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The Future of Petrochemicals

Towards more sustainable plastics and fertilisers

Executive summary

INTERNATIONAL ENERGY AGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 30 member countries, 7 association countries and beyond.

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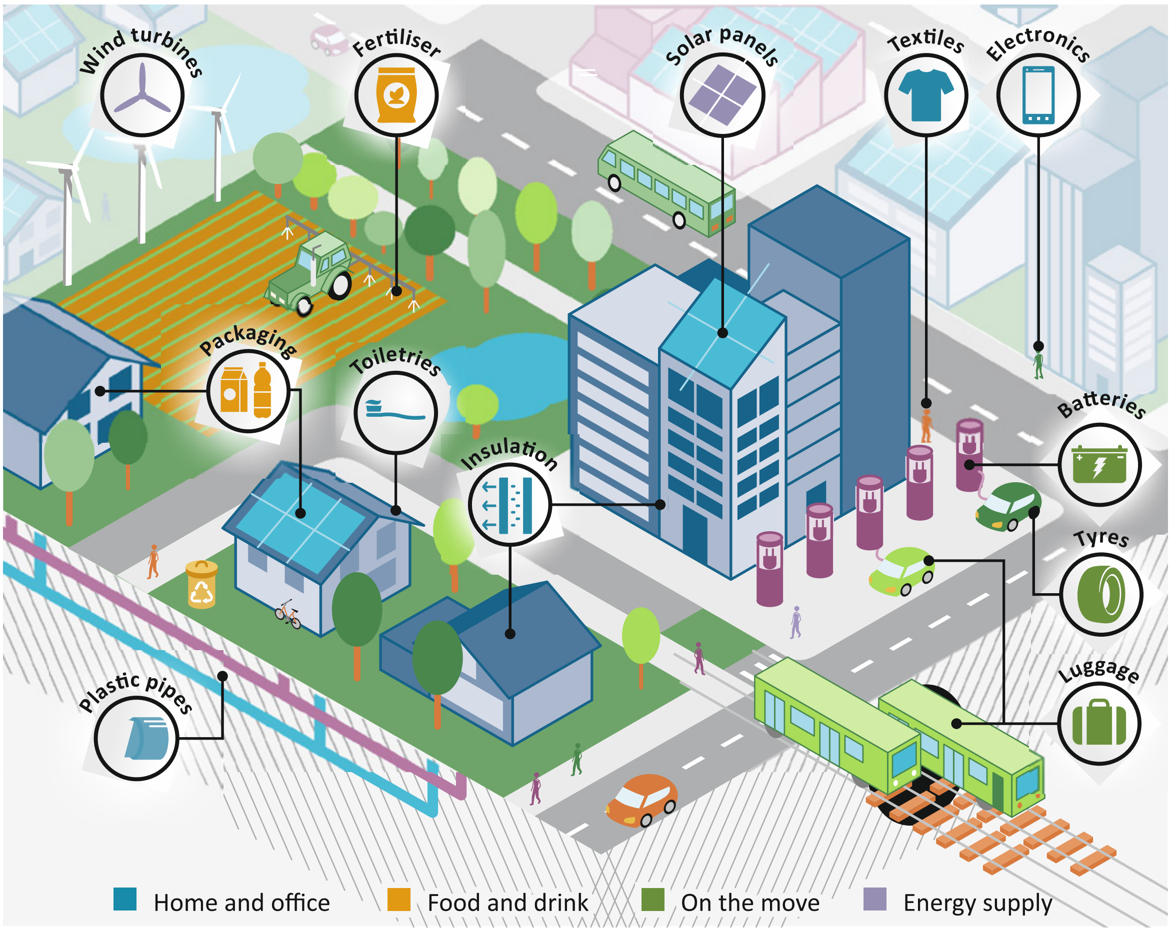
Executive summary

Petrochemical products are everywhere …

Petrochemicals, which turn oil and gas into all sorts of daily products – such as plastics, fertilisers, packaging, clothing, digital devices, medical equipment, detergents or tyres – are integral to modern societies. In addition to products critical to our daily lives, petrochemicals are also found in many parts of the modern energy system, including solar panels, wind turbine blades, batteries, thermal insulation for buildings, and electric vehicle parts.

