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Climate Strategy for Producer Countries: The Case of Saudi Arabia

Jim Krane, Ph.D.
Wallace S. Wilson Fellow for Energy Studies, Rice University's Baker Institute for Public Policy

Introduction[1]

The simultaneous collapse of oil production and social stability in Venezuela has provided a vivid preview of a potential pathway for oil-export states deprived of hydrocarbon rents to fund their national budgets.

While Venezuela's predicament is based on domestic policymaking, some observers suspect that climate action could provoke similar results, leaving oil exporting states with insufficient revenues to maintain public order.[2]

The notion of an encroaching threat to hydrocarbon demand and rents—as opposed to the debunked "peak oil supply" conundrum of the past decade—is leading policymakers to reassess long term assumptions about the oil business in two ways: by promoting diversification into alternate businesses, and by protecting and enhancing the competitiveness of their oil industries.

The two strategies appear compatible. The first prepares the economic landscape for a day when oil rents no longer dominate the state's fiscal revenue, whether from a plateauing of global oil demand or any other reason. The second seeks to insulate flows of oil and gas rents against the more direct challenges emanating from climate policy.

Saudi Arabia, the global oil market's largest supplier, has taken steps in both directions. Its initiatives toward diversification are well known and covered elsewhere.[3] This paper looks at the other, less explored climate strategy: near-term actions that the kingdom and other producer states have taken or may take in the next few years to maintain the continuity of oil exports amid the emergence of restrictions on fossil fuels.

Some of the strategies that Saudi Arabia has developed would alter the nature of its future participation in the oil business. From simply supplying energy commodities, the kingdom is increasing its involvement in importing markets and in bolstering oil-consuming technology.

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[1] **This working paper was initially presented at the Gulf Research Meeting in Cambridge, UK, on August 2, 2018.**

[2] Thijs Van de Graaf and Aviel Verbruggen, "The Oil Endgame: Strategies of Oil Exporters in a Carbon-Constrained World," *Environmental Science & Policy* 54 (2015): 456–62; Thijs Van de Graaf, "Battling for a Shrinking Market: Oil Producers, the Renewables Revolution, and the Risk of Stranded Assets," in *The Geopolitics of Renewables* (Springer, 2018), 97–121; Thijs Van de Graaf and Aviel Verbruggen, "Saving OPEC: How Oil Producers Can Counteract the Global Decline in Demand," *Foreign Affairs*, December 22, 2014, https://www.foreignaffairs.com/articles/persian-gulf/2014-12-22/saving-opec.

[3] Sources on the subject are too numerous to cite, but a few bear mentioning: Martin Hvidt, "Economic Diversification in GCC Countries: Past Record and Future Trends," *Research Paper*, Kuwait Programme series, 2013; Ali Aissaoui, "Saudi Arabia's Economic Diversification: Progress in the Context of the GCC and Challenges," in *Resources Blessed: Diversification and the Gulf Development Model*, ed. Giacomo Luciani (Berlin: Gerlach Press, 2012), 1–24; Bassam A Albassam, "Economic Diversification in Saudi Arabia: Myth or Reality?," *Resources Policy* 44 (2015): 112–17; Tim Callen et al., *Economic Diversification in the GCC: Past, Present, and Future* (International Monetary Fund, 2014); Giacomo Luciani, "Resources Blessed: Diversification and the Gulf Development Model," in *The Gulf Region: Economic Development and Diversification*, ed. Giacomo Luciani et al., 4 vols. (Berlin: Gerlach Press, 2012).

One strategy involves infrastructure and investment ties with developing states where expectations for growth in oil demand are high. A related effort emphasizes low-emission and non-combustion uses for crude oil, which are consistent with a transitioning energy system. Another has the kingdom increasing its cooperation with the global climate regime, pursuing a commitment to energy efficiency which does double duty in domestic oil demand management. Yet another strategy seeks to lobby the international community to moderate its targets for greenhouse gas emissions, and accept a higher level of human climate damage.

While this paper applies these strategies to Saudi Arabia, other producer countries should be expected to take similar steps. The realization that the world is over-endowed with hydrocarbon reserves that may never be produced is forcing a strategic alteration in oil market behavior. Oil and gas markets appear likely to grow more competitive, with producer states vying for market share and differentiating products based on environmental criteria.

What this portends for markets and demand over the longer term is unclear. One envisions the eventual emergence of multiple potential pathways. A cooperative path would see producers collude to manage reductions in production so that prices remain above their cost of extracting the marginal barrel. One can also imagine the emergence of a more hostile dynamic pitting fossil fuel producers against the efforts of climate-focused states and international organizations. Another possibility would see a "green paradox" path arise, with low-cost producers maintaining or even ramping up production, driving down oil prices and helping fossil fuels compete against alternatives.[4]

CONTRASTING STRATEGIES

This paper focuses on three types of *nearer-term* producer country climate strategies outlined above. Although they sometimes overlap, I have provisionally titled them "Dig In," "Join In," and "Throw In."

1. **DIG IN**: Producer governments overtly defend their oil and gas export industries. Their primary concern is not with the direct effects of climate change but indirect effects of climate action on global demand for exportable hydrocarbons, and the socioeconomic damage posed by loss of rents. By "digging in," states assume GHG accords such as the 2015 Paris Agreement remain aspirational rather than binding, and act to insulate or harden the hydrocarbon sector against the aims of such accords. Such actions include steps to enhance competition with rival producers, and to protect technologies linked to continued demand. This includes developing uses for crude oil that remain viable in a climate-constrained market.

[4] For more detailed discussion of possible oil market reactions to peak demand, see Anupama Sen and Bassam Fattouh, "Economic Diversification in the MENA in the Context of Peak Oil and the Energy Transition," in *Workshop on Sustainability in the GCC* (Gulf Research Meeting, University of Cambridge, UK, 2018).

a. **LOCK IN**: An important subset of the "Dig In" strategy is the bilateral "Lock In" of markets in key import states through direct investment.

2. **JOIN IN**: Producer governments "join in" to pursue economically rational domestic energy policies that provide secondary benefits in reducing greenhouse gas emissions. The Paris Agreement's Nationally Determined Contributions (NDCs) provide useful political cover for unpopular—albeit environmentally beneficial—actions like Saudi Arabia's reform of energy subsidies. Domestic reforms have the added benefit of freeing up oil and gas that can be exported at market prices.

3. **THROW IN**: The "Throw In" strategy suggests the adage "throw in the towel." Here, elites sympathetic to the interests of producer states concede that climate change is inevitable, and argue that some damage caused by human greenhouse gas emissions is preferable to costly GHG mitigation in line with the Paris goals.

