurement**	**Impacts of Adopting Steam-Generating Heat Pumps**	**Impacts of Adopting Electric Steam/Hot Oil Boilers**	**Baseline Scenario RE Procurement**	**Ambitious Scenario RE Procurement**
Status	10% of national energy comes from biomass and waste sources, with government plans to increase.	Biomass is widely used as an alternative fuel to coal, delivering energy cost and emissions savings.	7% of national energy supply comes from natural gas.	Natural gas has a higher cost than coal and is expected to rise.	Vietnam has a 2050 net zero target, and will likely transition to a clean grid earlier than other studied countries.	Direct PPAs were established in July 2024.	Leads to greater efficiency gains and energy savings relative to electric boilers. Can already result in substantial emissions and energy cost savings by 2030.	CO_2 emission reductions depend on share of RE procurement, and economic feasibility depends on RE cost.	2030 - 50% 2035 - 75% 2040 - 100%	2030 - 100% 2035 - 100% 2040 - 100%
Future Opportunities & Challenges	Availability of sustainable biomass (rice husks) is limited. Biomass adoption is well under way for textile plants. Textile mills will compete with other industries.	2030 - Monitor provenance and commence phase out due to higher risk of unsustainable biomass than other countries. 2035 - Phase out biomass as electrification becomes widely implementable. 2040 - Complete phase out of biomass.	Government is increasing natural gas imports for the power sector. Increased infrastructure is limited to port areas. Natural gas is unlikely to be available to textile manufacturers.	Substantially more expensive than coal in all time horizons, less emissions savings than sustainable biomass.	Electricity demand growing rapidly. Government has reduced solar incentives to mitigate grid challenges.	New mechanism means regulatory challenges for implementation. Ease of implementation should increase over time.	Steam generating heat pumps still need to be piloted and proven for the textile industry.	Not energy cost competitive in 2030 or 2035, but both electric steam and hot oil boilers can deliver emissions reductions. By 2040, energy costs are competitive with coal boilers, especially for electric steam boilers.		
Recommen-dation	Less available sustainable biomass than India and China due to high existing utilization. Higher risk of sourcing unsustainable biomass. Sourcing should be carefully monitored and certifications required. Monitor availability of certified sustainable biomass and transition to electrification when availability decreases and price increases. May need to transition sooner than other geographies to avoid increased emissions and other environmental impacts through unsustainable biomass.		Due to substantially higher costs compared to coal, minimal emissions reductions compared to other sources, and logistical challenges for facilities to access. Do not recommend as an alternative fuel in Vietnam.		Brands and textile manufacturers should encourage continued grid development to enable the planned increase of RE.	Brands and textile manufacturers should explore current feasibility of DPPAs and continue to collaborate to expand their scope and accessibility.	Implement lower temperature hot water heat pumps from 2025 onwards; pilot steam generating heat pumps so scaled deployment can occur by 2030.	Explore transition to electric steam and hot oil boilers by 2040.		