Figure ES.1 • The various roles of chemical products in modern society



Already a major component of the global energy system, the importance of petrochemicals is growing even more. Demand for plastics – the most familiar of petrochemical products – has outpaced all other bulk materials (such as steel, aluminium or cement), nearly doubling since the start of the millennium. The United States, Europe, and other advanced economies currently use up to 20 times as much plastic and up to 10 times as much fertiliser as India, Indonesia, and other developing economies on a per capita basis, underscoring the huge potential for growth worldwide.

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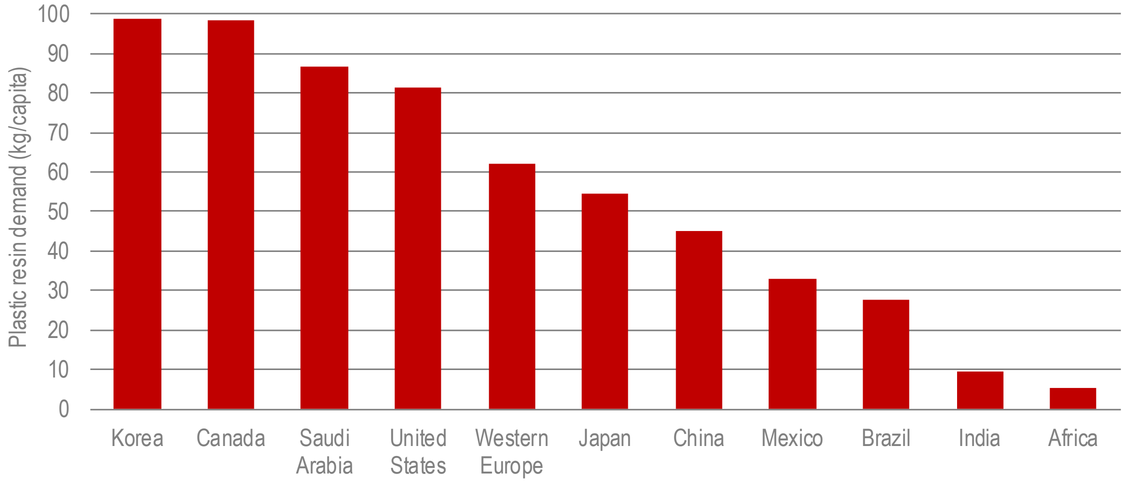
Figure ES.2 • Per capita demand for major plastics



Notes: Plastics includes the main thermoplastic resins and excludes all thermosets and synthetic fibre. The quantities are for 2015 and 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).

Source: METI (2016), *Future Supply and Demand Trend of Petrochemical Products Worldwide*, Tokyo, www.meti.go.jp/policy/mono_info_service/mono/chemistry/sekkajyukyuudoukou201506.html.

Feedstocks fly under the radar. Chemicals produced from oil and gas make up around 90% of all raw materials, which are known as feedstocks; the rest comes from coal and biomass. About half of the petrochemical sector's energy consumption consists of fuels used as raw materials to provide the molecules to physically construct products.

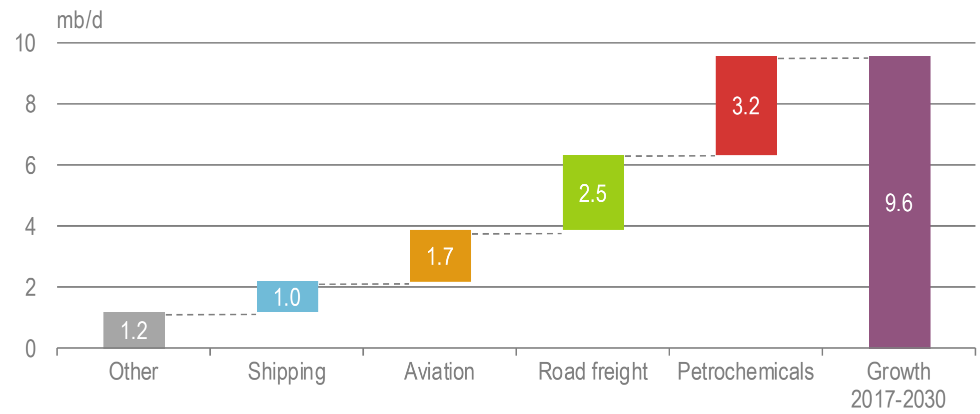
… and have become the fastest-growing source of oil consumption

The growing role of petrochemicals is one of the key "blind spots" in the global energy debate. The diversity and complexity of this sector means that petrochemicals receive less attention than other sectors, despite their rising importance.

