CIEL

Fueling Plastics

Fossils, Plastics, & Petrochemical Feedstocks

- Plastics are produced from chemicals sourced almost entirely from fossil fuels.
- Because fossil fuel production is highly localized, plastic production is also concentrated in specific regions where fossil fuel development is present, including, notably, the US Gulf Coast.
- Natural gas liquids, a key input for plastic production, are hard to transport. Petrochemical producers relying on natural gas liquids or ethane as a feedstock typically cluster geographically near sources of natural gas. The shale gas boom in the US is driving a massive expansion in new plastics infrastructure in the Gulf region.
- Naphtha, another key input for plastic production, is a product of oil refining, and its production is concentrated among major oil companies with refining capacity. In fact, only five companies – BP, Chevron, ExxonMobil, Shell, and China National Petroleum Corporation – account for over half of global naphtha sales.
- Because of the need to co-locate fossil fuel and plastic production, there is a high degree of vertical integration between the industries; major oil and gas producers own plastics companies, and major plastics producers own oil and gas companies. DowDuPont, ExxonMobil, Shell, Chevron, and BP are all integrated companies.

Origins of Plastic

Although plastic is a familiar material in everyday life, many people do not know where plastic comes from, or even how to define what "plastic" is. Broadly speaking, plastics are materials formed from organic polymers — giant molecules made by linking together long chains of smaller molecules, called monomers. These monomers, however, are themselves products of a supply chain that almost always starts at a wellhead, oil rig, or coal mine.

Virtually all (over 99%) of plastics are produced from chemicals sourced from fossil fuels. While there is a wide variety in types of plastic, five kinds of plastic con-

stitute over 90% (by weight) of all plastic produced:

- polyethylene (34.4%),
- polypropylene (24.2%),
- polyvinyl chloride (16.5%),
- polyethylene terephthalate (7.7%), and
- polystyrene (7.3%).[1]

Ethylene is a critical feedstock for the production of polyethylene, polyvinyl chloride (PVC), polyethylene terephthalate (PET), and polystyrene, which combined represent approximately 65% of global plastics production by weight. Propylene is the platform chemical for polypropylene. Therefore, the overwhelming majority of plastics can be traced to the product streams of just two industrial chemicals: ethylene and propylene.[2]

Ethylene and propylene are particularly critical in the production of plastic packaging, the largest and fastest growing category of plastics products and the biggest, though by no means only, contributor to the accelerating crisis of plastics pollution. Approximately 34% of plastic use in the United States[3] and 40% of plastic use in Europe[4] is used for packaging. Moreover, plastic packaging is comprised nearly exclusively of the five major thermoplastics discussed above, primarily polyethylene, polypropylene, and PET.[5]

Choice of Feedstocks

The abundant supply of natural gas in the United States has made natural gas liquids (NGL) the preferred input for ethylene production. Nearly 90% of US ethylene production is sourced from ethane-rich NGL.[6] Moreover, virtually all ethane in the United States, and one-third of propane, is used in ethylene production.[7] Because the largest gas producers are known — ExxonMobil is the largest[8] — it is possible to approximately apportion ethylene production in the United States based on natural gas exploration and development.[9]

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If trends in oil consumption and plastic production continue as expected, "the consumption of oil by the entire plastics sector will account for 20% of the total consumption by 2050."

The Middle East uses similarly large percentages of NGL in ethylene production.[10] By contrast, ethylene produced in China, Europe, Southeast Asia, and Japan is primarily made from naphtha.[11] Naphtha is a product of crude oil refining, with plastic production accounting for between four and eight percent of global oil consumption.[12] However, if trends in oil consumption and plastic production continue as expected, "the consumption of oil by the entire plastics sector will account for 20% of the total consumption by 2050."[13]

Because naphtha is a product of refining, not merely extraction, the naphtha market is highly concentrated. In 2014, the "top five players including BP, Chevron, ExxonMobil, Shell and CNPC accounted for over 50% of the industry revenue share."[14]