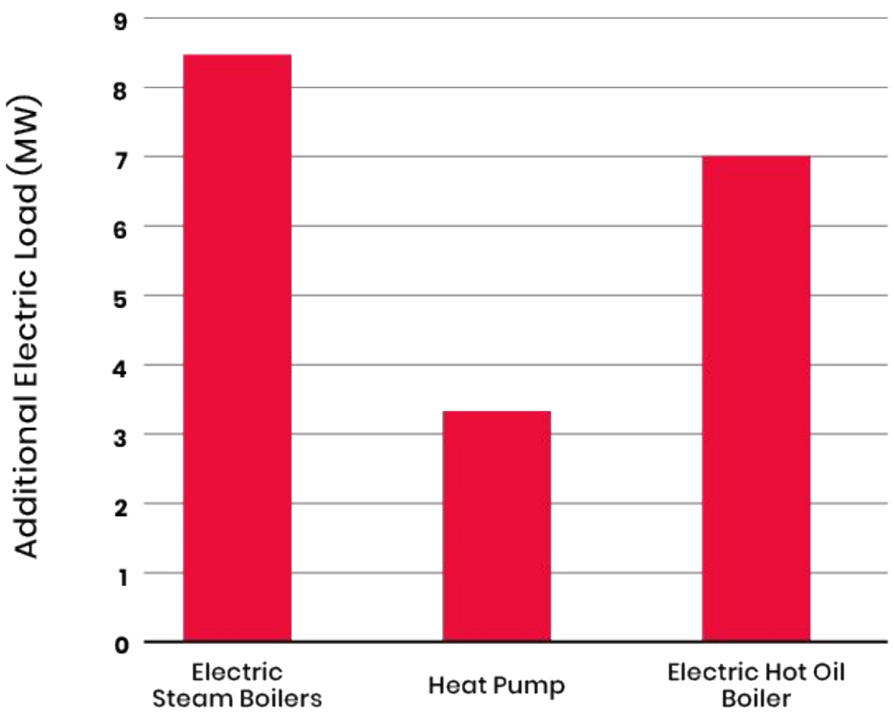
Country Comparison: Bangladesh

	Biomass		Natural Gas		Electrification			
Overview	**Biomass Availability**	**Impacts of Biomass Steam/ Hot Oil Boiler Adoption**	**Grid Electricity**	**Availability of RE for Procurement**	**Impacts of Adopting Steam-Generating Heat Pumps**	**Impacts of Adopting Electric Steam/Hot Oil Boilers**	**Baseline Scenario RE Procurement**	**Ambitious Scenario RE Procurement**
Status	Availability of sustainable biomass is lowest of countries studied.	The use of unsustainable biomass would result in more emissions increase relative to other countries due to the lower emission factor of natural gas, the currently used fuel.	92-98% of electricity is powered by fossil fuels. The grid already has major stability issues without an influx of RE or electrification. Significantly less mature grid structure than the other countries studied.	RE supply is limited. There are some ad hoc examples of PPAs, but no formal framework.	Leads to greater efficiency and energy savings relative to electric boilers. Can already result in substantial savings by 2030, even with minimal RE procurement.	Reducing emissions through electric boilers requires at least 50% share of procured RE. This is only achieved by 2040 in our Baseline Grid Plus RE Procurement pathway.	2030 - 0% 2035 - 30% 2040 - 50%	2030 - 30% 2035 - 50% 2040 - 100%
Future Opportunities & Challenges	Biomass availability competes with residential use and growing demand for power generation. Sustainable biomass supply cannot meet the textile industry's demand.	While biomass prices increase over time, so do natural gas prices. If sustainable biomass can be secured, this is a viable alternative fuel from an emissions perspective across the time horizons.	Increasing reliance on price-volatile fuel imports for electric power generation. Growing interest in energy storage and RE to increase grid capacity.	Discussions are underway to develop a Corporate Power Purchasing (CPP) framework for RE. Our analysis assumes RE will be widely available by 2035 based on current trajectories. This may change with a CPP framework.	Significant emissions and cost savings over time, but the technology needs to be piloted and demonstrated in Bangladesh.	2030- Emissions and costs would rise substantially for electric steam and hot oil boilers in 2030. 2035 - RE becomes available and we start to see emissions decreasing but costs remain slightly higher than natural gas for both technologies. 2040 - With RE widely available both steam and hot oil boilers see emissions reductions. Only steam boilers are price competitive.		
Recommen-dation	Due to limited sustainable supply, biomass will rarely be a viable alternative to natural gas.		Engage with policy makers to support grid decarbonization and modernization.	Engage with policy makers to support CPP implementation and enable electrification.	Evaluate the potential for heat pumps in the short-medium term. Despite the efficiency, there will be challenges associated with grid connectivity and reliability. This needs to be assessed site-by-site, and energy storage is likely to be a core feature to enable this technology.	Electric steam boilers under current assumptions can deliver emissions and cost savings from 2040. Electric hot oil boilers deliver emissions savings but remain more expensive even in 2040. Policy advocacy on corporate RE availability is key to unlocking electric boilers in Bangladesh.		