SAUDI ARABIA'S CLIMATE PROFILE

How does Saudi Arabia fit within the taxonomy above? Like other large producers of carbon-intensive fossil fuels, Saudi Arabia finds itself at the center of the global climate conundrum, increasingly recognized as major fossil fuel *producer*, *exporter*, *subsidizer*, and *consumer*. Saudi Arabia also stands to become an early and significant *victim* of climate change, since its arid geography and harsh summer climate is highly vulnerable to damage.[5]

Saudi Arabia also carries an outsized legacy of GHG emissions which began in the pre-nationalization era, due to large-scale methane venting that far outweighed its relatively minor emissions of carbon dioxide of the period. While Saudi CO_2 emissions have grown nearly 6% per year, roughly the same rate as its primary energy demand,[6] the kingdom's methane emissions peaked during the 1970s, a period when the kingdom's overall GHG emissions reached levels that were only surpassed within the last few years.[7] (Fig. 1)

At the time, the national oil company, then known as Aramco, was owned and operated by four US companies. After the Saudi government took full control in 1980, GHG emissions dropped as Saudi Aramco built up its Master Gas System based on capturing waste methane and

[5] Jeremy S. Pal and Elfatih A. B. Eltahir, "Future Temperature in Southwest Asia Projected to Exceed a Threshold for Human Adaptability," *Nature Clim. Change* 6, no. 2 (February 2016): 197–200.
[6] EDGAR, "Fossil CO2 & GHG Emissions of All World Countries, 2017," European Commission science database (Brussels: Emissions Database for Global Atmospheric Research, 2017), http://edgar.jrc.ec.europa.eu/overview.php?v=CO2andGHG1970-2016.
[7] Atmospheric methane has far more potent heat-trapping properties than CO_2, but after a decade or two its harm is reduced as it decays into CO_2. Over a decade, methane warms the planet by 86 times as much as CO_2. See: Gayathri Vaidyanathan, "How Bad of a Greenhouse Gas Is Methane?" *Scientific American*, Dec. 22, 2015. https://www.scientificamerican.com/article/how-bad-of-a-greenhouse-gas-is-methane

redirecting it to the power sector.[8] Fugitive (non-combustion) CO_2 from the oil industry was another major source of emissions which was curtailed after nationalization, dropping below 50% of total CO_2 emissions by 1979 and reaching 2.2% in 2008.

Once upstream fugitive emissions were reduced, the power sector grew to become the kingdom's largest source of carbon dioxide emissions. By 2008, electricity generation was responsible for 43% of GHG emitted, followed by transport at 27% and industry at 17%. Fugitive emissions from the Saudi energy industry totaled 10.5m metric tons of CO_2 equivalent in 2008, amounting to just 3% of the kingdom's entire GHG emissions of 382m metric tons.[9]

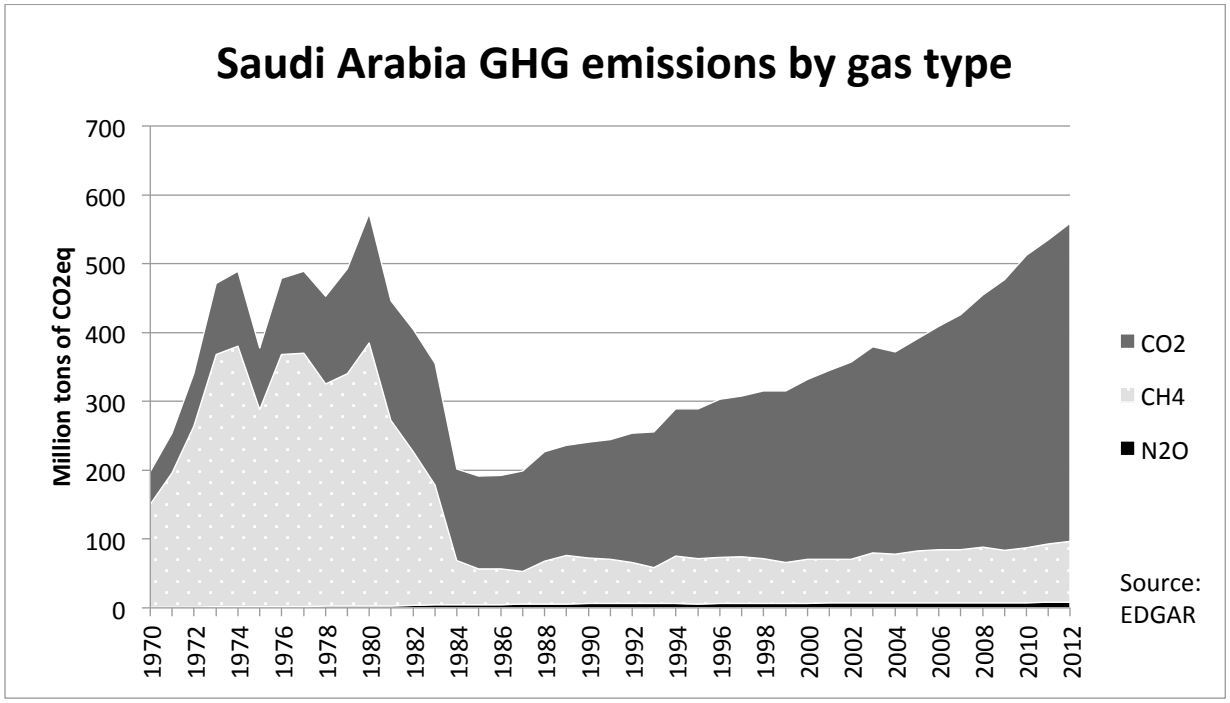

Figure 1: Saudi GHG emissions since 1970. Source EDGAR, "Fossil CO2 & GHG Emissions of All World Countries, 2017," European Commission science database (Brussels: Emissions Database for Global Atmospheric Research, 2017), http://edgar.jrc.ec.europa.eu/overview.php?v=CO2andGHG1970-2016.

Today's Saudi emissions flow mainly from Saudi energy consumption. By 2017, Saudi Arabia – the world No. 1 oil exporter – had become the world No. 5 oil consumer, after the United States, China, India and Japan. It consumed more oil than much larger countries, including Russia, Brazil or Germany.[10] As such, Saudi Arabia is a leading global emitter of GHGs. The kingdom was the world No. 9 carbon emitter in 2016, according to BP data, ahead of populous

[8] Jim Krane, "Stability versus Sustainability: Energy Policy in the Gulf Monarchies" (PhD dissertation, University of Cambridge, 2014), http://dx.doi.org/10.17863/CAM.5943.
[9] EDGAR, "Global Emissions EDGAR v4.2 (November 2011)," European Commission science database (Brussels: Emissions Database for Global Atmospheric Research, 2017), http://edgar.jrc.ec.europa.eu/overview.php?v=42
[10] BP, "Statistical Review of World Energy 2018," statistical report (London: BP, June 2018), https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html.

oil producers like Brazil, Mexico and Indonesia as well as developed states like Canada and Australia, but behind Iran, South Korea, Germany and Japan. However, BP data only reflect CO_2 emitted from fossil fuel combustion, and ignore other sources. When all GHGs are factored in, Saudi Arabia ranked as the No. 15 emitter in 2012, according to the most recent data collected by the EU's Emissions Database for Global Atmospheric Research (EDGAR). EDGAR GHG data rank the kingdom *behind* Brazil, Mexico and Indonesia, as well as Canada and Australia. (Table 1 and Fig. 2)