The difference in transportability is an important distinction between the use of NGL and naphtha for olefin production. Olefins are the basic chemical building blocks for a huge number of petrochemicals and petrochemical products, including plastics. Ethylene and propylene are by far the most important olefins.[15]

Whereas NGL is difficult to ship internationally, naphtha (like other components of the crude oil market) is more easily transported, with nearly 30% of naphtha production traded internationally.[16] In the wake of the natural gas boom, the United States is expected to surpass the Middle East to become the largest exporter of naphtha by 2020.[17] The increase in global feedstock production by 2020 is also expected to create a surplus of naphtha supply, exceeding market demand by 14 million metric tons.[18]

Growing US exports are expanding, not replacing, plastics production in other regions. European plastics producers led the world in production until the 2000s, after which Asia, led by China, became the largest plastic-producing region. Although Chinese investment is not slowing, European chemical company INEOS is currently planning expansions of two ethylene facilities and construction of a new propylene production plant in mainland Europe, representing the first major investments in European chemicals capacity in several years.[19] These facilities will be fed by NGL from liquid natural gas shipped from the United States, as opposed to naphtha from oil refining.[20]

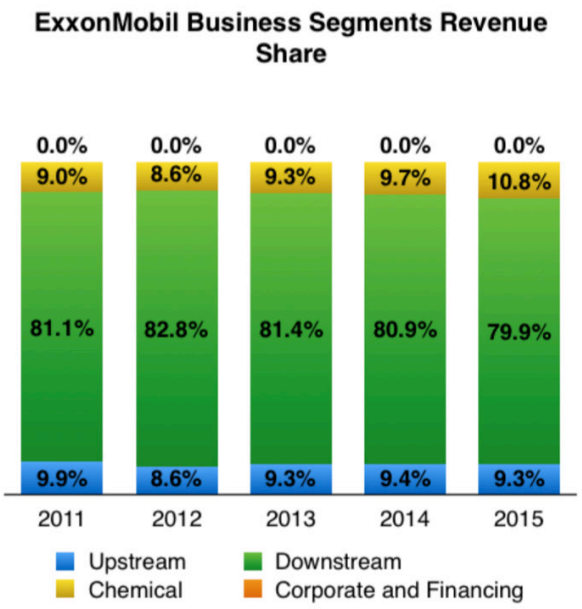
Industry Integration

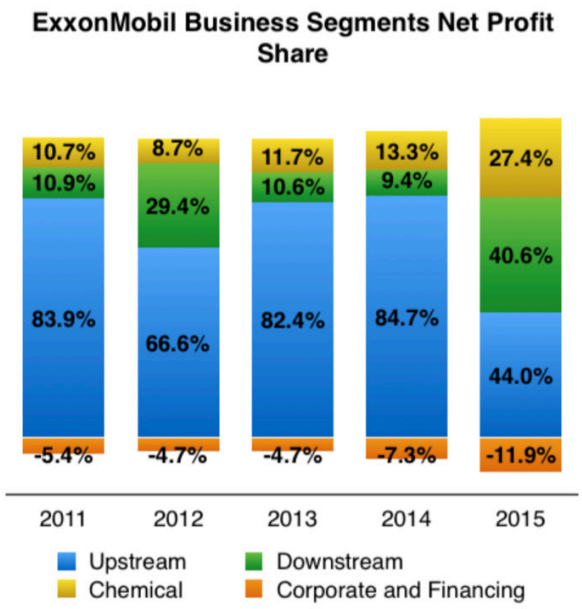
Because plastics production is part of the fossil fuels supply chain, many fossil fuel companies also produce plastic resins and products, either directly or through subsidiaries. For example, ExxonMobil, the world's largest investor-owned fossil fuel company, owns Exxon Chemical. As noted in a recent press release, "More than 90 percent of the Company's chemical capacity is integrated with large refineries or natural gas processing plants."[21] Shell, Chevron Phillips, Total, and Sinopec, one of China's largest state-owned oil companies, all own, operate, or are investing in plastics infrastructure.

In 2015, ExxonMobil earned a quarter of its net profit from its Chemicals segment.

