

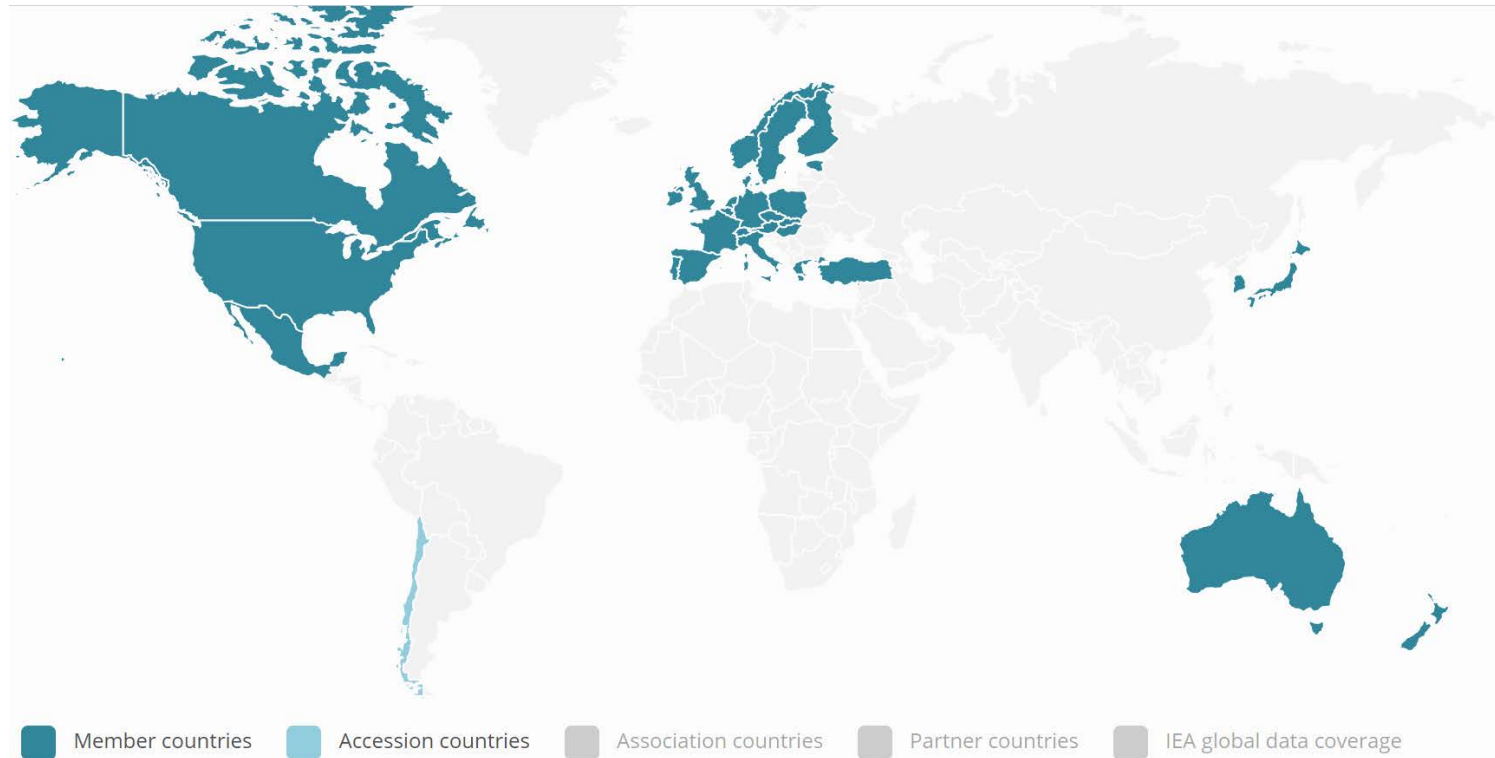


The Future of Petrochemicals

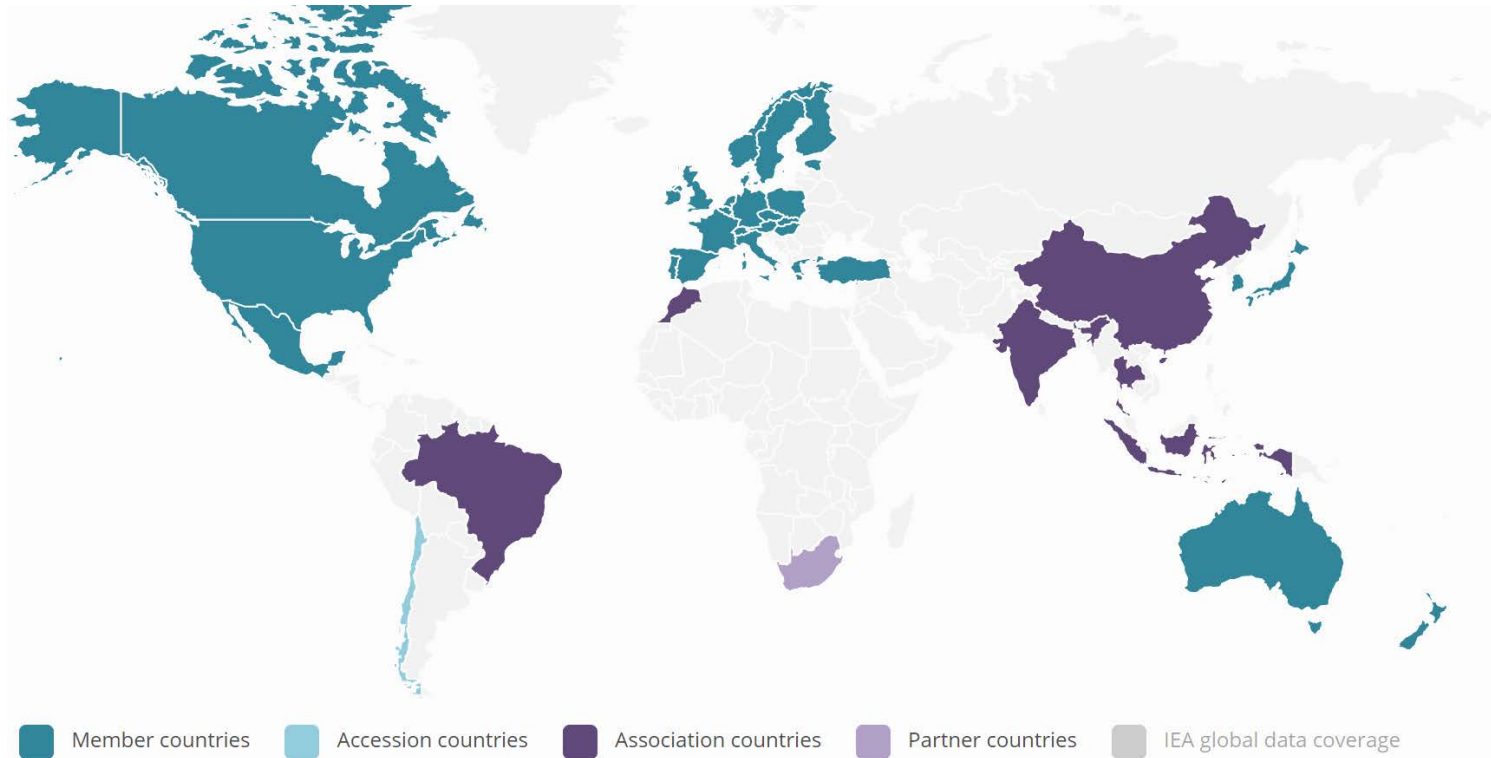
Mechthild Wörsdörfer, Director of Sustainability, Technology and Outlooks

7 December 2018, Brussels - EU Refining Forum

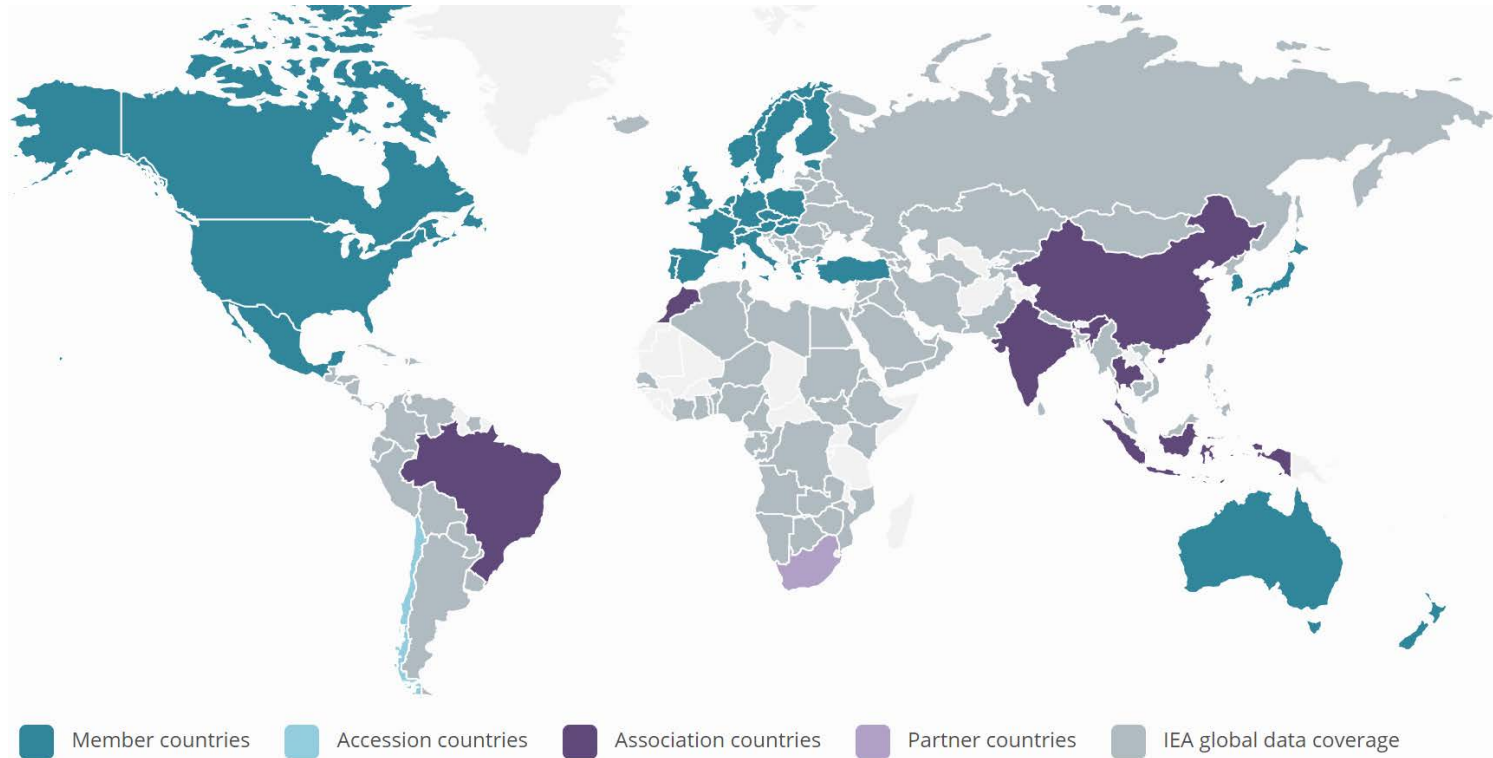




The IEA works around the world to support accelerated clean energy transitions with unparalleled data, rigorous analysis and real-world solutions.