Table 1: Saudi Arabia benchmarked against selected countries in terms of GHGs, population and economy, using GHG figures for 2012, most recent GHG data available for all

Country	Crude & NGL export (KBD)	2012 Population (million)	GDP (US$ bn 2011)	2012 GHG emissions per capita (ton of CO_2eq)	Average annual growth rate of GHG emissions since 1970
Australia	281	23	967	**26.4**	1.7%
UAE	2,625	9	532	**25.3**	2.2%
Canada	2,516	35	1,452	**20.6**	1%
USA	424	314	15,863	**19.5**	0.2%
Saudi Arabia	7,442	29	1,444	**19.2**	2.5%
Russia	4,858	143	3,602	**15.9**	0.6%
Iran	1,371	76	1,271	**10.3**	2.5%
Mexico	1,333	121	1,972	**6.0**	2.6%
Brazil	532	200.5	3,032	**5.6**	2.8%
Indonesia	315	249	2,302	**3.3**	3.4%
2012 data (most recent GHG emissions data available) Sources: IEA, World Bank and EDGAR					

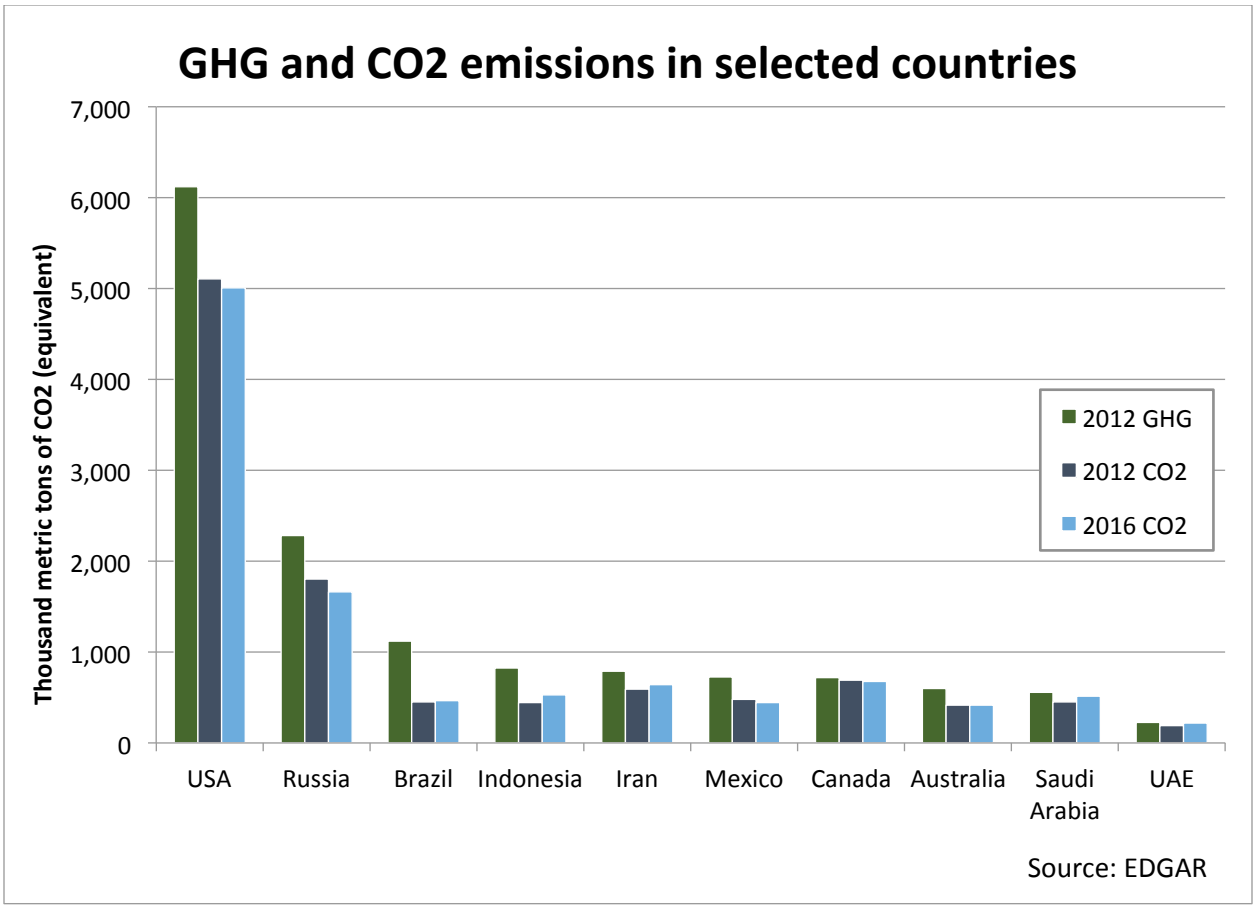

Figure 2: Saudi Arabia is ranked 15th in the world by its 2012 GHG emissions but 9th when judging by its 2016 CO_2 emissions.

When compared with its peers in the Gulf Cooperation Council (GCC), Saudi Arabia was the least prolific per-capita emitter, far outpaced by wealthy Qatar and Kuwait, and even ranking behind the United Arab Emirates, Oman and Bahrain. (Fig. 3) The high levels of per-capita GHG emissions in the smaller monarchies are partly due to small populations relative to the size of energy-intensive industries. Qatar's natural gas sector, including its LNG and gas-to-liquids industries, is a major emitter of both carbon dioxide and fugitive methane.[11] Other factors include high per-capita incomes, large homes, low electricity prices and a hot climate that generates demand for indoor cooling.[12] Electric power in the residential sector is nearly free in Kuwait, and is free in unlimited quantities for Qatari citizens.

[11] Fugitive methane constituted nearly half of Qatar's 2012 GHG emissions, or about 70 of 150 megatonnes of CO2 equivalent, according to EDGAR's dataset. EDGAR, "Fossil CO2 & GHG Emissions of All World Countries, 2017."
[12] Jim Krane, "Rationalizing Energy Demand through End-User Prices in the GCC," *Oxford Energy Forum*, no. 102 (November 2015).