Petrochemicals are rapidly becoming the largest driver of global oil consumption. They are set to account for more than a third of the growth in oil demand to 2030, and nearly half to 2050,[1] ahead of trucks, aviation and shipping. At the same time, currently dominant sources of oil demand, especially passenger vehicles, diminish in importance thanks to a combination of better fuel economy, rising public transport, alternative fuels, and electrification. Petrochemicals are also poised to consume an additional 56 billion cubic metres (bcm) of natural gas by 2030, equivalent to about half of Canada's total gas consumption today.

[1] Please visit the IEA website for more information on the modelling underlying this publication.

Figure ES.3 • Oil demand growth by 2030



Countries including the People's Republic of China[2] and the United States, will see the largest near-term capacity additions; longer-term growth is led by Asia and the Middle East. The United States is expected to increase its global market share for ethylene (steam cracking) to 22% by 2025, up from 20% in 2017. Along with the Middle East, the United States has a feedstock advantage in its access to low-cost ethane owing to its abundant natural gas supplies. This advantage allows both regions to gain the lion's share of ethane-based chemical exports in the short and medium term. Coal-based methanol-to-olefins capacity in China nearly doubles between 2017 and 2025, providing the material inputs for its large domestic manufacturing base. In the longer run, Asia and the Middle East both increase their market share of high-value chemical production by 10 percentage points, while the share coming from Europe and the United States decreases. By 2050, India, Southeast Asia and the Middle East together account for about 30% of global ammonia production.

The combination of a growing global economy, rising population, and technological development will translate into an increasing demand for petrochemical products. Although substantial increases in recycling and efforts to curb single-use plastics take place, especially led by Europe, Japan and Korea, these efforts will be far outweighed by the sharp increase in developing economies of plastic consumption (as well as its disposal). The difficulty in finding alternatives is another factor underpinning the robust overall demand growth for petrochemical products.

An evolving landscape for both petrochemical and oil and gas industries

Increasing global competition in the industry is driven by new supply dynamics for chemical feedstocks. After two decades of stagnation and decline, the United States has returned to prominence as a low-cost region for chemical production thanks to the shale gas revolution. Today, the United States is home to around 40% of the global capacity to produce ethane-based petrochemicals. Led by Saudi Arabia and Iran, the Middle East remains the low-cost champion for key petrochemicals, with a host of new projects announced across the region. China and Europe each account for around a quarter of the global capacity for naphtha-based, high-value chemicals, but they have only very small shares of capacity based on lighter feedstocks as a result of limited availability. China's burgeoning coal-based chemical industry, once a speculative proposition, now embodies steady technological improvements. India is poised to grow strongly from its current level of only 4% of global capacity to satisfy increasing domestic demand.

[2] Hereafter, "China".

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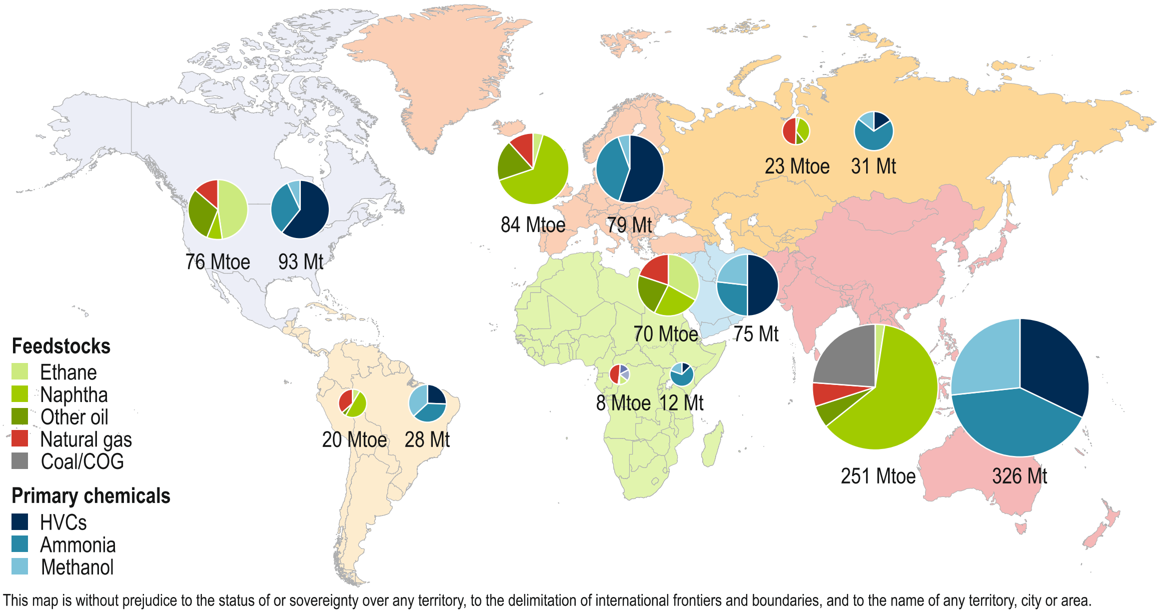
Figure ES.4 • Primary feedstock use and chemical production by region