Country Comparison: Indonesia

	Biomass		Natural Gas		Electrification					
Overview	**Biomass Availability**	**Impacts of Biomass Steam/ Hot Oil Boiler Adoption**	**Natural Gas Availability**	**Impacts of Natural Gas Steam/Hot Oil Boiler Adoption**	**Grid Electricity**	**Availability of RE for Procurement**	**Impacts of Adopting Steam-Generating Heat Pumps**	**Impacts of Adopting Electric Steam/Hot Oil Boilers**	**Baseline Scenario RE Procurement**	**Ambitious Scenario RE Procurement**
Status	As the world's largest producer of palm oil, palm kernel husks are readily available. This commodity, however, has an extremely high deforestation risk.	Sustainable biomass reduces emissions but offers limited cost savings (compared to other countries) due to subsidized coal prices.	14% of energy comes from natural gas. Only 3% is imported.	Natural gas is more expensive than coal and is expected to increase in price.	The grid is heavily reliant on coal. Less than 3% of the country's RE potential has been harnessed so far.	PPAs are being signed in other sectors, but the market is nascent.	Leads to greater efficiency and energy savings relative to electric boilers. Can already result in substantial savings by 2030, even with minimal RE procurement.	CO_2 emission reductions depend on RE procurement, and feasibility depends on RE cost.	2030 - 25% 2035 - 50% 2040 - 75%	2030 - 50% 2035 - 75% 2040 - 100%
Future Opportunities & Challenges	This biomass source is exported and targeted for power generation, increasing competition for supply.	Very high risk of unsustainable biomass; provenance must be carefully monitored.	Domestic production is declining and reliance on imported LNG is increasing, potentially impacting costs. Infrastructure for distribution is also less mature, limiting access for industrial facilities.	More expensive than coal in all time horizons; less emissions savings than sustainable biomass for steam boilers.	The Just Energy Transition Partnership will leverage international support to develop transmission infrastructure for RE integration. With plans to become a global battery exporter by 2030, energy storage should be cheaper, and grid and manufacturers will be able to adopt this technology.	Corporate RE mechanisms are emerging; however, scaling challenges persist. Limitations on private electricity suppliers and lack of regulatory frameworks continue.	Energy cost parity with coal is reached in 2030, and becomes more competitive after that. Emissions reductions begin in 2030.	2030 - Emissions and energy costs increase in the Baseline RE Procurement pathway. 2035 - Emissions decrease, but energy costs remain uncompetitive - even in 2040.		
Recommen-dation	Due to deforestation risks, biomass should be carefully evaluated to ensure certified sustainable sources are used. Only RSPO and other certified husks should be procured; however, these are in limited supply and more expensive.		Adopting natural gas as an alternative fuel is likely to be logistically challenging and increase cost. This will not be a large scale solution.		Engage with policy makers to support grid decarbonization and modernization.	Engage with policy makers to broaden possibilities for corporate RE procurement.	Explore heat pumps as a cost neutral but emissions saving solution from 2030 onwards.	Coal subsidies must be removed to make electric boilers economically feasible. Recommend to engage in policy advocacy.		

Potential Impacts of Electrification on the Electricity Demand



- Electrification will inevitably increase electricity demand and grid load.
- The installed capacity required to meet electricity demand depends on the energy source, with RE needing greater deployment or storage integration to match demand.

FIGURE: ADDITIONAL ELECTRICAL LOAD FROM ELECTRIFICATION OF STEAM AND HOT OIL BOILERS FOR A TYPICAL TEXTILE FACILITY with annual production of 8,000 ton/year

NOTE: THIS IS THE ADDITIONAL LOAD WITHOUT ASSUMING A CAPACITY FACTOR.