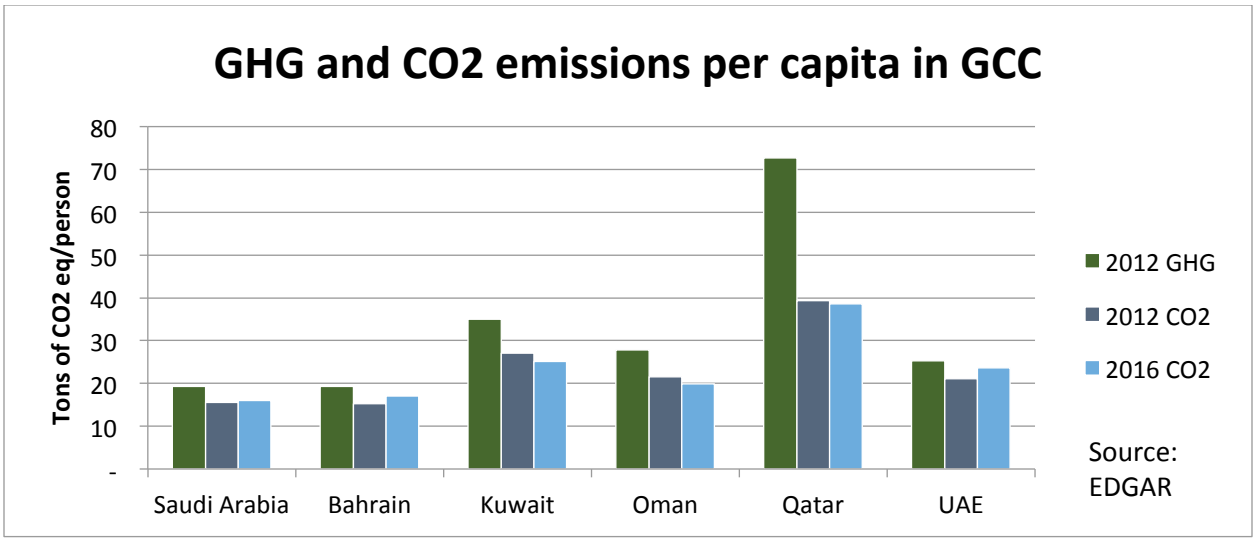

Figure 3: Saudi Arabia was at the low end of per capita GHG emitters among the Gulf monarchies. Source: EDGAR.

Of course, most of the emissions from Saudi Arabian energy products are tallied in the countries where final combustion takes place. When aggregated, the carbon emitted from Saudi Aramco's oil production has been identified as the world's No. 1 current and No. 2 historical source of GHGs among all commercial fossil fuel companies. Hydrocarbons produced by Saudi Aramco are responsible for about 4.3% of current global GHG emissions and about 3.2% of aggregate atmospheric accumulations.[13] Chevron, the former Standard Oil of California, which discovered oil in Saudi Arabia in 1938 and held the original Saudi concession, is responsible for about 1.2% of current emissions and 3.5% of historic emissions, the highest share among historical emitters.[14]

The GHG emissions attributed to Saudi Aramco are not only a byproduct of the company's business, but of the commercial activity that underpins the kingdom's economy and governance structures, since oil rents have long constituted the chief source of funds for the Saudi national budget. In fact, carbon extraction and marketing are even of strategic importance for Saudi Arabia, given that oil exports form the basis for the kingdom's geopolitical stature and its important partnership with the United States, which provides hard security for the region. Therefore, Riyadh, like producer governments elsewhere, should be expected to protect an industry so central to the survival of its regime, even to the detriment of the climate

[13] These figures include flaring and venting of GHGs during production. See: Benoit Mayer and Mikko Rajavuori, "National Fossil Fuel Companies and Climate Change Mitigation under International Law," *Syracuse J. Int'l L. & Com.* 44 (2016): 55.

[14] Emissions are from upstream production and final consumption of oil and gas products produced by Chevron. Mayer and Rajavuori. See also: Richard Heede, "Tracing Anthropogenic Carbon Dioxide and Methane Emissions to Fossil Fuel and Cement Producers, 1854–2010," *Climatic Change* 122, no. 1–2 (2014): 229–41.

affecting its national territory. The following sections describe the shape such protection might take.

STRATEGY No. 1 "DIG IN" – REDUCE VULNERABILITY OF OIL SECTOR TO CLIMATE ACTION

To executives of a national oil company (NOC) such as Saudi Aramco, the default concern about climate change tends to be the indirect threat posed to the oil-dominated economy, rather than the direct threat to habitability of the national territory. Saudi qualms regarding "security of demand" for crude oil also arise partly from the role of climate action within the ongoing energy transition.[15]

CLIMATE OBSTRUCTIONISM

In the past, Saudi concern was manifested in an obstructionist stance in international climate fora. Depledge argued that Saudi Arabia joined UN-led climate treaty negotiations because its leadership feared a successful agreement and wished to thwart, delay, or weaken it. The kingdom's confrontational stance was based on fears that mitigation policies would harm the kingdom more than the damage of climate change itself. [16]

Saudi tactics documented by Depledge involved the following:

- Allowing its position to be determined and led by the national petroleum ministry
- Highlighting skeptical views on climate science and downplaying the harmful effects of atmospheric carbon accumulations
- Employing negotiating techniques aimed at postponing or blocking progress
- Aligning with coal lobbies and other interests which oppose climate action
- Using financial incentives to persuade delegations from poorer countries to back the Saudi position.

As the global consensus on climate became more urgent, obstructionist Saudi tactics triggered negative publicity and damaged the kingdom's public image.[17] The kingdom turned to a more sophisticated set of strategies to protect its oil business.

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[15] James B. Smith, "WHAT CONCERNS SAUDI ARABIA ABOUT THE FUTURE OF ENERGY AND CLIMATE CHANGE," Diplomatic cable (Riyadh: US State Department via WikiLeaks, February 21, 2010).

[16] Joanna Depledge, "Striving for No: Saudi Arabia in the Climate Change Regime," *Global Environmental Politics* 8, no. 4 (2008): 9–35.

[17] See, for example: Jad Mouawad and Andrew C. Revkin, "Saudis Seek Payments for Any Drop in Oil Revenues." *New York Times*, Oct. 13, 2009; https://www.nytimes.com/2009/10/14/business/energy-environment/14oil.html ; and Gerard Wynn, "U.N. climate talks threaten our survival: Saudi Arabia." *Reuters*, April 8, 2009. https://www.reuters.com/article/us-climate-saudi-bonn-interview-idUSTRE5371QM20090408

PETROCHEMICALS and NON-COMBUSTION USES FOR CRUDES

Oil and gas have applications that do not involve burning it. For Saudi Arabia, the most important of these "non-combustion uses" is in producing petrochemicals. Demand for petrochemicals has grown more robustly than demand for oil-based fuels[18] and with higher shareholder returns than other sectors, including the upstream industries providing its feedstocks.[19] The conversion of crude oil and natural gas into chemical products comprises perhaps Saudi Aramco's most promising climate hedge. Chemicals represent a growing "climate proof" use for hydrocarbons, through which oil and gas feedstocks are converted into precursor resins and polymers that form the basis for finished products ranging from plastic auto components to foam cushions, paint and even toothpaste. The carbon is sequestered in the finished product, rather than released upon combustion, as is the case with gasoline and other fuels.

