Indonesian Industry Decarbonization Roadmaps

Presentation at the Dissemination Workshop of Indonesia Industry Decarbonization Roadmap and Policy Recommendations

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Energy Technologies Area
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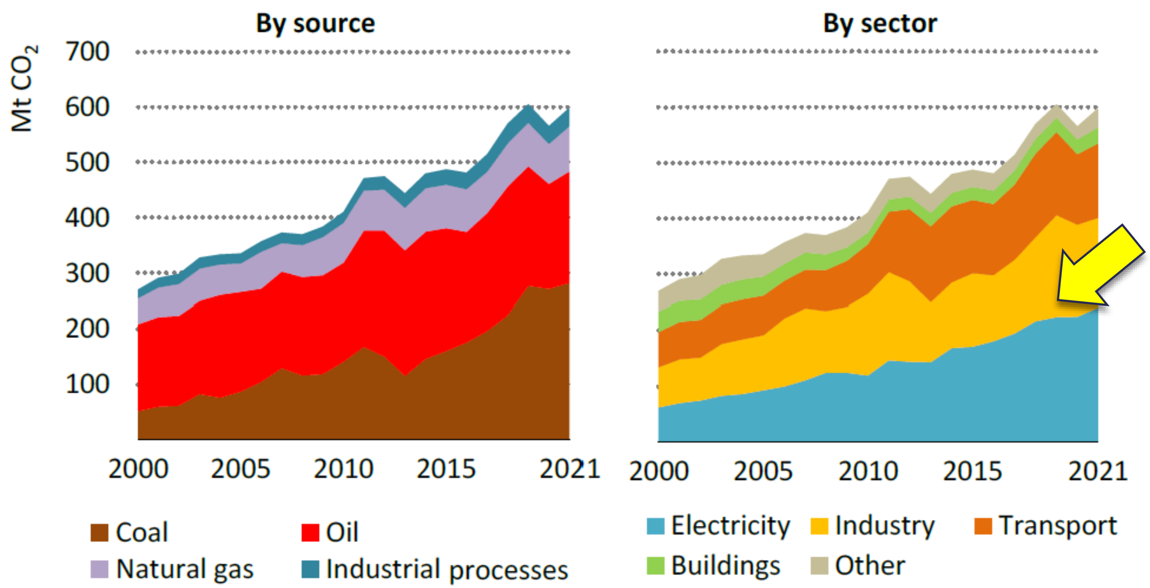
October 24, 2023

Indonesia's Industry Sector

- Industry sector in Indonesia:
  - Industry is one of the largest CO_2-emitting sectors in Indonesia
  - Indonesia has pledged to achieve net-zero by 2060 or sooner.
  - Lack of assessment on how Indonesian industry can achieve net-zero emissions by mid-century.

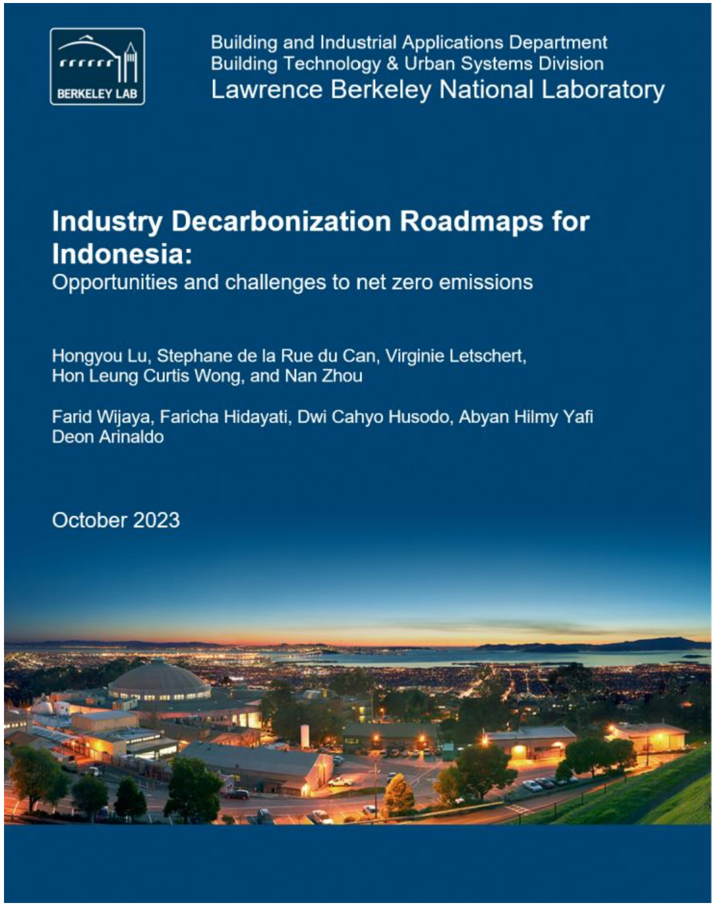


- Industry accounts for 1/3 of national energy-related CO_2 emissions – when only accounting for direct emissions from onsite fossil fuel use.
- Industrial CO_2 emissions are even larger – when indirect emissions from electricity consumption are included.

Source: IEA, 2020.

Project Objectives and Draft Report Completed

- **Project objectives:**
  - Develop industry-specific decarbonization roadmaps to support Indonesia to achieve its updated NDC goals
  - Engage local stakeholders to assess local conditions in Indonesia
  - Provide policy recommendations
  - Establish one of the first industry decarbonization roadmaps for Indonesia
- **Sectors:**
  - Iron and Steel
  - Cement
  - Ammonia
  - Pulp and Paper
  - Textiles
- **Stakeholder engagement:**
  - Held six Focused Group Discussions (FGDs) in June 2023 with industry and policy stakeholders:
    - Ministry of Industry (MOI)
    - Ministry of Energy and Mineral Resources (MEMR)
    - Indonesia Cement Association (ASI)
    - Indonesia Iron and Steel Industry Association (IISIA)
    - Association of Indonesia Fertilizer Producers (APPI)
    - Indonesian Chemical Industry Federation (FIKI)
    - Indonesia Pulp and Paper Association (APKI)
- **Local partner:** Institute for Essential Services Reform (IESR)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Industry Decarbonization Roadmaps for Indonesia:
Opportunities and challenges to net zero emissions

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October 2023

ENERGY TECHNOLOGIES AREA

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Methodology: Industry Decarbonization Pillars





Material Efficiency and Demand Reduction	**Energy Efficiency Improvement**	**Electrification**	**Fuel Switching**	**CCUS**
Material efficiency (e.g., lightweight, longer lifetime, prefabrication, optimize cement content in concrete, improving manufacturing yields)	Component (e.g., kilns, furnaces, boilers) and system (e.g., process heating, steam system, motors, compressed air, pumps) energy efficiency improvement	Expand electricity end-use in industry applications	Alternative fuels (e.g., industrial wastes, municipal solid wastes)	CCUS in the cement industry (e.g., post-combustion, oxy-fuel combustion, indirect calcination)
Material substitution (e.g., use of engineered wood; alternative cements)	Waste heat and waste pressure recovery Energy management	Onsite or grid power generation using renewables	Solar thermal; biomass; geothermal	CCUS in the steel industry (e.g., Top-gas recycling with CCS, DRI with CCS)
Material reuse and recycling (e.g., direct component reuse, reduce construction wastes, increase recycling rates)	Integrative design and system optimization	Low-temperature heat electrification Medium-to-high temperature heat electrification	Hydrogen as feedstock and fuel	Carbon utilization Carbon to ethanol and other chemicals

Methodology: Scenarios Development

- Scenarios are constructed to analyze energy and CO_2 impacts of different decarbonization pathways.
- Developing scenarios allow us to test and evaluate the implications of different narratives.

- **Three Scenarios:**
  - **Reference** — Business as usual, no new policies, slow adoption of low-carbon technologies.
  - **Near Zero 2060** — Achieve near-zero emissions in modeled industrial sectors by 2060; support Indonesia's 2060 carbon neutrality goal; allow near-zero emissions, with residual emissions be offset by removals and mitigation measures in other sectors.
  - **Accelerated 2050** — Approaching net-zero emissions by 2050; aggressive adoption of low-carbon technologies; achieve maximum technical potential.

Key Findings

- **It is technically feasible to achieve near-zero emissions in Indonesia's industrial sector by 2060,** the target year of carbon neutrality in Indonesia's updated NDC. Achieving net-zero emissions by 2050, as aspired in the government goals, will require extraordinary efforts and a much more accelerated pace of adoption of low-carbon technologies.

- **To achieve announced national economic development targets, it would require significant growth in the industrial sector**, which provides the foundational materials and infrastructure for urbanization, improved living standards, and other industry (renewables, batteries, EVs) development that is necessary for energy transition.

- Industrial capacity expansion is expected in several key industries, e.g., iron and steel, driven by domestic construction demand and transfer of industrial capacity from other Asian countries (China, Japan, and South Korea, etc.). **However, the current industry development is not on track with the Near Zero 2060 Scenario.**

- **Industry investment and policy decisions made today have important implications for 2050 and 2060. Industry development can be met by clean, low-carbon, and cost-effective technologies.** It is urgent and critical to develop policy strategies and create the right market conditions to speed up the adoption and scale up.

Key Findings

- **National strategies on carbon-intensive materials** (e.g., steel, and cement), **green energy carriers** (e.g., hydrogen and ammonia), and **cross-cutting technologies** (e.g., industrial heat pumps, and CCS) need to be developed. **Coordinated approach on infrastructure development** (pipelines, storage sites, power transmission and distribution systems) and utilization is necessary.

