

GETTING SMART ABOUT OIL IN A WARMING WORLD

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CAPTURING THE COMPLEXITY OF CRUDES

International efforts to reduce greenhouse gas (GHG) emissions are necessary to avoid irreversible damage to the global climate.¹ While there has been significant recent progress toward reducing emissions from some fuels (mainly in the electricity sector), inertia is still the rule elsewhere. For example, petroleum fuels still occupy a key strategic position in the global economy, providing an overwhelming share (more than 95 percent) of transport energy, along with petrochemical feedstocks, fuel oils, asphalt, and other petroleum products. The world will likely consume oil for some time to come.

Because of the range of emissions from global oils, it matters which oil is burned on the path to a low emissions future. One way to choose among oils is to compare their direct emissions from fuel combustion (which follow closely from the carbon content of the unprocessed crude), but this method can be misleading. Total emissions, including those from the production, refining, and transport of oils, do not always align well with underlying carbon content.

Some researchers have attempted to assess total emissions of transport fuels,² but until recently such analyses have not captured the full complexity of crude oil. The updated version of the Oil-Climate Index (OCI) gives a comprehensive view of the

total climate risks associated with about one-quarter of the crude oil now traded on global markets.

CHALLENGING TRADITIONAL THINKING

Efforts to assess and influence the GHG emissions of oil over the past few decades have focused mainly on petroleum products sold to end users, such as gasoline and diesel fuels.³ Sometimes these efforts promoted alternative fuels (to displace petroleum products), sometimes they pushed efficiency in vehicles, and sometimes they suggested taxing gasoline or diesel fuel. The product focus was common because everyone assumed that oil's emissions did not vary much from barrel to barrel, and understanding of the oil supply chain was limited.

These product-centric analyses usually made at least two consequential errors that underestimated the variation in total emissions associated with crude oil:

- *Poor boundary choices:* Focusing on transport fuels means that these analyses often did not track all carbon in the oil barrel and so missed co-products, including petrochemical feedstocks, asphalt, petroleum coke (also known as petcoke), and other residual fuels. These co-products' GHG emissions (and market values) do not correlate well with those of gasoline, diesel, and jet fuel.

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- *Using averages that did not capture the full range of observed variability in emissions:* All analytical techniques (especially those used in estimating “typical” emissions) use averages, but some averaging reduces accuracy. Most calculations of end-use petroleum product emissions rely on average characteristics for upstream production and midstream refining emissions, implicitly assuming that there is little variation in such emissions (which is not necessarily true).

These problems have sometimes led policymakers astray. Fortunately, there is another way to analyze crude oil emissions that can yield important insights, complementing those from the product-centric approach.

AN ALTERNATIVE APPROACH

The crude-centric analytical approach of the OCI analyzes emissions for a barrel of oil from a particular oil field,⁴ considering all products from each barrel as well as the entire supply chain from upstream production and crude transport, to midstream refining, to downstream product transport and end use. The power of this approach is its ability to target where in the supply chain emissions occur and to identify differences in emissions associated with different types of oil,⁵ which can be substantial.

Here are some of the advantages of the crude-centric approach:

- It allows for a more accurate assessment of the climate risks to producers of barrels of reserves in the ground and refiners of particular oils, with specific focus on extra-heavy oils; gas-rich oils that flare associated gas; depleted oils; remote oils; and oils in environmentally sensitive ecosystems.
- It permits more comprehensive and readily updated tracking of total oil sector GHG emissions than the product-centric approach, and creates new options for innovative policies.
- It creates opportunities for producers, refiners, transporters, investors, commodity traders, policymakers, and consumers to reduce emissions throughout the oil supply chain.

Looking at oil’s total GHG equivalent emissions per barrel,⁶ per unit of energy content, and per dollar of total product value (as we do in the OCI web tool⁷) yields insights that are not available from the product-centric approach.

HIGHLIGHTING OCI METHODS

Upstream (Production) Emissions

Finding oil, extracting it, and processing it for transport to a refinery are the first steps in the supply chain, and together these comprise upstream operations. The resulting GHG emissions are modeled in the Oil Production Greenhouse gas Emissions Estimator (OPGEE). The emissions from different oils have diverse sources, including pumping and compression, steam generation, flaring and venting of associated gas,⁸ and ecosystem disruption or degradation.

Midstream (Refining) Emissions

Crude itself is not ready for direct consumption. Refineries turn crude oil into marketable petroleum products by using heat, applying pressure, adding hydrogen, and removing carbon to reconfigure hydrocarbon molecules. This transformation can be GHG intensive, depending on the oil.