Note: The pie charts are sized in proportion to the total quantity (Mtoe or Mt) in each case.

Source: IFA (2018), *International Fertilizer Association Database*, http://ifadata.fertilizer.org/ ucSearch.aspx; expert elicitation

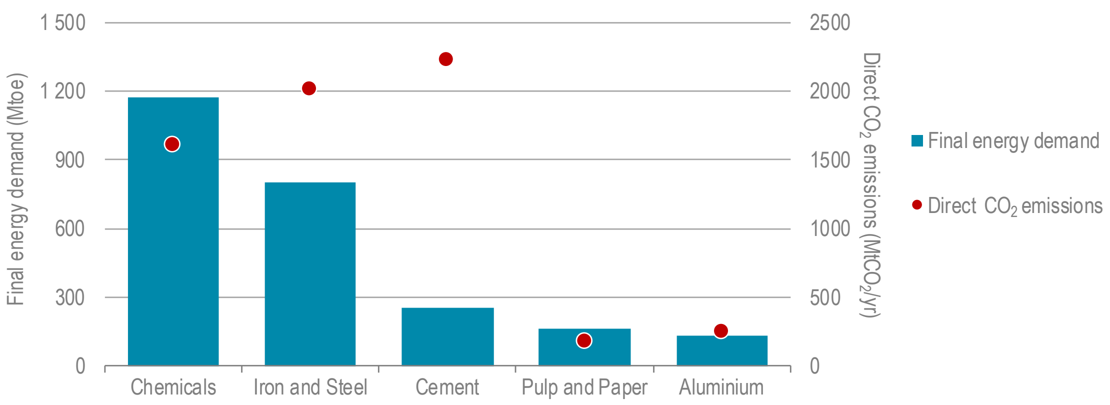
Oil companies are increasingly pursuing integration along the petrochemical value chain. Against a backdrop of slower gasoline demand growth, robust growth prospects for chemical products, and attractive margins, oil companies are further strengthening their links with petrochemical markets. New, direct crude-oil-to-chemicals process routes may also come into play, offering alternatives to traditional refining/petrochemical operations although the technology remains challenging for now. For example, Saudi Aramco and SABIC have recently announced a large crude-to-chemicals project of 0.4 mb/d, five times the size of the only existing facility in Singapore.

The production, use and disposal of chemicals take an environmental toll …

Petrochemicals face a number of climate, air quality, and water pollution challenges. Petrochemical products provide substantial benefits to society, including a growing number of applications in various cutting-edge, clean technologies critical to a sustainable energy system. However, the production, use and disposal of these products poses a variety of sustainability challenges that need to be addressed.

Even though the chemical sector consumes roughly as much energy as the steel and cement sectors combined, it emits less CO_2 than either sector. Still, this amounts to around 1.5 $GtCO_2$, which is 18% of all industrial-sector CO_2 emissions, or 5% of total combustion-related CO_2 emissions. This is in part because the chemical industry consumes more oil and gas than other heavy industries, which tend to rely more on coal. Another contributing factor is that the carbon contained in chemical feedstocks is mostly locked into final products (such as plastics) and released only when the products are burned or decompose.