Electrification

Efficiency Improvements

Electrified technologies significantly lower overall energy use.

Emissions Reduction

All electrification technologies achieve emissions reductions by 2035.

Heat Pump Advantage

Heat pumps deliver emissions and cost savings in every geography by 2030.

The Importance of Renewable Energy Procurement

Grid Electricity

Electrifying industrial processes without renewable energy simply shifts emissions to power generation.

Corporate RE Procurement

Companies can secure low-cost, low-emission electricity through Power Purchase Agreements (PPAs) and onsite generation.

Policy advocacy and market signals are necessary to create the enabling environment for electrification.

In Summary

Natural Gas

Lowers direct emissions but may increase GHG impact due to methane leakage. Not a viable transition fuel in studied countries due to logistical and cost constraints.

Biomass

Significant CO_2 reduction potential **IF** sourced biomass is sustainable. Limited long-term viability due to supply constraints. Rate of biomass phase out depends on local supply.

Electrification

Most viable long-term solution, when paired with renewable energy. The only Net Zero compatible technology.

Roadmap & Recommendations

Implementation Guidelines for Electrification Technologies in Textile Plants

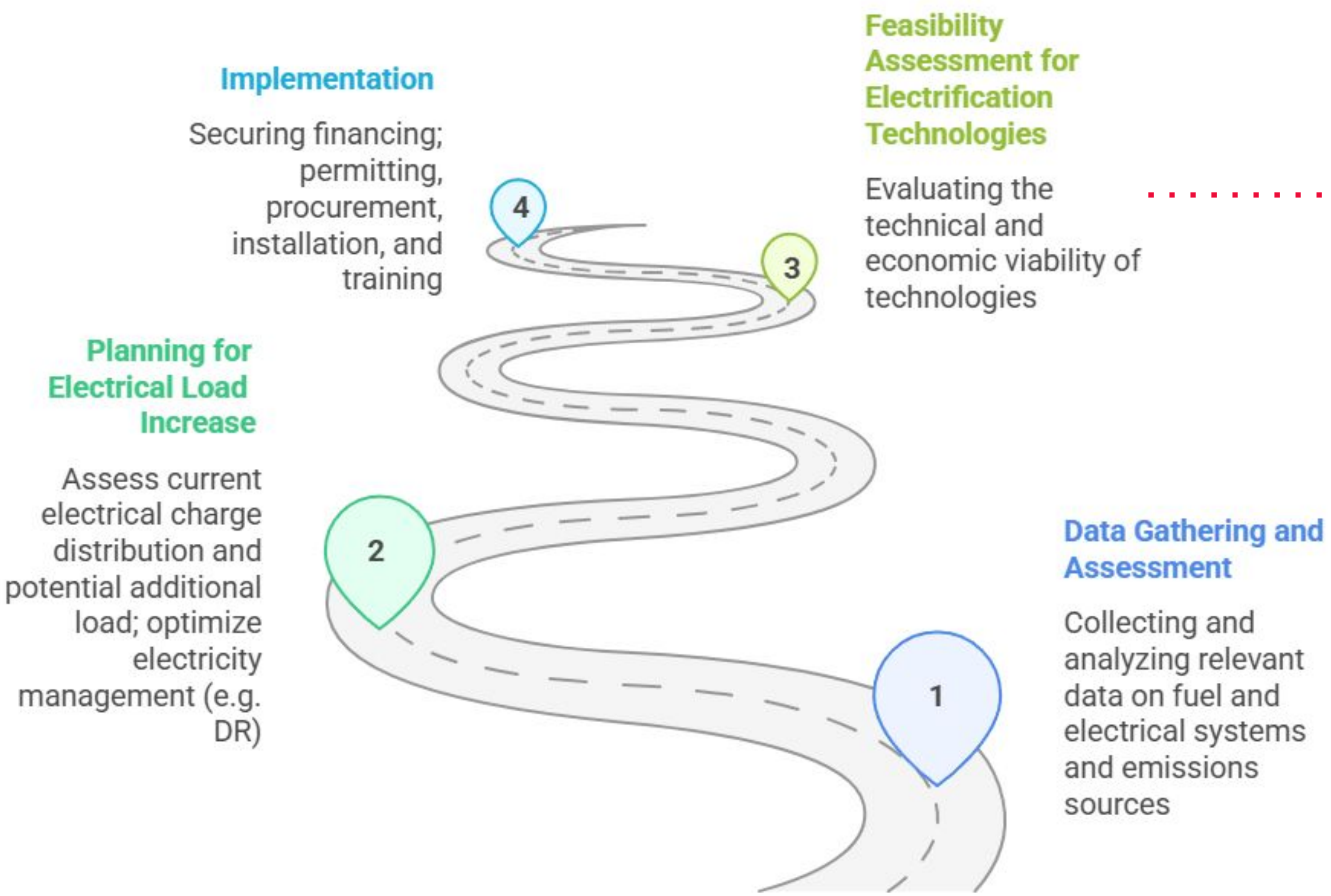


FIGURE: SUMMARY SCHEMATIC OF STEPS FOR IMPLEMENTATION FOR ELECTRIFICATION OF HEATING IN TEXTILE PLANTS

Textile Heating Electrification Tool

www.globalefficiencyintel.com

Financing Mechanisms for Low-Carbon Thermal Energy Technologies in the Textile Industry

FIGURE: SUMMARY SCHEMATIC OF FINANCIAL STRATEGIES FOR LOW-CARBON THERMAL ENERGY ADOPTION IN THE TEXTILE INDUSTRY

Decision Tree For Textile Facilities Seeking To Adopt Low-Carbon Thermal Energy Technologies

- If sustainable biomass can be procured (e.g. agricultural residues), our modeling shows this pathway can deliver reductions in the near term.
- However, in the longer term, the supply of sustainable biomass will be limited. It is for this reason that we see electrification as the more viable low-carbon solution for the industry.