The Petroleum Refinery Life-Cycle Inventory Model (PRELIM) is the first open-source refinery model that estimates energy and GHG emissions associated with various crudes (or crude blends) processed in different refinery types using a variety of processing equipment. PRELIM provides the second of the three components in the crude-centric oil life-cycle assessment, and influences the OCI in two important ways: it estimates midstream GHG emissions, and it predicts what petroleum product volumes a particular refinery will produce for end-use consumption.

Downstream (Product Transport and End-Use Combustion) Emissions

Petroleum products flow from the outlet of the refinery gate, then are transported to end users and consumed. Most of these products (such as gasoline, diesel, and jet fuel) are used in transportation, other co-products (such as residual fuels and petroleum coke) are often combusted in stationary engines and power plants, while others (like petrochemical feedstocks and asphalt) are not combusted at all. The Oil Products Emissions Model (OPEM) uses the product outputs from PRELIM to calculate emissions from petroleum product transport and end use.

KEY OCI RESULTS

The newly updated analysis in Phase 2 has extended the OCI to include 75 oils representing over 25 percent of global oil production (see figures 1 and 2).⁹ This is up from 30 oils in Phase 1, which represented 5 percent of global production. In

addition to greatly increasing the coverage of global crudes, the new analysis maps oils, incorporates flaring data obtained by remote sensing from satellites, and highlights operating decisions that affect emissions.¹⁰

In this second phase of the OCI analysis, upstream production and midstream refining GHG-equivalent emissions per barrel each vary by about a factor of ten from lowest to highest, and downstream emissions for the highest-emitting oil are about 50 percent larger than for the lowest-emitting oil. Total GHG emissions per barrel for the highest-emitting oil in the Phase 2 sample are about 60 percent higher than for the lowest-emitting oil. If oil's associated gas is used or sold instead of flared or vented, the high end of the emission range can be 80 to 90 percent higher than the low end.

KEY LESSONS FOR OIL SECTOR STAKEHOLDERS

Crude-centric thinking points to differences between oils and disaggregates their GHG emissions, leading to actionable insights for industry, private investors, public sector policymakers, NGOs, researchers, and other oil stakeholders.

Industry

- Data transparency must become the new normal. The OCI only includes data for 25 percent of global production. Assessing all currently produced crudes (as well as prospective resource opportunities) will only be possible with more open-source industry data on upstream operations, oil assays, refinery characteristics, and product logistics.
- The OCI offers industry new information and insights into their investment and operational decisions to better manage climate risks. Such analyses will help industry answer questions like: “How could refinery investments shift in a world pushing for rapid GHG emissions reductions?” and “How can our exploration and development plans minimize climate risks to future production portfolios?”

Investors

- Climate risk is a new challenge for anyone investing in oil. Such investors have not yet taken climate risks into account in any significant way, even though oil investments are capital intensive and long lived.
- Oil resources are becoming more heterogeneous and complex, and tools like the OCI can help assess how future climate policies and market shifts could affect profitability on an oil-by-oil basis.

- Socially responsible investors need tools like the OCI to help them decide whether to divest from oil altogether or influence industry to modify its supply chain.

Policymakers

- The OCI illuminates what data public agencies need to standardize and routinely collect in order to assess and manage climate risks of different oil resources.
- The index can help financial regulators determine how climate risks may affect the way reserves are tracked on an oil company's balance sheet.
- The OCI offers policymakers a way to guide more effective decisionmaking. It can help answer questions like: “How can public policies help promote better management of oil resources through more carbon-aware operational decisions, like choosing lower-emitting oils to exploit, controlling flaring, managing petcoke, and using solar-generated steam and renewable hydrogen where possible?”

NGOs and Academia

- There is a pressing need for standardized reporting (which is currently lacking) on oil composition (assays), data on upstream impacts, and destinations of high-emitting oil byproducts such as petcoke and residual oils.
- The uncertainties and variability in emissions estimates from the crude-centric approach warrant further exploration.
- Future oil analyses must also focus on the margin, instead of just comparing energy innovations assuming an average oil. Such marginal comparisons will yield vital information for all participants in oil markets.
- The OCI can help researchers check and improve GHG emissions inventories to make sure that all of an oil's emissions are correctly counted.