- Industry decarbonization requires a fast-decarbonizing power sector. Near zero emissions in industry requires access to clean, low-cost electricity. **Policies that support industry to connect to renewable power or develop its own renewable electricity renewables are very important.**

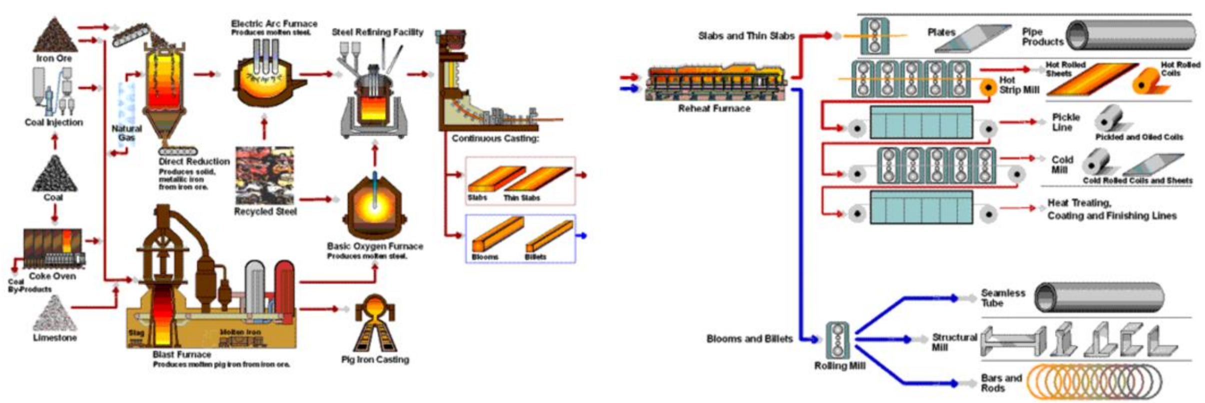
- **Industry decarbonization is inevitable but multifaceted.** It has the potential to develop new industry, grow local economy, reduce air pollution, and be more competitive in global trade. It is critical to involve all stakeholders in this process to minimize negative impacts to local communities, and leverage this opportunity to reduce inequality.

Iron and Steel Industry in Indonesia

- **Iron and steel industry is the largest energy-consuming industry in Indonesia.**
  - Crude steel production has been increasing sharply, driven by a growing society (infrastructure projects, increasing population, urbanization, etc.)
  - AAGR: 14% per year from 2011 to 2021

Process	2020 (GJ/t steel)
Blast Furnace (BF)-Basic Oxygen Furnace (BOF)	20.4
Scrap-Electric Arc Furnace (EAF)	2.3
Direct Reduction of Iron - EAF	10.7
Steel Rolling	2.1

Source: WorldSteel, various years.

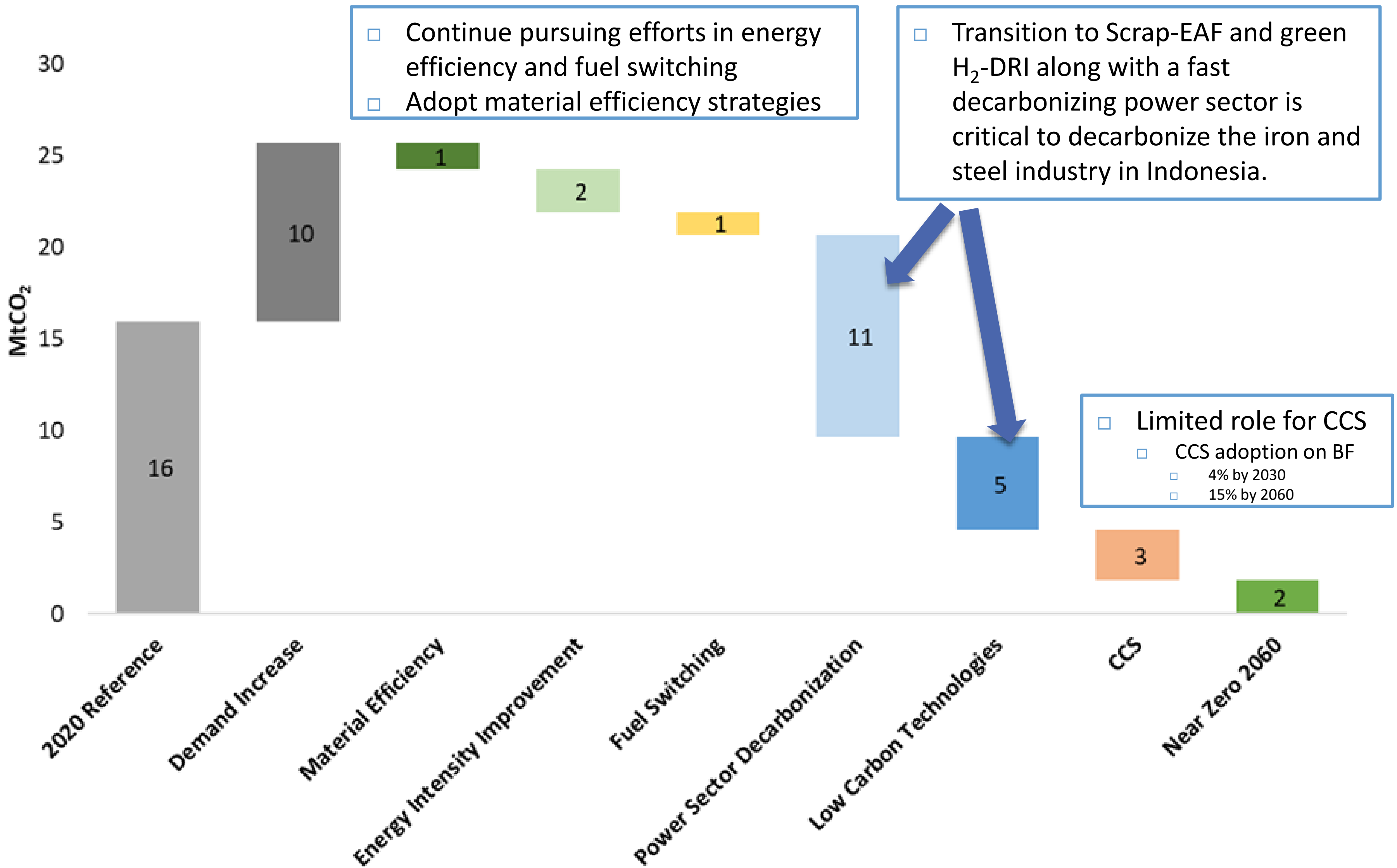


Source: AISI 2022.

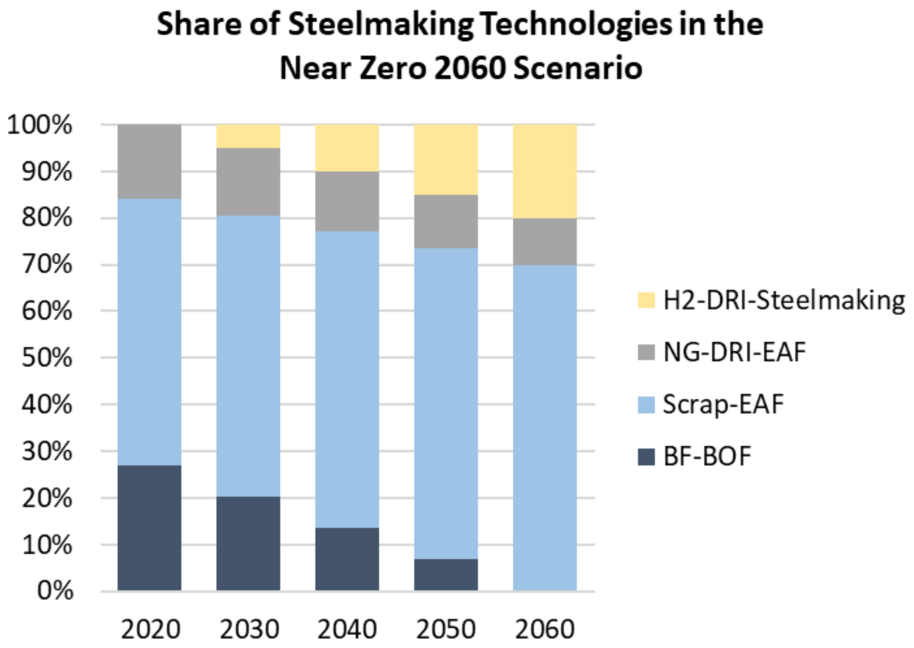
Technologies and measures to decarbonize the iron and steel industry

Material Efficiency	Energy Efficiency	Low-Carbon Steelmaking Technologies and Fuel Switching	CCUS
• Improved design and construction • Design for circular principles • Improved semi-manufacturing yields • Improved product manufacturing yields	• Improving thermal energy efficiency	• Increased use of electric arc furnaces (EAF)	• CCU technologies: carbon to methanol, carbon to chemical
• Extending product lifetime	• Improving electrical energy efficiency	• Onsite renewables	• Post-combustion CCS on BF
• Lightweight and higher strength materials • Alternative materials and construction	• Smart energy management	• Alternative reducing agent (hydrogen, biomass)	• CCS on DRI process
• Direct component reuse (without melting)	• Integrative design/system optimization	• Hydrogen DRI • Molten Oxide Electrolysis • Electrowinning aqueous • Electrowinning – molten salt	• CCS on smelting reduction process

CO_2 Impacts of Key Mitigation Options under the Near Zero 2060 Scenario for the Iron and Steel Industry in Indonesia

