Powering the Transformation:

Electrification and Renewable Feedstock Pathways for Korea's Petrochemical Industry

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RE taxation policies

Industrial Decarbonization (IND)

Clean transition for carbon-intensive industries

Climate Risk (CR)

Physical risk analysis
Social cost of carbon

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Powering the Transformation - Agenda

01 **Korea's petrochemical industry**
Oversupply crisis and the need for carbon transition

02 **Electrification technologies**
Replacing naphtha cracking and heat systems

03 **Renewable feedstock production**
Bio-based & recycled feedstock production

04 **Economics of the transition**
Cost premiums and the decisive role of clean power

05 **Roadmap & policy recommendations**
Sequencing deployment and closing the policy gaps


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Powering the transformation:
strategic electrification and renewable feedstock pathways for Korea's petrochemical industry

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SUMMARY
- South Korea's petrochemical sector faces two simultaneous pressures: global oversupply is eroding profitability, while tightening international carbon standards are raising the bar for market access. Electrification and renewable feedstock substitution address both at once, offering a path to restore competitiveness while cutting emissions across the full production lifecycle.
- Key technology priorities are: electric furnaces as early brownfield retrofit options for naphtha cracking; heat pumps and electric boilers for longer-term steam-system transformation; and renewable feedstocks such as bio-based, recycled, and methanol-based pathways to diversify low-carbon production routes.
- Successful deployment will depend on policy and infrastructure support as much as on technology readiness. Expanded access to low-cost renewable electricity, grid upgrades, a national sectoral roadmap, de-risking instruments for first movers, and dedicated renewable feedstock supply chains are all necessary to move from pilot projects to commercial-scale transition.

Korea's Petrochemical Industry at a Glance

#4 World's 4th-Largest Petrochemical Producer
(2024, KCIA) by basic olefin capacity

12.8Mt Annual Ethylene Capacity
(2024, KCIA) Produced by naphtha crackers

€37.8B Petrochemical Exports
(2025, MOTIE) ~6% of total exports

Ethylene production capacity by company in each of the major Korean petrochemical complexes (2025)

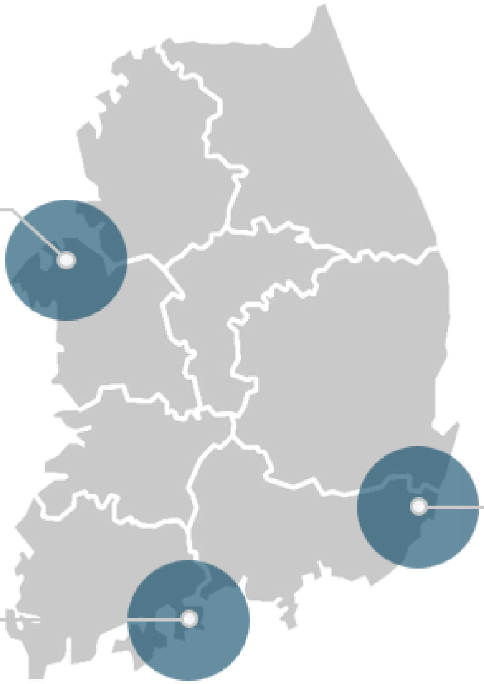
(Unit: 1,000 tonnes/yr)

Daesan Complex (Area 15.3km², 4 NCC units)

- Lotte Chemical 1,100
- LG Chem 1,300
- Hanwha TotalEnergies 1,525
- HD Hyundai Chemical 850

Yeosu Complex (Area 32.0km², 4 NCC units)

- Lotte Chemical 1,230
- LG Chem 2,000
- Yeochun NCC 2,285
- GS Caltex 900



Ulsan Complex (Area 74.4km², 2 NCC units)

- Korea Petrochemical Ind 900
- S-Oil 182
- SK Geo Centric 660

A Sector at a Crossroads

Two forces are compelling a rapid transition to restore competitiveness.