Some of the biggest plastics companies, in turn, own fossil fuel operations. DowDuPont, the largest chemical company in the world, owns a hydrocarbon business which, according to its annual statement, is

ExxonMobil Revenue & Profit by Segment*





**How ExxonMobil Makes Money? Understanding ExxonMobil Business Model*, Revenues and Profits, http://revenuesandprofits.com/how-exxonmobil-makes-money/ (last visited Sept. 15, 2017).

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"one of the largest global producers of ethylene, an internal feedstock that is consumed primarily within Performance Plastics."[22] This makes DowDuPont an unexpected but large player in opening natural gas frontiers like Argentina's Vaca Muerta region.[23] LyondellBassell, the second largest plastics producer, also operates an oil refinery in the US Gulf region.

This integration is not just convenient, but represents significant expansions of revenue and acts as a hedge for companies as fossil fuel prices fluctuate. Moreover, as earnings in companies' upstream operations declined with dropping oil prices, they recuperated some of those profits with greater margins in their chemicals segments.[24] For example, in 2015, ExxonMobil's Chemicals segment accounted for roughly 10% of its revenues but more than 25% of its overall profits.[25]

Ethylene and Propylene

The market dynamics that govern ethylene production also shape propylene production. Propylene is primarily produced as a co-product in ethylene production; crackers that turn ethane into ethylene turn propane into propylene as well. However, two trends are changing the nature of global propylene production. First, changing feedstocks in the United States are reducing propylene production. Second, China's massive fossil fuel reserves are being harnessed to produce propylene.

Different cracking processes produce different amounts of propylene. As a result of the natural gas boom, many of the United States' ethylene producers shifted from cracking naphtha to cracking NGL, which produces less propylene.[26] Moreover, crackers designed to process pure ethane streams (as opposed to blended NGL, including ethane, propane, butane, isobutene, and pentanes) can produce little to no propylene at all.[27] In the wake of this change, producers have begun constructing and operating "on purpose" propylene production facilities to manufacture propylene deliberately, instead of as a co-product, using propane as a feedstock.[28] Although this change may serve to decouple the explicit link between ethylene and propylene production, it may make propylene production in the United States a more discrete and traceable activity.

The more important development affecting global propylene production is China's decision to invest heavily in new production facilities. China is already the world's leading propylene producer. Growth in propylene production is expected to be faster there than in any other region, likely growing to over half the global market by 2025.[29] The overwhelming majority of this production, as well as China's ethylene production, will be controlled by state-owned enterprises.[30]

Conclusion

While not all fossil fuels are used to make plastic, all (or virtually all) plastic is made from fossil fuels. Moreover, the largest players in each industry — DowDuPont, ExxonMobil, Shell, Chevron, BP, and Sinopec — are all integrated companies that produce both fossil fuels and plastics.

Understanding these linkages and their role in driving plastics production and plastic investment, is key to addressing the growing crisis of global plastics pollution and identifying the role corporate actors play in that crisis.

Endnotes

1. *See* PlasticsEurope, *The Plastic Industry* 3 https://committee.iso.org/files/live/sites/tc61/files/The%20Plastic%20Industry%20Berlin%20Aug%202016%20-%20Copy.pdf (last visited July 11, 2017).

2. *See* PlasticsEurope, Poly-ethyleneterephthalate (PET): Bottle Grade (2008), *available at* http://www.plasticseurope.org/Documents/Document/20100312112214-FINAL_EPD_PET_BottleGrade_270409-20081215-016-EN-v1.pdf; Petroleum Technology History Part 2 – Refining Byproducts, http://www.greatachievements.org/?id=3679 (last visited July 12, 2017).

3. *See* American Chemistry Council, 2012 Distribution of Plastic Resin Sales and Captive Use (2013), *available at* https://plastics.americanchemistry.com/resin-report-subscriptions/Major-Markets-2012-Report.pdf.

4. *See* PlasticsEurope, Plastics – The Facts 2016 (2016), *available at* http://www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf

5. *See id.*; American Chemistry Council, *supra* note 3.