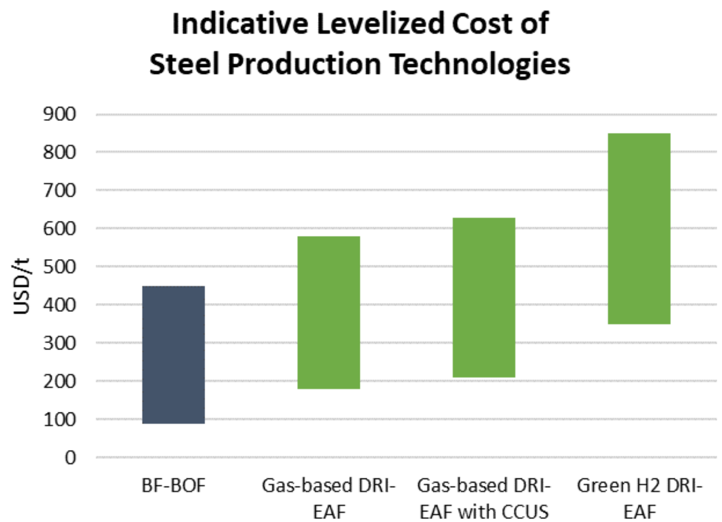


Low-Carbon Steelmaking Technologies



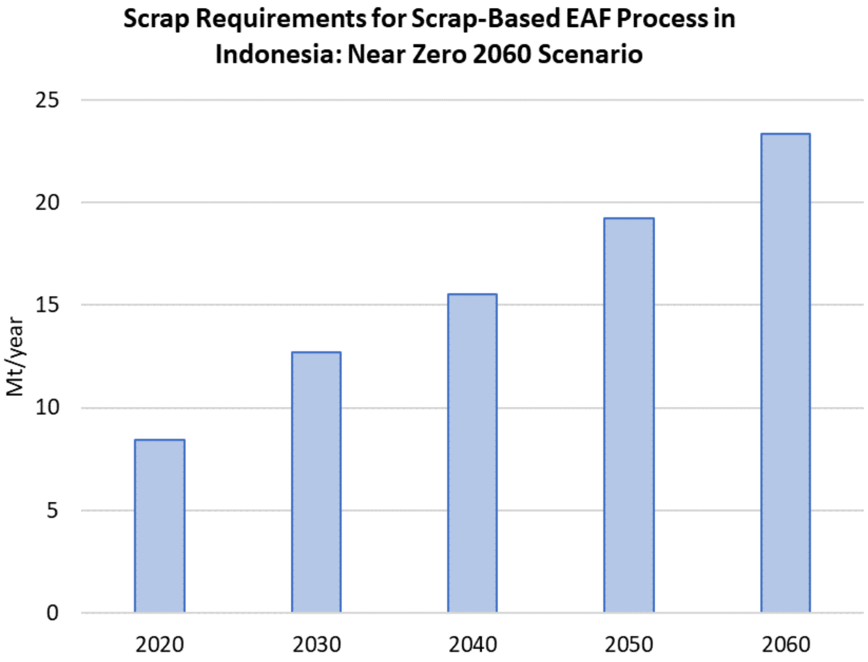
- Phasing out BF-BOF by 2060 in the Near Zero 2060 Scenario
- Increasing the share of scrap-based EAF to 70% by 2060
- The production share of natural-gas based DRI is decreased to 10%
- The share of green H2-DRI-EAF is increased to 20%

- Indicative levelized cost of steel production technologies
  - Low-carbon steelmaking technologies tend to be 10% - 100% more expensive than conventional primary steelmaking (without carbon pricing)
  - Cost is sensitive to natural gas and electricity prices



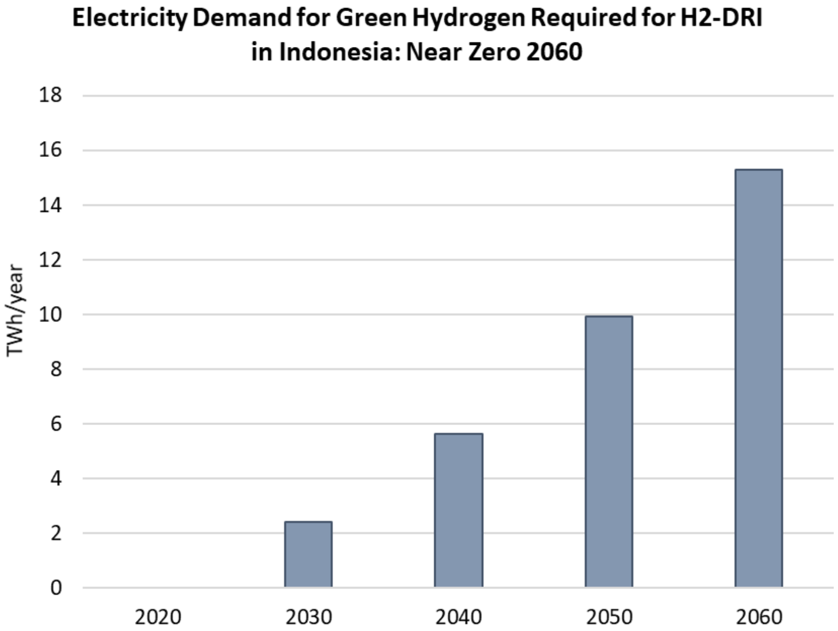
Source: IEA.

Scrap Demand



- Total scrap required will be approximately 13 Mt/year by 2030 and increasing to 23 Mt/year by 2060
  - Based on total production forecast ("steady demand" scenario), the share of scrap-EAF, and scrap intensity in EAFs
- The increase of scrap demand is not small, but it can be met by regional scrap resources, driven by peak steel demand and increased scrap availability in China.
  - A global steel study showed that by 2050, a total of 100 Mt of scrap is available in Southeast Asia, and more than 600 Mt of scrap is available from China alone

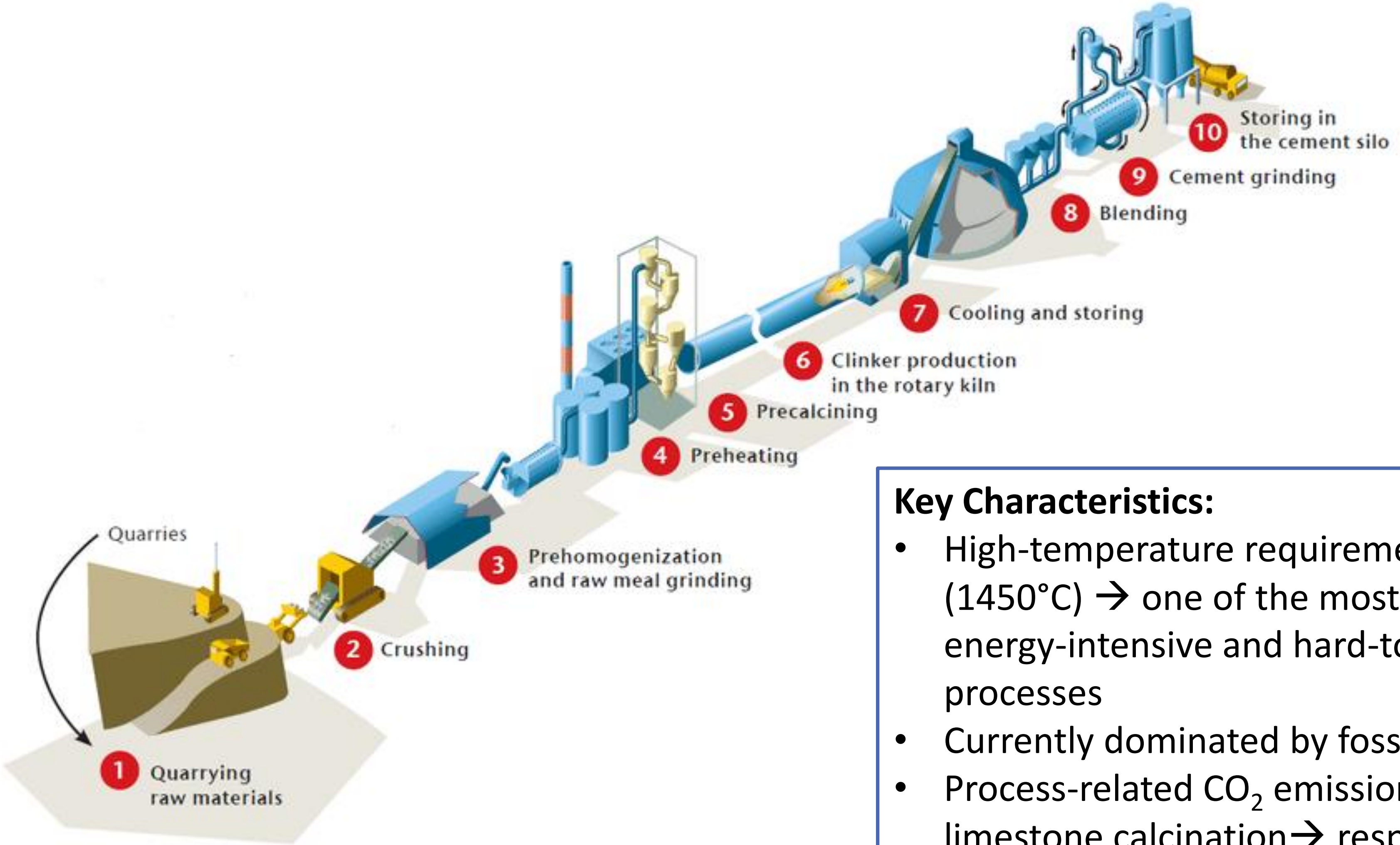
Demand for Green Hydrogen and Clean Electricity



- In the Near Zero 2060 Scenario, we estimated that Indonesia's iron and steel industry would require 47,000 tonnes/year of green hydrogen by 2030, and increases to 300,000 tonnes/year by 2060

- Indonesia would require additional 2.4 terawatt-hours (TWh) of zero-carbon power generation per year by 2030 and 15 TWh/year by 2060. In comparison, Indonesia generated a total of 65 TWh zero-carbon electricity in 2022.

