AIM and LoCARNet Peer-to-Peer Meeting for Sharing Experience and Lessons

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Decarbonization Pathway of Cement Industries in Indonesia

GHG Emissions in ASIA

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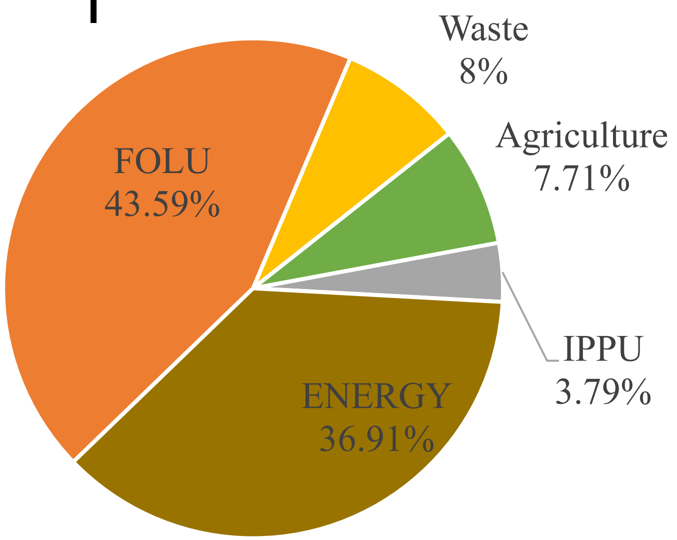
INTRODUCTION

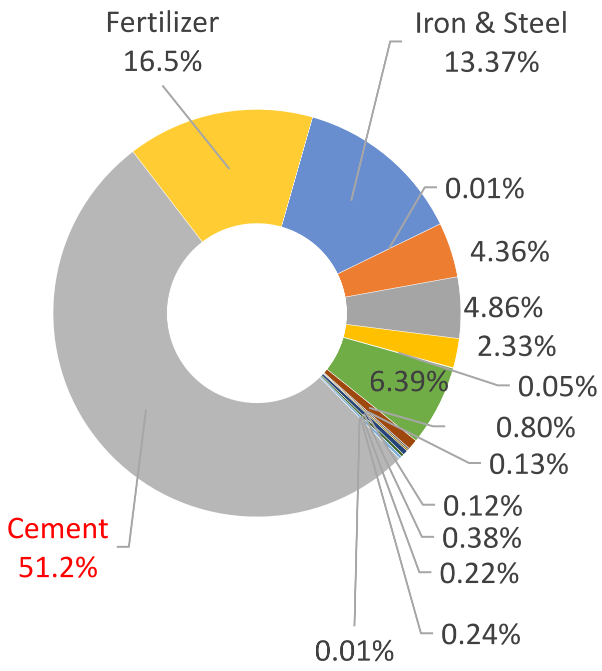
WHY DECARBONIZATION IN CEMENT INDUSTRY IS IMPORTANT

GHG Emssions from Cement Industry in Indonesia

National GHG Emissions from IPPU (30.1 KTon CO2e), 2022

1. Contribution of Cement industry in IPPU Emissions

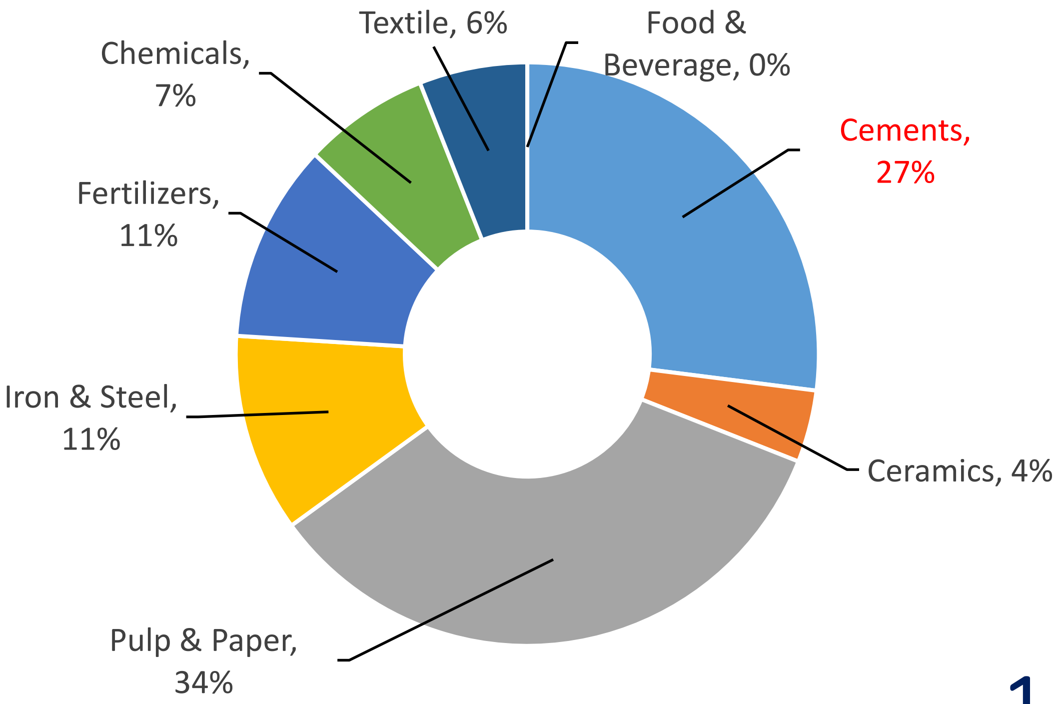




*FOLU : Forestry and other land use
*IPPU : Industrial Process and Product Use

National GHG EMissions from Energy (747 KTon CO2e), 2022

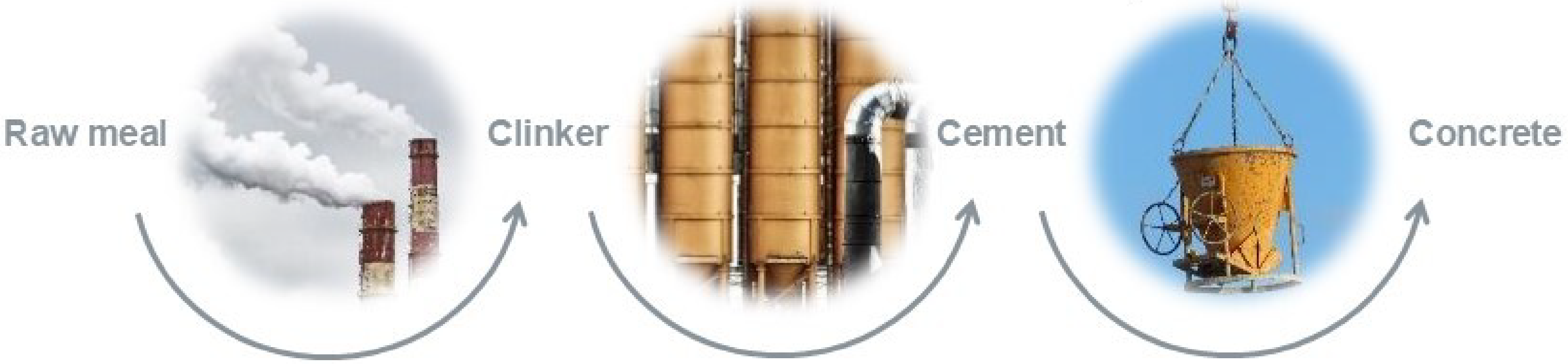
2. Contribution of Cement industry in Energy Emission