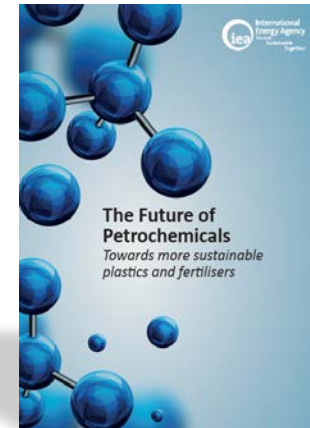
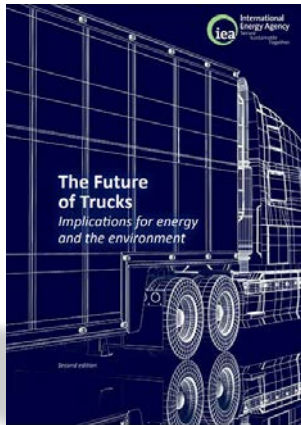


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Exploring key “blind spots” in global energy

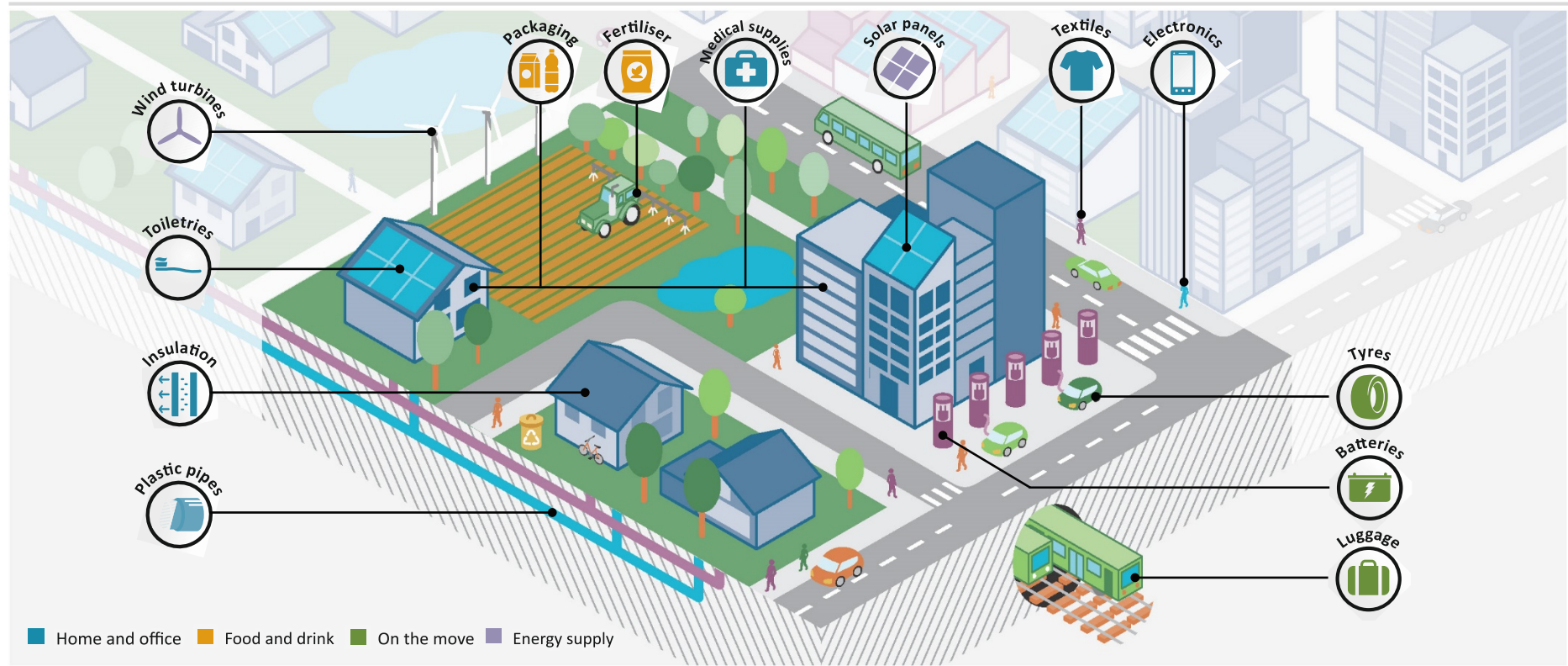


The IEA is shining a light on areas of the energy system that do not garner as much attention as they deserve.

Petrochemicals today

Chemicals, society, the energy system and the environment

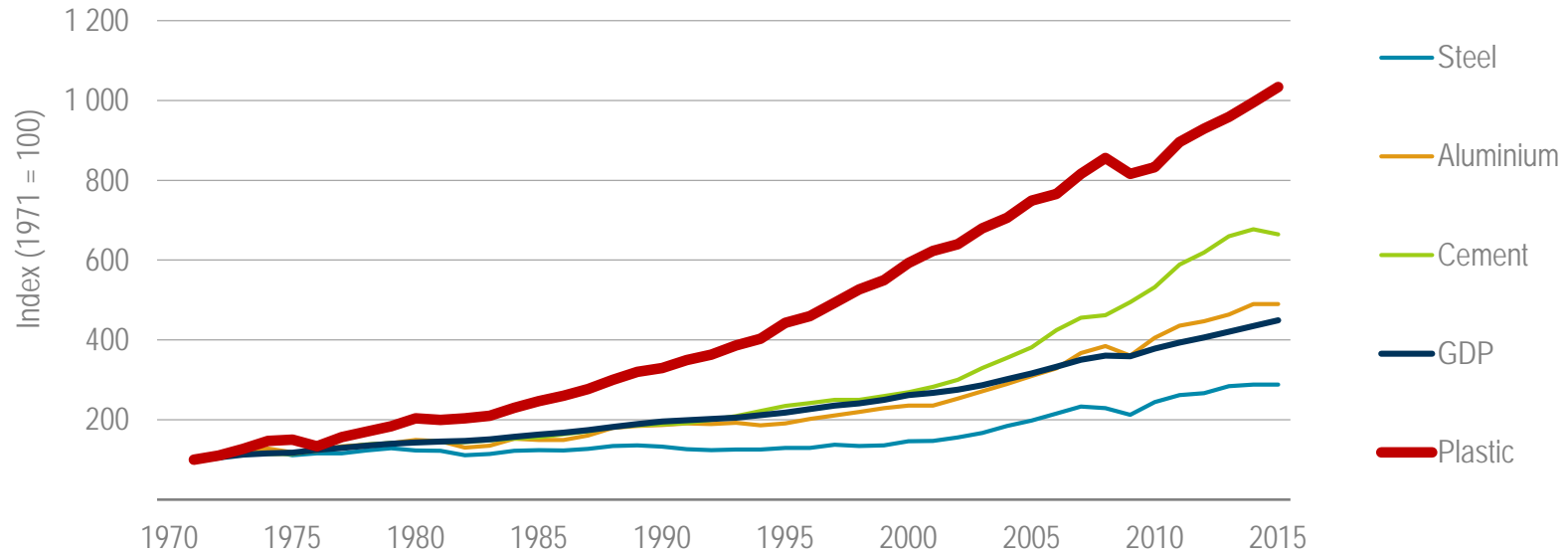
Petrochemicals are all around us



Our everyday lives depend on products made from petrochemicals, including many products for clean energy transitions.

Petrochemical products have been growing fast

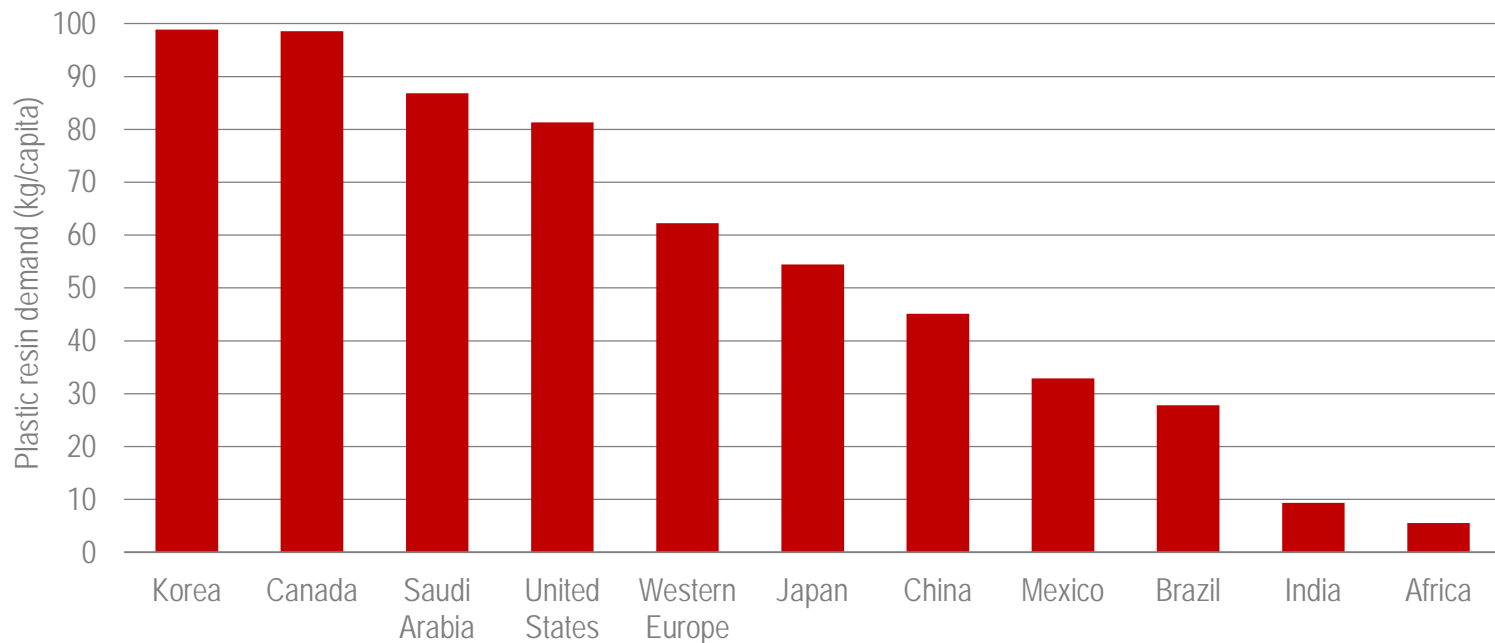
Production growth for selected bulk materials and GDP



Demand for plastic has grown faster than for any other bulk material, nearly doubling since the millennium.