NEXT STEPS FOR ADDRESSING OIL-CLIMATE ISSUES

Continued expansion of the OCI will yield new opportunities for emissions reductions. To capture those opportunities, industry must actively support and policymakers must actively engage in efforts to assess life-cycle emissions from oils, both for those in current production and for prospective future resources. We suggest the following next steps for oil industry stakeholders:

- *Commit to open-source oil sector GHG reporting*, including collecting the technical data needed to model all oils through the OCI or similar tools, to explore uncertainties, and more fully evaluate economic and environmental trade-offs.¹¹

- Use the OCI to identify where in the supply chain significant innovations are possible for deep reductions in oil sector GHG emissions, such as renewable hydrogen feedstocks in refining, microbial extraction methods, and carbon dioxide injection for enhanced oil recovery (which can, in some cases, store CO₂ safely underground).
- Expand remote sensing to monitor and verify the oil industry's climate impacts, including satellites that measure flaring and venting of associated gas as well as land-use impacts throughout the oil supply chain.
- Use the OCI to design a smart tax on oil's GHG emissions, bringing the power of supply chain innovation to meet climate commitments made at the UN Climate Change Conference in Paris in 2015.

Focusing mainly on petroleum products has handicapped efforts to help the oil industry make choices consonant with a low-carbon world. The OCI's crude-centric approach can bring attention to changes in the supply chain, spur oil innovations, minimize climate risks to investors, enable smarter public policies, and reduce total GHG emissions. To accomplish these goals will require widespread adoption of this new way of thinking, as well as further expansion of the OCI to include new data and analysis.

NOTES

- 1 Florentin Krause, Wilfred Bach, and Jonathan G. Koomey, *Energy Policy in the Greenhouse* (New York: John Wiley and Sons, 1992); Malte Meinshausen et al., "Greenhouse-Gas Emission Targets for Limiting Global Warming to 2 Degrees C," *Nature* 458 (April 30, 2009): 1158–62, <http://www.nature.com/nature/journal/v458/n7242/full/nature08017.html>; Jonathan Koomey, "Moving Beyond Benefit-Cost Analysis of Climate Change," *Environmental Research Letters* 8, no. 4 (December 2, 2013): <http://iopscience.iop.org/1748-9326/8/4/041005/>; and International Energy Agency, *World Energy Outlook 2010* (Paris: International Energy Agency, 2010), <http://www.worldenergyoutlook.org>.
- 2 Argonne National Laboratory, "GREET Model," updated October 2, 2015, <https://greet.es.anl.gov>.
- 3 Air Resources Board, "Low Carbon Fuel Standard," California Environmental Protection Agency, last modified June 23, 2016, <http://www.arb.ca.gov/fuels/lcfs/lcfs.htm>; and European Commission, "Fuel Quality Directive," last modified June 8, 2016, <http://ec.europa.eu/environment/air/transport/fuel.htm>.

- 4 Deborah Gordon, Adam Brandt, Joule Bergeson, and Jonathan Koomey, *Know Your Oil: Creating a Global Oil-Climate Index* (Washington, DC: Carnegie Endowment for International Peace, 2015), <http://goo.gl/Jly9Op>.
- 5 The OCI data can motivate improvements in the supply chain, leading to more targeted policies than U.S. President Barack Obama's administration's recently proposed per-barrel tax on crude oil. See Nick Snow, "Obama Proposes \$10/bbl Crude Oil Tax to Fund Transportation Plan," *Oil and Gas Journal*, February 4, 2016, <http://www.ogj.com/articles/2016/02/obama-proposes-10-bbl-crude-oil-tax-to-fund-transportation-plan.html>.
- 6 To estimate GHG equivalent emissions, the OCI uses global warming potentials (GWPs) and emissions of carbon dioxide, methane, and nitrous oxide. The United Nations Intergovernmental Panel on Climate Change 2013 assessment report states that the one-hundred-year GWP including climate feedbacks for carbon dioxide (CO₂) is by definition equal to 1. The GWP for methane (CH₄) is 34 times times that of CO₂, and for nitrous oxide (N₂O), it is 298 times that of CO₂. These GWPs are taken from chapter 8, table 8.7, page 714: https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf.
- 7 The OCI web tool contains data and a detailed methodology. It also dynamically modifies graphs to show the data of interest. See it at: <http://oci.carnegieendowment.org>.
- 8 Flaring refers to burning excess natural gas at the well head, doing no useful work. Venting means the natural gas is simply released to the atmosphere. The warming effect is different because the first pathway creates carbon dioxide, and the second releases methane, which is a much more potent warming agent.
- 9 See the OCI web tool, op.cit. note 7. Note that the ranking of oil emissions changes when analyzing based on volume or heating value.
- 10 Christopher Elvidge, Mikhail Zhizhin, Feng-Chi Hsu, and Kimberly Baugh, "VIIRS Nightfire: Satellite Pyrometry at Night," *Remote Sensing* 5, no. 9 (2013): 4423–49.
- 11 Marginal cost data on a field-by-field basis would allow greater understanding of the effects of backing out marginal oils on costs and emissions.