National GHG Emissions Inventory, BTR 1, MoE, 2024

Limestone calcination accounts for ~50 to 60% and fossil fuel combustion for ~30 to 40% of cement emissions

Cement/concrete production process



	Calcination of limestone	Fuel combustion for kiln	Non-clinker related emissions
Description	The calcination process that extracts lime (CaO) from limestone ($CaCO_3$) is a chemical reaction that produces CO_2 as a byproduct.	Emissions from the combustion of fuels used to heat the kiln where the calcination process takes place up to 1,450°C.	Emissions associated with powering the mill that crushes raw materials, the clinker cooler, cement mill, and the transportation of materials
% of cement emissions	~50-60%	~30-40%	~10%
CO_2 emissions	479 kg/tonne	319 kg/tonne	127 kg/tonne
Energy intensity	4.25 GJ/tonne	3,150 MJ/tonne	745 MJ/tonne

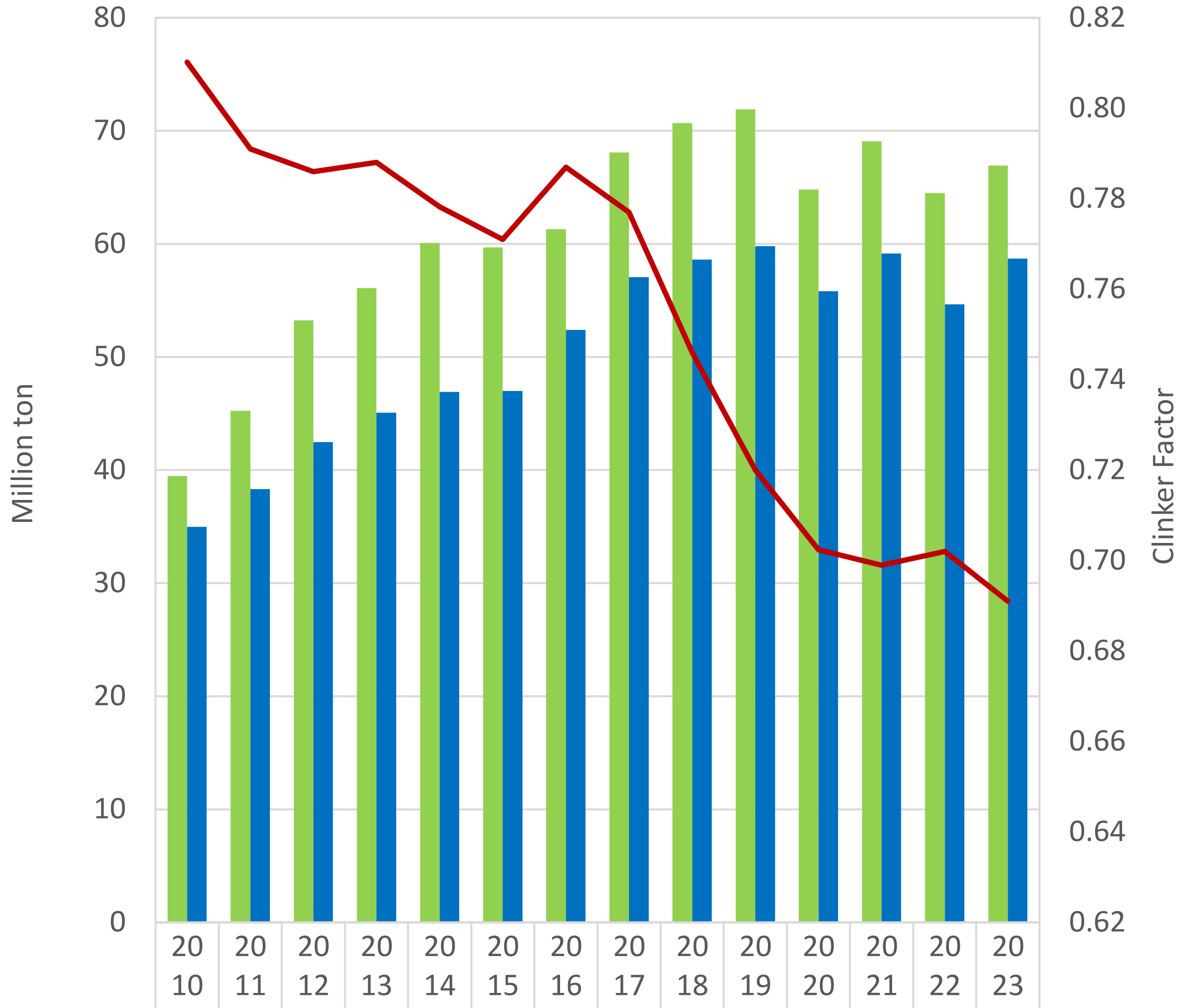
Cement Supply Chain Faces Regulatory (climate norms) Constraints, high energy consumption, logistics cost, market pressures (competion, CBAM)