Global oversupply

- Korea's NCC utilisation has fallen to ~70%, down from the ~90% range due to persistent global overcapacity
- Prolonged losses from China-driven oversupply have forced a government-led restructuring: in August 2025 the Ministry of Trade, Industry and Energy set a target to cut 2.7–3.7 Mt of NCC capacity (18–25% of the national total)

Decarbonisation demand

- Growing international demand for decarbonisation is reshaping market conditions, with buyers increasingly requiring lower-carbon materials
- The EU's Carbon Border Adjustment Mechanism (CBAM) and broader global carbon frameworks are raising the bar for market access

Decarbonisation of the petrochemical sector is needed to build global competitiveness through clean chemicals

Emissions profile of Korea's Petrochemical Sector

#2
second-largest emitter in Korea's industrial sector

53Mt CO_2e
Scope 1 emissions in 2023 ~8% of national emissions

70%
Of direct emissions originate at NCC(Naphtha Crackers)

423.5 PJ
Of petroleum products as combustion fuel for process heating

The Transformation Strategy: Three Levers

1 Restructuring & diversification

12.8 -> 9.2

Mt/yr ethylene capacity by 2030

- Utilisation ~70% -> 90%
- Cuts emissions, focus on clean chemicals

2 Electrification

70%

of direct emissions — at the NCCs

- Cracking + steam stages
- Effective cuts via pilots by 2035

3 Renewable feedstock

58%

of lifecycle CO2 is end-of-life

- Bio · e-methanol · recycled
- Reduces fossil-fuel dependence

Electrification I - Replacing Naphtha Cracking

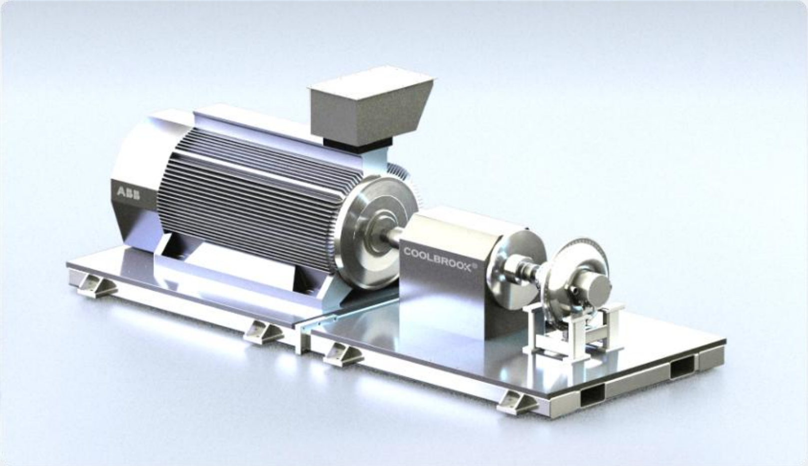
Cracking is the single largest energy use and emission source - 70-80% of complex energy. Two high-temperature electric pathways target it.

Electric furnaces (>850 °C, TRL 6)

- **Resistive, inductive or arc heating** replaces combustion; >90% CO2 cut on renewable power.
- **Energy intensive:** ~5,400 GWh/yr per 1 Mt ethylene. Siting near affordable clean power is decisive.
- **Demo plant:** BASF-SABIC-Linde plant at Ludwigshafen, Germany (6 MW, 1.25 t/h Ethylene)

Shock-wave heating (1,000–1,700 °C, TRL 4-6)

- **Supersonic flow, not combustion** - 1,000-1,700C generated in milliseconds.
- **More efficient:** ~850 GWh/yr per 1 Mt ethylene
- **Higher yield, higher CAPEX:** the +25% ethylene yield is offset by the steep upfront cost of precision rotor engineering
- **Pilot plant:** Coolbrook's RotoDynamic Reactor in Netherland (1 MW, 1 t/h Ethylene)



Electrification II - Steam & Heat Systems

Steam accounts for ~10% of Scope 1 emissions, and because it is usually supplied through shared cluster infrastructure, a single investment can cut emissions across several producers at once.