Figure ES.5 • Global final energy demand and direct CO_2 emissions by sector in 2017

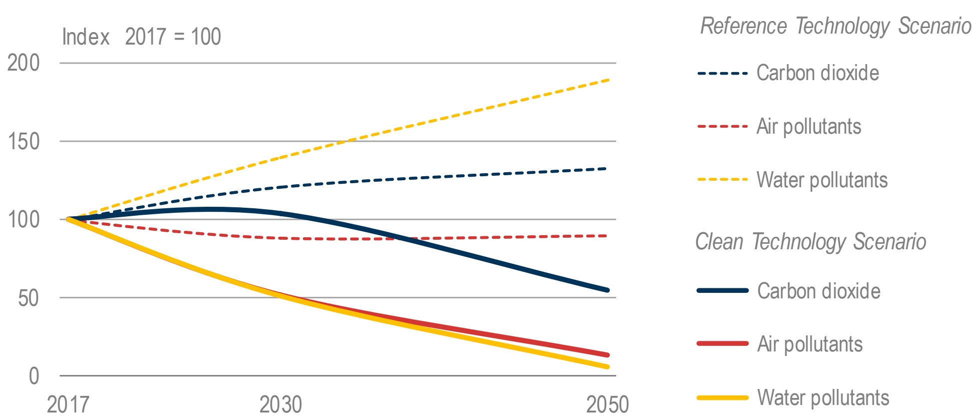


Notes: *Final energy demand* for chemicals includes feedstock, and, for iron and steel, it includes energy use in blast furnaces and coke ovens. *Direct CO_2 emissions* includes energy and process emissions in the industry sector.

… but solutions are achievable and cost-effective

In our Clean Technology Scenario (CTS), which provides an ambitious but achievable pathway for the chemical sector, environmental impacts decline across the board. In the CTS, air pollutants from primary chemical production decline by almost 90% by 2050; and water demand is nearly 30% lower than in the base scenario. The CTS also emphasises waste management improvements to rapidly increase recycling, thereby laying the ground work to more than halve cumulative, ocean-bound, plastic waste by 2050, compared to the base scenario – a major step to curb the 10 million tonnes of plastic waste that leak into the world's oceans every year, an environmental problem that is garnering much attention across the globe.

Figure ES.6 • Annual pollutants from chemical production



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

By 2050, cumulative CO_2 emission savings from increased plastic recycling and reuse are equivalent to about half the annual emissions from the chemical sector today. In the CTS, the global average collection rate of plastic waste increases nearly three-fold by 2050. This results in increased production of recycled plastics and a cumulative saving of around 5% in high-value chemical demand, compared to current trends. This outcome poses a significant technical

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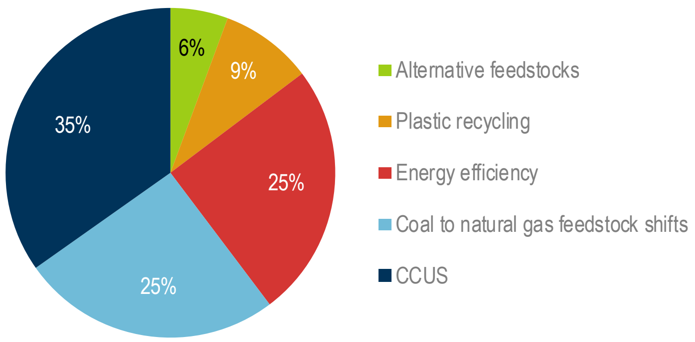
challenge, requiring mature economies to raise average collection rates to the maximum practical level and emerging economies to match the best rates achieved today.

The sector's clean transition is led by carbon capture, utilisation and storage (CCUS), catalytic processes, and a shift from coal to natural gas. Some of the most cost-effective opportunities for CCUS can be found in the chemical sector, which explains its leading role among scalable options for reducing emissions. Catalytic alternatives to traditional process routes can provide more than 15% of energy savings per unit of production. Shifts from coal to natural gas for both ammonia and methanol production, mainly in China, result in decreases in both process emissions and energy intensity. Despite falling investment costs, processes based on electricity and biomass struggle to compete on cost in most regions, due to high prices in a world where these low-carbon energy carriers are in high demand.

Figure ES.7 • Cumulative direct CO_2 emission reductions in the CTS



Notes: Cumulative direct CO_2 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. CO_2 emission savings resulting from feedstock shifts within the same energy commodity (e.g. naphtha to ethane) are included in energy efficiency.

The surge in the share of lighter oil products required for petrochemical feedstocks may pose challenges for refining in the CTS. Oil demand related to plastic consumption overtakes that for road passenger transport by 2050. This has important implications for refiners whose processes are currently set up to produce both heavy and light products. The increase in light tight oil (LTO) production in the United States is expected to help address the challenge because LTO is an easier starting point for producing lighter oil products. However, the long-term sustainability of this contribution will also depend on how the resource base, technology, and market conditions of LTO evolve.

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