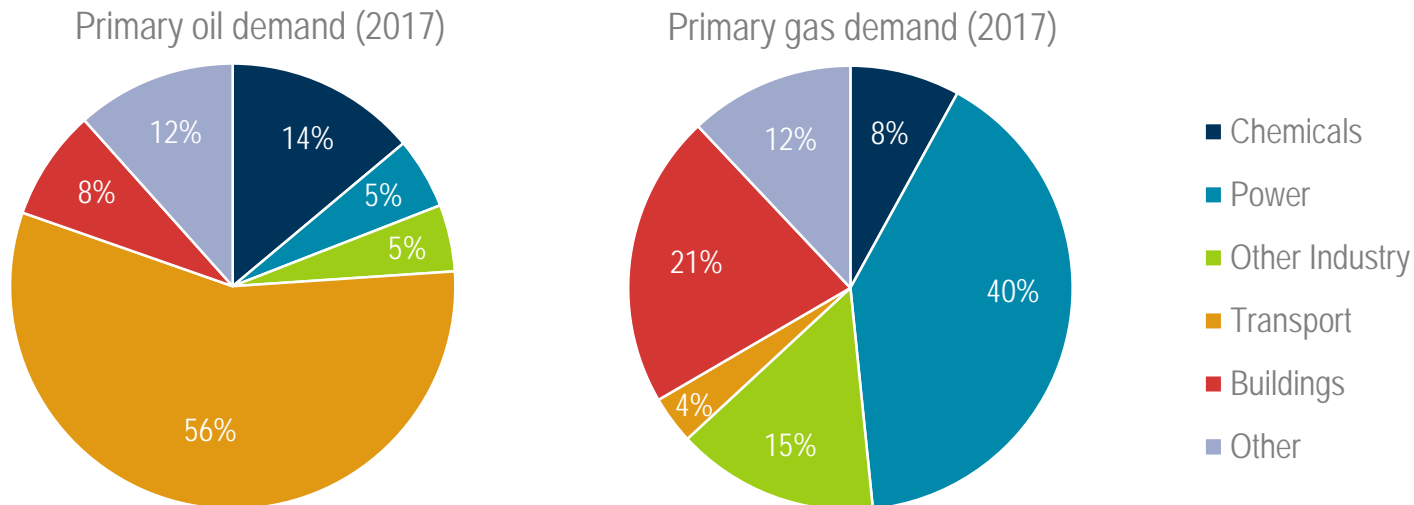
Plastics are a key driver of petrochemical demand

Per capita demand for major plastics in 2015



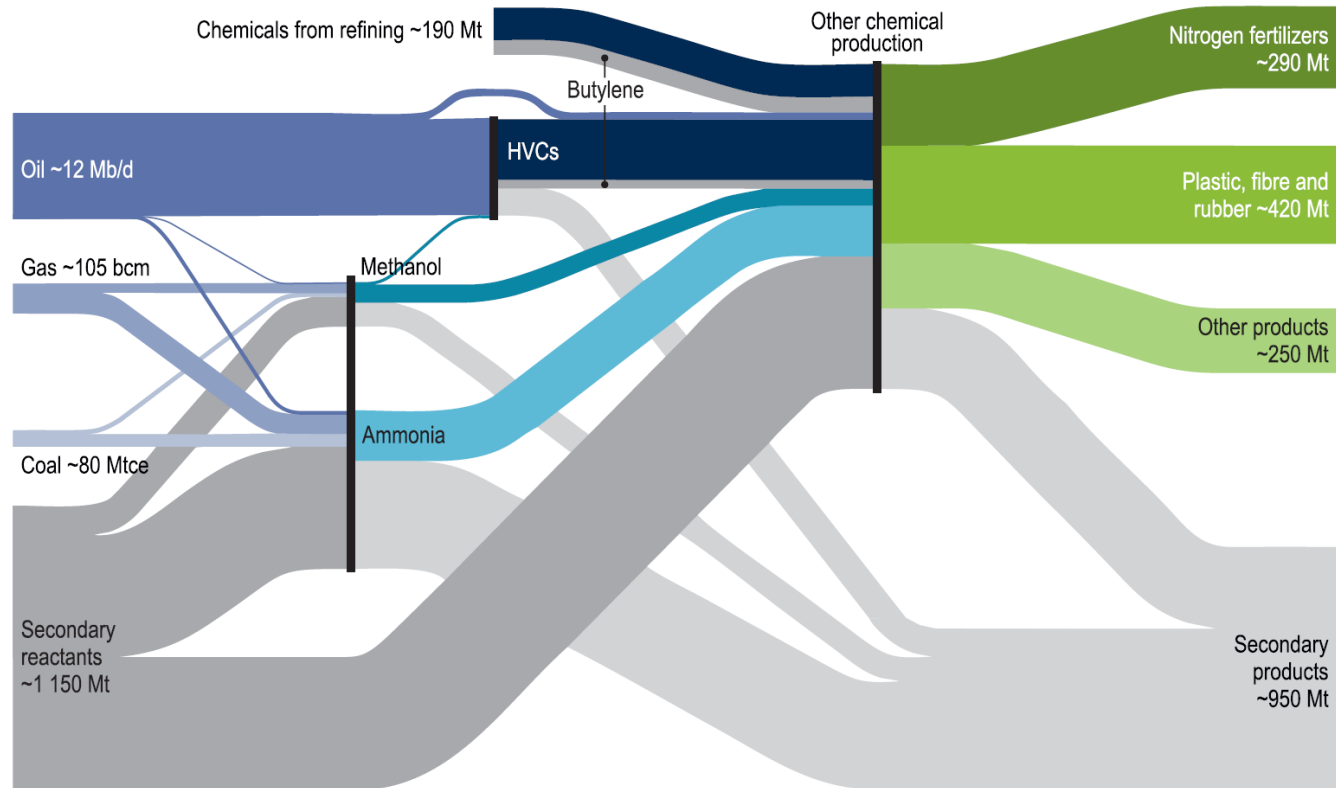
Higher-income countries consume up to 20 times as much plastic per capita as lower-income economies, indicating significant global growth potential.

The importance of petrochemicals in oil and gas demand



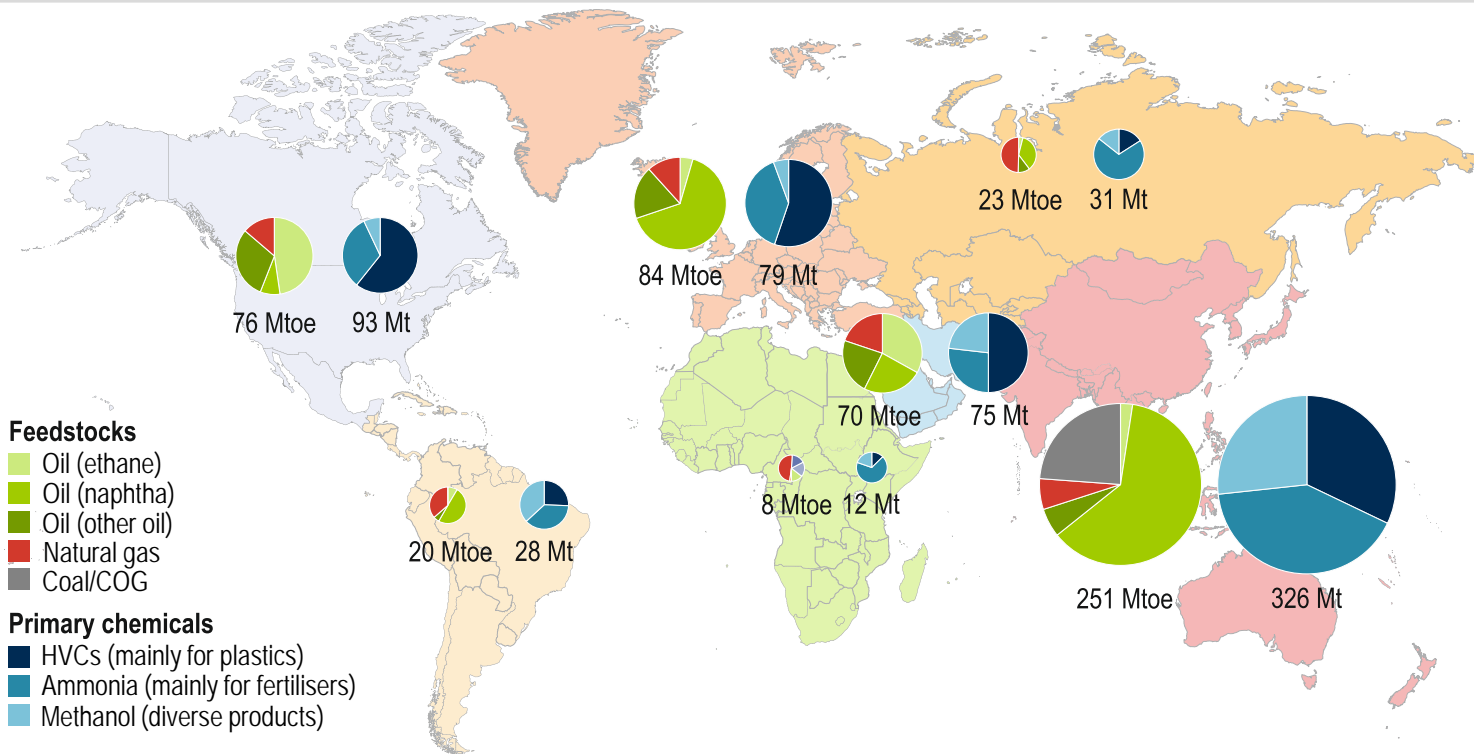
Today, petrochemicals account for 14% of global oil, and 8% of global gas demand.

“Feedstocks” fly under the radar



Feedstock accounts for half of the chemical sector's energy inputs, of which oil and gas account for more than 90%.

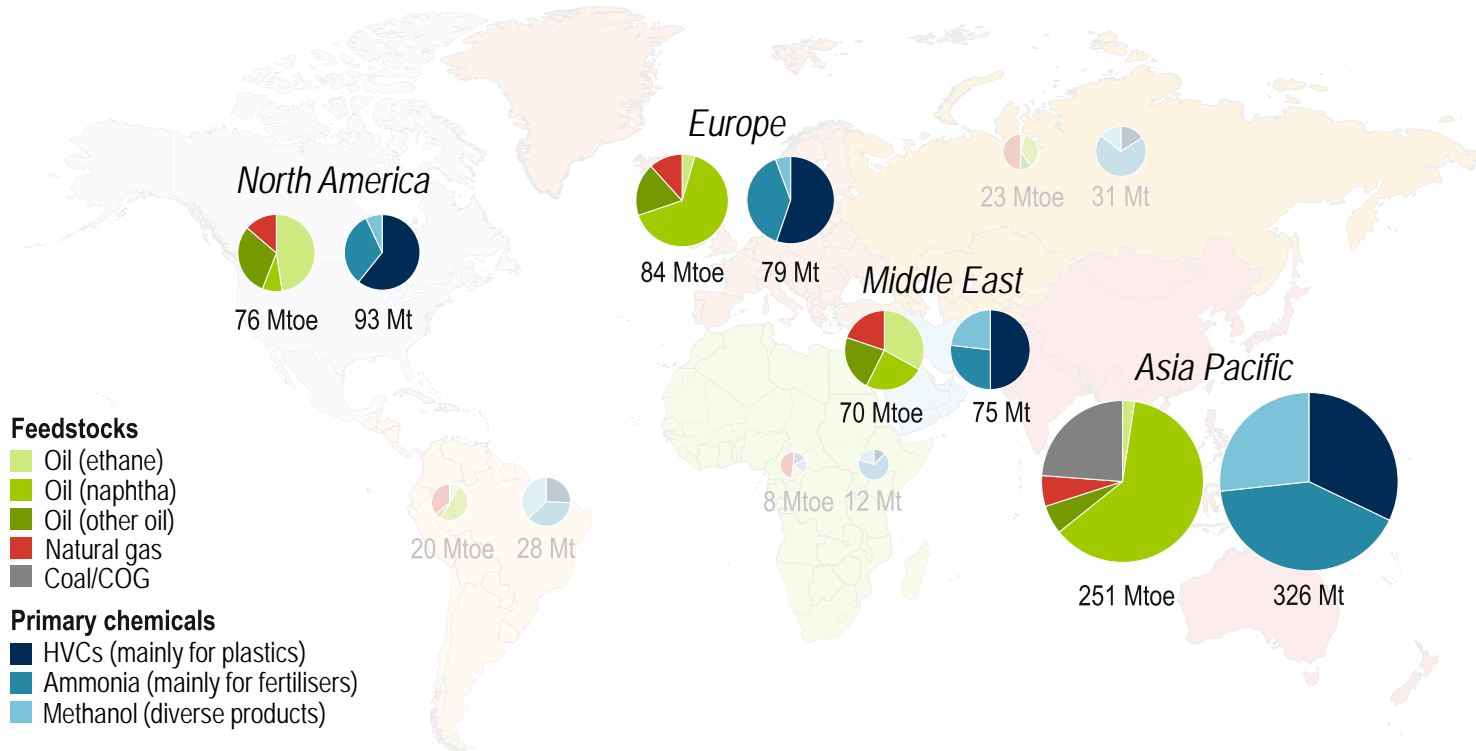
No “one size fits all” for production and feedstock



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Asia dominates both global primary chemical production and naphtha feedstock consumption. North America is the leader in ethane-based petrochemical production.