Cement Manufacturing Process



Source: IEA 2009.

Key Characteristics:

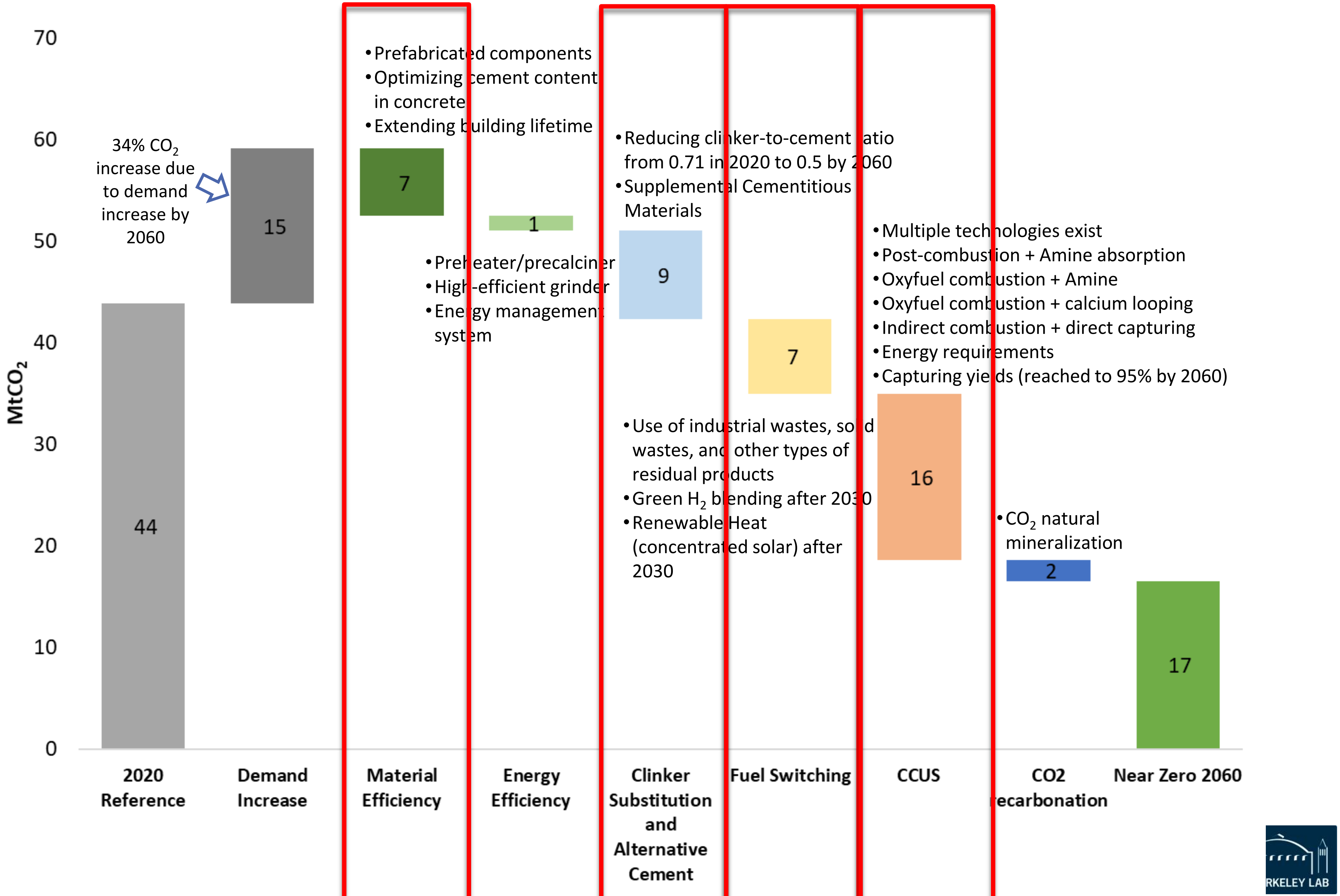
- High-temperature requirements (1450°C) → one of the most energy-intensive and hard-to-abate processes
- Currently dominated by fossil fuels
- Process-related CO_2 emissions from limestone calcination→ responsible for 50-60% total CO_2 emissions in the cement industry

Commercialized and Emerging Technologies and Measures to Decarbonize the Cement Sector

Material Efficiency	Energy Efficiency	Clinker Substitution and Alternative Cement	Fuel Switching	CCUS
• Improved building design • Optimizing cement content in concrete	• Improving thermal energy efficiency	• Use of SCM: coal fly ash, BF slag	• Alternative fuels: industrial wastes, municipal solid wastes, agricultural byproducts	• Post-combustion CO_2 capturing technologies
• Increased use of precast components and post-tensioning of floor slabs • Extending product lifetime	• Improving electrical energy efficiency	• Use of SCM: calcined clay, end-of-life binder	• Onsite renewables	• Oxyfuel combustion CO_2 capturing or calcium looping
• Alternative materials (e.g., mass timber) • Additive manufacturing	• Smart energy management	• Use of SCM: other by products (silica fume, bauxite residue, agricultural byproduct ashes, etc.)	• Hydrogen blending	• Integrated calcium looping with the calcination process
• Recycling construction wastes • Recycle concrete into recycled concrete aggregates	• Integrative design/system optimization	• Alternative cement chemistry	• Concentrated solar	• CO_2 mineralization (CO_2 mixing and curing)

Indonesia's Cement Industry:
CO_2 Impacts of Key Mitigation Options under the Near-Zero 2060 Scenario

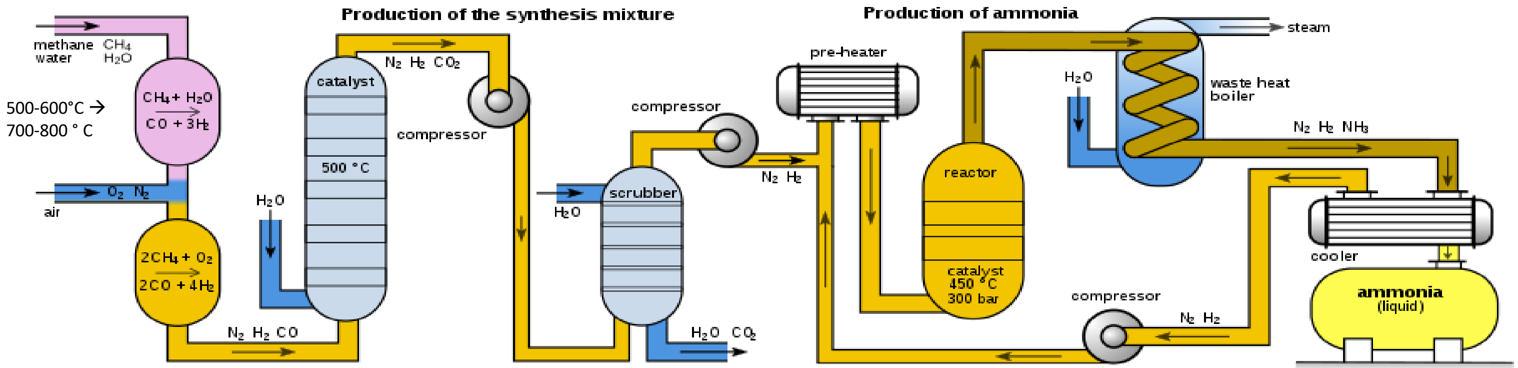
Updated results



Ammonia

- Ammonia (NH_3) is a key ingredient for making mineral nitrogen fertilizers, which are critical inputs for societies to produce food, feed, and plants (fibers).
  - Ammonia is also used for other industrial applications, such as explosives, plastics, rubber, synthetic fibers, and other chemical uses.
- Indonesia is the 5th largest ammonia producer in the world, and about 72% of the ammonia produced is used for fertilizers.