Saudi-based companies have made major investments in petrochemical plants, both inside the kingdom and outside. Domestic investment includes the $20 billion Sadara joint venture with Dow Chemical, the largest single-phase chemical plant ever built. Internationally, Saudi Aramco and SABIC, the state-held petrochemical giant, have proposed joint venture projects in the United States, China, Malaysia and India.[20] Demand for plastic goods is closely correlated with GDP growth, with large markets emerging in developing countries where populations are moving into the middle class. To increase its competitiveness in the sector, Saudi Aramco is investing in technology for direct conversion of crude oil into chemicals, bypassing the refining phase and reducing energy inputs.[21]

Lubricant production is another climate-compliant use for crude oil, since lubricants are (ideally) not combusted. Improvements in lubricant performance have also decreased fuel consumption by reducing friction and improving the efficiency of machine operations.[22] As with

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[18] The IEA in 2018 estimated that petrochemicals formed the fastest-growing demand source for crude oil, with an estimated 25% of overall growth focused on the sector by 2023. See: "Oil 2018," International Energy Agency, March 5, 2018. https://www.iea.org/oil2018/

[19] Obi Ezekoye, Andjelka Milutinovic, and Theo Jan Simons, "Chemicals and capital markets: Back at the top." McKinsey research article, May 2018. https://www.mckinsey.com/industries/chemicals/our-insights/chemicals-and-capital-markets-back-at-the-top

[20] Examples include an ethylene plant proposed in Texas in 2017 that would combine investments from SABIC and Exxon Mobil; a Saudi Aramco-Sinopec-ExxonMobil integrated refining and petrochemical plant operating in Fujian, China since 2009. Further, in 2018, Saudi Aramco announced a combined refining-petrochemical venture in India that would link it with three Indian firms; and in Malaysia, the Saudi company announced joint ventures with Petronas, Malaysia's state-owned oil company, for an integrated refinery and petrochemical project in southern Malaysia.

[21] Robert Brelsford, "Aramco, SABIC let contract for crude oil-to-chemicals complex." *Oil and Gas Journal*, April 30, 2018; https://www.ogj.com/articles/2018/04/aramco-sabic-let-contract-for-crude-oil-to-chemicals-complex.html

[22] Katrien Boonen and Ive Vanderreydt, "Evolution of Environmental Impacts and Benefits of Motor Oil from a Lifecycle Perspective." Slide presentation, Benelux Technical Lubricants Seminar, Sept. 12, 2017; http://www.essenscia.be/en/Document/Download/16770

plastics, lubricating oil can be recycled, which improves environmental efficiency but reduces growth prospects of the market.

DIFFERENTIATING AMONG CRUDE OIL GRADES BY CARBON INTENSITY

Saudi Arabia and other big Middle East oil producers have long enjoyed low average costs of producing their oil reserves, in comparison with other oil producing states. Low lifting costs have maximized rent incomes, since oil prices are based on the cost of the marginal barrel, or the highest-cost global oil that can be produced under a prevailing market price.[23] Now it turns out that production cost is a strong indicator of a crude oil's carbon intensity.

That is because cost of production is partly based around the energy expended in lifting crude oil from the reservoir to the surface, and in processing and transporting it. Lifting costs are lowest in prolific reservoirs with low water content and high levels of natural drive pressure, requiring minimal use of energy-intensive enhanced oil recovery (EOR) techniques such as steam flooding or gas- or water-injection. Lower water content within crude oil also decreases the mass of the crude lifted to the surface and energy expended in surface processing.[24] Refining processes also account for carbon intensity, with lighter, sweeter crudes requiring less processing, while heavier, more sour crudes needing more energy to break down into products.

A further factor affecting carbon intensity of oil production relates to frequency of flaring of natural gas produced in association with crude oil. Flaring—or burning off gas at the wellhead—releases even more CO_2 into the atmosphere. Saudi Arabia and some of its neighbors, such as the UAE, Qatar and Kuwait, flare very little natural gas, preferring to capture the gas for domestic use. Other neighbors, such as Iran and Iraq, flare gas at high rates, which adds to the carbon footprint of their crude oil. Flaring in shale fields has turned the United States into another flaring frontrunner, raising the average carbon intensity of US oil. [25] (Fig. 4)

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[23] Typical explanations for oil price formation are based on the cost of producing the marginal barrel, including a return on investment. Other research suggests other factors, such as global GDP growth, play a stronger role. See, for example: Rolf Golombek, Alfonso A. Irarrazabal, and Lin Ma, "OPEC's Market Power: An Empirical Dominant Firm Model for the Oil Market," *Energy Economics* 70 (2018): 98–115, https://doi.org/10.1016/j.eneco.2017.11.009. Still others argue that "social costs" of financing an oil producing country's economy are more relevant to price formation. See: Spencer Dale and Bassam Fattouh, "Peak Oil Demand and Long-Run Oil Prices," Academic paper (Oxford: Oxford Institute for Energy Studies, January 2018), https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/01/Peak-Oil-Demand-and-Long-Run-Oil-Prices-Insight-25.pdf.

[24] Mohammad S Masnadi et al., "Well-to-Refinery Emissions and Net-Energy Analysis of China's Crude-Oil Supply," *Nature Energy* 3, no. 3 (2018): 220.

[25] Russia was No. 1 in flaring in 2016, followed by Iraq, Iran, Venezuela, Algeria and the United States. Big oil producers in the Persian Gulf flared much smaller amounts. Saudi Arabia was No. 13, Kuwait was No. 25, Qatar was No. 28 and the UAE was in 31st place, with less gas flared than even minor oil producing countries such as the United Kingdom and Vietnam. See: World Bank, "Global Gas Flaring Reduction Partnership (GGFR): Upstream Gas Flaring;" http://www.worldbank.org/en/programs/gasflaringreduction#7