No “one size fits all” for production and feedstock

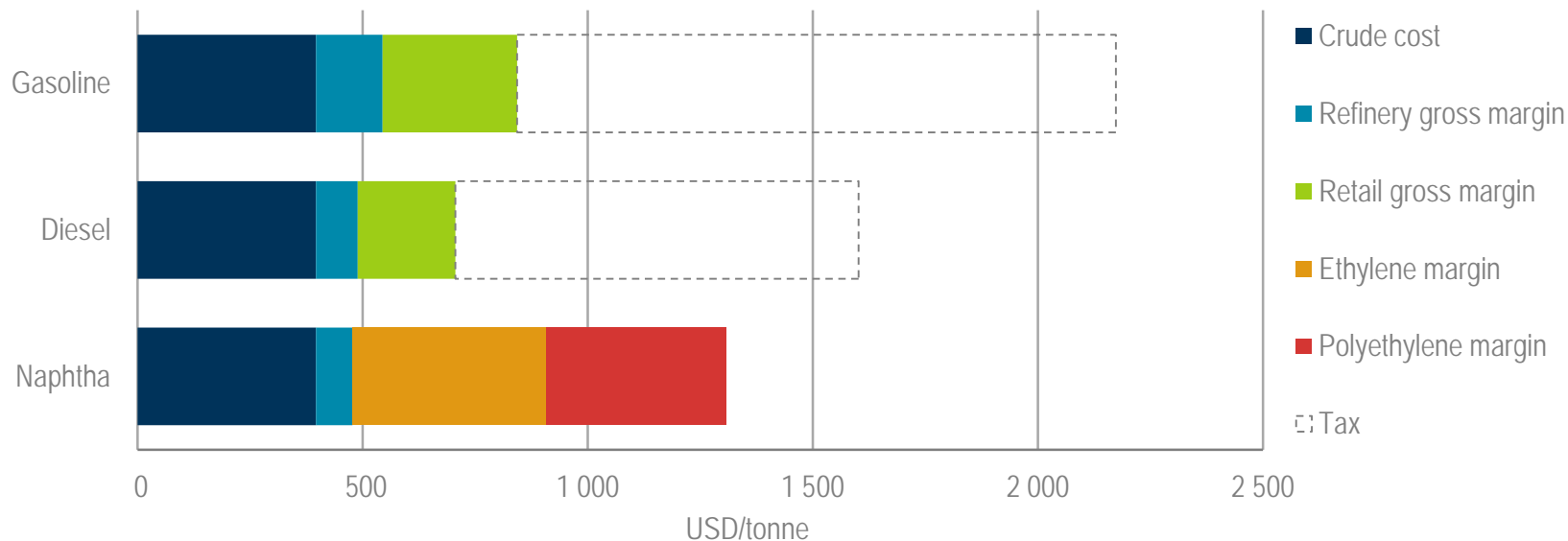


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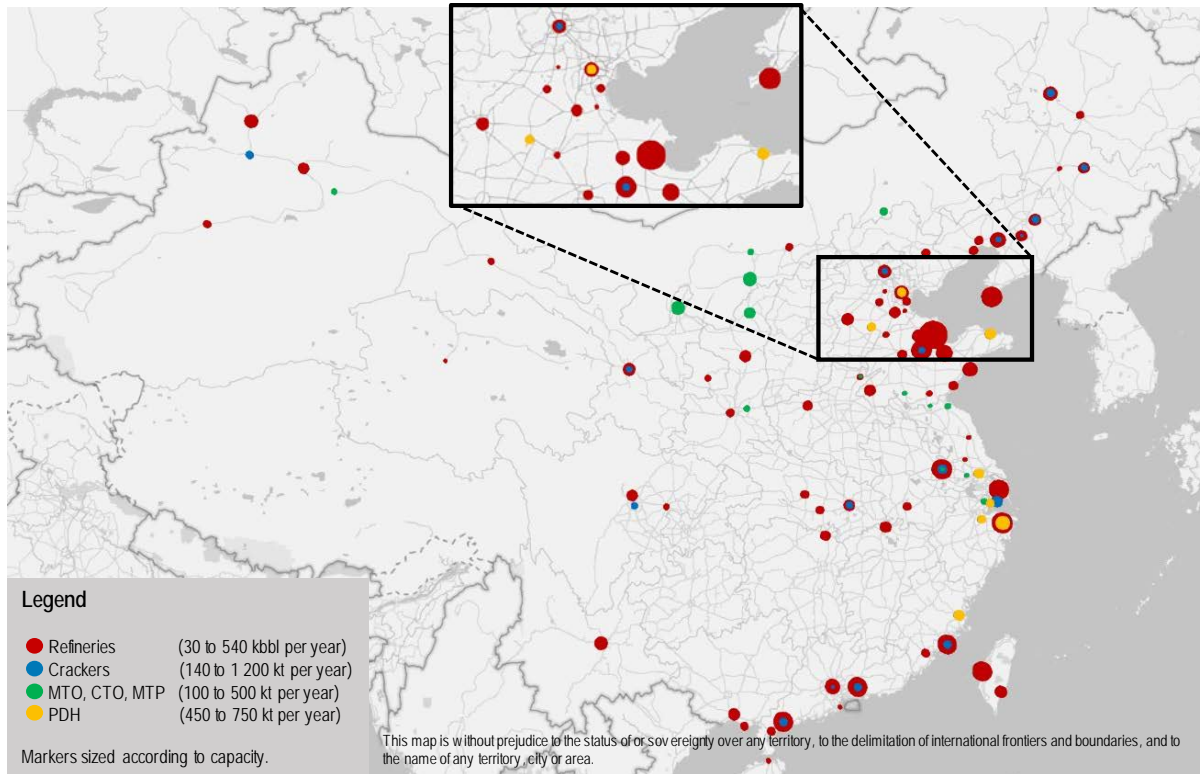
Oil companies are strengthening links with petrochemicals

Indicative economics for fuels and petrochemicals in Europe



For integrated refiners, the petrochemical path can offer higher margins than fuels.

Levels and types of integration vary between regions

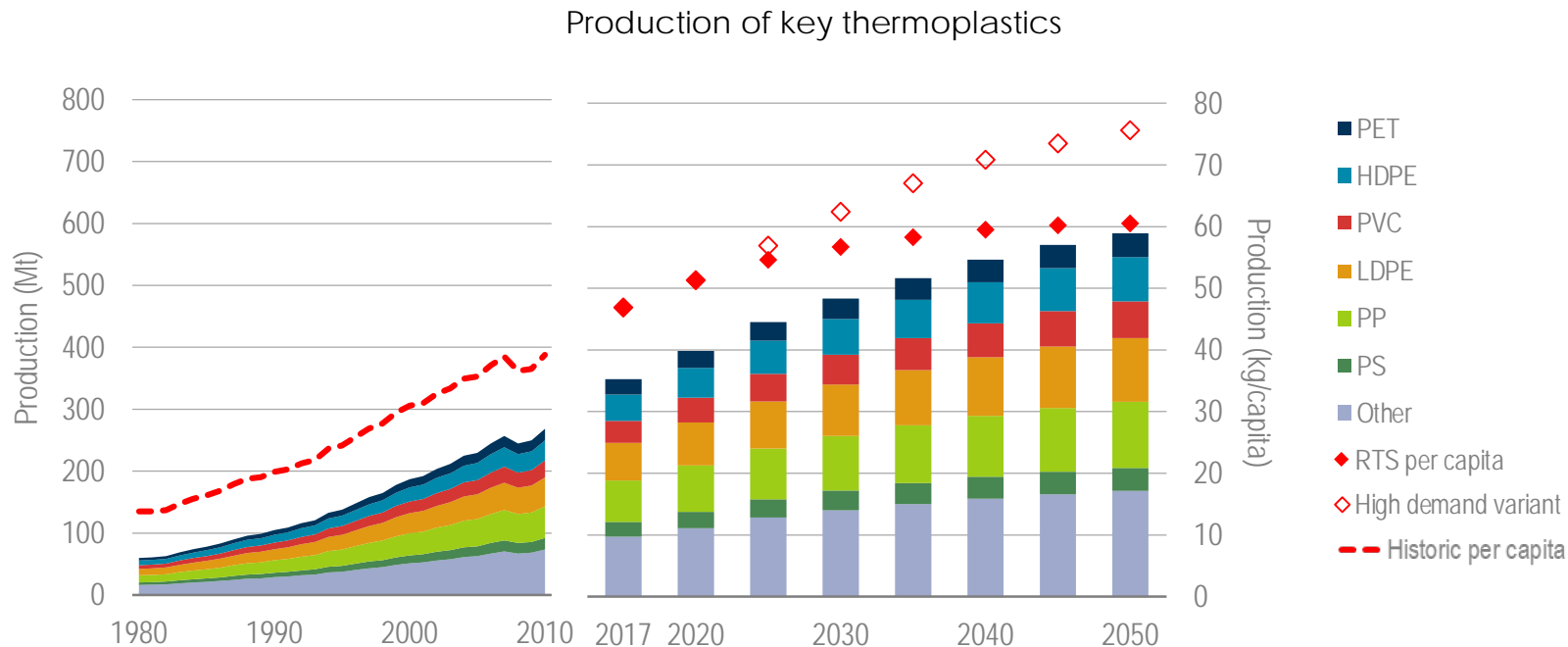


China's petrochemical capacity follows refinery placement, with naphtha crackers concentrated in the 11 coastal provinces, while methanol-based output tends to be located in coal-producing regions.

What is the current trajectory for petrochemicals?

