Appendix: A Simple Model for Reinstating the Crude Export Ban[1]

To estimate the impact of reinstating the U.S. crude oil export ban on global carbon emissions, we follow the approach outlined in Bordoff & Houser (2015),[2] and in particular, the simple model outlined in the technical appendix (Houser, Mohan & Delgado 2015).[3] We apply their basic argument in reverse, by modeling the impact of reinstating the export ban as an *inward* shift of the U.S. supply curve.

Because there are many uncertainties in how oil markets will evolve in future years, and how they would react to a reinstated export ban, we consider a range of parameters. In each scenario, the global oil price and the domestic production levels used are averages over the 2020 to 2030 time period, taken from either the U.S. EIA's Annual Energy Outlook 2019 Reference Case, the EIA's High Oil and Gas Resource and Technology (HOG) Case,[4] or the Rystad UCube Base Case.[5] The oil price is the Brent crude price reported in 2019 U.S. dollars. Table 1 below summarizes the parameters used in the various scenarios.

This simple model first estimates the decline in domestic crude oil production due to an export ban-imposed discount, as follows (**Equation 1**):

$$\Delta Q_{US} = (D / P_1) \cdot E_{S,US} \cdot Q_{US}$$

Here, $E_{S,US}$ is the price elasticity of supply for U.S. producers, D is the discount, P_1 is the global oil price, and ΔQ_{US} is the change in domestic production from the baseline (Q_{US}). The inward shift of the U.S. and global supply curve by this quantity causes an increase in the global oil price and a decline in global oil consumption. This assumes that OPEC or other producing nations will not coordinate to target production levels.

Following Erickson & Lazarus (2014, 2018),[6,7] we estimate this impact on global oil consumption as a function of global elasticities of supply and demand (**Equation 2**):

$$\Delta Q_{Global} = \Delta Q_{US} \cdot E_{D,Global} / (E_{D,Global} - E_{S,Global})$$

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[1] The full policy briefing is available online at: https://www.greenpeace.org/usa/research/crude-export-ban-carbon/

[2] Bordoff, J. & T. Houser. 2015. *Navigating the US Oil Export Debate*. Center on Global Energy Policy, January. https://rhg.com/research/navigating-the-us-oil-export-debate/

[3] Houser, T., S. Mohan & M. Delgado. 2015. Technical Appendix: A Simplified Model of US Crude Export Restrictions. Rhodium Group, January. https://rhg.com/wp-content/uploads/2015/01/RHG_CrudeExports_TechnicalAppendix.pdf

[4] U.S. EIA. 2019. Annual Energy Outlook 2019. Table: Petroleum and Other Liquids Supply and Disposition. https://www.eia.gov/outlooks/aeo/data/browser/#/?id=11-AEO2019&sourcekey=0

[5] Rystad Energy UCube, December 2019.

[6] Erickson, P. & M. Lazarus. 2014. 'Impact of the Keystone XL pipeline on global oil markets and greenhouse gas emissions.' *Nature Climate Change*, 4:778–781. https://www.nature.com/articles/nclimate2335

[7] Erickson, P. & M. Lazarus. 2018. 'Would constraining US fossil fuel production affect global CO_2 emissions? A case study of US leasing policy.' *Climatic Change*, 150:29–42. https://link.springer.com/article/10.1007%2Fs10584-018-2152-z

Here, $E_{D,Global}$ is the price elasticity of demand, and we consider scenarios where the global elasticity of supply might differ from the elasticity for U.S. producers. We use Equation 3 of Erickson & Lazarus (2014) to estimate the global oil market response to the supply shift. Because the AEO 2019 does not provide international supply estimates for the HOG Case, we don't make use of the full model described in Houser, Mohan & Delgado (2015). However, we note that in the Reference Case (where international supply estimates are available) the two models give virtually identical results.

Finally, given the change in global oil consumption, we multiply by the lifecycle emissions of a barrel of oil — we use the Carnegie Endowment's Oil Climate Index factor of EF_{oil} = 510 kg CO_2-eq per bbl[8] — to calculate the total carbon impact of the export ban (**Equation 3**):

$$\Delta Em_{Global} = \Delta Q_{Global} \cdot EF_{oil}$$

Table 1: Range of Parameters for Export Ban Scenarios

Scenarios	Discount	Oil Price	U.S. Production (million bpd)	$E_{S,US}$	$E_{S,Global}$	$E_{D,Global}$	$E_D/(E_D-E_S)$
Zero Discount	$0/bbl	$82.67	14.05	0.1	0.1	-0.072	0.42
EIA Ref	$10/bbl	$82.67	14.05	1.0	1.0	-0.3	0.23
EIA HOG	$10/bbl	$78.40	16.18	1.0	1.0	-0.3	0.23
Rystad	$10/bbl	$59.29	15.99	1.0	1.0	-0.3	0.23
EIA Ref split	$10/bbl	$82.67	14.05	1.0	0.4	-0.3	0.43
EIA HOG split	$10/bbl	$78.40	16.18	1.0	0.4	-0.3	0.43
Rystad split	$10/bbl	$59.29	15.99	1.0	0.8	-0.3	0.27

Note: Oil price is the Brent oil price, reported in 2019 U.S. dollars. Both oil prices and U.S. production represent average levels over the 2020-2030 time period.