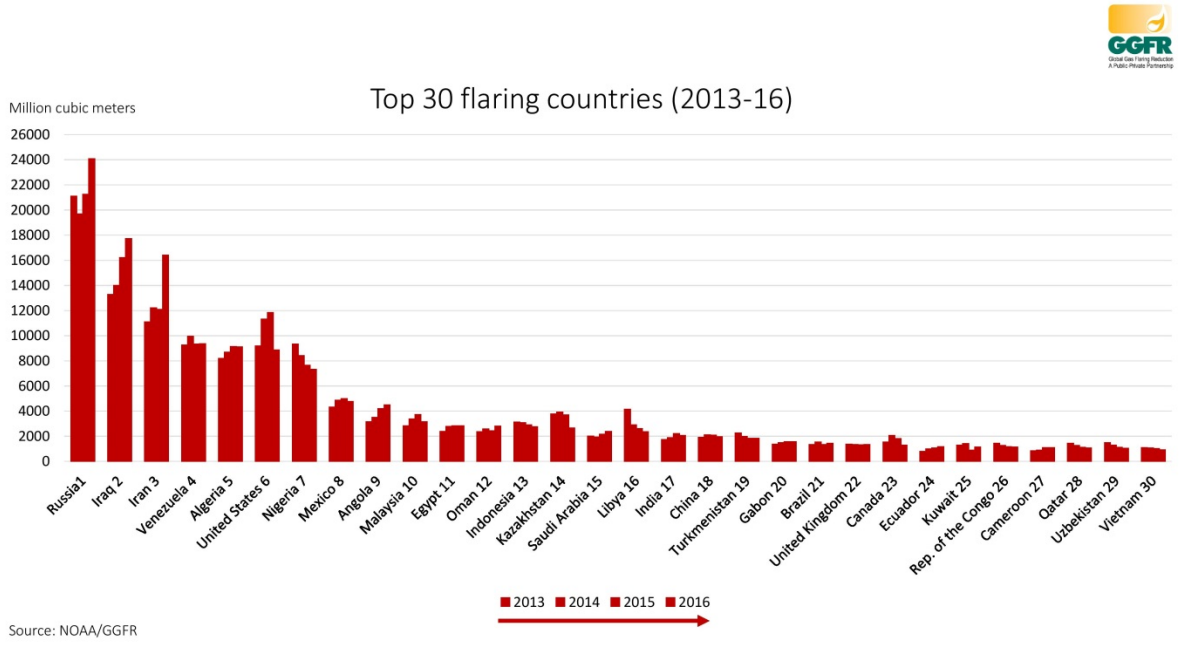

Figure 4: Source World Bank, NOAA, GGFR 2017

Masnadi et al. measured well-to-refinery carbon emissions from various crude oil grades supplied to China. They found Saudi crudes—from the five Ghawar sub-fields—at the low end of the carbon intensity scale, preceded by oil from Kuwait and the UAE. (Fig. 5) At the high end of the scale was ultra-heavy crude from Venezuela's Orinoco Belt fields, where energy-intensive steam flooding is used to increase viscosity of crude oil that, in its natural state, appears closer to a solid.[26] Likewise, the bitumen deposits that form Canada's oil sands crude require steam-assisted techniques—or outright surface mining—as well as energy-intensive "upgrading" that adds to their carbon intensity. After combustion, Canadian oil sands crudes are 17% more carbon-intense than average crude oil burned in the United States, because production of oil sands crude emits 80% more GHGs than that of the average US barrel.[27]

[26] Masnadi et al., "Well-to-Refinery Emissions and Net-Energy Analysis of China's Crude-Oil Supply."
[27] Richard K. Lattanzio, "Canadian Oil Sands: Life-Cycle Assessments of Greenhouse Gas Emissions," US Government report (Washington: Congressional Research Service, March 10, 2014), https://fas.org/sgp/crs/misc/R42537.pdf.

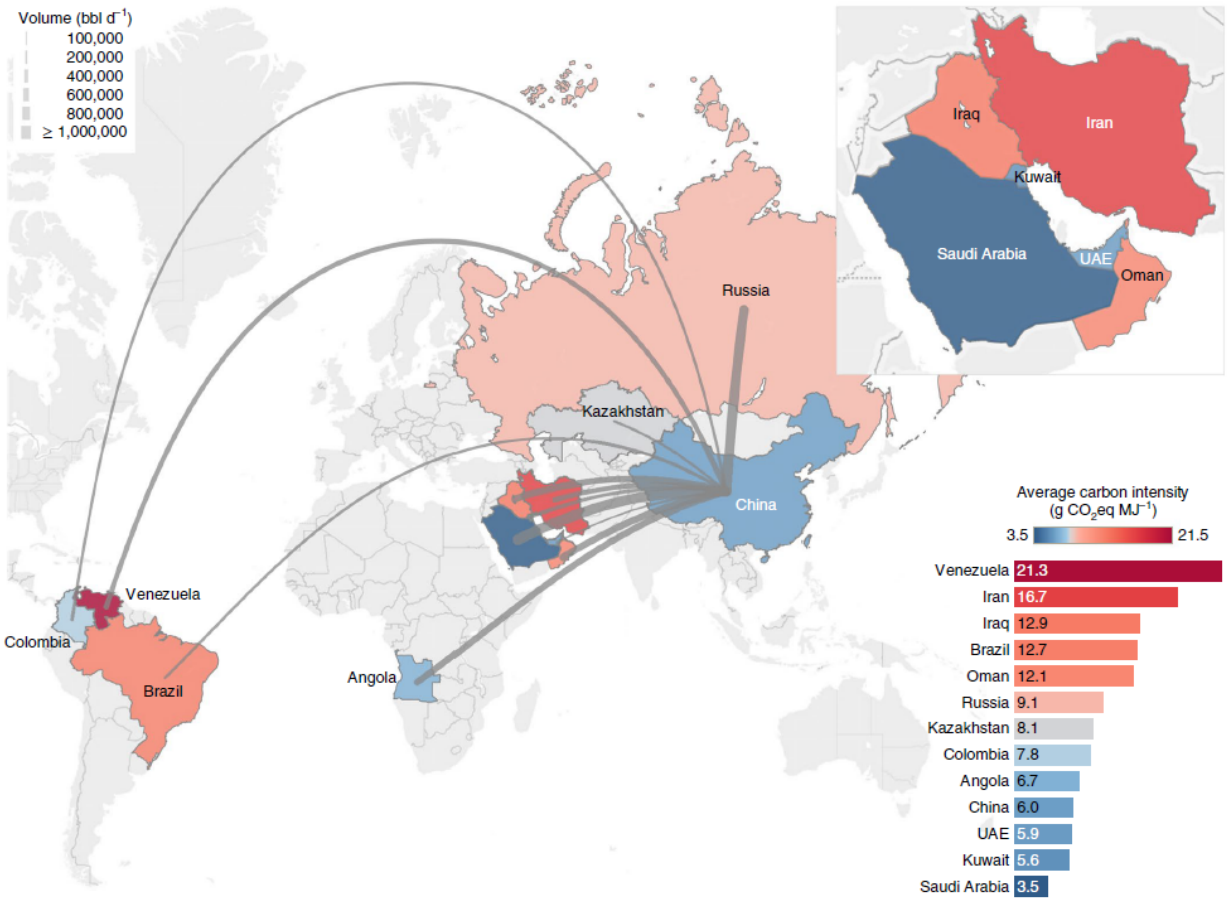

Fig. 5 | 2015 China's crude-oil supply map. Country-based upstream volume-weighted average GHG intensities (colours) and their corresponding volumetric shares (grey stream lines) in Chinese crude supply. GHG emissions are estimated on the basis of the co-product displacement method. The map is produced using Tableau (https://www.tableau.com/). For clarity, countries that supply < 1% of China crude mix are excluded (see Supplementary Data 2 for carbon intensity data for each field). See Fig. 6 for representativeness degree of each country's data.

Figure 5: Saudi Arabia and Venezuela sit on opposite ends of the carbon intensity scale. (Source: Masnadi et al. 2018)

Given such a timely environmental advantage, Saudi Aramco will begin highlighting the low carbon intensity of its crude oil as a marketing strategy.[28] Low carbon intensity could even translate into a price advantage in countries that levy carbon taxes, if carbon taxes were designed to differentiate among crude grades by carbon intensity. More typically, carbon taxes apply an average value to oil products irrespective of origin.