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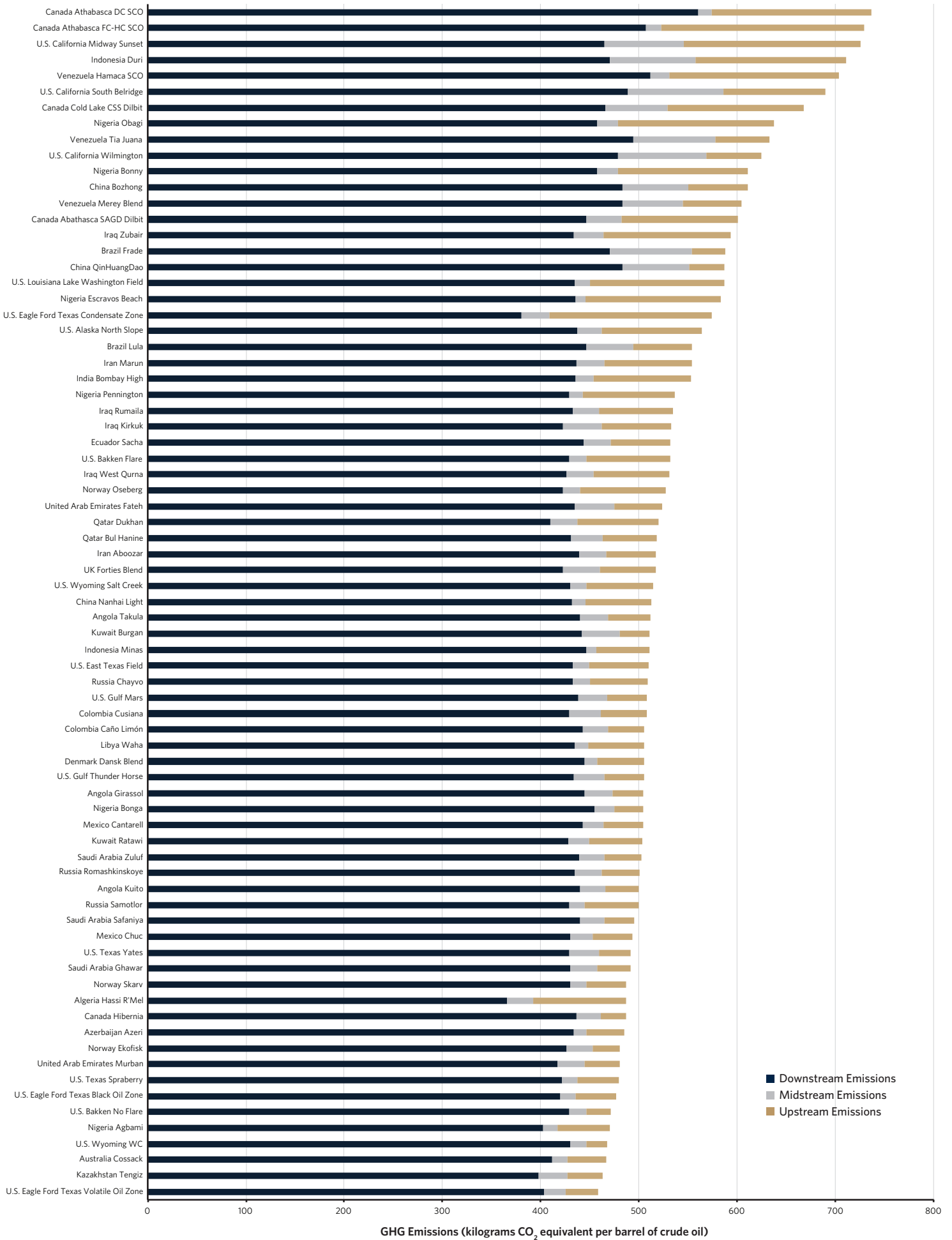