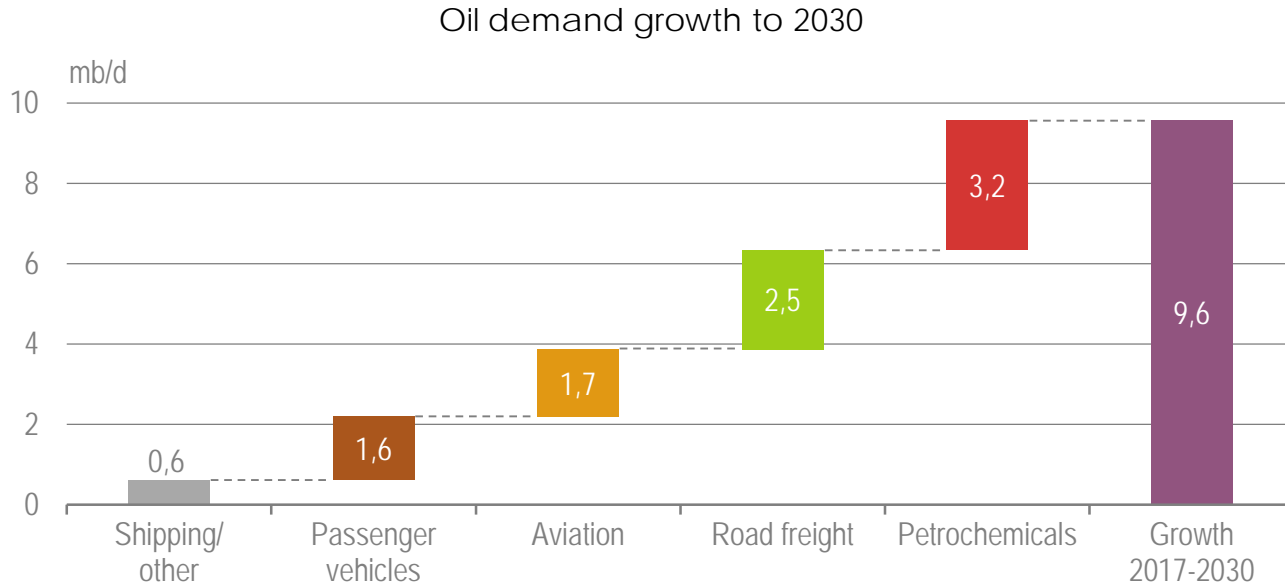
The Reference Technology Scenario (RTS)

Plastics continue their strong growth trajectory...



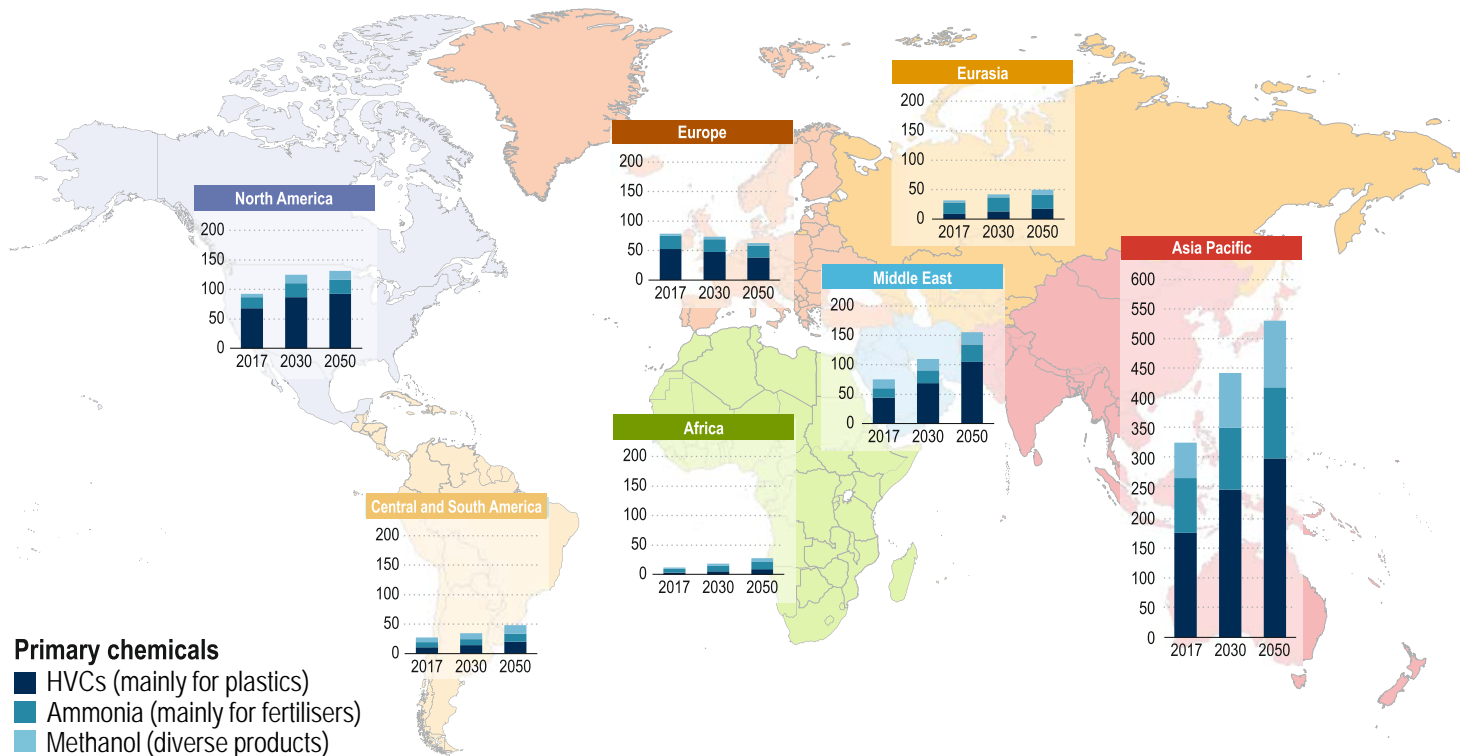
Production of key thermoplastics more than doubles between 2010 and 2050, with global average per capita demand increasing by more than 50%.

Petrochemicals grow more than any other oil demand driver



Petrochemicals are the fastest growing sector of oil demand – over a third of growth to 2030 and nearly half to 2050.

Underpinned by robust growth for primary chemicals



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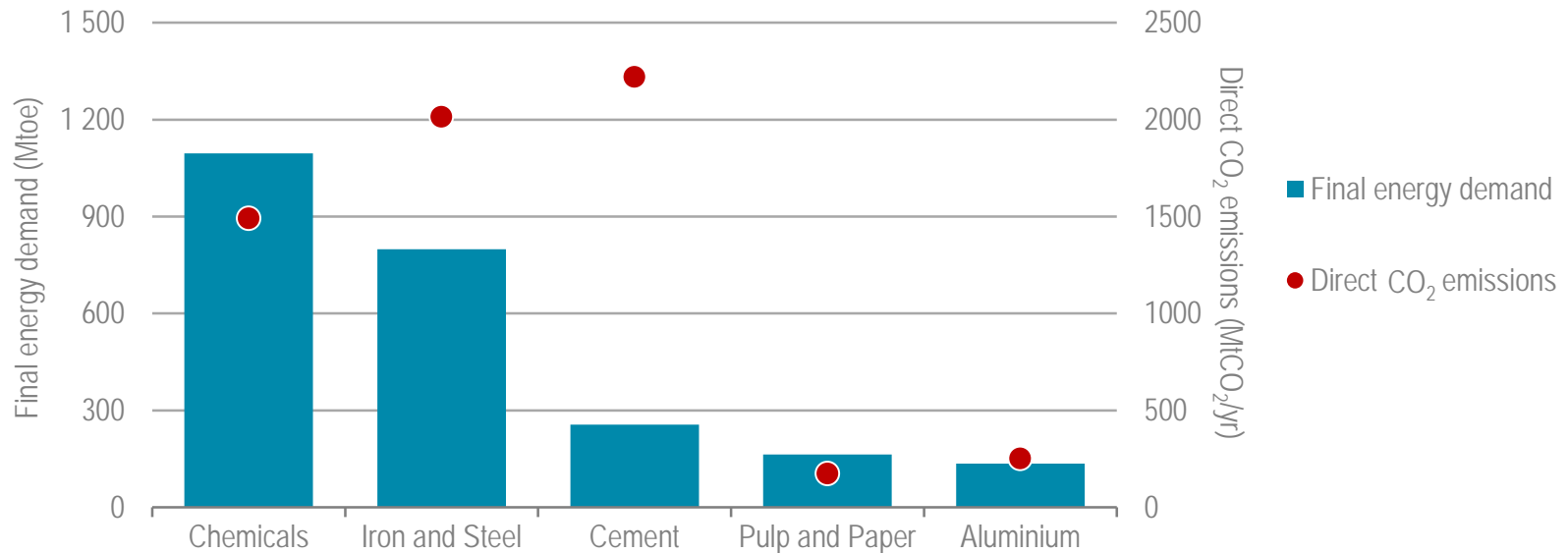
Regions with a feedstock advantage and a strong source of domestic demand account for the lion's share of production increases in the longer term.

An alternative, more sustainable pathway

The *Clean Technology Scenario* (CTS)

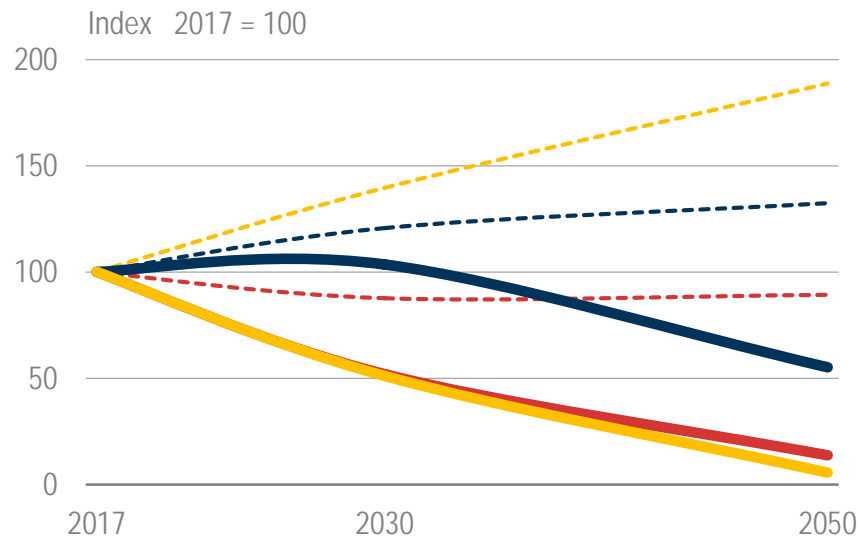
Petrochemicals take an environmental toll

Global final energy demand and direct CO₂ emissions by sector in 2017



Despite being the largest industrial energy consumer, the chemical sector ranks third among industrial CO₂ emitters.