Industrial heat pumps (120-160 °C, TRL 7-8)

- **Upgrades waste heat** from distillation columns, compressors and crackers; electricity powers only for the temperature lift
- **Most efficient option:** coefficient of performance up to 3(three units of heat per unit of electricity).
- **Demo plant:** BASF Ludwigshafen, Germany

  (50 MWth input, 360 MWth output, 150 t/h Steam)

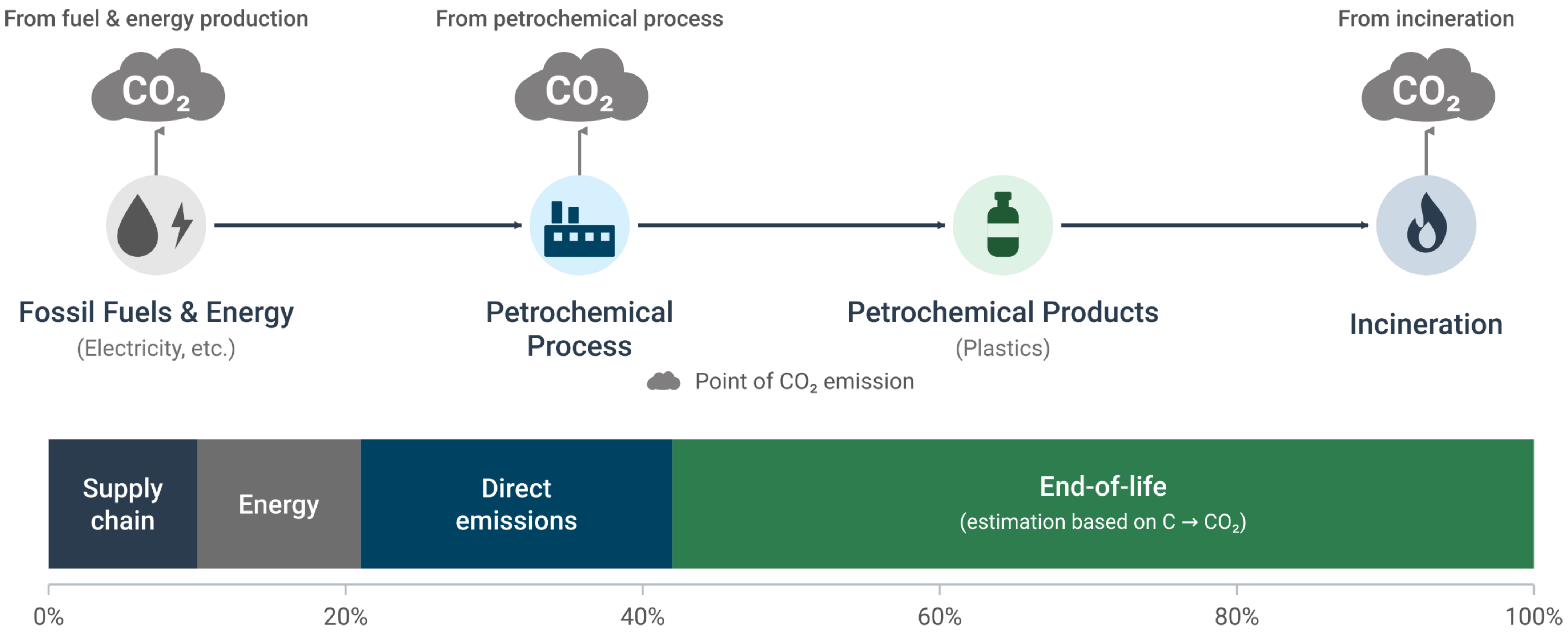
Electric boiler (300-350 °C, TRL 8-9)

- **Electrode boilers** pass current directly through pressurised water, using the water itself as the conductor; reaches up to 99% efficiency
- **Grid-flexible:** output adjustable from 5% to 100%, so it can follow swings in power price and renewable supply
- **Demo plant:** InfraLeuna at Leuna, Germany