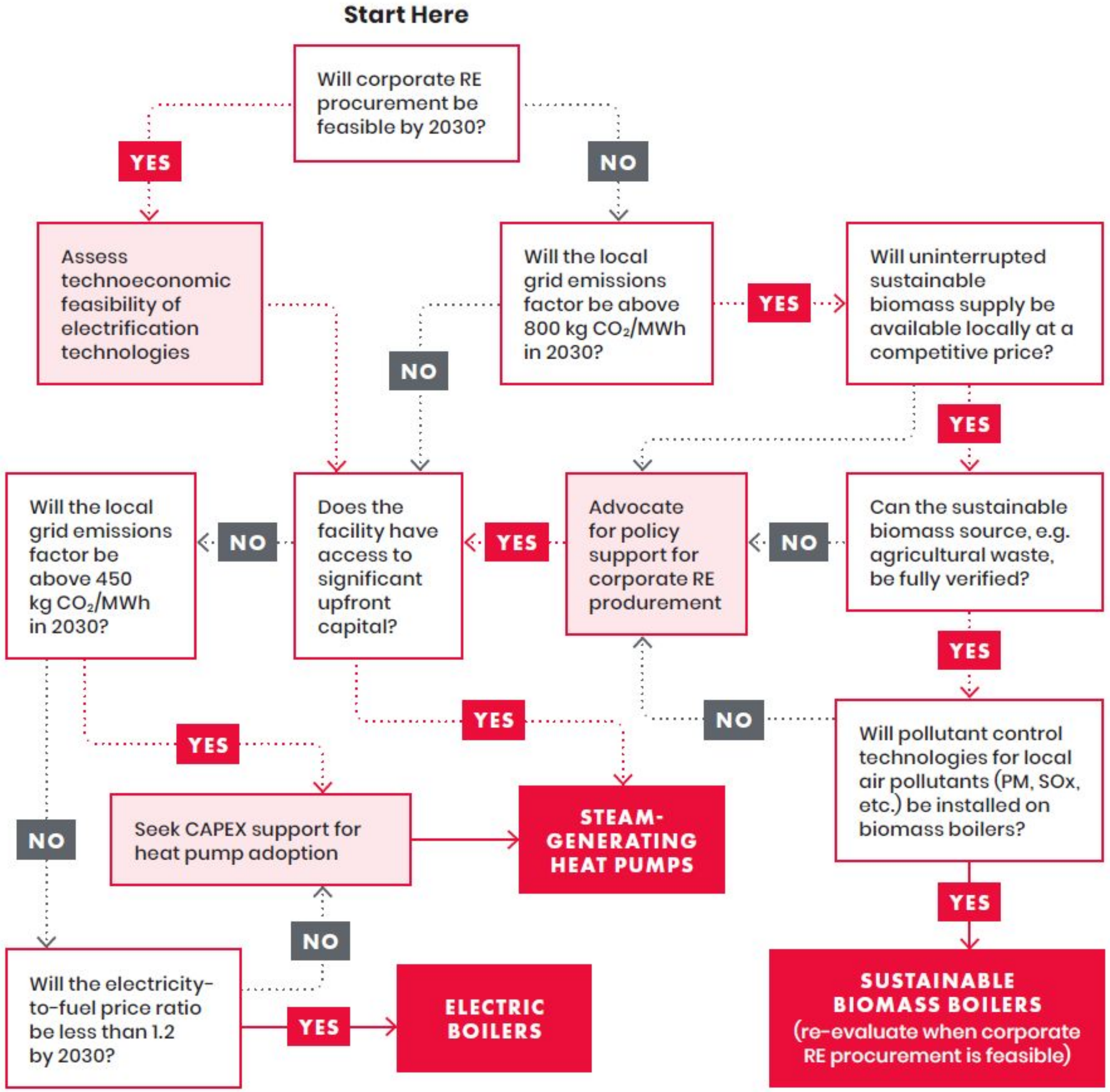


FIGURE: DECISION TREE FOR TEXTILE FACILITIES IN THE STUDIED COUNTRIES SEEKING TO ADOPT LOW-CARBON THERMAL ENERGY TECHNOLOGIES