Pollutants from primary chemical production



Reference Technology Scenario

--- Carbon dioxide

--- Air pollutants

--- Water pollutants

Clean Technology Scenario

— Carbon dioxide

— Air pollutants

— Water pollutants

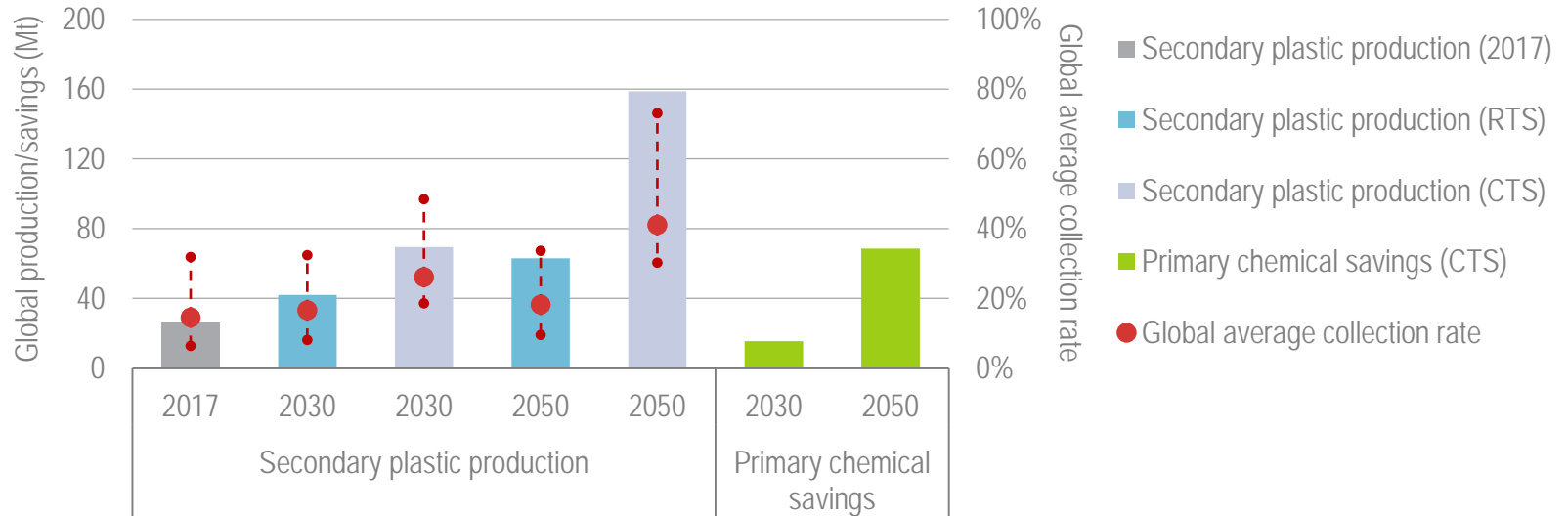
Relevant UN SDGs



By 2050, environmental impacts under the *Clean Technology Scenario* decrease across the board, including CO₂, air and water pollutants.

Plastic recycling increases sharply in the CTS

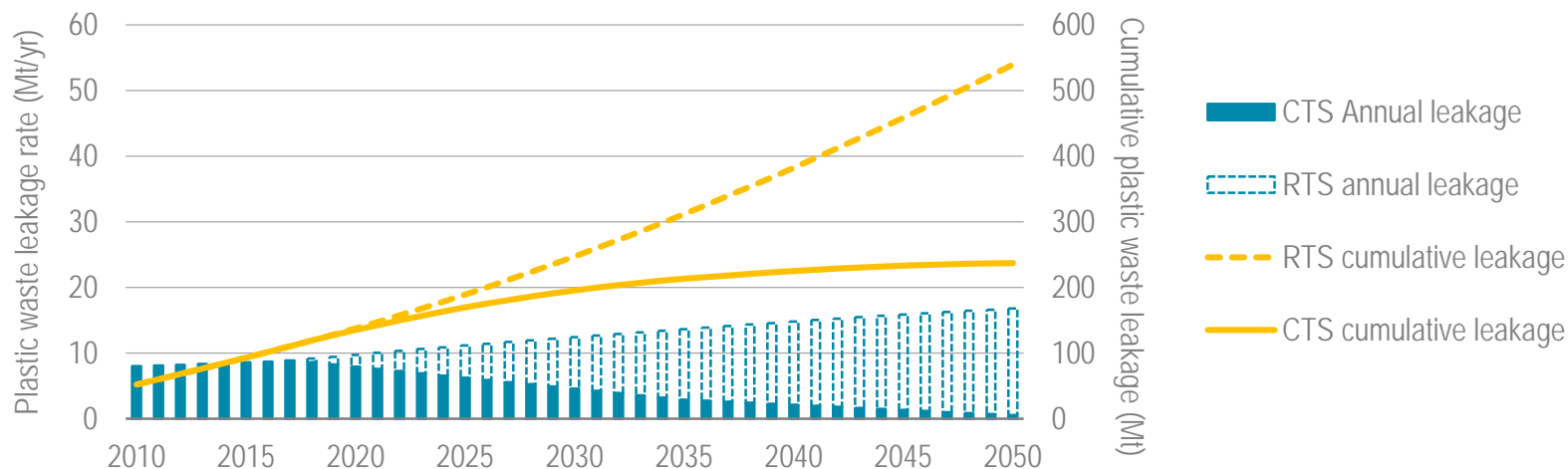
Secondary plastic production, primary chemical production savings and plastic collection rates



By 2050, the collection rate for recycling nearly triples in the CTS, resulting in a 7% reduction in primary chemical demand.

Plastic waste leakage is an urgent pollution problem

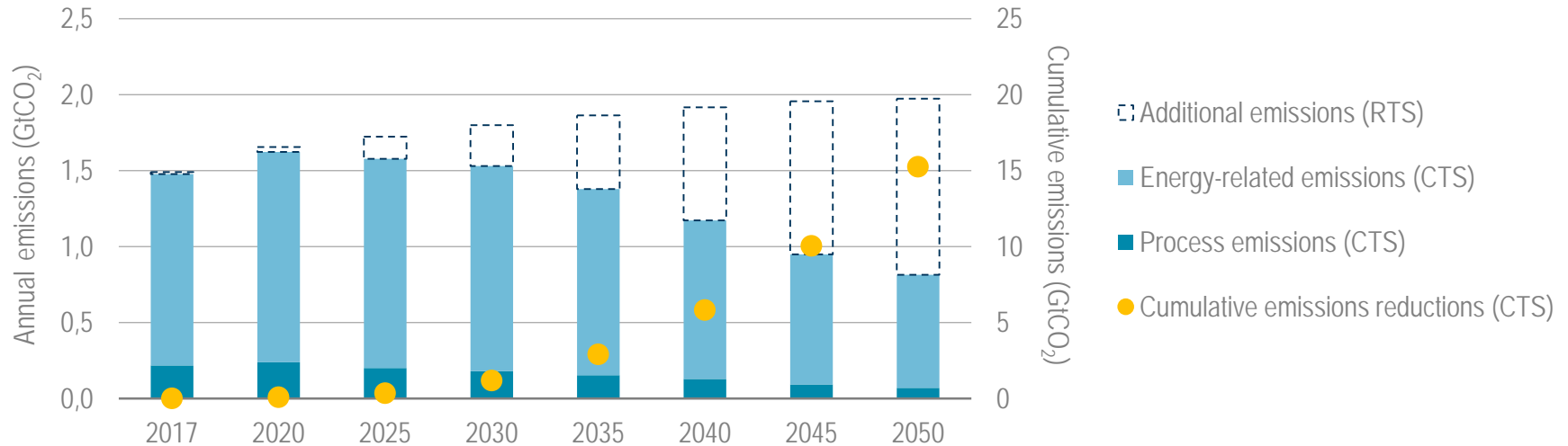
Annual and cumulative ocean-bound plastic leakage by scenario



The recycling infrastructure necessary in the CTS lays the groundwork to drastically reduce plastic pollution from today's unacceptable levels. Cumulative leakage more than halves by 2050, relative to the RTS.

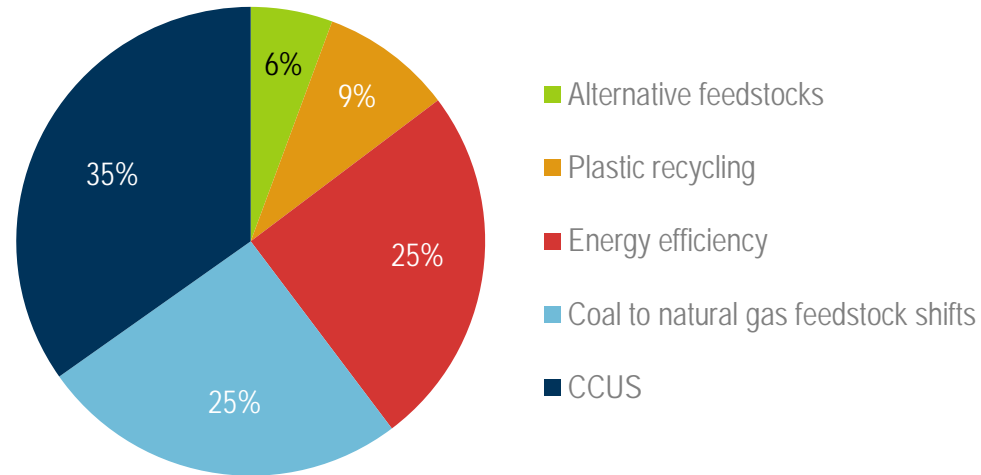
Reducing CO₂ emissions in the chemical sector

Direct CO₂ emissions by scenario



Chemical sector emissions of CO₂ decline by 45% by 2050 in the CTS, with energy-related emissions declining much less steeply than process emissions.

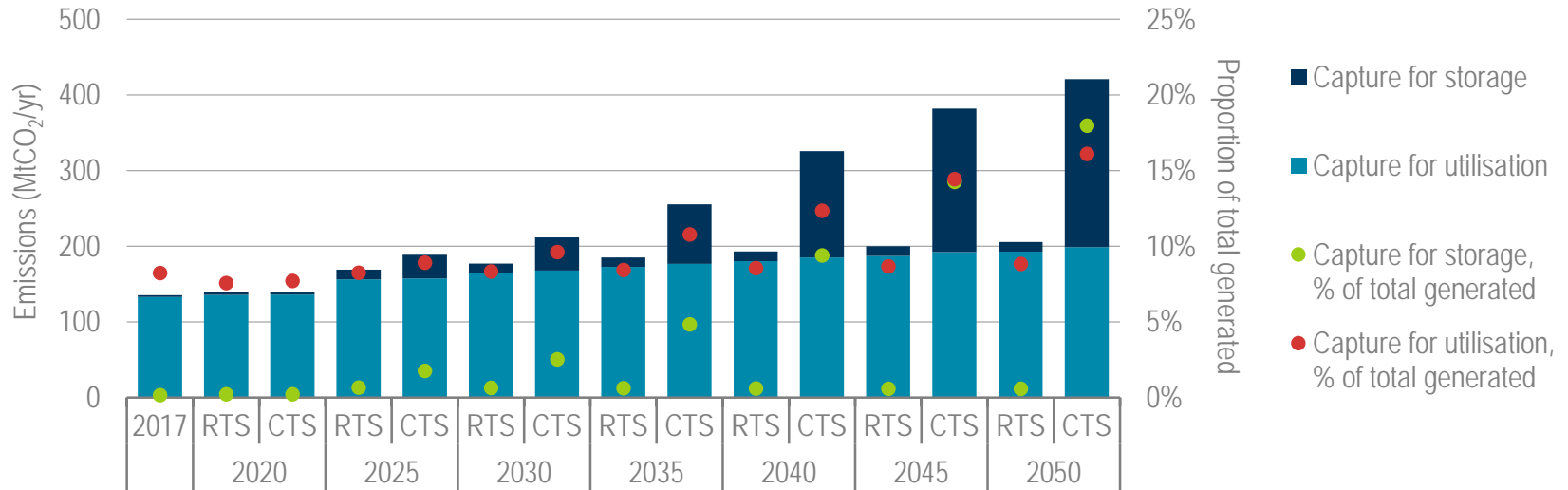
Contribution to cumulative CO₂ emissions reductions between the CTS and RTS