Hydrogen Production **Ammonia Production**

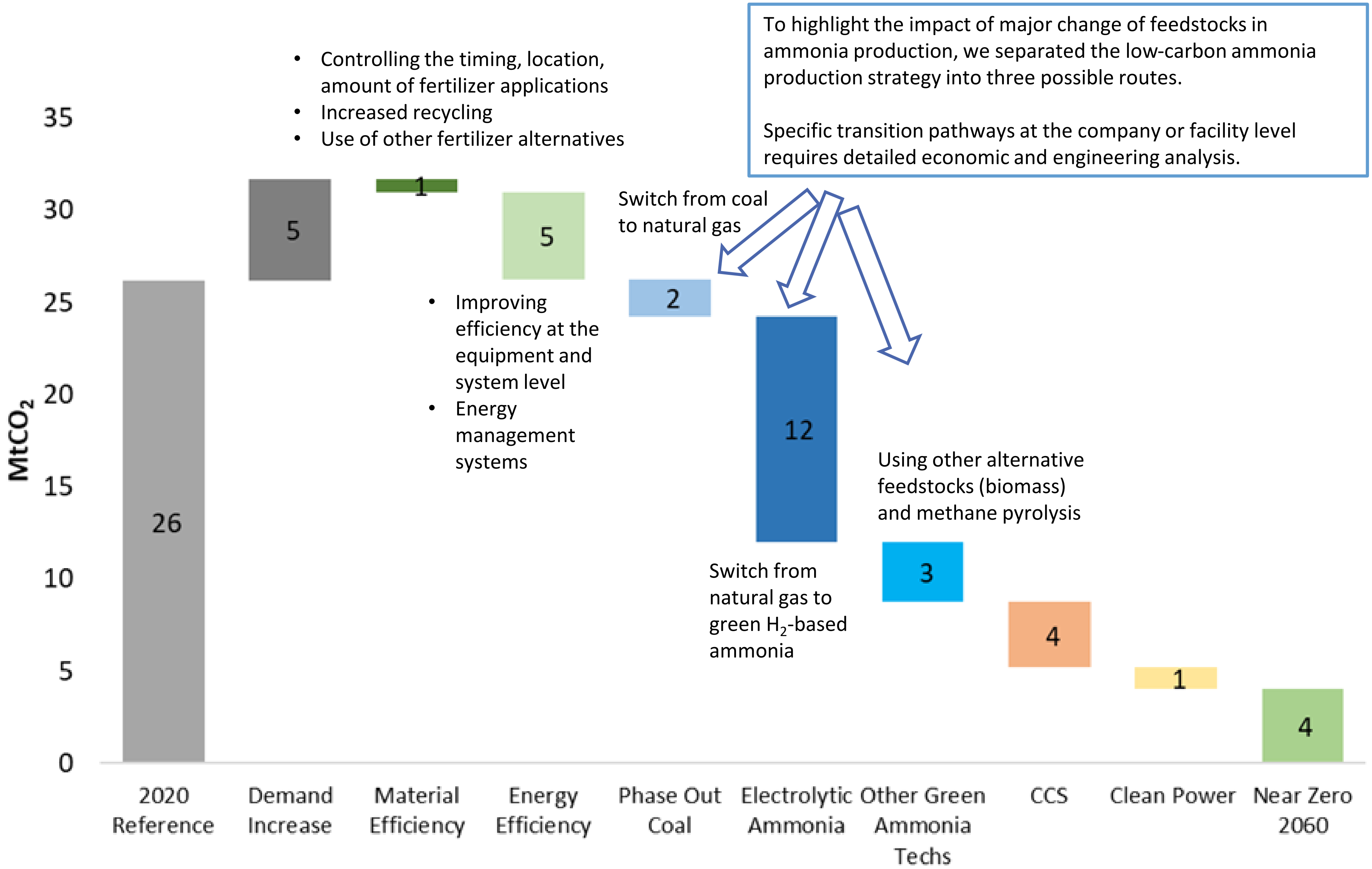


Primary and secondary reformers | Water Shift | CO_2 separator Amine (MEA) absorption | Methanation | Ammonia synthesis 400-600 ° C 100-400 bar

Technologies and measures to decarbonize the ammonia industry

Material Efficiency	Energy Efficiency	Green Ammonia	CCS
• Increase uptake efficiency of fertilizers • Reduce leakage to water and air	• Improving thermal energy efficiency • Improving electrical energy efficiency	• Green hydrogen based ammonia production	• Natural gas based ammonia production with CCS
• Reduce food wastes	• Smart energy management	• Biomass-based ammonia production	• Coal-based ammonia production with CCS
• Increase plastic recycling	• Integrative design/system optimization	• Methane pyrolysis	• Biomass gasification with CCS (not modeled)

CO_2 Impacts of Key Mitigation Options under the Near Zero 2060 Scenario for the Ammonia Industry in Indonesia



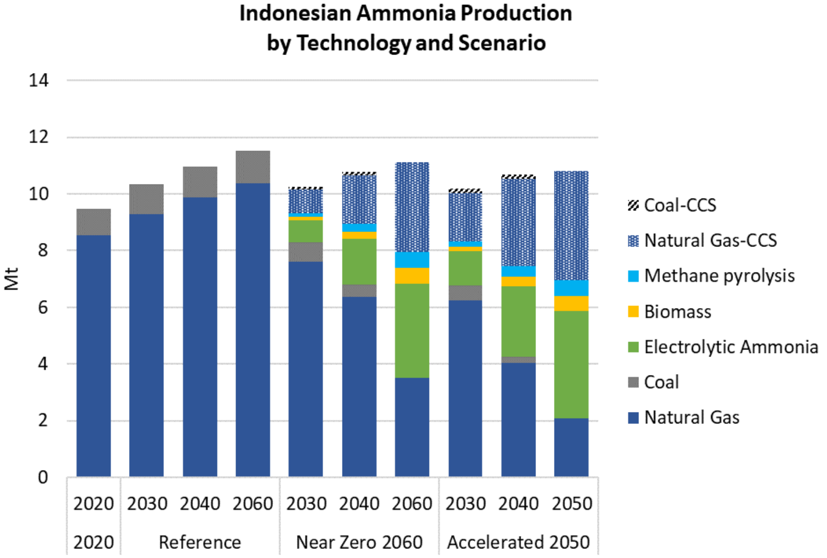
Note: CO_2 emissions include both direct and indirect CO_2 emissions.

Green Ammonia Production Technologies

Green Ammonia Production Routes	Technologies	Technology Readiness Levels (TRL)
Ammonia synthesis	Electrolytic ammonia production	8 (industrial pilots)
	Biomass gasification ammonia production	5 (large prototype)
Direct ammonia production	Methane pyrolysis	7 (precommercial demonstration)
	Electrochemical process	1-3 (concept stage)
	Photochemical process	1-3 (concept stage)
	Plasmatic synthesis	1-3 (concept stage)
	Metallocomplexes	1-3 (concept stage)
	Bio-chemical (biomass digestion) process	1-3 (concept stage)

Sources: IEA 2021b; Olabi et al. 2023; Mitchell Crow 2023; Sánchez, Martín, and Vega 2019; Mission Possible Partnership 2022a; Smith, K. Hill, and Torrente-Murciano 2020.

- The share of low-carbon ammonia production
  - **Near Zero 2060:** 18% of total production by 2030, and 69% by 2060
  - **Accelerated 2050:** 32% of total production by 2030, and 81% by 2050
- Need to develop a national green hydrogen strategy: site selection, permitting, access to renewables, and industry prioritization
- Require renewable, low-cost electricity
- Infrastructure development strategy

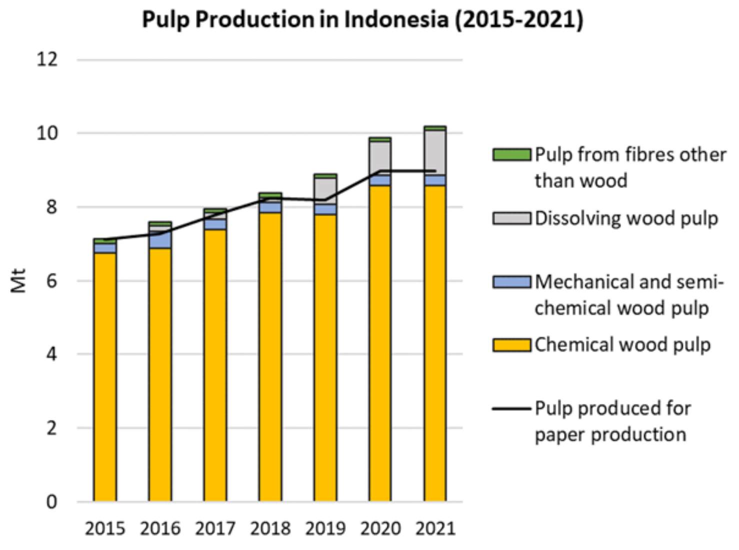


Pulp and Paper Production in Indonesia

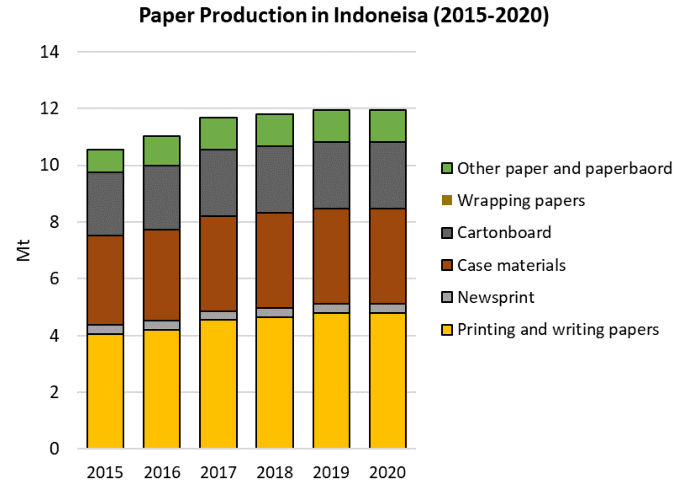
- Indonesia is a main pulp and paper producer in the world, accounting for 5% of the world's wood pulp production by 2020.

- Total pulp production has been increasing 6% per year on average from 2015 to 2021.
  - 85% of total pulp production comes from chemical wood pulp.

- Total paper production grew 3% per year on average from 2015 to 2021.