Supply chain stages

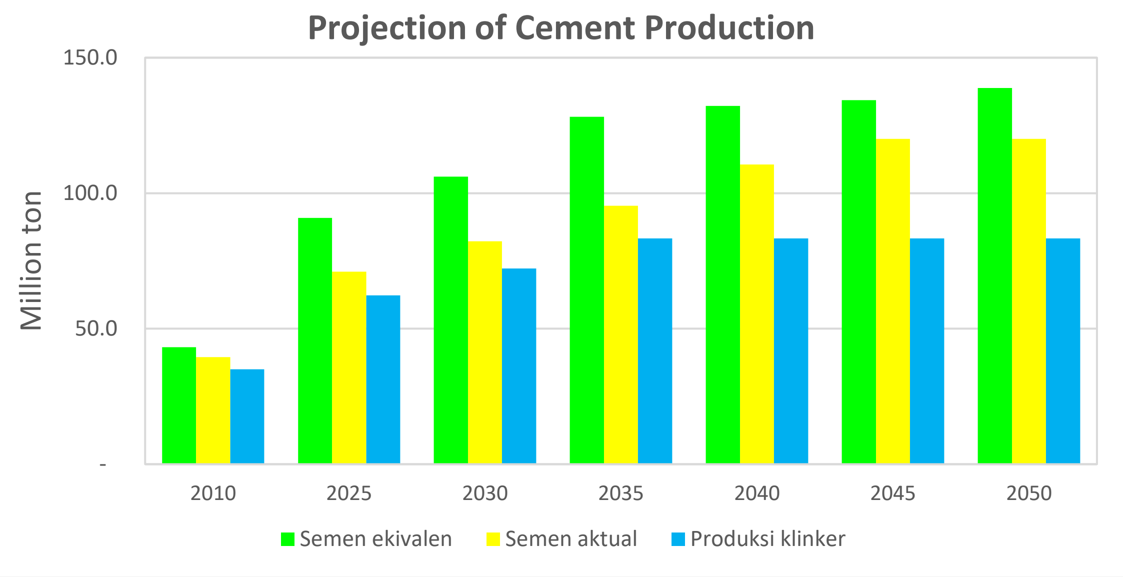
Extraction & Raw Materials	Manufacturing	Distribution	Sales & Market Demand	End Use & Application
• Environmental degradation • Regulatory constraints on land use • Fluctuating quality of raw materials	• High energy consumption and carbon emissions, especially in clinker production • Aging infrastructure, leading to inefficiencies • Compliance with stringent environmental regulations	• Logistics costs, impacted by fuel prices and infrastructure limitations • Emissions from transportation • Supply chain disruptions	• Competitive market pressures • Sensitivity to economic cycles affecting construction demand • Navigating state-specific requirements like New York's low embodied carbon concrete regulations	• Ensuring product performance under diverse environmental conditions • On-site storage and handling issues • Adapting to innovative building practices and materials

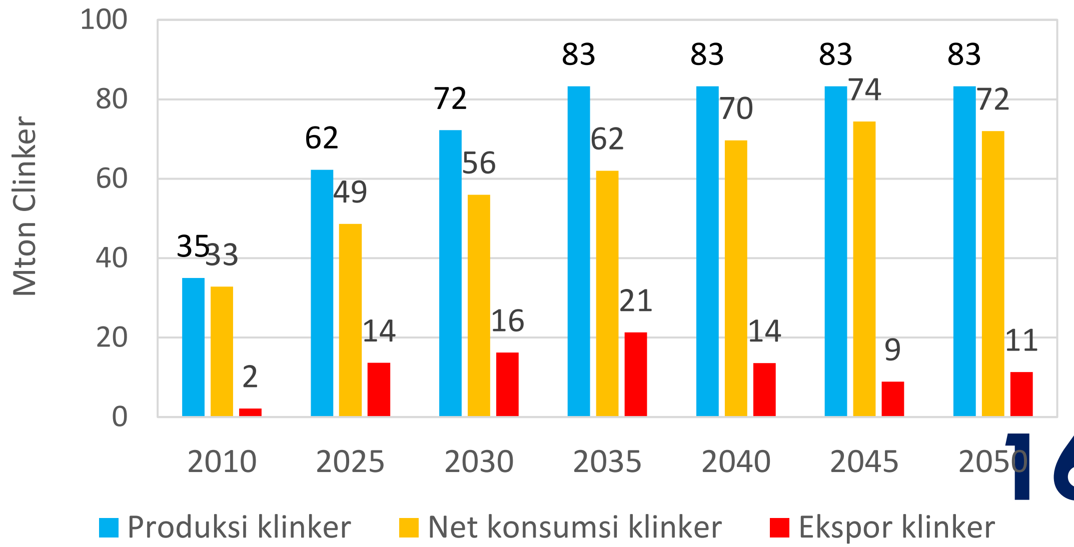
Pain points (row above)

Cement Production and Target Development



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Produksi Semen	39	45	53	56	60	59	61	68	70	71	64	69	64	66
Produksi Klinker	35	38	42	45	46	47	52	57	58	59	55	59	54	58
Clinker Factor	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6