Multi-stakeholder Roadmap

	Plan & Pilot Stage: 2025-2030	Deployment Stage: 2030-2035	Scale-Up Stage: 2035-2040
Apparel Brands	• Work with suppliers on energy efficiency and reducing energy needs, using the best available technologies and innovations. • Initiate pilot electrification projects paired with RE procurement where it is available (China and India). • Work with textile manufacturers to plan for and procure RE. Focus on navigating DPPA in Vietnam and engaging in advocacy for corporate RE procurement in Bangladesh and Indonesia. • Standardize industry definitions of sustainable biomass using existing guidelines. • Verify sustainable biomass sourcing and assess supply over time. • Leverage agricultural residue supply in China; verify any additional biomass use in India and Vietnam; discourage biomass in Indonesia; carefully assess impacts in Bangladesh. • Support RE development and RE grid integration. • Advocate for grid infrastructure and corporate procurement mechanisms in Bangladesh and Indonesia.	• Facilitate biomass phase-out due to projected cost increase and decreased availability of sustainable biomass in India, Vietnam, and Indonesia. • Assess electrification feasibility and adopt where possible, recognizing that heat pumps as the most efficient electrification technology. • Accelerate RE procurement in China, India, and Vietnam. • Establish RE goals in Bangladesh; encourage RE adoption in Indonesia • Provide technical and financial support for electrification deployment, especially heat pumps. • Seek out additional funding for electrification and financing partnerships (e.g., CDB in China, SBI in India). • Advocate for improved RE frameworks and • cost-competitive PPAs.	• Fully transition away from biomass across all countries. • Work with Bangladesh on natural gas phaseout and electrification adoption. • Scale electrification with RE adoption. • Continue to advocate for improved RE frameworks and cost-competitive PPAs in all countries. • Support policies that align with fully decarbonized thermal energy in the textile industry.
Textile Manufacturers	• Continue energy efficiency work and explore innovative solutions to reduce thermal energy needs. • Assess RE procurement feasibility. • With brand support, begin pilot projects in China, India, and Vietnam. • Request standardized definitions and approaches to sustainable biomass from brands. • Ensure verifiable and sustainable biomass sourcing. • Plan for medium-term electrification as biomass becomes less viable and prices increase. • Advocate for access to existing RE procurement mechanisms in China, India, and Vietnam. • Collaborate with brands to advocate for RE procurement mechanisms in Indonesia and Bangladesh. • Promote policies for sustainable biomass MRV.	• Phase out biomass as sustainable and affordable sources decline in India, Vietnam, and Indonesia. • Secure long-term RE procurement agreements. • Prioritize emerging RE opportunities in Bangladesh and Indonesia. • Seek technical and financial assistance from brands for electrification, especially heat pumps. • Participate in financing initiatives with brands and government. • Advocate for grid-ready infrastructure and RE affordability in Bangladesh.	• Fully phase out biomass across all countries. • Phase out natural gas in Bangladesh. • Fully adopt electrification technologies powered by 100% RE in all countries. • Seek additional efficiency and cost-saving measures that can leverage electrification (e.g. demand response programs) in China and India. • Continue collaboration with a wide-range of entities, including apparel brands, financial institutions, utilities, and policymakers.

Multi-stakeholder Roadmap

	Plan & Pilot Stage: 2025-2030	Deployment Stage: 2030-2035	Scale-Up Stage: 2035-2040
Policymakers	• Provide incentives and grants for electrification pilot projects in the textile sector. • Work on harmonizing standards and regulations for sustainable biomass across regions.	• Provide capacity building and multi-stakeholder convenings to share knowledge around successful electrification deployments. • Move from government grants towards tax incentives and market mechanisms to encourage wider deployment.	• Allocate ongoing resources for grid modernization and RE integration in plants. • Plan for integrated textile production and RE clusters where possible, such as in low-carbon industrial parks in China and Vietnam.
Financial Institutions	• Establish pilot project financing mechanisms for textile manufacturers, particularly for heat pump CAPEX. • Support capacity building and preparatory activities for electrification in Bangladesh and Indonesia.	• Incorporate pilot project results to develop a business case for electrification technologies. • Leverage private sector finance	• As low-carbon technologies are increasingly competitive, focus on favorable commercial finance. • Provide financing for associated infrastructural upgrades, e.g. grid modernization.
Utilities	• Work with policymakers to ensure grid readiness for industrial electrification. • Streamline corporate RE procurement mechanisms. • Offer favorable rates, at a minimum for T&D charges for electrification projects.	• Seek financing for grid modernization projects. • Offer electrification technical support to textile manufacturers. • Implement smart grid technologies.	• Work with other stakeholders to manage additional load from industrial electrification. • Deploy programs to effectively manage load (e.g. time-of-use pricing and demand response).

Call to Action & Next Steps

Aii's Call to Action

1

Critical Juncture

The textile sector is at a turning point. Immediate action is needed to achieve this long-term transition.

2

Brand Leadership

Brands must drive market change through policy advocacy, public electrification strategies, and technical and financial support for implementation.

3

Supplier Implementation

Suppliers should lead implementation with brand support.

Achieving a Just Transition

Brand Priorities

Prioritize supplier engagement and collaboration on low carbon transition.

Transparency

Develop business cases for suppliers through transparency and commitment.

Collective Effort

Brands, suppliers, policymakers, financiers, and utilities must work together to develop the enabling environment.

Climate Solutions Focus

1

Thermal Load Reduction

Doubling down on reducing thermal energy needs in facilities.