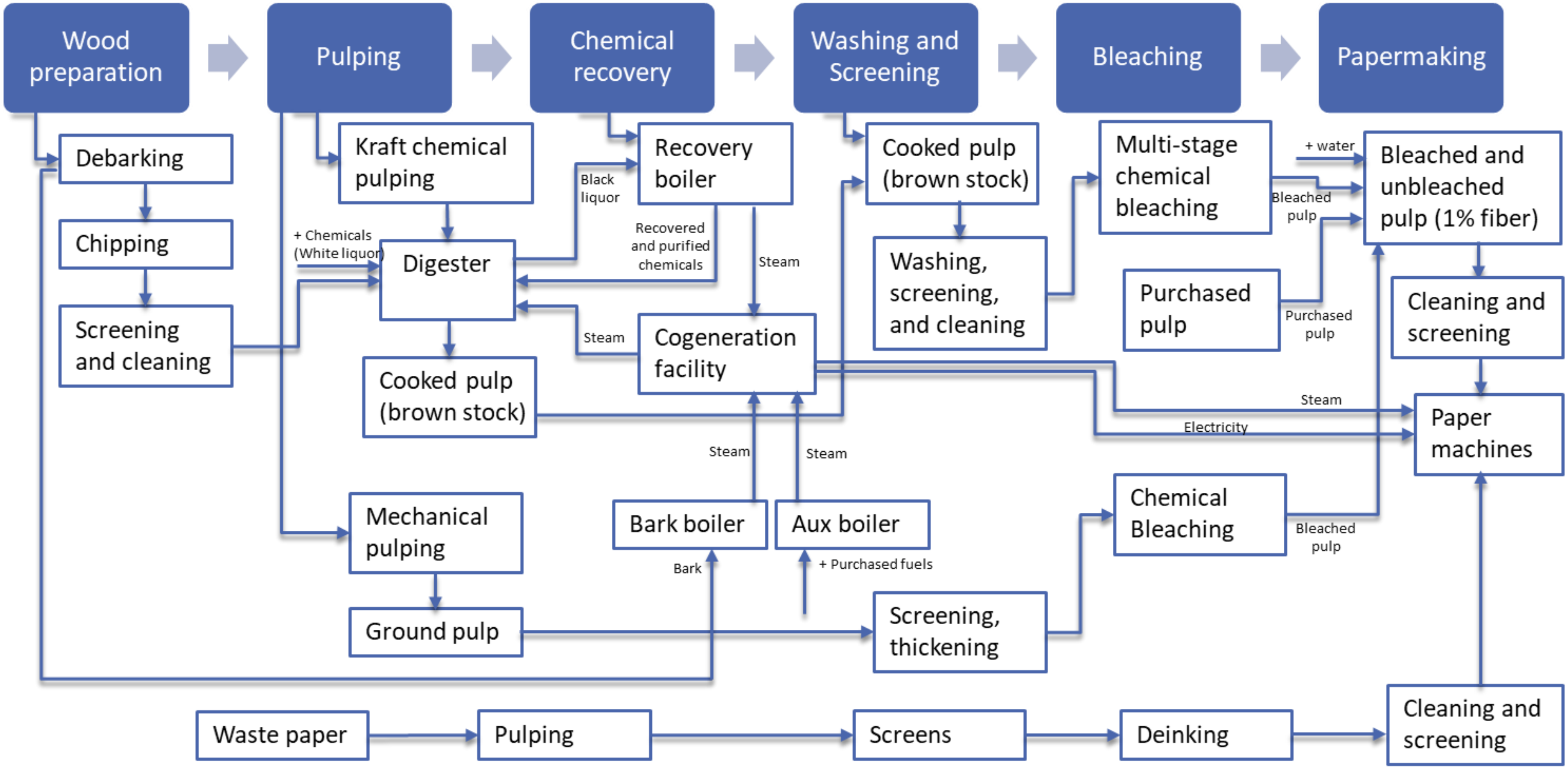


Source: FAO 2023a.



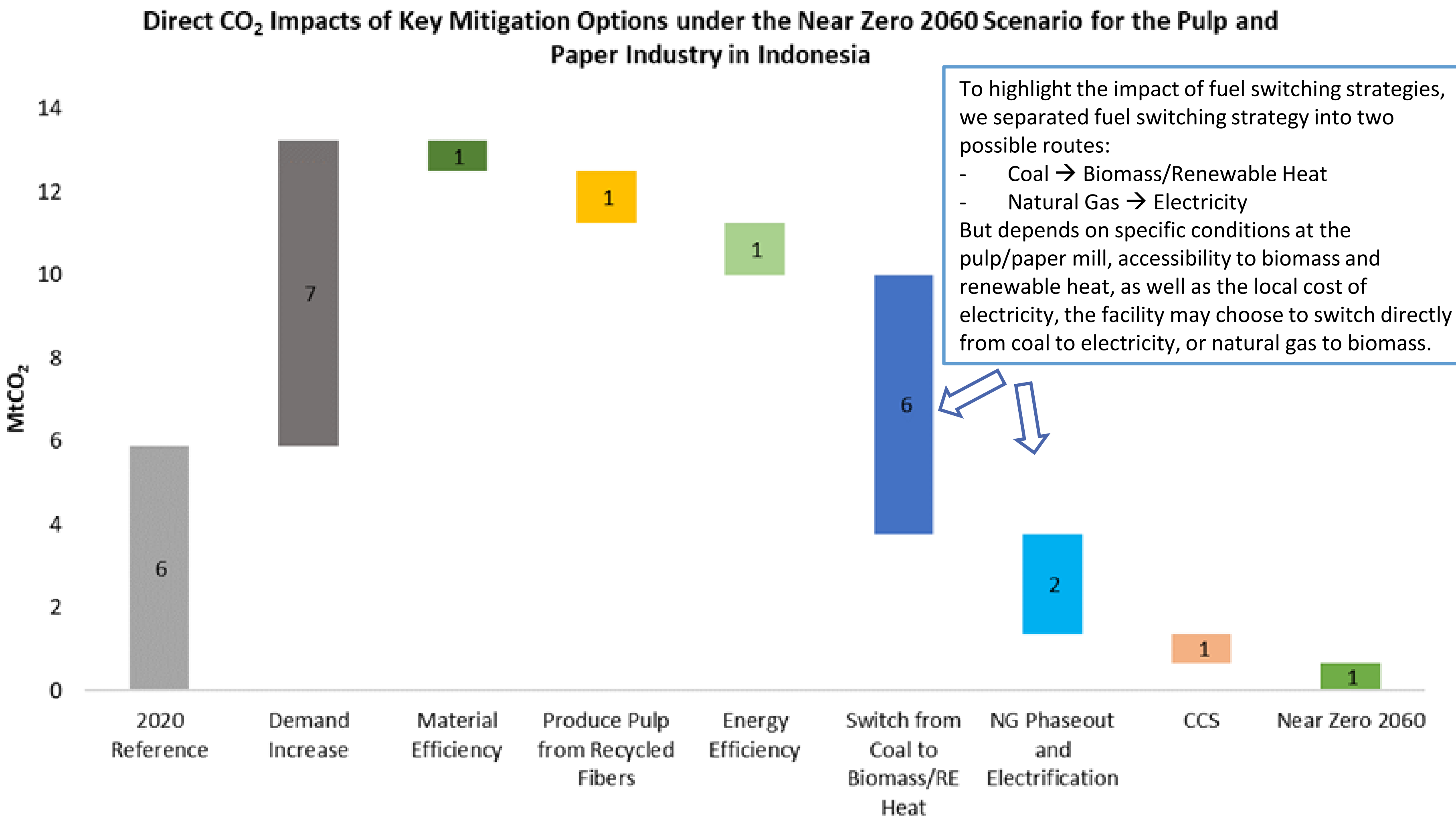
Source: FAO 2023a.

Pulp and Papermaking Process: Complex and Integrated



Source: LBNL analysis.

Achieving Near Zero Direct CO_2 emissions by 2060 in the Indonesian Pulp and Paper Industry



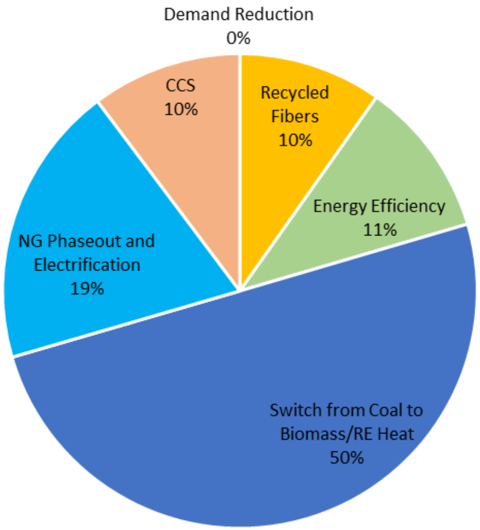
To highlight the impact of fuel switching strategies, we separated fuel switching strategy into two possible routes:

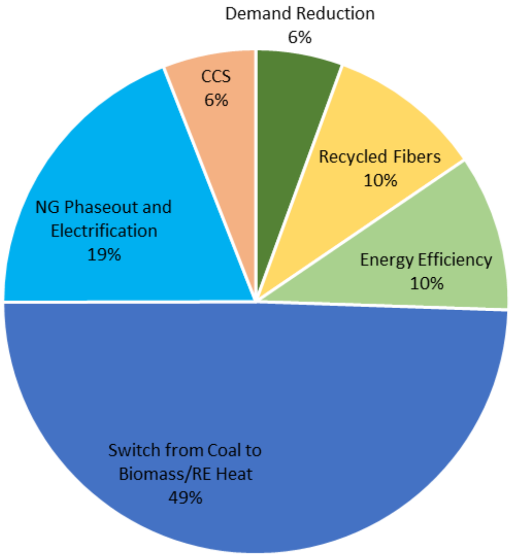
- Coal → Biomass/Renewable Heat
- Natural Gas → Electricity

But depends on specific conditions at the pulp/paper mill, accessibility to biomass and renewable heat, as well as the local cost of electricity, the facility may choose to switch directly from coal to electricity, or natural gas to biomass.

Achieving near-zero emissions of both direct and indirect CO_2 emissions would require Indonesia's power sector to be decarbonized well before 2060.