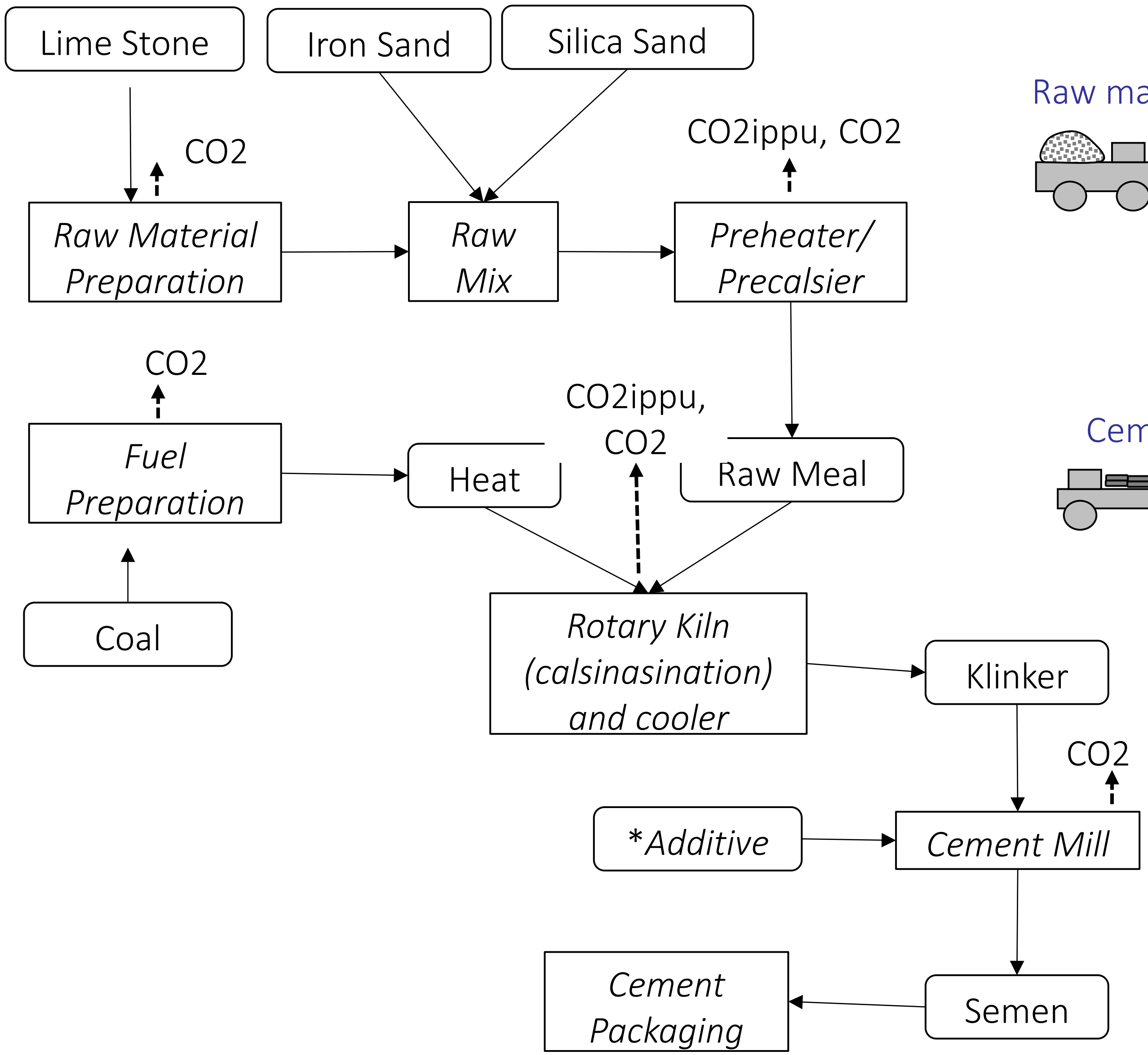


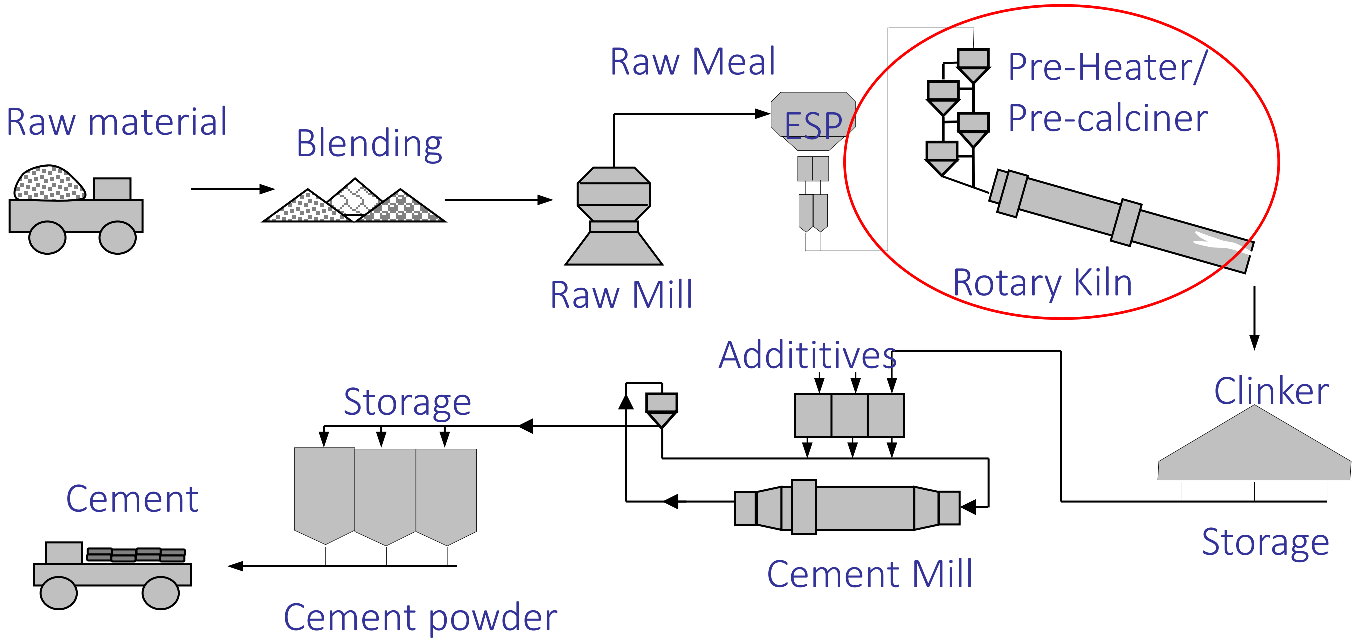


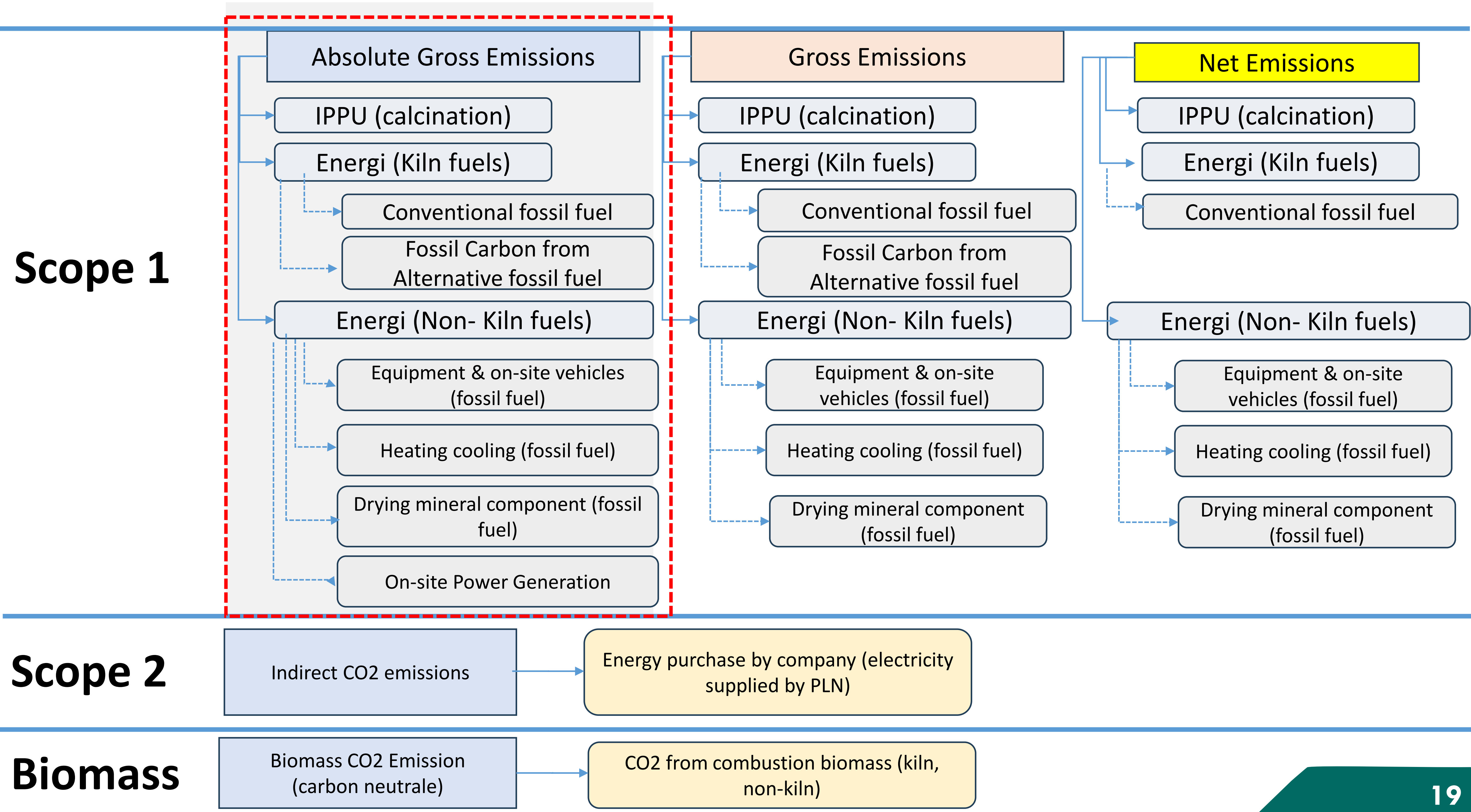
DECARBONIZATION IN CEMENT INDUSTRIES

Alternative Fuels and Raw Material (Clinker Substitution/Blended Cement)