2

Renewable Energy Transition Initiative

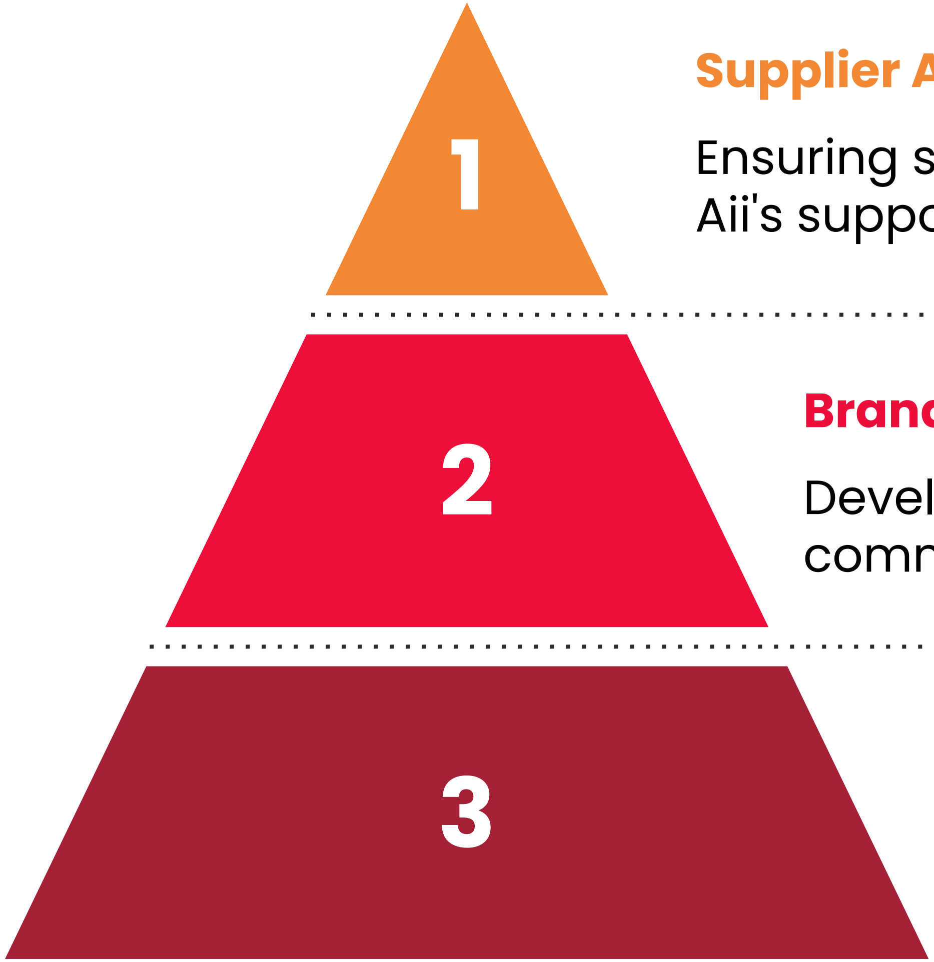
Launching in China, piloting in India and Vietnam in 2025.

3

CSP Grant Funding

Supporting suppliers and innovators to develop electrification case studies.

Ecosystem Leadership



Supplier Advisory Council

Ensuring supplier needs are at the core of Aii's support of the low-carbon thermal energy transition.

Brand Electrification Market Signal

Developing long-term electrification commitments with brands.

Financial Ecosystem Leadership

Supporting brands to unlock budgets for supplier decarbonization and develop a portfolio of financial solutions.

Aii's Support: Industry Collaboration

Carbon & Energy Benchmark

Create the long-term business case for decarbonization.

Renewable Electricity

Explore how Aii might support RE procurement.

Industry Decarbonization Roadmap

Starting September 2025, engage the top 1,500 emitting suppliers in decarbonization efforts.

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