6. See *How Much Oil Is Used to Make Plastic?*, Energy information Administration (last updated May 17, 2017), https://www.eia.gov/tools/faqs/faq.php?id=34&t=6; Mitsubishi Chemical Techno-Research, Global Supply and Demand of Petrochemical Products relied on LPG as Feedstock (Mar. 7, 2017), *available at* http://www.lpgc.or.jp/corporate/information/program5_Japan2.pdf [*hereinafter* Mitsubishi Presentation]; Jan H. Schut, *How Shale Gas Is Changing Propylene*, Plastics Engineering (Feb. 20, 2013), https://plasticsengineeringblog.com/2013/02/20/how-shale-gas-is-changing-propylene/.

7. *See* Charles K. Ebinger & Govinda Avasarala, Natural Gas Liquids 7 (2013), *available at* https://www.brookings.edu/wp-content/uploads/2016/06/Natural-Gas-Liquids.pdf

8. *See Top 40 producers*, Natural Gas Supply Association, http://www.ngsa.org/download/analysis_studies/Top%2040%202015%20 2nd%20quarter.pdf.

9. It is important to stress, however, that this apportionment is not exact: the ratio of NGL per cubic meter of natural gas in the United States varies between approximately 10% in "dry natural gas" to 30% in "wet natural gas." *See* Kinder Morgan, The Role of Natural Gas Liquids (NGLs) in the American Petrochemical Boom 2 (2017), *available at* https://www.kindermorgan.com/content/docs/White_Natural_Gas_Liquids.pdf.

10. *See* Mitsubishi presentation, *supra* note 6, at 9.

11. *Id.*

12. *See* The New Plastics Economy: Rethinking the Future of Plastics, World Economic Forum 7 (2016), *available at* http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf.

13. *Id.*

14. *See* Naphtha Market Analysis By Application (Chemical, Energy & Fuel) And Segment Forecasts To 2022, Grand View Research (Mar. 2015), *available at* http://www.grandviewresearch.com/industry-analysis/naphtha-market [hereinafter Naphtha Market Analysis].

15. *See Products & Technology: Olefins*, American Chemistry Council, https://www.americanchemistry.com/ProductsTechnology/Olefins/ (last visited Sept. 11, 2017).

16. *See* News Release, HIS Markit, By 2020, U.S. to Emerge as Largest Exporter of Light naphtha, Essential for Production of Gasoline and Chemicals, HIS Says (Apr. 21, 2015), *available at* http://news.ihsmarkit.com/press-release/chemicals/2020-us-emerge-largest-exporter-light-naphtha-essential-production-gasoline-.

17. *See id.*

18. *See id.*

19. *See* Press Release, INEOS, INEOS Plans Massive European Expansion Programme (Jun. 12, 2017), https://www.ineos.com/news/ineos-group/ineos-plans-massive-european-expansion-programme/.

20. *See id.*

21. *See* News Release, ExxonMobil, ExxonMobil to Acquire One of World's Largest Aromatics Plants (May 10, 2017), *available at* http://news.exxonmobil.com/press-release/exxonmobil-acquire-one-worlds-largest-aromatics-plants.

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24. *See* Adam Levine-Weinberg, *Big Problems Ahead for Big Oil in 2016*, The Motley Fool (Dec. 20, 2015, 2:30 PM), https://www.fool.com/investing/general/2015/12/20/big-problems-ahead-for-big-oil-in-2016.aspx.

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27. *See id.*

28. *See* Schut, *supra* note 6.

29. *See* Mitsubishi Presentation, *supra* note 6, at 11.

30. *See China Focus: China's Ethylene Production Embracing New Era of Expansion*, Xinhua Finance Agency (Jan. 4, 2017, 9:55 AM), http://en.xfafinance.com/html/Industries/Materials/2015/34311.shtml.

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Fossils, Plastics, & Petrochemical Feedstocks is the first in an ongoing series, *Fueling Plastics*, that examines the links between plastics and fossil fuels.

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