GHG Emissions Sources in Cement Production






Scope 1
Absolute Gross Emissions
IPPU (calcination)
Energi (Kiln fuels)
Conventional fossil fuel
Fossil Carbon from Alternative fossil fuel
Energi (Non- Kiln fuels)
Equipment & on-site vehicles (fossil fuel)
Heating cooling (fossil fuel)
Drying mineral component (fossil fuel)
On-site Power Generation
Gross Emissions
IPPU (calcination)
Energi (Kiln fuels)
Conventional fossil fuel
Fossil Carbon from Alternative fossil fuel
Energi (Non- Kiln fuels)
Equipment & on-site vehicles (fossil fuel)
Heating cooling (fossil fuel)
Drying mineral component (fossil fuel)
Net Emissions
IPPU (calcination)
Energi (Kiln fuels)
Conventional fossil fuel
Energi (Non- Kiln fuels)
Equipment & on-site vehicles (fossil fuel)
Heating cooling (fossil fuel)
Drying mineral component (fossil fuel)
Scope 2
Indirect CO2 emissions
Energy purchase by company (electricity supplied by PLN)
Biomass
Biomass CO2 Emission (carbon neutrale)
CO2 from combustion biomass (kiln, non-kiln)

Current deployable measures combined can abate ~40% of cement industry emissions by 2050

Major technology type of cement decarbonization

Potential approach	1 Clinker substitution	2 Energy efficiency	3 Alternative fuels	4 Alternative production methods	5 Alternative binder chemistries	6 CCUS
Abatement potential*	30-40%	Up to 20%	1-8%	25-100%	25-100%	85-99%
Cost ($/tonne of cement)	-5 to -25	0 to -5	5 to -5	N/A, emerging technologies	N/A, emerging technologies	25 to 55
Deployment timeline	~2030	~2030	~2030	~2040	~2050	~2040
TRL**	7 to 9	9	9	3 to 5	3.5 to 9	6 to 7.5
ARL***	2 to 7	5 to 9	4 to 5	1	1	1
Status	• Broadly high TRL, deployment-ready, and economically viable today			• High abatement potential, not yet demonstrated at commercial scale, requires further technological maturity and customer acceptance		
Pathway to commercial scale	• Rapid deployment, incentivized by demand signal from large buyers and enabled by accelerated validation of low-carbon blends			• Accelerated buildout of greenfield plants, enabled by cost reductions and coordinated procurement to create investable demand signal • CCUS enabled by tax credits, policy support, and cost reductions as deployments ramp		

Observations

- Current deployable measures **can abate ~30% of emissions by the early 2030s and ~40% of emissions by 2050**, while the remaining ~60 to 70% of emissions will require other technologies.
- Key technologies have performance and cost uncertainty.
- Decarbonization approaches may come with structural cost increases; however, many of the currently deployable measures are cost saving.

Notes: * Unconstrained abatement potential for a given tonne of cement produced for each approach in isolation; ** Technology Readiness Level (1-9) measures the maturity of evolving technologies; *** Adoption Readiness Level (1-9) measures factors for private-sector uptake beyond technology readiness, including value proposition, market acceptance, resource maturity, and license to operate.

Source: Department of Energy Liftoff Report (2023)

Credit: Hoshi Ogawa, Sho Tatsuno, Jessica Cong, Isabel Hoyos, Hyae Ryung Kim, and Gernot Wagner (17 September 2024); share/adapt with attribution. Contact: gwagner@columbia.edu

Potential for Decarbonization and Cost

Contribution to Indonesia’s climate commitments and sustainability goals

Structure of AIM/End-use Model in Cement

Energy / Raw Materials — **Technology** — **Service**

- Coal
- Biomassa
- RDF & Industrial Waste (Alternative Energy)
- Raw Material Alternatives
- Electricity

→

- *Waste Heat Recovery Boiler*
- *Raw Mix Processing*
- *Cement Grinding (optimization) or adjustment in Process*
- *Feeding Facility (pump (rice, liquid,) belt conveyor rdf, weighing systems)*
- *Precombustion Technology (w/o combustor) Advance Process Control*
- *VSD and Pre-Processing equipment (Platform)*
- *H2 injection*
- *Conversion EP to BAG FILTER*
- *SOLAR PV (reduksi scope 2*
- *CCUS for NZE 2050 (tech-economic feasible)*

→

Cement

Flow at Real Condition

Flow of Simulation

Energy Consumption and GHG EMissions ← Technology Selection ← Service Demand

Energy Data

- Energy Price
- Type of Energy
- Energy Constraint
- Emissions Factor
- Availability of Alternative Fuel/Energy

Teknology Database

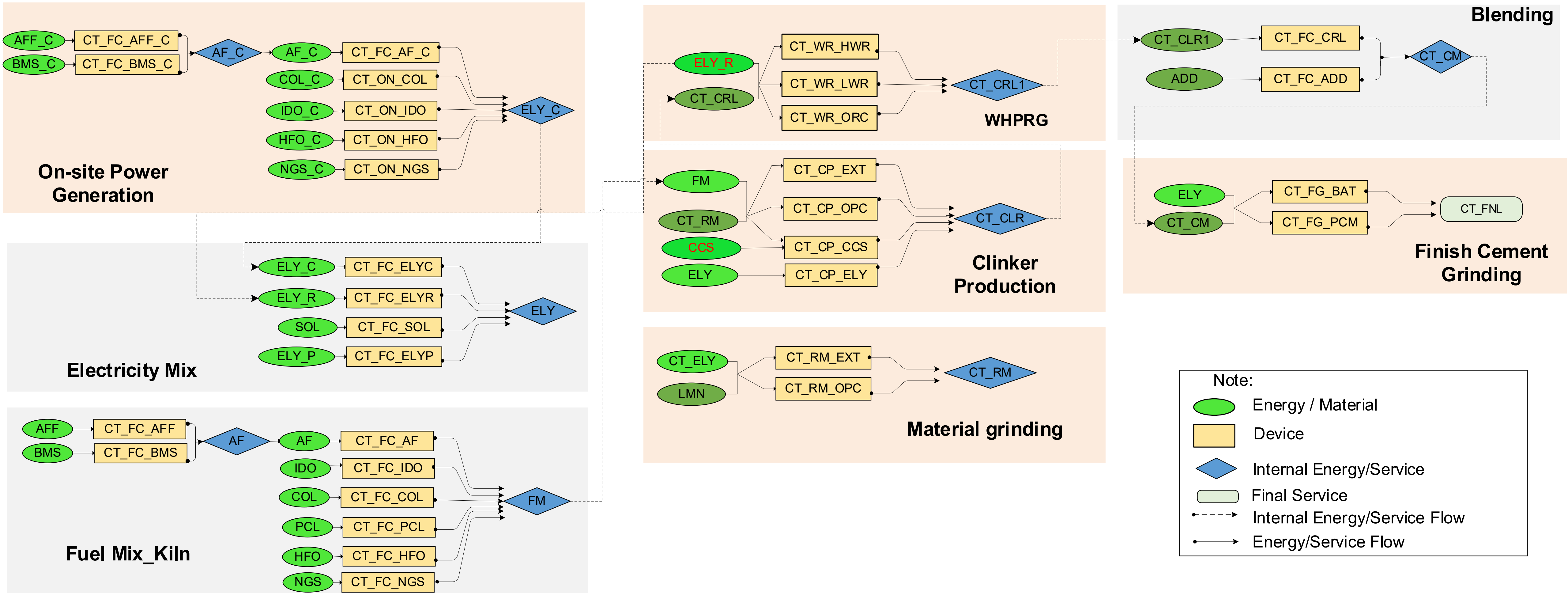
- Lifetime of Technology
- Energy Consumption
- Clinker to Cement Ratio
- Cost of Technology
- Investment and Operationl
- **Efficiency and Penetration**
- Technology Availability

