

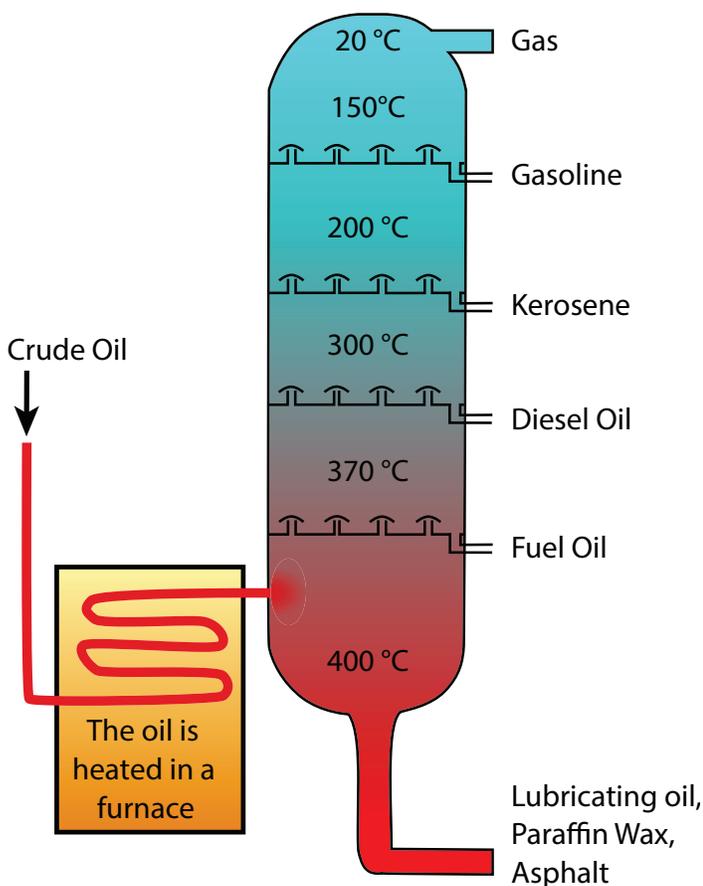
# Oil Refining and Gas Processing

Turning complex mixtures into usable products

## Introduction

Crude oil and natural gas are complex chemical mixtures that are generally unsuitable for direct use. Oil refining and gas processing turn these mixtures into a wide range of fuels and other products while removing low-value and polluting components.

Refining and processing have both positive and negative environmental impacts: although they remove harmful pollutants and produce cleaner-burning fuels, the operations at refineries and processing plants may release harmful pollutants into the environment, affecting local air and water quality.



During crude oil distillation, different fuel types condense and are extracted at different temperatures. Image credit: Wikimedia Commons users Psarianos and Theresa Knott.<sup>1</sup>

## Oil Refining

Crude oil is a mixture of many different hydrocarbon molecules of a range of sizes. Smaller molecules vaporize at lower temperatures, so crude oil can be **distilled** to separate out the different hydrocarbons. In the distillation process, crude oil is vaporized and the hot vapor rises up a column, cooling as it rises. Different hydrocarbons vaporize at different temperatures, so they condense into liquid form at different points in the column, separating the crude oil into different components that can then be further processed to optimize them for their final use.

Gasoline and diesel are the most lucrative products extracted from crude oil, so refineries use a range of techniques to maximize the production of these fuels. This may include **cracking** (breaking larger molecules down into smaller molecules<sup>2</sup>), **hydrotreating** (replacing impurities such as sulfur with hydrogen to improve fuel quality<sup>3</sup>), **reforming** (turning smaller molecules into gasoline<sup>2</sup>), **alkylation** (using an acid to produce high-octane gasoline from smaller molecules<sup>4</sup>), and **blending** (mixing different liquids together to produce uniform products that meet regulatory standards<sup>5</sup>). During the blending stage, ethanol from industrial ethanol plants is also blended into gasoline to increase its octane content, reduce carbon monoxide emissions, and meet the requirements of the Renewable Fuel Standard.<sup>6</sup>