As Table 2 shows, Saudi medium crude priced at $70/barrel with a $25/ton carbon tax would cost $81.64 per barrel. A barrel of Venezuelan Orinoco crude would be priced at $85.98, a $4.34 premium. At a $50 carbon tax, the effect would be magnified. The Saudi barrel would be nearly $9 cheaper, at $93.29, versus $101.97 for the Orinoco.

[28] Author conversation with Saudi oil official, on condition of anonymity, Dhahran, Feb. 13, 2018.

Table 2: Carbon taxes on Saudi and Venezuelan crudes at $70 per barrel

Crude oil source	Upstream GHG intensity (g CO_2eq/ MJ)	Upstream GHG tax per barrel @ $25 tonne	Upstream GHG tax per barrel @ $50 tonne	Total GHG tax @$25 tonne*	Total GHG tax @$50 tonne*
Saudi average	3.5	$ 0.54	$ 1.07	$ 11.64	$ 23.28
Venezuela average	21.3	$ 3.26	$ 6.52	$ 14.36	$ 28.72
Ghawar	4.1	$ 0.63	$ 1.25	$ 11.73	**$ 23.46**
Orinoco	31.9	$ 4.88	$ 9.76	$ 15.98	**$ 31.97**

* includes upstream CO_2 emissions as well as those from transport, refining and final combustion. Note that Venezuelan heavy crude oil typically sells at a discount to more valuable lighter grades, a distinction that is not captured in this analysis.
Source: Baker Institute, Masnadi et al. 2018

BACKING INTERNAL COMBUSTION ENGINES OVER EVs

The kingdom also plans strategic investments to prolong the use of gasoline in transportation, by maximizing the efficiency of the internal combustion engine, so that oil-fueled transportation remains cost-competitive with electric vehicles. From the Saudi perspective, an efficient hybrid vehicle is preferable to an all-electric vehicle that uses no petroleum. Saudi Aramco touted its vehicle research—and the "unparalleled energy density of hydrocarbons"—at the North American International Auto Show in Detroit in 2018. On display were high-efficiency gasoline compression ignition engines as well as a car with on-board carbon capture and storage capability.[29] In August 2018, Saudi Aramco announced it would cooperate with Japanese auto manufacturer Mazda to develop more efficient engines and gasoline that would reduce GHG emissions from the transport sector.[30] These developments would improve petroleum's competitiveness versus alternative fuels and technologies.

The 'LOCK IN' STRATEGY

A subset of the "Dig In" strategy is the "Lock In" approach, where NOCs purchase oil and gas infrastructure inside importing countries. Refineries have been the main target, and Saudi Aramco the largest proponent.

Aramco has created joint ventures that provide influence or even control over the refinery configuration and, by extension, the supply of crude oil the refinery processes. Aramco has

[29] Author interviews Saudi Aramco, Dhahran, Feb. 13, 2018. See also: "Aramco showcases flagship technologies at Detroit auto show," Saudi Aramco press release, Jan. 31, 2018. http://www.saudiaramco.com/en/home/news-media/news/flagship-technologies-detroit-auto-show.html

[30] "Saudi Aramco, Mazda Motor Corporation and AIST collaborate to develop the world's most advanced engine/ fuel combination." Saudi Aramco press release, Aug. 8, 2018. http://www.saudiaramco.com/en/home/news-media/news/Saudi-Aramco-Mazda-and-AIST-collaborate-on-advanced-engine.html

bought stakes in refineries in China,[31] South Korea,[32] Japan,[33] and the United States[34] and was in the process of negotiating further purchases in India[35] and Malaysia.[36] Similarly, the Kuwait Petroleum Co. has purchased a 35% ownership and operational stake in a refinery in Vietnam configured around Kuwaiti crude.[37]

At times when oil markets are in oversupply—perhaps due to weakening demand amid a transition to cleaner energy—Saudi Aramco can ensure that Saudi crudes have preferential access to Saudi-owned refineries.[38] The tactic is reminiscent of that adopted in the early 20th century by the Seven Sisters cartel, which controlled market entry through integrated ownership of upstream, midstream and downstream infrastructure. Other states, which lack the "integration" pursued by Aramco could find ready markets lacking.

STRATEGY No. 2 "JOIN IN" CLIMATE ACTION

For now, climate change in producer states is primarily seen as an indirect threat to demand for oil and gas. But producer countries are also vulnerable to the direct threat of climate change, and to the multilateral call to "join in" the campaign against global warming. As international resolve has coalesced around the desirability of GHG mitigation, the Saudi climate negotiating stance has grown more accepting of the scientific consensus and the need for action. The 2015 Paris Agreement saw Saudi Arabia and its neighbors declaring nationally determined contributions (NDCs) to reduce emissions of GHGs.

Saudi Arabia has shifted its public stance to one of support for climate action. Energy minister Khalid Al-Falih issued a statement in support of the 2016 Congress of Parties (COP) 22 in

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[31] Aramco owns a share of the Fujian Refining & Petrochemical Co. (company website, http://www.frep.cn/en/view-category?categoryId=ff800808129f00d8e0129f00d94e31100) and is in the process of purchasing stakes in two more, as well as entering long-term supply contract with a private Chinese refiner. See: Rania El Gamal, "Saudi Aramco eyes partnerships as it expands refining, petrochems." *Reuters*, June 12, 2018; https://www.reuters.com/article/us-saudi-aramco-downstream-exclusive/exclusive-saudi-aramco-eyes-partnerships-as-it-expands-refining-petrochems-idUSKBN1J81M9; See also: "New Private Chinese Refinery In Talks For Long-Term Saudi Oil Supplies," *Oilprice.com*, May 31, 2018; https://oilprice.com/Latest-Energy-News/World-News/New-Private-Chinese-Refinery-In-Talks-For-Long-Term-Saudi-Oil-Supplies.html;

[32] S-Oil refinery (company website: http://www.s-oil.com/en/company/History.aspx)

[33] Showa Shell Sekiyu K.K., 2017 company corporate report, p.101; http://www.showa-shell.co.jp/english/ir/corporate/2017/cr_2017_eng_full.pdf

[34] Robbie Gramer, "Saudi Arabia Now Controls the Largest Oil Refinery in North America," *Foreign Policy*, May 3, 2017; https://foreignpolicy.com/2017/05/03/saudi-arabia-now-controls-the-largest-oil-refinery-in-north-america-energy-middle-east-aramco/

[35] Rania El Gamal, "Saudi Aramco eyes partnerships as it expands refining, petrochems." *Reuters*, June 12, 2018

[36] Heesu Lee and Serene Cheong, "A Saudi-Backed Asia Refinery Is Going to Be a Fuel Juggernaut," *Bloomberg*, May 17, 2018; https://www.bloomberg.com/news/articles/2018-05-17/fuel-juggernaut-coming-as-saudi-backed-asia-refinery-giant-stirs

[37] Vietnam's Second Refinery To Be Fully Operational By Early August," *Reuters*, June 6, 2018; https://www.rigzone.com/news/wire/vietnams_second_refinery_to_be_fully_operational_by_early_august-06-jun-2018-155842-article

[38] Jim Krane, "A Refined Approach: Saudi Arabia Moves beyond Crude," *Energy Policy* 82 (2015): 99–104.