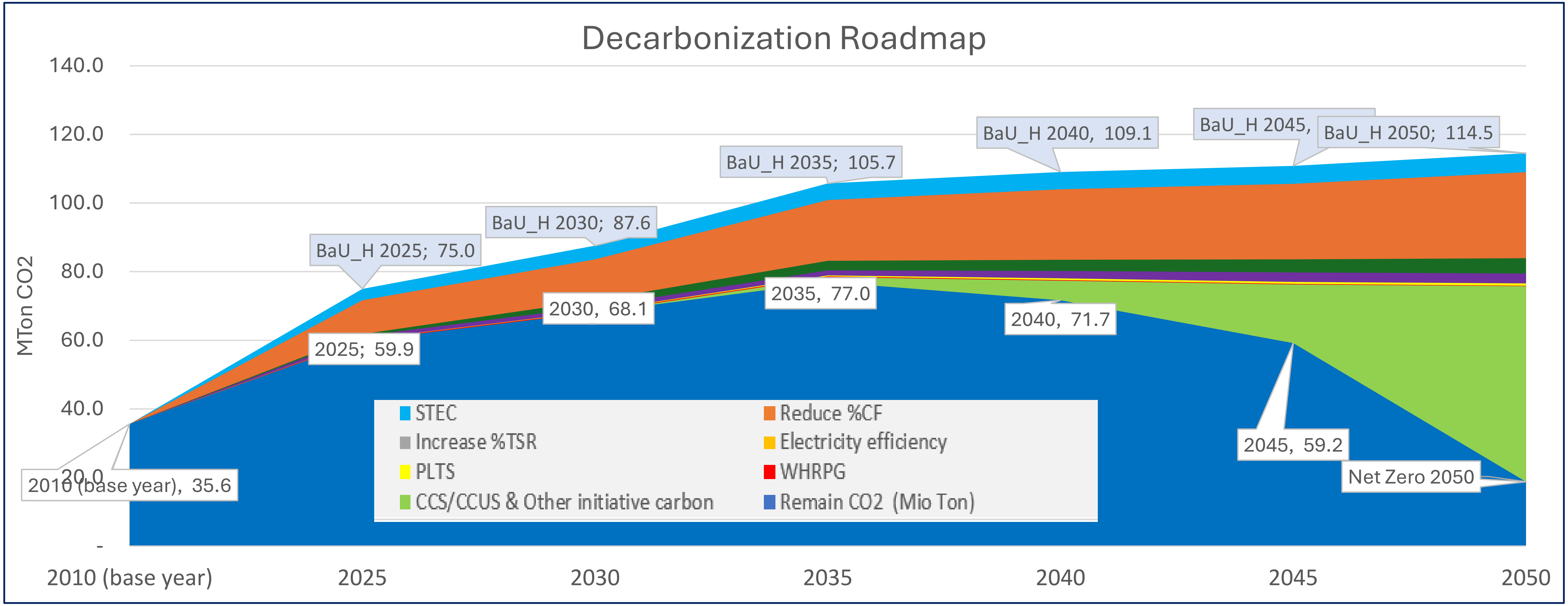
Socio-Economic Scenario

- Production Growth
- Economic growth (Sectoral)
- Industrial Structure
- Indutry Development
- Demand of Cement/Clinker

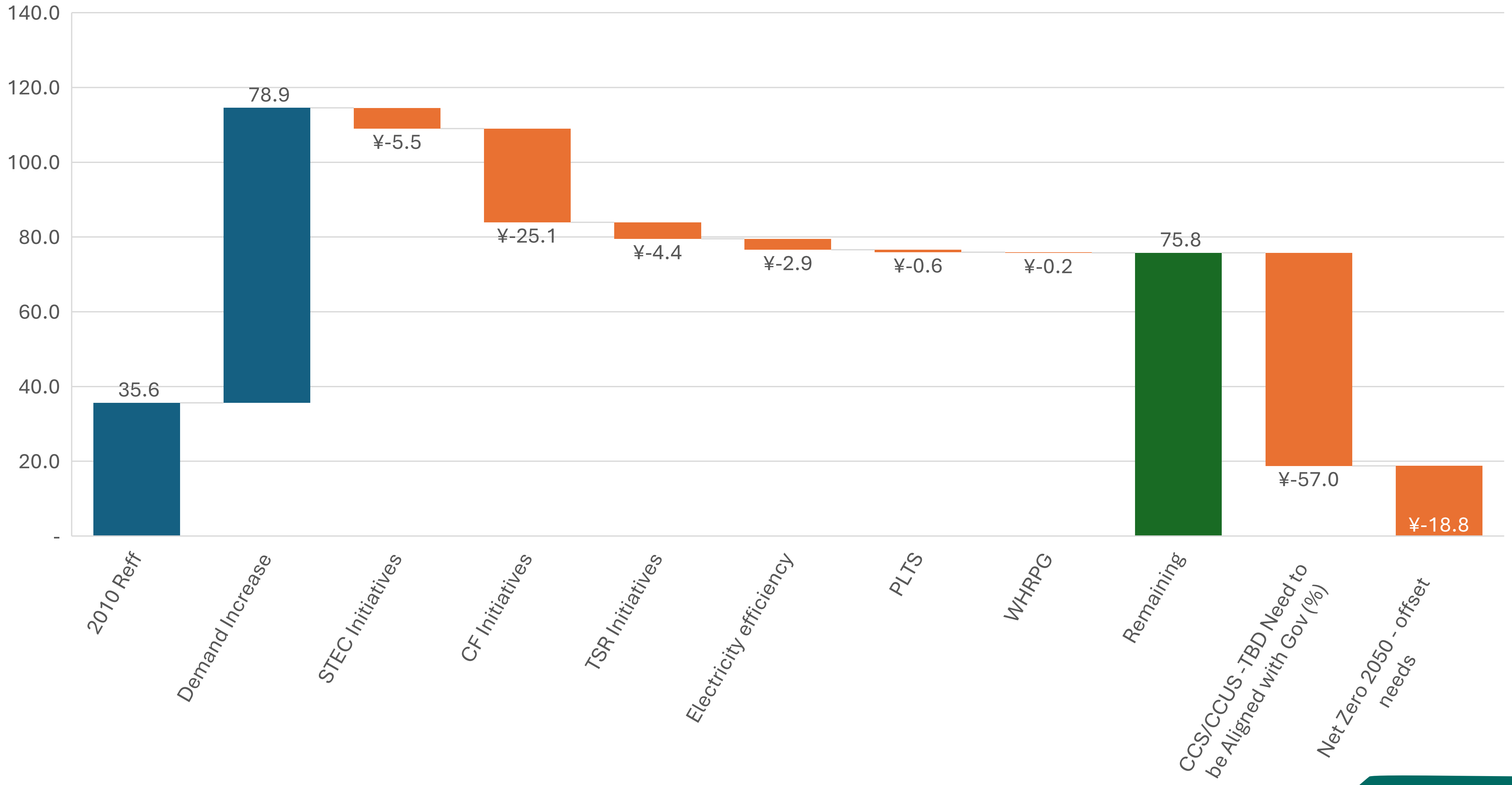
(Manual book AIM/enduse NIES Japan, 2006)