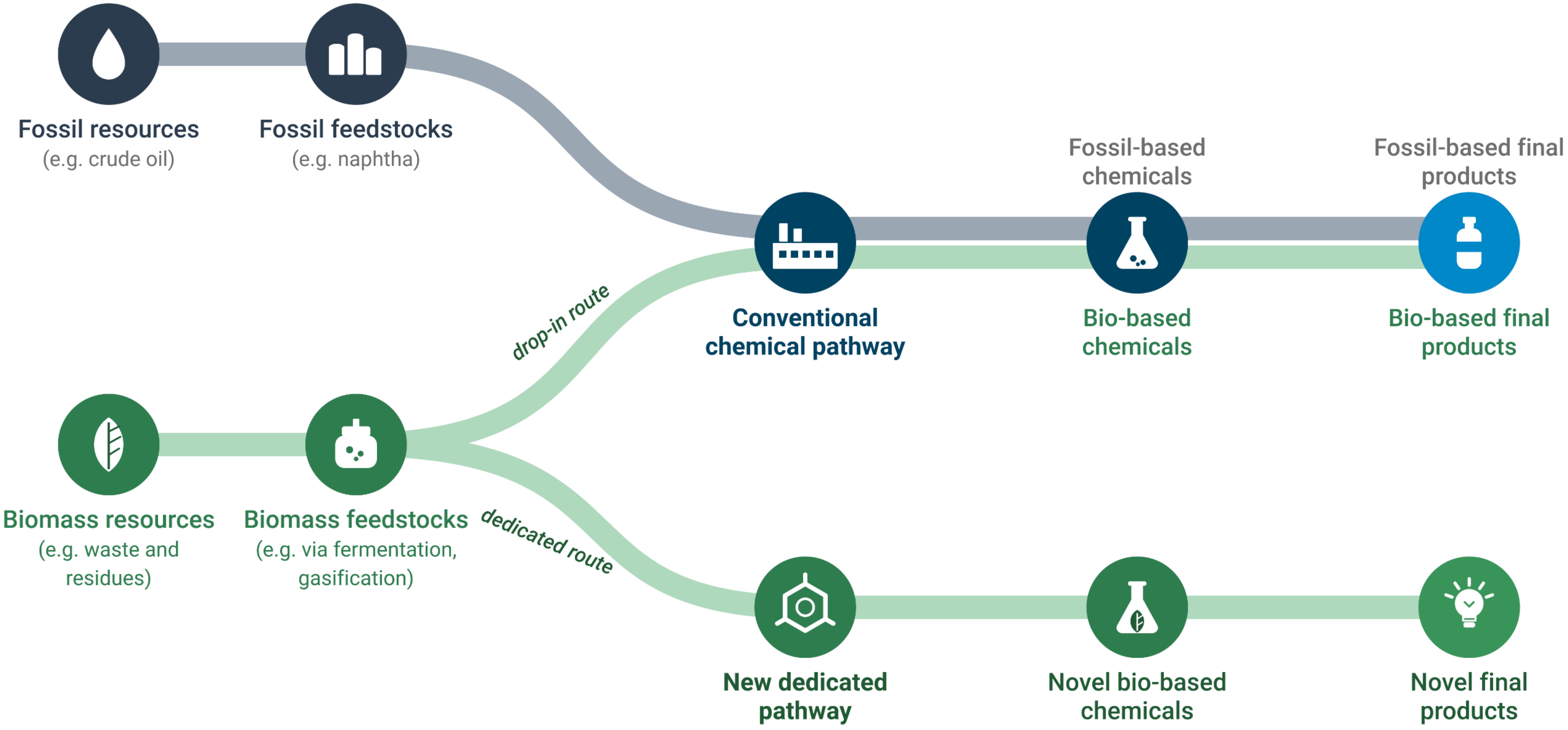
  (35 MW, 45 t/h Steam)

The Need for Alternative Feedstock Production

Estimated distribution of life-cycle emissions for basic chemicals produced in Germany (2019)



Pathways of Bio-based Chemical



Renewable Feedstock Pathways

Where electrification cuts process emissions, feedstock substitution tackles the fossil origin of the carbon itself.

Bio-based feedstock

- **Drop-in feedstock:** thermochemically converted biomass co-processed in existing crackers, directly replacing fossil naphtha
- **Bio-oil:** fast pyrolysis of dry woody/agri residues (400-600 °C); upgraded to bio-naphtha via two-stage hydrotreatment
- **Bio-crude:** hydrothermal liquefaction of wet biomass (250-370 °C, 100-300 bar) — no pre-drying needed, suits high-moisture waste