**A ambitious, balanced portfolio of options are required to deliver emissions reductions;
24% cumulative reduction from RTS to CTS from 2017 to 2050.**

CCUS delivers more than one third of CO₂ savings in the CTS

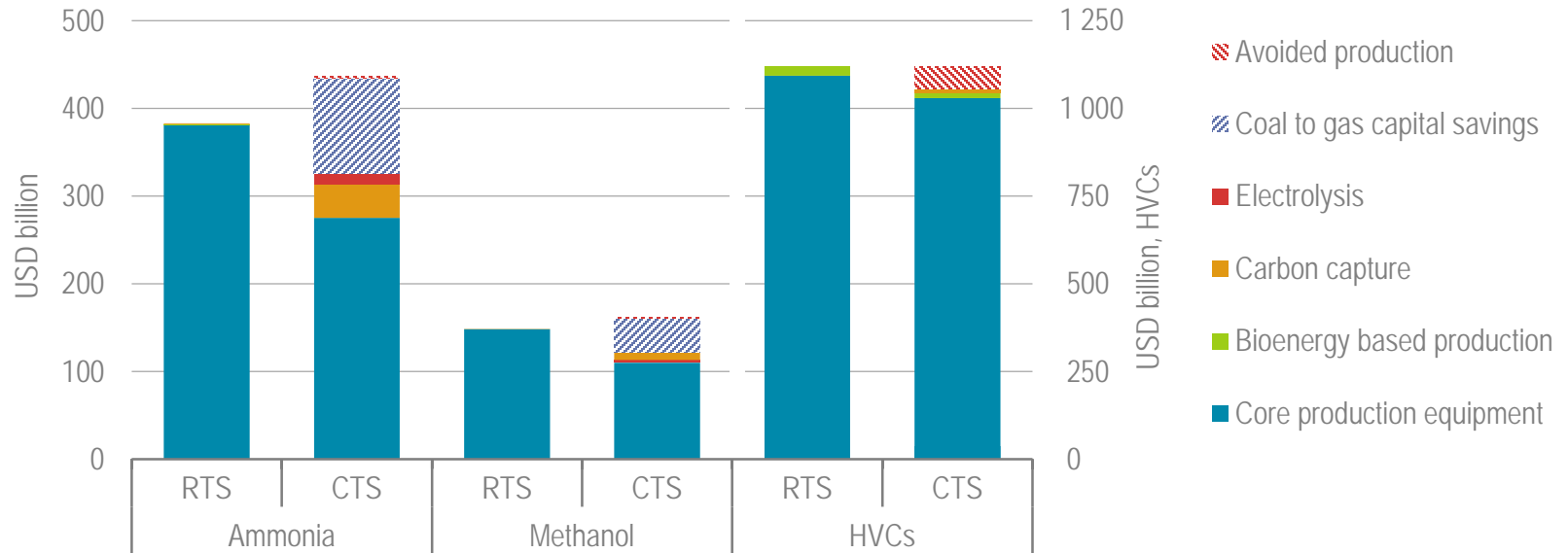
CCU/S deployment in the CTS and the RTS



Additional CO₂ capture capacity deployed in the CTS relative to the RTS is primarily for storage applications.

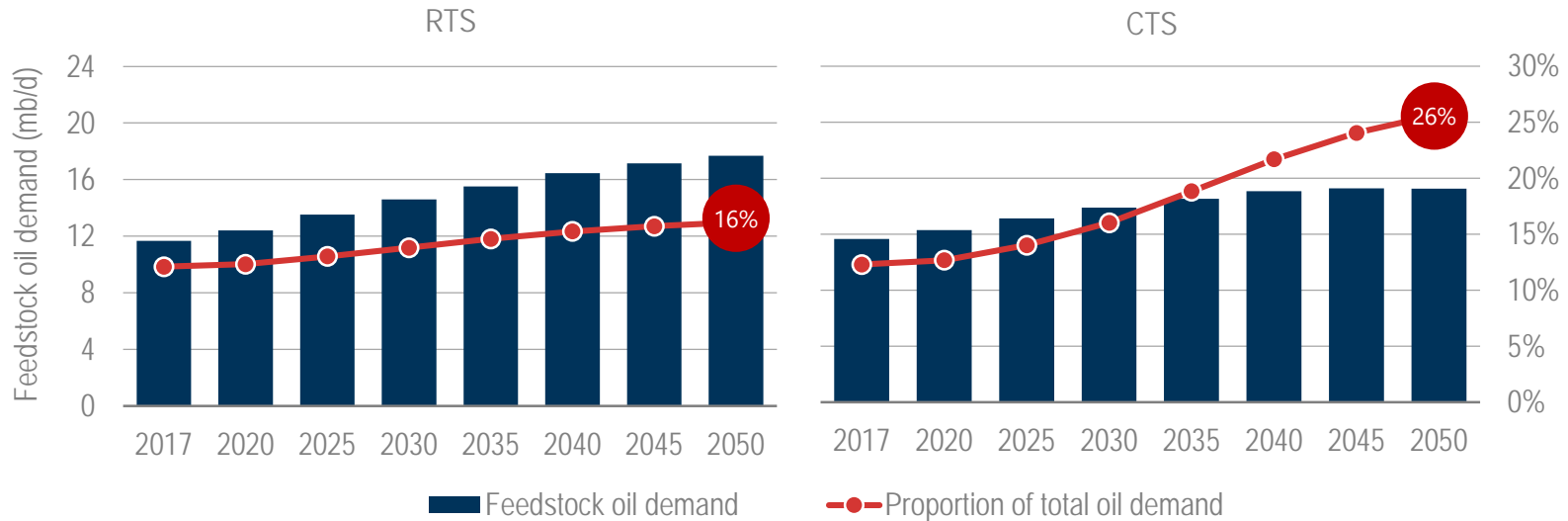
The CTS can be pursued cost-effectively

Cumulative capital investments by scenario



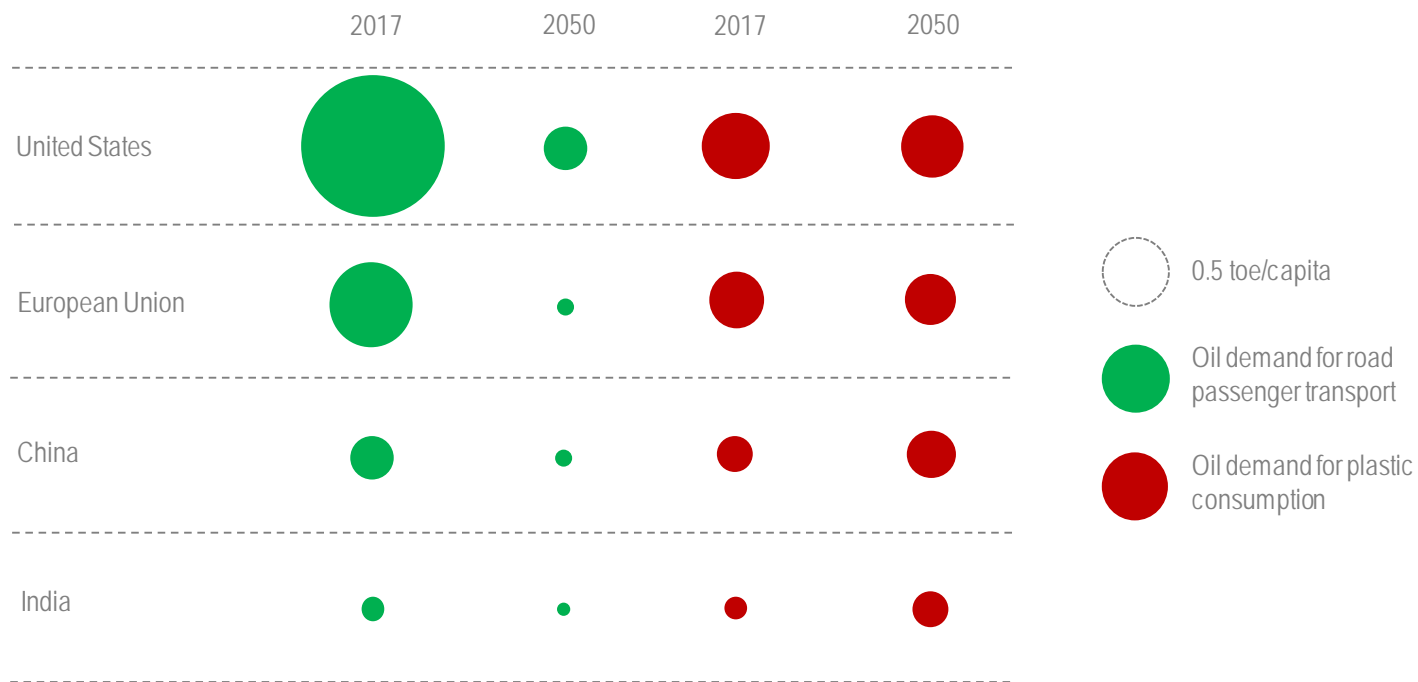
Savings due to recycling and coal-to-gas feedstock switching mean the CTS (USD 1.5 trillion) is less capital-intensive than the RTS (USD 1.7 trillion).

Oil demand for chemical feedstock and share in total oil demand by scenario



The share of chemical feedstock in total oil demand in the CTS is much higher, as oil demand for other sectors declines much more sharply.

Oil demand from road passenger transport versus plastics



Petrochemical feedstock is the only oil growth segment in the CTS. By 2050, per capita oil demand for plastics overtakes road passenger transport in several regions.

Production of chemicals

1. Directly stimulate investment in R&D of sustainable chemical production routes and limit associated risks.
2. Establish and extend plant-level benchmarking schemes for energy performance and CO₂ emissions; incent adoption through fiscal incentives.
3. Pursue effective efforts to reduce CO₂ emissions.
4. Pursue stringent air quality standards, including for industry.
5. Fuel and feedstock prices should reflect actual market value.

Use and disposal of chemical products

1. Reduce reliance on single-use plastics other than for essential non-substitutable functions.
2. Improve waste management practices around the world.
3. Raise consumer awareness about the multiple benefits of recycling.
4. Design products with disposal in mind.
5. Extend producer responsibility to appropriate aspects of the use and disposal of products.

- Petrochemicals are deeply embedded in our economies and everyday lives; they also play a key role in many clean energy technologies.
- Petrochemicals are the largest driver of global oil demand – more than a third of growth to 2030, and nearly half to 2050.
- The United States, China and the Middle East lead the growth in petrochemicals production.
- The production, use and disposal of chemicals take an environmental toll, but achievable and cost-effective steps can be taken.
- The IEA will continue to shine a light on energy “blind spots”: trucks, air conditioners, modern bioenergy...now petrochemicals...and more to come.



<https://www.iea.org/petrochemicals/>



General notes

Primary chemicals refers to HVCs, ammonia and methanol. HVCs = high-value chemicals (ethylene, propylene, benzene, toluene and mixed xylenes), COG = coke oven gas.