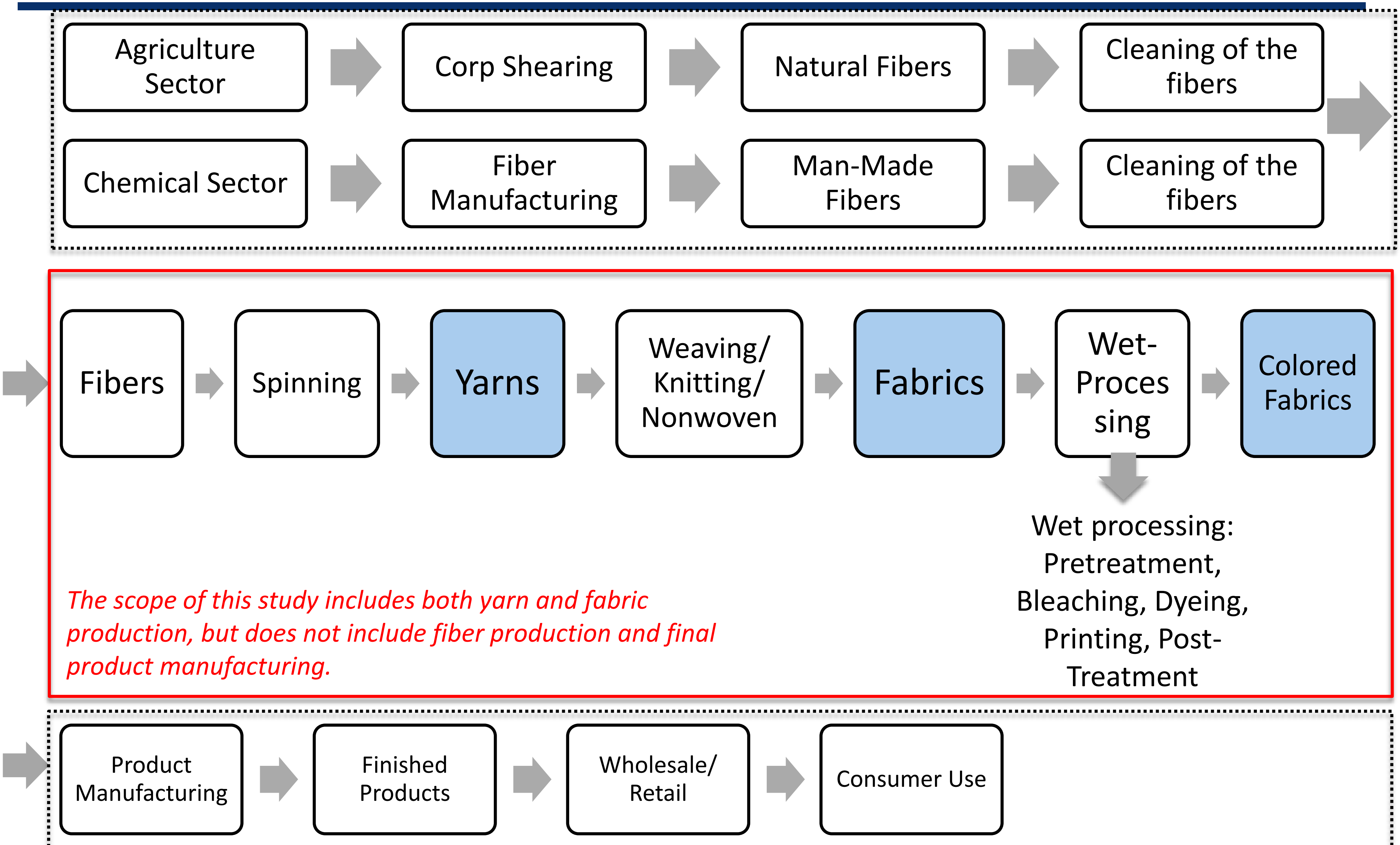
Achieving Near Zero Direct CO_2 emissions by 2060 in the Indonesian Pulp and Paper Industry





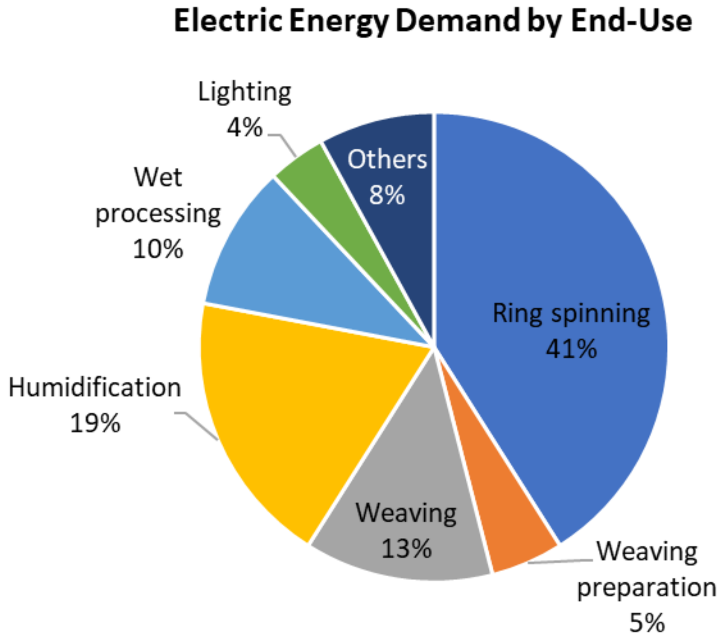
- **Electrification and renewable heating technologies** play the most important role in reducing CO_2 emissions in the Indonesian pulp and paper industry, in both the near term (2020-2030) and the mid-to-long term (2030-2060), accounting 69% and 68% of total cumulative CO_2 emission reduction potentials during the respective periods
- **Increased use of recycled fibers** to produce pulp, and **continued strengthen of energy efficiency** can each deliver 10% of CO_2 emission reductions by 2030
- **Demand reduction measures** to improve material efficiency through digitalization and use of multi-media accounts for 6% of total cumulative CO_2 reductions from 2030-2060

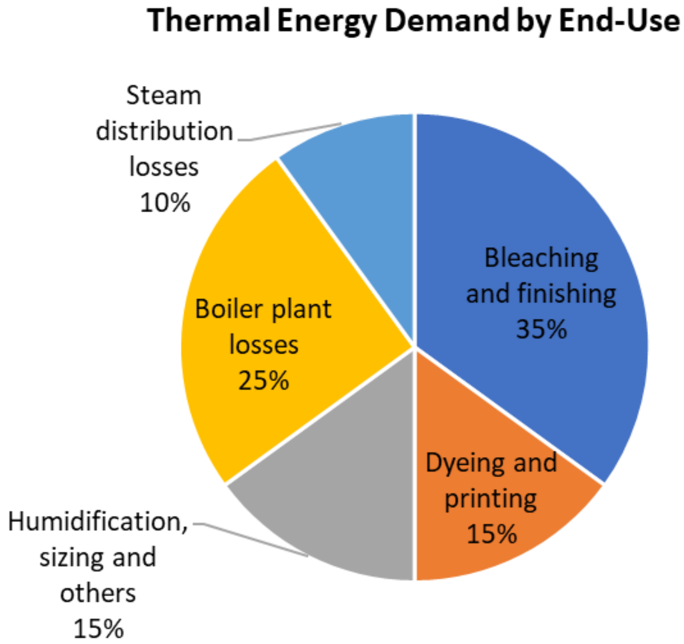
Textile Industry and Scope of this Analysis



Source: LBNL analysis.

Typical electric and thermal energy demand by end-use in a typical integrated textile plant





Sources: Palamutcu 2015; Hasanbeigi and Price 2012; Sathaye et al. 2005.

Commercialized and emerging electrotechnologies

Technology	Maturity	Cost	Industry applications
Electric boiler	Commercial (>200°C)	Low-Medium	Many industries, with steam demand
Hybrid boiler	Commercial (>200°C)	Medium	Many industries, with steam demand
Heat pump	<100°C: commercial 100-150°C: emerging >150°C: R&D	Low Medium High	Many industries, with corresponding temperature needs
Infrared drying	Commercial		
Resistance heating	Commercial (<1000°C)		
Extrusion porosification	Commercial		
Induction heating	Commercial (<1000°C)		
Friction heating	Commercial		
Ohmic drying	Emerging		
Microwave, radiofrequency	Emerging		
Pulsed electric field	Emerging		
Ultrasound	Emerging		
Pulsed light	Emerging		
Ultraviolet	Emerging		
Electroslag, vacuum, plasma	Emerging		

Source: Author analysis.