Wet biomass

Electro-based methanol

- **MTO route:** methanol converted directly to ethylene and propylene, bypassing the cracker; needs new MTO reactor investment
- **E-methanol:** electrolytic H_2 + captured CO_2 (power-to-methanol); on-site CCU reuses cracker CO_2 as feedstock
- **E-bio-methanol:** biomass syngas + electrolytic H_2; lower H_2 demand makes it cheaper and the more attractive near-term option

Lignocellulosic biomass

Recycled feedstocks

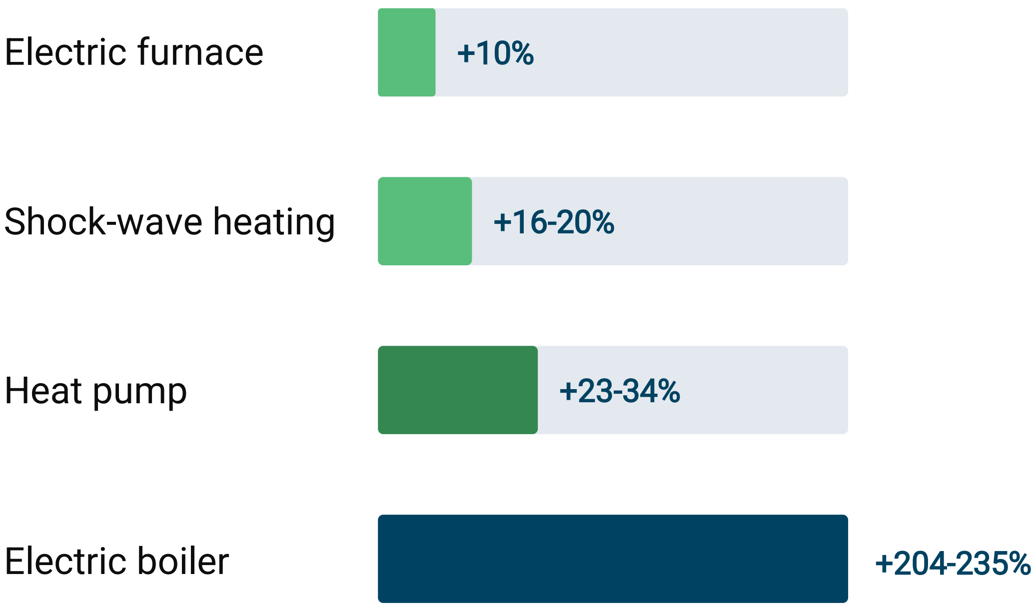
- **Chemical recycling:** pyrolysis breaks PE and PP into pyrolysis oil, a naphtha substitute compatible with existing crackers
- **Waste-plastic pyrolysis:** LG Chem Dangjin plant with Mura Technology (20 kt/yr, 2025); still uses some gas heat
- **Plasma-torch pyrolysis:** KIMM world-first electric torch (1,000-2,000 °C, 2025); decomposes mixed unsorted plastics, still early stage

Economics of the Transition – Electrification Technology

Electricity Tariffs in Korea

- **Current tariff (large corporate) :** EUR 0.115/kWh · KRW 182.7
- **PPA (renewable power purchase agreement) :** EUR 0.118/kWh · KRW 188.6
- **DESZ (Distributed Energy Special Zone*) :** EUR 0.104/kWh · KRW 165.8 * zones under Korea's Distributed Energy Act

