The Future of Petrochemicals

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

Various roles in society, the energy system and the environment
Petrochemicals are all around us

Our everyday lives depend on products made from petrochemicals. Many products needed for the clean energy transition also rely on petrochemicals.
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…”

Asia dominates both global primary chemical production and naphtha feedstock consumption. North America is the leader in ethane-based petrochemical production.
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Among the main costs of production, feedstock is the most influential factor in determining regional production advantages.
Oil companies are strengthening links with petrochemicals

For integrated refiners, the petrochemical path can offer higher margins than fuels.
The bulk of the US petrochemical capacity is located on the Gulf Coast, coinciding with substantial refining capacity. The region is a hotspot for both natural gas and crude oil processing.
Despite being the largest industrial energy consumer, the chemical sector ranks third among industrial CO₂ emitters.
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, accounting over a third of growth to 2030, and nearly half to 2050.
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.
Feedstocks remain in familiar territory in the RTS

The Middle East and North America utilise available ethane, while Europe and Asia Pacific stick to naphtha and coal.
An alternative, more sustainable pathway

The Clean Technology Scenario (CTS)
The Clean Technology Scenario helps achieve several UN Sustainable Development Goals. By 2050, environmental impacts decrease across the board, including CO₂, air and water pollutants.
By 2050, the collection rate for recycling nearly triples in the CTS, resulting in a 7% reduction in primary chemical demand.
Challenges for refiners as feedstock dominates oil demand...

The share of chemical feedstock in total oil demand in the CTS is much higher than in the RTS, despite lower absolute volumes, as oil demand for other sectors declines much more sharply.
Petrochemical feedstock is the only oil growth segment in the CTS. By 2050, per capita oil demand for plastic consumption overtakes that of road passenger transport in several regions.
Reducing CO₂ emissions in the chemical sector is key…

Chemical sector emissions of CO₂ decline by 45% by 2050 in the CTS, with energy-related emissions declining much less steeply than process emissions.
A balanced portfolio of options are required to deliver cumulative emissions reductions relative to the RTS of 24% between 2017 and 2050, in the CTS.

A more sustainable chemical sector is achievable

**Contribution to cumulative CO₂ emissions reductions between the CTS and RTS**

- Alternative feedstocks: 35%
- Plastic recycling: 25%
- Energy efficiency: 25%
- Coal to natural gas feedstock shifts: 25%
- CCUS: 6%
- Plastic recycling: 9%
- Energy efficiency: 6%

A balanced portfolio of options are required to deliver cumulative emissions reductions relative to the RTS of 24% between 2017 and 2050, in the CTS.
CCU/S delivers more than one third of CO₂ savings in the CTS

Additional CO₂ capture capacity deployed in the CTS relative to the RTS is primarily for storage applications.
Plastic waste leakage is an urgent pollution problem

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.
The CTS can be pursued cost-effectively

Cumulative capital investments by scenario

- **RTS (USD 1.7 trillion)**: Core production equipment, Electrolysis, Coal to gas capital savings, Avoided production, Carbon capture, Bioenergy based production
- **CTS (USD 1.5 trillion)**: Core production equipment, Electrolysis, Coal to gas capital savings, Avoided production, Carbon capture, Bioenergy based production

**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)**
Beyond the CTS: What if only alternative feedstocks were used?

By 2050, total primary chemical production could require up to 1.25x total industrial electricity demand and 7.5x industrial biomass demand.
Top 10 policy recommendations (1/2)

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. Incentivise their adoption through fiscal incentives.

3. Pursue effective regulatory actions to reduce CO₂ emissions.

4. Require industry to meet stringent air quality standards.

5. Fuel and feedstock prices should reflect actual market value.
Use and disposal of chemical products

6. Reduce reliance on single-use plastics other than for essential non-substitutable functions.

7. Improve waste management practice around the world.

8. Raise consumer awareness about the multiple benefits of recycling.


10. Extend producer responsibility to appropriate aspects of the use and disposal of products.
Conclusions

Wrapping up
Conclusions: Shining a light on “blind spots” of global energy

- Petrochemical products are deeply embedded in our economies and everyday lives. They also play a key role in many components of clean energy technologies.

- Petrochemicals are the largest driver of global oil demand, accounting for more than a third of the growth to 2030, and nearly half to 2050.

- China, the United States 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 to make these more sustainable.

- The IEA will continue to shine a light on energy “blind spots”: trucks, air conditioners, modern bioenergy... now petrochemicals... and more to come.
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.

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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).


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Petrochemicals includes process energy and feedstock.

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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.

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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.

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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 notes (continued)

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Final energy demand for chemicals includes feedstock, and, for iron and steel, it includes energy use in blast furnaces and coke ovens. Direct CO$_2$ emissions includes energy and process emissions in the industry sector. Mtoe = million tonnes of oil equivalent.

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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 show 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.

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

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COG = coke oven gas; ROW = rest of the world. Electricity denotes the use of electrolytic hydrogen, and is displayed in terms of electricity input.

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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.

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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
Cumulative direct CO₂ emission reductions refer to primary chemical production and not to the total chemical sector, and cover the period 2017-50. Coal to natural gas savings include the reduction of process emissions in the production of methanol and ammonia. CO₂ emission savings resulting from feedstock shifts within the same energy commodity (e.g. naphtha to ethane) are included in energy efficiency.

Technology selection in the modelling underlying this analysis is based on constrained least-cost optimisation covering energy and investment costs. The investment estimates provided include the capital expenditure on core process technology and CO₂ emission mitigation technologies, including carbon capture, installed between 2017 and 2050. The assessment is expenditure based within the sites of primary chemical production. Therefore, costs associated with plastic waste collection, sorting, processing and secondary production are not included, nor are costs relating to CO₂ transportation and storage. Investments required for air pollution mitigation technologies are not included. Investment costs are not attributed to energy savings from improved operation and maintenance practices, unless they require new process equipment. Installation, construction and labour costs are not included since it is the investments that relate to the chemical sector specifically that are relevant to this analysis. If included, variation in local construction and labour practices would cloud the underlying trends, not to mention the greater uncertainty associated with such costs. All cumulative investment cost estimates are quoted in undiscounted terms.

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.

Primary chemical production is based on the CTS projection. The energy required to produce primary chemicals from refining is estimated based on the average energy intensity of HVC production in 2017.