Energy-Service flow Industri Semen (termasuk mitigasi) dalam Model AIM/Enduse

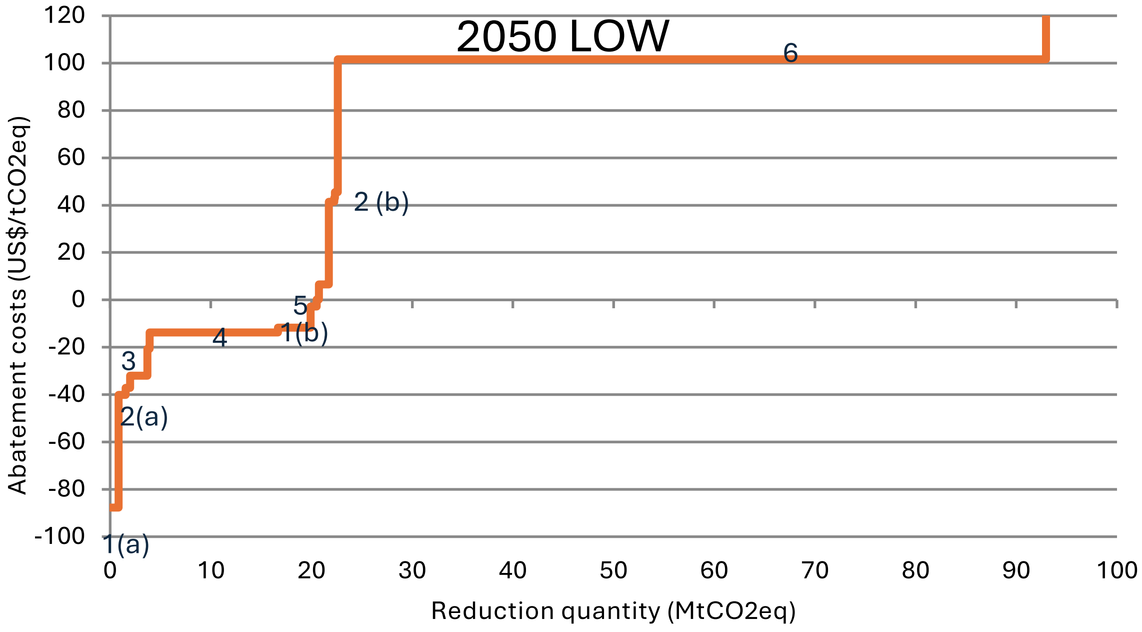


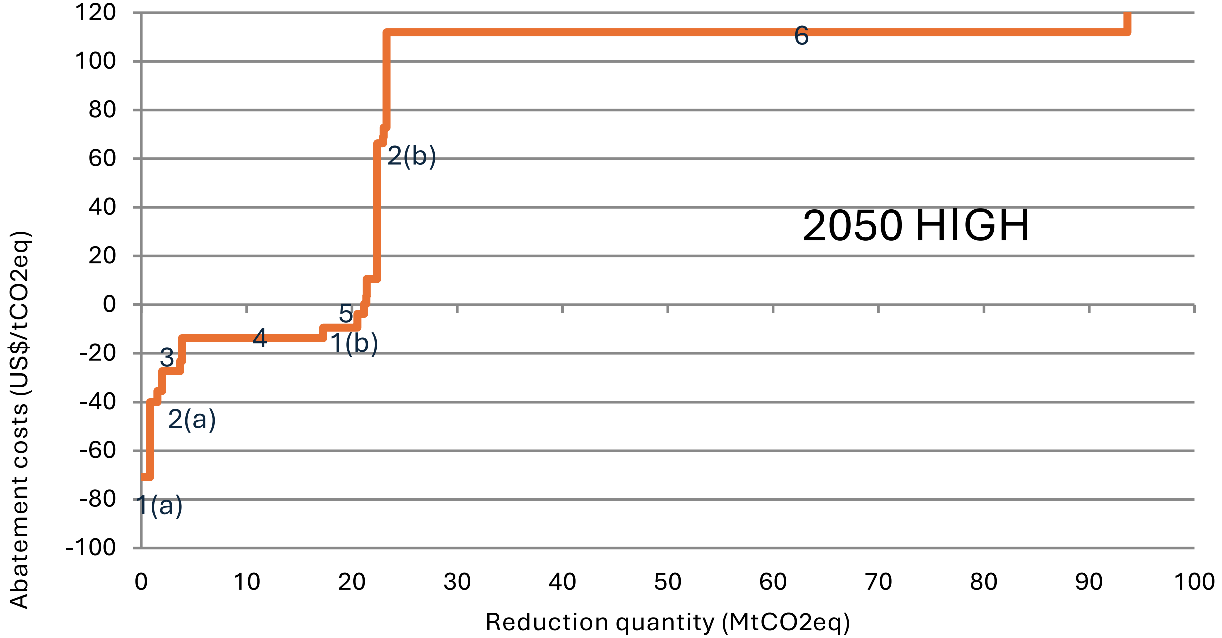


Parameter	2010 (base year)	2025	2030	2035	2050
Actual Cement Production (Ton)	39.475.000	70.998.611	82.306.849	95.416.196	120.000.000
Reduction of Clinker to Cement Ratio (%)	81,02	68,5	68,00	65,00	60,00
Clinker Production	34.988.081	62.274.830	72.193.596	83.300.000	83.300.000
% TSR Alternatif to Fosil Fuels	1	7	15	18	25
% TSR Biomassa	2	4	8	10	15
Spesifik thermal energy - Mj/ton Cli	3.725	3.390	3.385	3.380	3.355
Electricty (MWh)	4.080.051	5.430.597	6.259.111	7.080.775	6.474.507