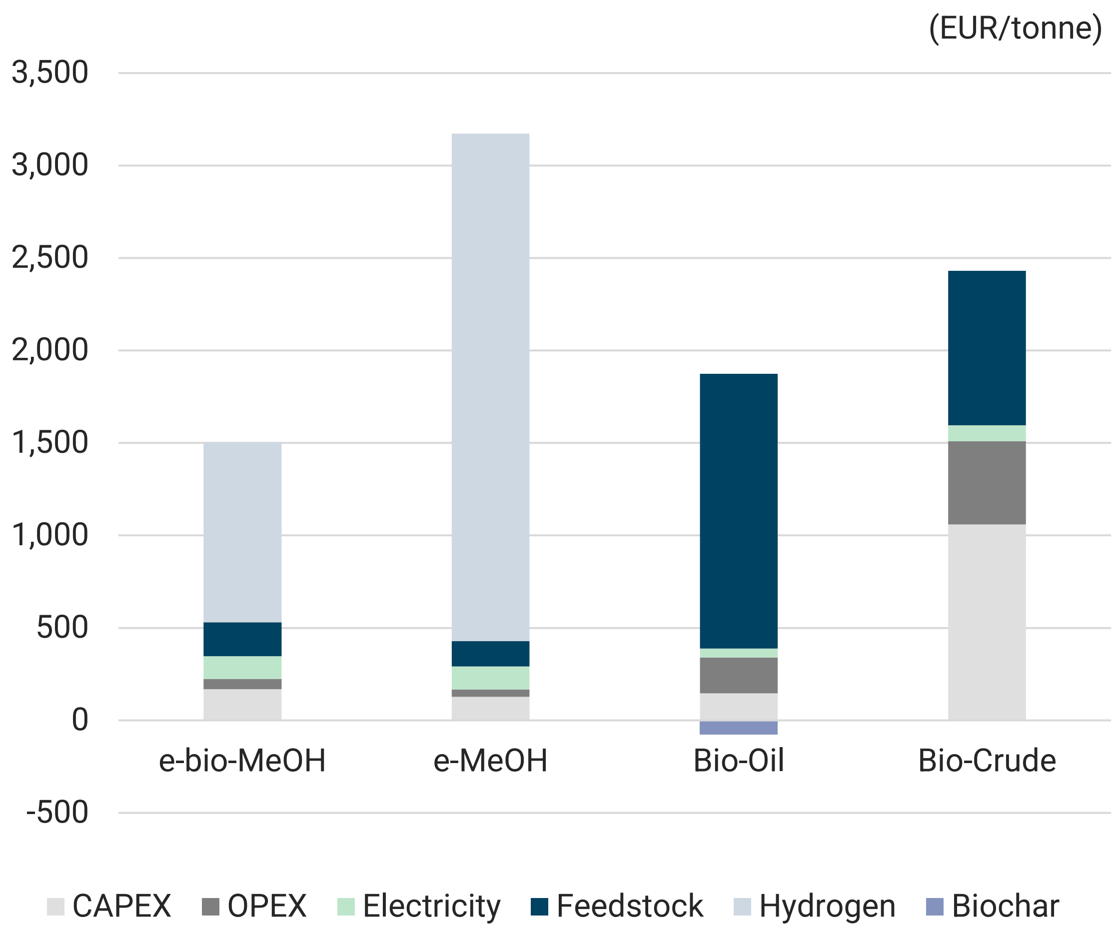
Cost premium vs conventional



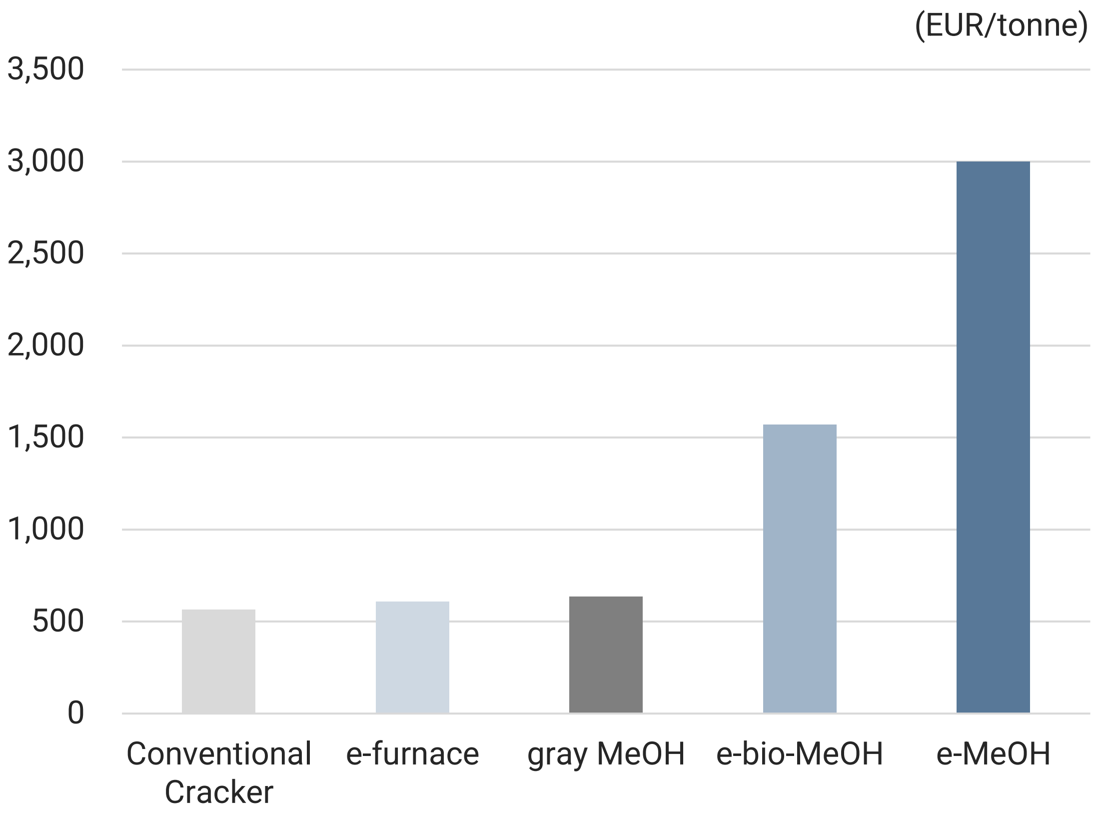
Technology	Conventional	Current tariff	PPA	DESZ
High-temperature cracking processes (ethylene production cost, EUR/t)				
Electric furnace	2,616	2,879 (110%)	2,903 (111%)	2,811 (107%)
Shock-wave heating	2,616	3,114 (119%)	3,139 (120%)	3,043 (116%)
Steam and heat systems (steam production cost, EUR/t)				
Heat pump	27	35 (131%)	36 (134%)	33 (123%)
Electric boiler	27	90 (335%)	93 (345%)	82 (304%)

Economics of the Transition – Renewable Feedstock

Breakdown of levelised production costs for feedstock



Levelised production costs of ethylene by process



Policy Instruments Supporting Petrochemical Decarbonization

Policy type		Description
Upstream Energy and feedstock access	Energy access	Policies supporting renewable electricity, grid access, and the supply of hydrogen and low-carbon fuels for industrial production
	Circular & bio-based feedstocks	Policies promoting recycled and bio-based materials as substitutes for fossil-based feedstocks
Midstream Production processes	Carbon pricing	Emission trading systems that put a carbon price on industrial production
	Investment & financing support	Public funding, state-aid and R&D programmes for low-carbon industrial technologies
	Petrochemical industrial strategy	National and sectoral plans targeting the structural transition of the petrochemical industry towards green and high-value production