## Products of Oil Refining

Different crude oils have different compositions, containing different mixtures of hydrocarbons and variable amounts of sulfur and other impurities. The proportions of different refined products will vary with changes in the types of oil being refined, demand for different products, and regulations that influence this demand. Roughly 80-85% of all crude oil ends up as gasoline, diesel, or jet fuel. The rest is used to produce liquefied petroleum gases, petrochemical feedstocks, and a variety of other products.<sup>7</sup> In 2016, 141 U.S. refineries produced a daily average of 9.3 million barrels of gasoline, 3.7 million barrels of low-sulfur diesel, and 1.6 million barrels of jet fuel.<sup>8</sup>

## Natural Gas Processing

In 2017, the United States produced 33 trillion cubic feet of natural gas.<sup>9</sup> A small fraction of this was used in field operations, re-injected into underground reservoirs, vented, or flared; the rest was processed by 550 gas processing plants to produce 27 trillion cubic feet of pipeline-quality natural gas.<sup>10,11</sup> Pipeline-quality gas must meet rigid standards for energy content and purity<sup>12</sup> for residential, commercial, and industrial use, including natural gas power plants.

Before processing, natural gas consists mostly of methane, with varying proportions of other hydrocarbons, carbon dioxide (CO<sub>2</sub>), sulfur dioxide, nitrogen, water vapor, and helium.<sup>13</sup> Gas processing removes some of the non-methane components of natural gas in order to:

- Improve combustion and reduce corrosion by removing water
- Prevent the formation of damaging acids by removing harmful or corrosive gases – especially sulfur and CO<sub>2</sub> – that might otherwise react with small amounts of water to form acids
- Standardize the energy content of the gas to ensure uniform combustion in furnaces and other equipment, notably by removing non-combustible gases such as CO<sub>2</sub> and nitrogen
- Extract valuable minor gases for other uses (e.g., other hydrocarbons and helium)

Non-methane hydrocarbons extracted during gas processing are collectively called “natural gas liquids” (NGLs) because they form liquids more easily than methane at high pressure or low temperature. Of the NGLs, the most common are ethane, propane, and butane. Ethane and propane are further processed in large quantities to make feedstocks for plastics (see “Non-Fuel Products of Oil and Gas” in this series), while propane and butane are compressed into liquids to provide an energy-dense source of gas fuel for off-grid uses.

The main methods used to remove non-methane components from natural gas are absorbents and cooling. A variety of absorbents may be used, including special oils (for NGLs), glycol (for water), amines (for sulfur and CO<sub>2</sub><sup>14</sup>), and zeolite or oil absorption (for nitrogen<sup>15</sup>). Chilling natural gas down to different temperatures allows different components to be removed as they condense into liquids. This is the most common method for nitrogen removal: the natural gas is chilled until the methane liquefies, allowing the nitrogen gas to be vented off.<sup>16</sup> NGLs may be removed in a single mixture that is then heated to different temperatures



Oil refineries (open squares) and gas processing plants (blue) in the United States as of February 2018. Not shown: two refineries in Hawaii and five in Alaska. Image credit: U.S. Energy Information Administration.<sup>17</sup>

to isolate each NGL in turn.<sup>18</sup> After processing, the gas is deemed “dry” and ready to be shipped via pipelines to end users.

## Refining, Processing, and the Environment

Refining and processing reduce the environmental impact of oil- and gas-derived fuels by removing harmful pollutants and improving their reliability during combustion. However, refineries and processing plants have their own environmental impacts, with corresponding procedures for minimizing those impacts. More information on these can be found in other parts of this series: “Mitigating and Regulating Methane Emissions” and “Air Quality Impacts of Oil and Gas.”

Carbon dioxide (CO<sub>2</sub>) occurs in varying proportions in natural gas and is removed at processing plants to improve the quality of the gas. Most of this CO<sub>2</sub> is vented to the atmosphere, accounting for roughly 0.4% of total U.S. greenhouse gas emissions (for comparison, methane leaks from the natural gas production and distribution chain are estimated to account for roughly 3% of U.S. emissions).<sup>19</sup> A small number of gas processing plants capture the CO<sub>2</sub> removed from natural gas during processing; this captured CO<sub>2</sub> is injected into oil fields to enhance oil recovery.<sup>20</sup>

## References & More Resources

For a complete listing of references, see the “References” section of the full publication, *Petroleum and the Environment*, or visit the online version at: [www.americangeosciences.org/critical-issues/petroleum-environment](http://www.americangeosciences.org/critical-issues/petroleum-environment)