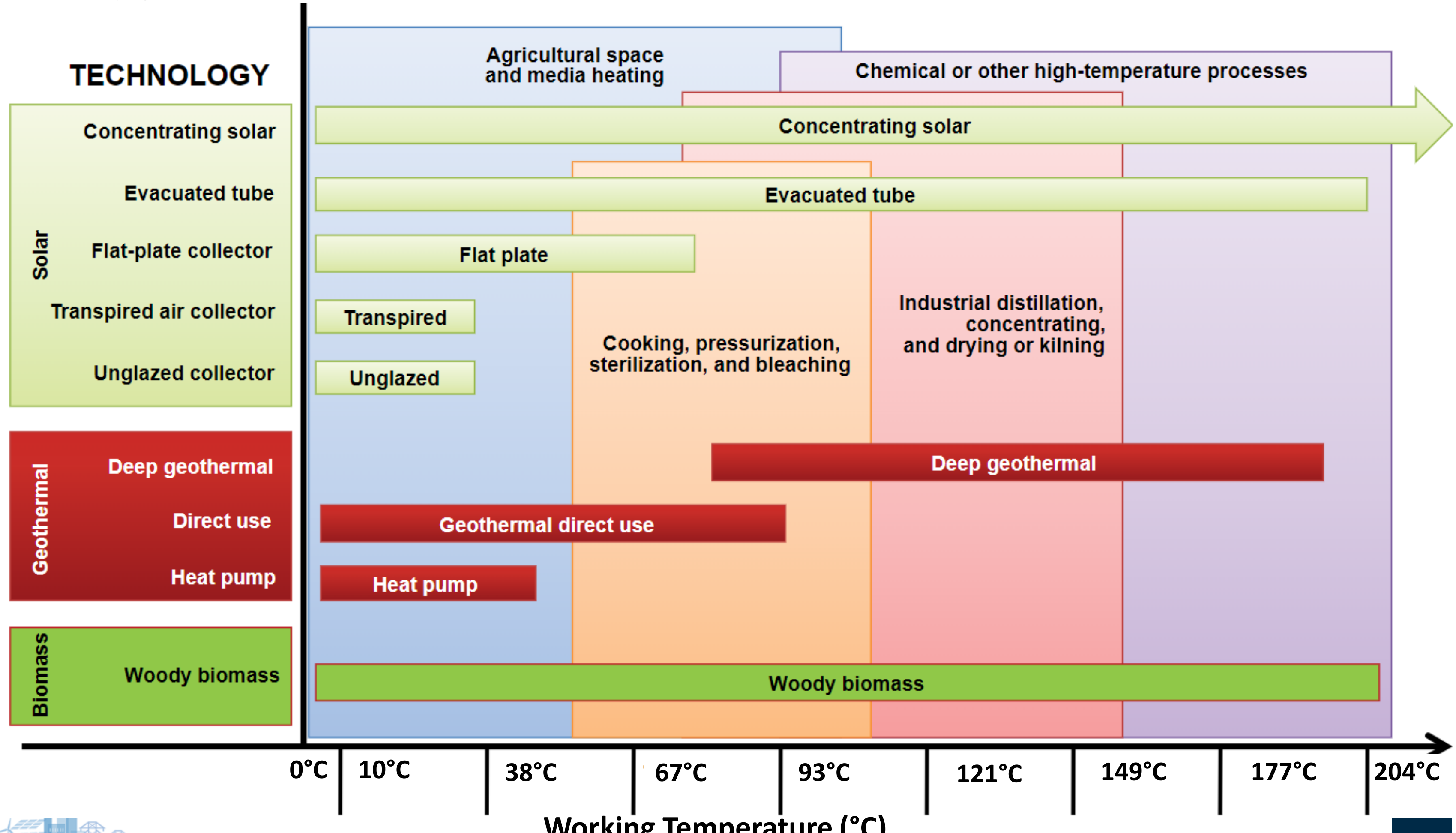
Replace onsite fossil fuel heat production with electrification technologies, e.g., switching from coal-fired boilers to industrial heat pumps, can also reduce combustion losses and improve energy efficiency.

In addition, it can also bring other co-benefits, e.g., reduced maintenance cost, reduced insurance cost, improved productivity, and reduced air pollution.

Industrial electrification should be pursued together with fast decarbonization in the power sector.

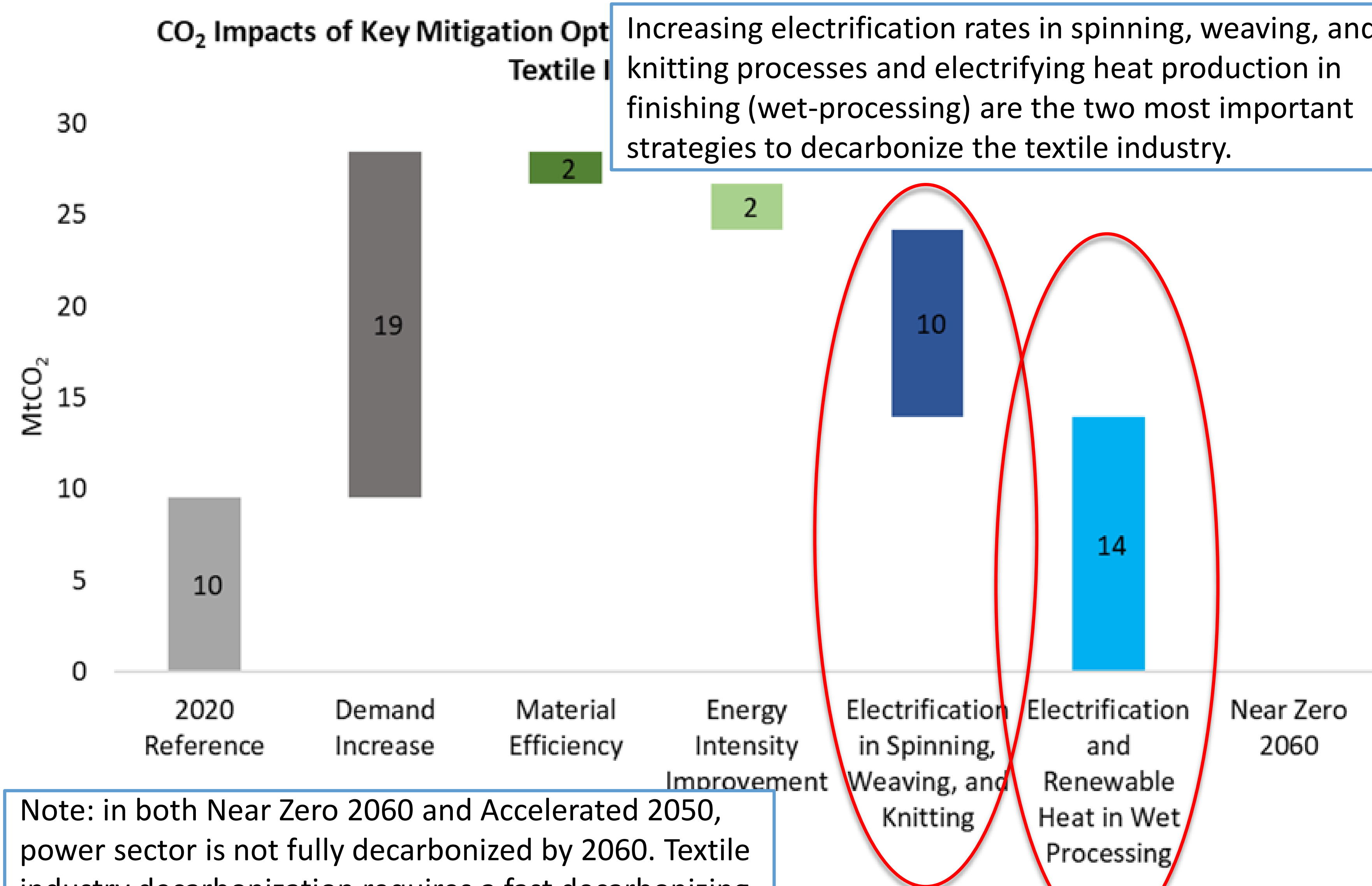
Renewable Heat Technologies

- Solar, geothermal, and biomass-based renewable heat technologies:
  - Concentrated solar
  - Evacuated tube solar
  - Deep geothermal



Source: US EPA, 2022.

CO_2 Impacts of Key Mitigation Options under the Near Zero 2060 Scenario for the Textile Industry in Indonesia



Increasing electrification rates in spinning, weaving, and knitting processes and electrifying heat production in finishing (wet-processing) are the two most important strategies to decarbonize the textile industry.

Note: in both Near Zero 2060 and Accelerated 2050, power sector is not fully decarbonized by 2060. Textile industry decarbonization requires a fast decarbonizing grid/power system.

Key Findings

- **It is technically feasible to achieve near-zero emissions in Indonesia's industrial sector by 2060,** the target year of carbon neutrality in Indonesia's updated NDC. Achieving net-zero emissions by 2050, as aspired in the government goals, will require extraordinary efforts and a much more accelerated pace of adoption of low-carbon technologies.

- **To achieve announced national economic development targets, it would require significant growth in the industrial sector**, which provides the foundational materials and infrastructure for urbanization, improved living standards, and other industry (renewables, batteries, EVs) development that is necessary for energy transition.

- Industrial capacity expansion is expected in several key industries, e.g., iron and steel, driven by domestic construction demand and transfer of industrial capacity from other Asian countries (China, Japan, and South Korea, etc.). **However, the current industry development is not on track with the Near Zero 2060 Scenario.**

- **Industry investment and policy decisions made today have important implications for 2050 and 2060. Industry development can be met by clean, low-carbon, and cost-effective technologies.** It is urgent and critical to develop policy strategies and create the right market conditions to speed up the adoption and scale up.

Key Findings

- Indonesia needs to consider a portfolio of technologies and measures for industry decarbonization. **Different strategies play different roles in specific industries.**
  - Iron and steel: transition to scrap-EAF (near term), followed by H_2-DRI-EAF (mid-to-long term); while at the same time pursue energy efficiency and material efficiency. Very limited role for CCS.
  - Cement: increase use of supplemental cementitious materials (SCMs), implement material efficiency and energy efficiency measures (near term), zero-carbon fuels (mid-to-long term); conduct R&D and pilots on CCS, but caution on cost and verifiability (mid-to-long term).
  - Ammonia: improve energy efficiency (near term), switch to zero-carbon (H_2, biomass) feedstocks (mid term); implement pilots on methane pyrolysis and CCS (long term).
  - Pulp and paper: improve energy efficiency, implement material efficiency and recycling (near term); switch from coal to other renewable sources in papermaking (mid term)
  - Textile: fully electrify spinning, weaving, and knitting processes (near term); adopt industrial heat pumps and other renewable sources in wet processing (mid term)

Key Findings

- **National strategies on carbon-intensive materials** (e.g., steel, and cement), **green energy carriers** (e.g., hydrogen and ammonia), and **cross-cutting technologies** (e.g., industrial heat pumps, and CCS) need to be developed. **Coordinated approach on infrastructure development** (pipelines, storage sites, power transmission and distribution systems) and utilization is necessary.

- Industry decarbonization requires a fast-decarbonizing power sector. Near zero emissions in industry requires access to clean, low-cost electricity. **Policies that support industry to connect to renewable power or develop its own renewable electricity renewables are very important.**

- **Industry decarbonization is inevitable but multifaceted.** It has the potential to develop new industry, grow local economy, reduce air pollution, and be more competitive in global trade. It is critical to involve all stakeholders in this process to minimize negative impacts to local communities, and leverage this opportunity to reduce inequality.

Thank you!

- Comments and Questions?

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