	Industrial regulation & standards	Binding frameworks requiring technology upgrades, emission reductions and phase-out of ageing facilities
Downstream Product	Product regulation	Regulations on single-use plastics, packaging and vehicle materials that directly reduce demand for fossil-based petrochemical products
	Sustainable product design	Eco-design requirements setting durability, recyclability and material efficiency standards across value chains

A Phased Deployment Roadmap

Phased technology deployment	2025-2035 Pilot & first commercial	2035-2045 Scale-up	By 2050 Near net-zero
Electric furnace	●○○ First pilot demonstrations	●●○ Expansion to 2+ cracking units	●●● Mainstream cracking technology
Renewable-feedstock cracker	●○○ R&D & large-scale validation	●●○ Pilot-to-commercial transition	●●● Commercial at scale
Heat pump / electric boiler	●●○ Deployment at selective sites	●●● Full deployment	●●● Standard utility infrastructure
Electricity requirement (TWh/yr)	5.2 up to	12.3 up to	sustained high plateau as electrification matures

Policy Recommendations

Korea has the industrial base (K-ETS, DESZ, the petrochemical support package). Five moves close the remaining gaps.

1. **Establish a national transition roadmap**
   Set phased deployment targets and align grid investment with electrification timelines.

2. **Expand renewable electricity & grid**
   One e-furnace needs ~5.2 TWh/yr (+4.3 TWh vs conventional); reinforce substations in parallel.

3. **De-risk first-mover investment**
   Carbon Contracts for Difference (CCfDs) plus DESZ market reform bridge the cost gap.