140.0
120.0
100.0
80.0
60.0
40.0
20.0
-
35.6
78.9
¥-5.5
¥-25.1
¥-4.4
¥-2.9
¥-0.6
¥-0.2
75.8
¥-57.0
¥-18.8
2010 Reff
Demand Increase
STEC Initiatives
CF Initiatives
TSR Initiatives
Electricity efficiency
PLTS
WHRPG
Remaining
CCS/CCUS - TBD Need to be Aligned with Gov (%)
Net Zero 2050 - offset needs

Parameter	2025	2030	2035	2040	2045	2050
Production of Actual Cement (Ton)	70.998.611	82.306.849	95.416.196	110.613.522	120.000.000	120.000.000
Production of Equivalent Cement (Ton)	90.912.161	106.167.053	128.153.846	132.222.222	134.354.839	138.833.333
Reduction Clinker to cement ratio (%)	68,5	68,0	65,0	63,0	62,0	60,0
Clinker Production	62.274.830	72.193.596	83.300.000	83.300.000	83.300.000	83.300.000
% TSR Biomass	4	8	10	11	13	15
% TSR Alternatif Fosil Fuels	7	15	18	20	22	25
% TSR Traditional Fosil Fuels	89	77	72	68	64	60
Spesifik thermal energy - Mj/ton Cli	3390	3385	3380	3375	3365	3355
Specific Electricity Consumption (Kwh/ton Cem aktual)	101,7	99,8	97,3	88,7	80,6	75,7
Specific Electricity Consumption (Kwh/ton Cem eq)	79,4	77,3	72,7	72,9	70,6	65,4
Grid Emission Factor (ton CO2/MWh)	0,84	0,80	0,70	0,66	0,63	0,60
Supply form National Grid (MWh)	5.430.597	6.259.111	7.080.775	7.302.571	7.067.931	6.474.507
Energy from Local Generation (Captive from Cement) (TJ/year)	13.262	13.443	13.924	13.791	13.035	11.729
Installed Solar PV at Cement Plant (MWp)	79	131	208	319	408	489
Waste Heat Recovery Power Generation (MWh)	253.696	326.942	338.641	335.416	317.033	285.267
CO2 from local power generation (Captive), Scope 1 (kg CO2/kWh)*	0,32	0,32	0,32	0,32	0,32	0,32
Specific CO2 from Electricity Consumption, Scope 1 (captive) and Scope 2 (3rd party/National Grid), kg CO2/ton cem eq.)	55	51	42	40	37	31
Specific CO2 of Scope 2 (electricity from Grid), (kg CO2/ton cem eq)	50	47	39	37	33	28
Specific Net-CO2 (Scope 1 w/o fossil carbon from AFR, (kg CO2/ton cem eq.)	572	541	506	483	467	443
Specific Gross** CO2 (Scope 1 w fossil carbon from AFR, (kg CO2/ton cem eq.)	585	569	538	518	505	484
Total Specific CO2 (Scope 1& 2 with fossil carbon from AFR and Captive (kg CO2/ton cem eq)	641	620	581	558	542	515
CCS/CCUS (MTon CO2e)			1,4	5,7	17,1	57,0
Remaining GHG Emissions – Offset (Mton CO2e)	59,9	68,1	77,0	71,7	59,2	18,8
Scope 1 (Mton CO2)	55,2	63,0	73,2	72,3	71,6	71,6
Scope 2 (Mton CO2)	4,7	5,2	5,2	5,1	4,7	4,1





❑ Required Investment in 2050, low scenario

Aksi Mitigasi	CAPEX	OPEX	Abatement Cost (USD/ton CO2e)
WHRPG	46	-	-20,6
Fuel switching (Alternatif fuel) % TSR	494	-	-27,3
Penurunan %CF	0,28	1.072	-13,8
Efisiensi energi	2.044	.	-11,2
PLTS	315	.	-2,8
CCS/CCUS - TBD Need to be Aligned with Gov	18.706	6.395	101,5

❑ Required Investment in 2050, High Scenario

Aksi Mitigasi	CAPEX	OPEX	Abatement Cost (USD/ton CO2e)
WHRPG	41	-	-23.2
Fuel switching (Alternatif fuel) % TSR	494	-	-22,1
Penurunan %CF	0,33	1.248	-13.8
Efisiensi energi	2.402	.	- 4.1
PLTS	338	.	-3.7
CCS/CCUS - TBD Need to be Aligned with Gov	21.986	7.515,6	111.9

Notes: 1 (a) = %TSR alternative fuels, 1 (b) %TSR biomass, 2 (a) = energy efficiency in clinker production (ASD, SP/NSP, optimizing process control system), 2 (b) = energy efficiency for efficient vertical mill, high-efficient separator, VSD, and improved cement grinding, 3 = WHRPG, 4 = reduksi %CF, 5 = PLTS, 6 = CCS/CCUS

CONCLUDING AND REMARKS

Impact Analysis on the Incremental Cost and Domestic Demand of Cement

Impact Analysis on the Incremental Cost and Domestic Demand of Cement

Parameter	Low Production Capacity	High Production Capacity	Unit
Production of Actual Cement	114	120	Million ton
Production of Equivalent Cement	139	139	Million ton
Clincer Production	83	83	Million ton
%-CF 2050	60%	60%	%
Reduction CF from BaU (%)	21%	21%	%
Clincer Reduction (Juta ton)	24,0	25,2	Million ton
Total additive	41,2	48,0	Million ton
Hazardous Waste	6,18	7,20	Million ton
Additive (non Hazardous Waste)	35,04	40,80	Million ton
Clinkler Price	33,33	33,33	USD/ton
Revenue from treatment/utilzation of non-hazardous waste	6,67	6,67	USD/ton
Cost of Additive	21,50	21,50	USD/ton
Cost Reduction from clinker Reduction	800	841	Million USD
Revenue from treatment/utilzation of hazardous waste	41	48	Million USD
Total Cost of Additive (non hazardous waste)	753	877	Million USD
Total Cost Reduction	88	12	Million USD
Cost Reduction/ton Actual Cement actual	0,77	0,10	USD/ton Cement
Cost Reduction/ton Clinker	1,06	0,14	USD/ton Clinker

Thank you

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