Brent oil prices from the latest Rystad model were reported as 2019 U.S. dollars, whereas the 2019 AEO uses 2018 U.S. dollars. We converted the AEO prices to 2019 dollars by multiplying by the ratio of the Consumer Price Index-Urban for those years: (255.538 / 251.107) = 1.02.[9]

Using the parameters, oil price, and production baseline found in Houser, Mohan & Delgado (2015), Equation 1 reproduces the 1.2 million bpd production decline quoted in Bordoff & Houser (2015). For the parameters and scenarios considered here, Table 2 below shows the changes in U.S. production (Equation 1), global consumption (Equation 2), and global emissions (Equation 3 — note: these are annual emissions).

[8] This represents lifecycle emissions from the median U.S. crude oil (U.S. East Texas Field) analyzed by the Carnegie Endowment for International Peace. Oil Climate Index. http://oci.carnegieendowment.org/

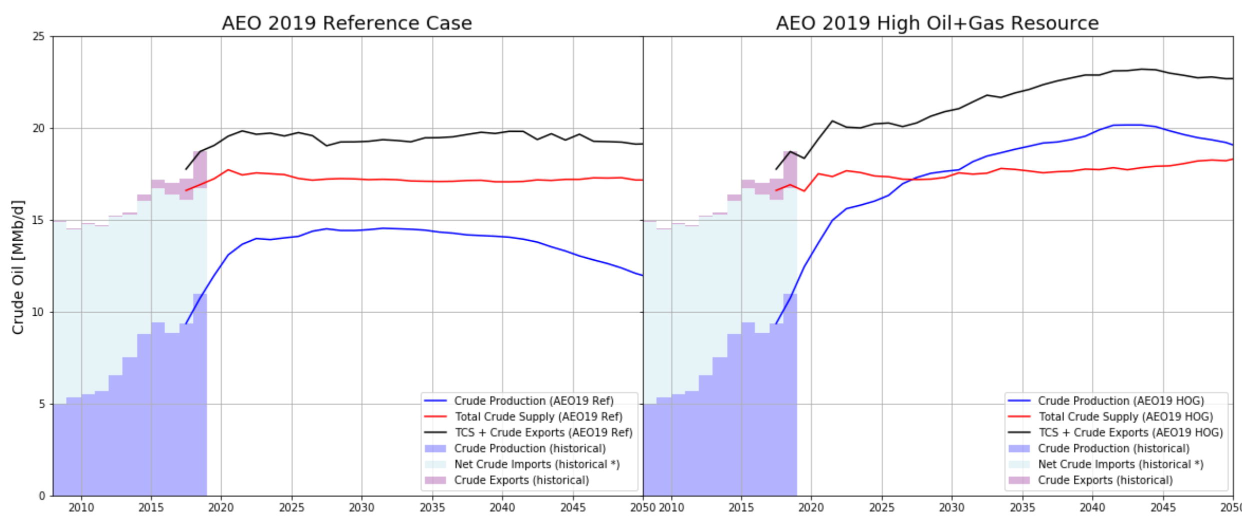
[9] U.S. Bureau of Labor Statistics, Consumer Price Index. https://www.bls.gov/cpi

Table 2: Change in U.S. Production, Global Consumption, and Annual GHG Emissions for Each Scenario

Scenarios	Δ U.S. Production (million bpd)	Δ Global Consumption (million bpd)	Δ Global Emissions (Mt CO_2-eq/yr)
Zero Discount	0.0	0.0	0.0
EIA Ref	-1.70	-0.39	-73.0
EIA HOG	-2.06	-0.48	-88.7
Rystad	-2.70	-0.62	-115.9
EIA Ref split	-1.70	-0.73	-135.6
EIA HOG split	-2.06	-0.88	-164.6
Rystad split	-2.70	-0.74	-136.9

Figure 1 compares historical crude production as well as AEO19 forecasts for both the Reference and HOG cases. The figure shows domestic production (blue line) and total crude supply (red line), which is equal to domestic production plus net crude imports. The top black line is total crude supply plus crude exports, which is equivalent to domestic production plus gross imports.

Figure 1: Historical crude oil data (2008-2018) and AEO19 Reference Case and HOG forecasts (2017-2050).



Note: For both historical and forecast data we plot domestic crude production and net crude imports[10] (the sum of which is termed Total Crude Supply), as well as crude exports.

[10] For clarity in plotting, historical data on Net Crude Imports includes small amounts from stock changes and other adjustments. For the AEO forecasts, TCS values include small amounts of crude from ‘Other’ sources in early years, but which are zero after 2025.

Since lifting the crude export ban, the U.S. has seen a large increase in domestic production — from 9.2 million bpd in January 2016 to 12.7 million bpd in October 2019, a 38 percent increase[11] — and a corresponding rapid rise in crude exports — from 0.5 million bpd in January 2016 to 3.4 million bpd in October 2019, a 590 percent increase.[12] Looking at annual totals from 2016 to 2018, domestic crude production increased by 2.1 million bpd, of which roughly 68 percent went to increased exports. During that time period, gross imports remained roughly constant,[13] and refinery and blender net crude oil inputs increased by only 5 percent.[14]

[11] U.S. EIA. Petroleum & Other Liquids: U.S. Field Production of Crude Oil. https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPUS2&f=M

[12] U.S. EIA. Petroleum & Other Liquids: U.S. Exports of Crude Oil. https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCREXUS2&f=M

[13] U.S. EIA. Petroleum & Other Liquids: U.S. Imports of Crude Oil. https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mcrimus1&f=a

[14] U.S. EIA. Petroleum & Other Liquids: Supply and Disposition. https://www.eia.gov/dnav/pet/pet_sum_snd_d_nus_mbblpd_a_cur-2.htm