4. **Build renewable feedstock supply chains**
   Secure domestic biomass, waste plastics and CO2 offtake; advance bio and methanol routes together.

5. **Reform DESZ access & tariffs**
   Affordable clean power is decisive - the e-furnace premium falls from ~10% to ~7%.

Applied Case - A Clean Yeosu Complex by 2035

Translating the strategy into Korea's largest olefin hub, using its Distributed Energy Special Zone.

2035 Blueprint

① Electric furnace
Proposed for two crackers
Ethylene capacity 1.4 Mt/yr

② Heat pump
Adoption at a new complex
Steam capacity ~0.8 Mt/yr

③ CCUS cluster development
Built in Yulchon complex
CO2 Capture scale 3 Mt/yr

④ CCU feedstock production
Pilot facility in operation
Demonstration planned

https://nextgroup.or.kr/en/research/publications

A Net Zero Roadmap for South Korea's Petrochemical Industry

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Sugang Kim, Rachel Eun Ko

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Strategic Transformation of Korea's Petrochemical Complexes

Regional Strategies and Policy Agenda for Yeosu, Daesan, and Ulsan

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SUMMARY

- The global petrochemical industry is facing structural stagnation due to oversupply, threatening the regional economies of Korea's three main complexes (Yeosu, Daesan, Ulsan). Current government measures lack effectiveness and fail to account for each site's specific challenges and capabilities. The Korea petrochemical industry needs to shift to a new growth sector, backed by real investment to ease regional stagnation.
- Key transition strategies identified for each complex are:
  Yeosu: Technology testbed for transition to clean chemical industry
  Daesan: Commercialization of alternative feedstocks and introduction of low-carbon infrastructure
  Ulsan: Leadership in clean hydrogen and plastics recycling businesses
- Key transition technologies' economic analysis shows heat pumps and methane pyrolysis lower long-term costs and eliminate greenhouse gases. Electric heating raises costs with renewable energy use but cuts carbon emissions by over 90%. About 2.9 trillion KRW short-term investment, renewable infrastructure expansion, and financial support are needed for successful transition and commercialization across the three petrochemical complexes.

ISSUE BRIEF
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Electrification Pathways for Yeosu Petrochemical Complex: Strategies for a Clean Industrial Transition

Utilizing Distributed Energy Special Zones and Virtual Power Plants

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SUMMARY

- Korea's petrochemical industry is undergoing structural transformation driven by global oversupply. The Yeosu Petrochemical Complex, the nation's largest basic petrochemicals producer, faces serious threats to its competitiveness and viability, yet government responses have focused narrowly on capacity reduction and restructuring with no clear transition roadmap. With Jeollanam-do now designated as a Distributed Energy Special Zone, the complex has a timely opportunity to accelerate its shift toward a clean chemical industry hub by leveraging the region's abundant renewable energy.
- Electric furnaces and industrial high-temperature heat pumps are the core electrification technologies for replacing fossil fuel combustion with renewable electricity. Jeollanam-do's renewable installed capacity is projected to reach 29 GW by 2030 and 62.5 GW by 2035, and direct trading under the Special Zone designation is expected to lower procurement costs below conventional PPA rates, improving the economic case for electrification.
- Realizing this transition requires resolving key institutional and infrastructure prerequisites: expanding renewable generation capacity near the complex, establishing a substation expansion plan aligned with electrification timelines, permitting concurrent use of existing PPAs alongside Special Zone direct trading, and formally recognizing Virtual Power Plant (VPP) operators as eligible direct trading counterparties.
- Scenario analysis shows that electricity demand will trough following NCC restructuring, then recover incrementally to approximately 23 TWh by 2035. Expanded district energy generation and growing direct procurement from distributed sources will contain overall cost increases, and surplus by-product methane from electric furnace adoption can be sold externally, further limiting the net cost burden.
- The first half of 2026, with the Petrochemical Special Act enforcement decree and the Comprehensive Support Measures for the Chemical Industry Ecosystem both pending, is a critical window to put in place the investment incentives and institutional framework needed for the Yeosu Petrochemical Complex to transition into a clean chemical industrial complex.

THANK YOU

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Q&A