Slide 8

Outputs of different industrial sectors are displayed on an indexed basis referred to 1971 levels. *Aluminium* refers to primary aluminium production only. *Steel* refers to crude steel production. *Plastics* includes a subset of the main thermoplastic resins. Sources: Geyer, R., J.R. Jambeck and K.L. Law (2017), "Production, use, and fate of all plastics ever made", <https://doi.org/10.1126/sciadv.1700782>; Worldsteel (2017), *Steel Statistical Yearbook 2017*; IMF (2018), *World Economic Outlook Database*; USGS (2018a), *2018 Minerals Yearbook: Aluminium*; USGS (2018b), *2018 Minerals Yearbook: Cement*; USGS (2018c), *2018 Minerals Yearbook: Nitrogen*.

Slide 9

Plastics includes the main thermoplastic resins and excludes all thermosets and synthetic fibre. The quantities shown reflect the apparent consumption (production less exports plus imports) by the next tier in the manufacturing chain following primary chemical production (e.g. plastic converters for plastics). Source: METI (2016), *Future Supply and Demand Trend of Petrochemical Products Worldwide*, Tokyo.

Slide 10

Petrochemicals includes process energy and feedstock.

Slide 11

All flows in the diagram are sized on a mass basis. Secondary reactants and products are the compounds specified within chemical reactions that do not form part of the feedstock or main products. Key examples include water, CO₂, oxygen, nitrogen and chlorine. Some of the secondary products entering the sector on the left of the figure may well coincide with those leaving it on the right – CO₂ emitted from ammonia facilities and utilised in urea production is a key example. Mtce = Million tonnes of coal equivalent. Source: Adapted from Levi, P.G. and J.M. Cullen (2018), "Mapping global flows of chemicals: From fossil fuel feedstocks to chemical products", <https://doi.org/10.1021/acs.est.7b04573>.

Slides 12-13

The left pie chart of the pair for each region displays feedstock usage, while the right pie chart displays primary chemical production. The pie charts are sized in proportion to the total quantity (Mtoe or Mt) in each case. Source: IFA (2018), *International Fertilizer Association Database* and expert elicitation.

Slide 14

Fuel and feedstock costs are calculated based on average prices during 2017, whereas capital expenditure (CAPEX) and fixed operational expenditure (OPEX) are assumed to remain constant both over time and between regions, for a given technology. CAPEX assumptions: USD 1 500 /tHVC for ethane steam cracking; USD 1 000/t HVC for MTO; USD 2 050/tHVC for naphtha steam cracking. Fixed OPEX: 2.5-5.0% of CAPEX. Discount rate is 8%. A 25 year design life is assumed for all equipment. Energy performance ranges: 12-19 gigajoules (GJ)/tHVC for naphtha steam cracking; 14-17 GJ/tHVC for naphtha steam cracking; 11 GJ/tHVC for MTO. Feedstock requirements correspond to those shown in Figure 2.4. Process energy requirements include fuel, steam and electricity, are calculated on a net basis, assuming full utilisation of available fuel gas in the product stream. ME = Middle East, US = United States. Sources: Feedstock prices from Argus Media (2018), *Key Prices*, www2.argusmedia.com/en/methodology/key-prices.

Slide 17

Other refers to a selection of other thermoplastics: acrylonitrile butadiene styrene, styrene acrylonitrile, polycarbonate and polymethyl methacrylate. Volumes of plastic production shown are independent of the level of recycling. The impact of recycling is registered in the lowering of demand for primary chemicals required to produce the plastic volumes shown above. The RTS high demand sensitivity variant is a separate scenario performed to explore the sensitivity of our results to higher than expected demand. Only the per capita demand figures are shown for the high demand sensitivity variant in Figure 4.2. Details of the high demand sensitivity variant analysis can be found in the online annex accompanying this publication. Sources: Data consulted in making projections from Geyer, R., J.R. Jambeck and K.L. Law (2017), "Production, use, and fate of all plastics ever made", <https://doi.org/10.1126/sciadv.1700782>; Levi, P.G. and J.M. Cullen (2018), "Mapping global flows of chemicals: From fossil fuel feedstocks to chemical products", <https://doi.org/10.1021/acs.est.7b04573>; OECD (2018), *Improving Markets for Recycled Plastics: Trends, Prospects and Policy Responses*.

Slide 18

Other includes the net contribution of all other oil demand sectors.

Slide 21

Final energy demand for chemicals includes feedstock, and, for iron and steel, it includes energy use in blast furnaces and coke ovens. Direct CO₂ emissions includes energy and process emissions in the industry sector. Mtoe = million tonnes of oil equivalent.

Slide 22

All environmental impacts relate to primary chemical production (ethylene, propylene, benzene, toluene, mixed xylenes, methanol and ammonia). *Air pollutants* includes nitrous oxides, sulphur dioxide and fine particulate matter. *Water pollutants* refers to ocean-bound plastic leakage. *Carbon dioxide* refers to direct emissions from the chemical and petrochemical sector.

Slide 23

Error bars show the range of resin-specific global average collection rates. Projected volumes of total plastic production are independent of the level of recycling. The impact of recycling is registered in the lowering of demand for primary chemicals. Sources: Data consulted in making projections from Geyer, R., J.R. Jambeck and K.L. Law (2017), "Production, use, and fate of all plastics ever made", <https://doi.org/10.1126/sciadv.1700782>; Levi, P.G. and J.M. Cullen (2018), "Mapping global flows of chemicals: From fossil fuel feedstocks to chemical products", <https://doi.org/10.1021/acs.est.7b04573>; OECD (2018), *Improving Markets for Recycled Plastics: Trends, Prospects and Policy Responses*.

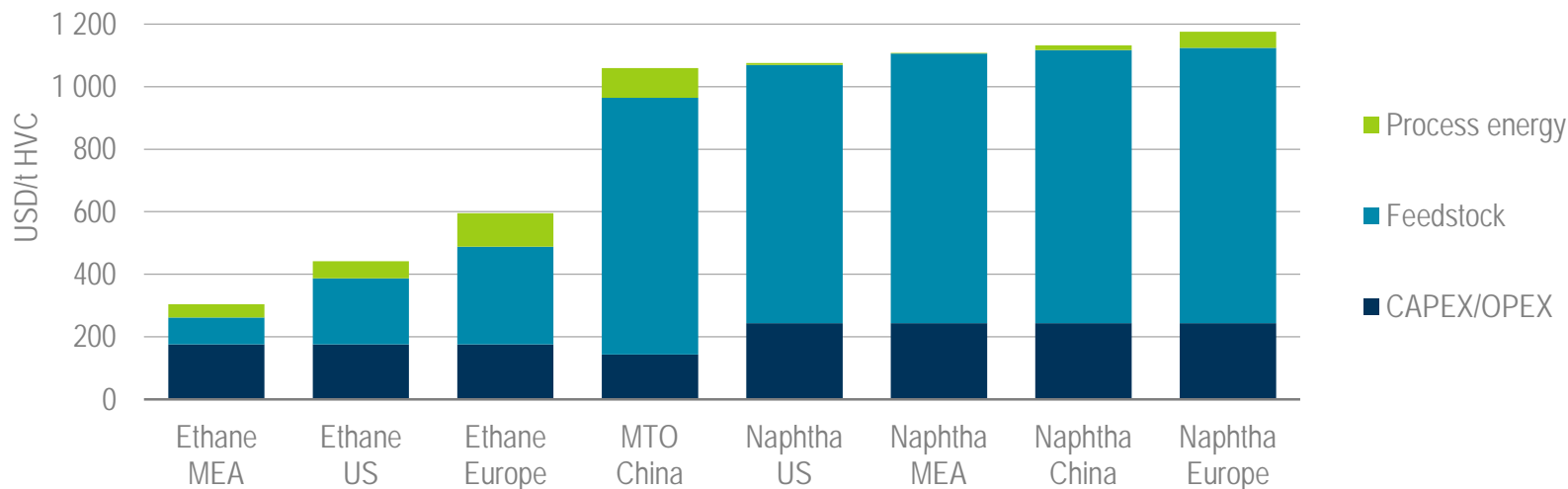
Slide 24

In the RTS, quantities of plastic leakage are estimated based on projections of plastic waste and estimates of current rates of leakage, the latter of which are assumed to remain constant. Current rates of leakage from Jambeck, J.R. et al. (2015), "Plastic waste inputs from land into the ocean", <https://doi.org/10.1126/science.1260352>.

Slide 30

toe/capita = tonne of oil equivalent per capita. The diameter of each circle is proportionate to the oil demand per capita for each year/sector/region. *Plastic production* refers to the oil demand for feedstock and process energy used for the primary chemicals needed for such level of plastic considering global average energy intensities.

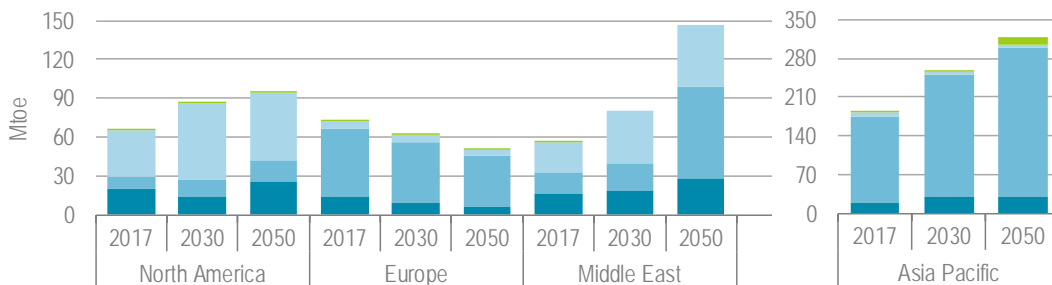
Simplified levelised cost of petrochemicals in 2017



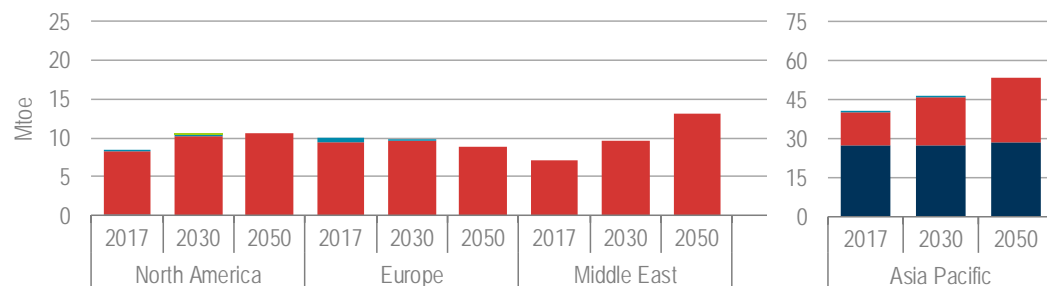
Among the main costs of production, feedstock is the most influential factor in determining regional production advantages.

Feedstocks remain in familiar territory in the RTS

HVCs – (mainly for plastics)



Ammonia – (mainly for fertilisers)



- Coal/COG
- Natural gas
- Other oil
- Naphtha
- Ethane
- Bioenergy
- Electricity

The Middle East and North America utilise available ethane, while Europe and Asia Pacific stick to naphtha and coal.