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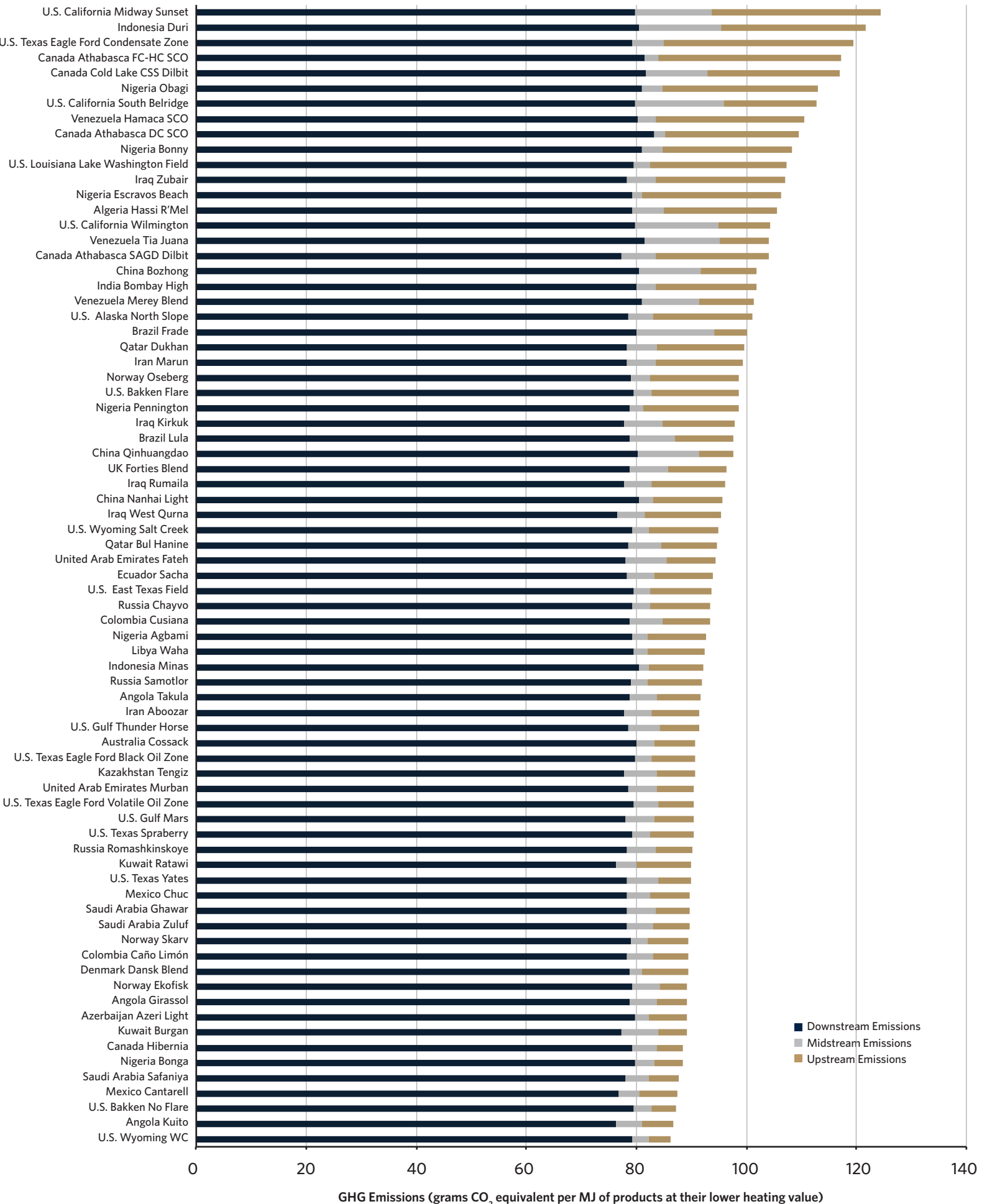
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Figure 1: Estimated Greenhouse Gas Emissions per Barrel From 75 Global Oils in the OCI



Source: Deborah Gordon, Adam Brandt, Joule Bergerson, and Jonathan Koomey, "Oil-Climate Index," Carnegie Endowment for International Peace, last modified September 2016, <http://oci.carnegieendowment.org/>.

Figure 2: Estimated Greenhouse Gas Emissions per Unit of Energy in the Petroleum Products From 75 Global Oils in the OCI



Source: Deborah Gordon, Adam Brandt, Joule Bergerson, and Jonathan Koomey, "Oil-Climate Index," Carnegie Endowment for International Peace, last modified October 2016, <http://oci.carnegieendowment.org/>.