Marrakesh. "We view the Paris Agreement as balanced and fair, and this will pave the way to effective implementation in addressing our climate goals and sustainable development goals holistically," al-Falih said. "It is encouraging to note that the Paris Agreement has achieved the threshold for entry into force, and Saudi Arabia is determined to see it implemented."[39]

The revised Saudi posture accepts the necessity of reducing GHG emissions, but in a selective way. Domestically, the kingdom has launched two reforms of fossil fuel subsidies, raising prices and reducing demand for transport fuels, electricity and desalinated water. These reforms have economically rational goals of reducing government spending on energy provision and decreasing the "cannibalism" of exportable energy commodities. But they serve double-duty as environmental policy, since they also reduce growth in the kingdom's GHG emissions.

Internationally, Saudi Arabia promotes an altogether different strategy, featuring efforts that protect the interests of oil-exporting states in ways that do not harm demand for fossil fuels. Supported strategies include:

- **Carbon capture and storage (CCS)**: CCS involves capturing carbon emissions after combustion and storing them permanently underground. CCS technology has progressed slowly, and adoption has been undermined by expense and inefficiency, and the slow uptake in carbon pricing required to spur adoption. CCS actually *increases* fossil fuel input for the same energy output because capturing and compressing CO_2 requires combusting additional fuel. Saudi Arabia and the UAE are members of the Carbon Sequestration Leadership Forum, and the kingdom has pledged to capture and use CO_2 in various applications, including in petrochemical production and EOR.
- **Flaring reductions**: As mentioned, Saudi Arabia has succeeded in curtailing wasteful flaring of natural gas, but other countries—including the United States—have been less successful. Altogether 3.5% of global gas consumption, or 149 billion cubic meters—more than Japan's entire 2017 consumption—is burned as waste.[40] Many fossil fuel proponents acknowledge that "cleaning up" the sector itself would reduce pressure to curtail final consumption.
- **Focus on "alternate" GHGs**: Saudi officials want more attention paid to GHGs such as methane and nitrous oxides, which, although forming a smaller portion of overall emissions, carry much higher heat-trapping properties than CO_2. Nitrous oxides are largely used in fertilizers in the agricultural sector. Most methane pollution flows from

[39] Ministry of Energy, Industry & Mineral Resources of Saudi Arabia, "Saudi Arabia Takes Its Place as Global Citizen at COP 22," Government press release (Riyadh: Ministry of Energy, Industry & Mineral Resources of Saudi Arabia, 2017), https://docs.wixstatic.com/ugd/bc5fc9_455265c3bb8a41db987af3d3f72308cc.pdf.
[40] World Bank, "Global Gas Flaring Reduction Partnership (GGFR): Upstream Gas Flaring;" http://www.worldbank.org/en/programs/gasflaringreduction#7

leaks in upstream oil and gas infrastructure. Saudi Arabia has championed the Global Methane Initiative to reduce fugitive methane emissions.[41]

The Saudi COP 22 brief also argues that fossil fuels should be retained in a future energy mix due to their synergies with renewables. The kingdom sees CO_2 emissions as a "harmful side effect" that can be mitigated with technological solutions.[42] In 2014, Saudi Aramco joined the Oil and Gas Climate Initiative, a group of 11 major oil companies each pledging $100 million for research into low-emissions fossil fuel technology.

RENEWABLES AND NUCLEAR POWER

The Saudi climate approach also leans on aspirations for replacing oil-fired power generation with zero-carbon renewable and nuclear electricity generation within the kingdom. There are strong economic rationales for policies that push oil out of the Saudi power generation sector, given oil's international market value and the very low cost of solar power in a country with world-leading insolation and vast tracts of empty land. But, as of mid-2018, neither nuclear nor renewable generation had an appreciable presence in the kingdom. In 2017, Saudi Arabia produced just 0.04% of its electricity – 135 gigawatt-hours of a total of nearly 376,000 GWhs – from solar means, the only non-hydrocarbon source of electricity currently online in the country.[43] Instead, a rising share of the Saudi power market was being claimed by natural gas. (Table 3)

Table 3: Power generation by source in Saudi Arabia. (Source: ECRA 2017, BP 2018)

KSA Power Generation 2017	
Natural gas	59%
Oil-based fuels	41%
Renewables (solar)	0.04%

SOCIAL LICENSE TO OPERATE

In the coming years, the kingdom and Saudi Aramco appear likely to highlight these efforts, as well as the low carbon-intensity of its crude, lack of flaring and fugitive methane, and its investments in high-efficiency engines to claim credentials as an "environmentally responsible" supplier of necessary fossil fuels. The business associations it has supported around these issues may in future set minimum compliance standards and issue "green" certifications or endorsements for fuels that meet standards.

[41] Global Methane Initiative, "Partner Countries: Saudi Arabia." (undated) https://www.globalmethane.org/partners/country.aspx?country=saudiarabia
[42] Ministry of Energy, Industry & Mineral Resources of Saudi Arabia, "Saudi Arabia Takes Its Place as Global Citizen at COP 22."
[43] BP, "Statistical Review of World Energy 2018."

Oil's lack of substitutes in the transportation sector, particularly the aviation market, means that these sectors are unlikely to be decarbonized for decades. Oil-based fuels will be necessary far into a climate-constrained energy future. Attention will necessarily turn to the GHG footprints of the various grades of crude in the global oil supply. Suppliers which minimize CO_2 and GHG emissions from their upstream, midstream and downstream supply chains will gain competitive advantage, allowing consumers, refiners and importing states to differentiate among "clean" and "dirty" oil-based fuels.

Saudi Arabia is positioning itself to present a strong case as a "climate friendly" fuel supplier. As such, the social acceptability of Saudi crude oil is more than a "Join In" climate action strategy. It also becomes a "Dig In" strategy, since it might also extend the longevity of Saudi supply in the global oil market—and the social stability in a kingdom where politics are structured around oil rents.

STRATEGY No. 3 "THROW IN" AND ACCEPT CLIMATE DAMAGE

Finally, there is the "Throw In" strategy, a collective approach whereby producer governments lobby for a relaxation of the atmospheric GHG accumulation limit of 450 parts per million of CO_2 equivalent. This is the maximum GHG concentration associated with limiting the global average temperature increase to 2°C, which forms the basis for the Paris agreement.

As an alternative, fossil fuel producers, scholars and others have been developing a relaxed climate strategy they describe as a more "pragmatic" path toward de-carbonizing global energy systems. The strategy amounts to a concession (i.e. "throwing in the towel") that costs of compliance with 2°C emissions limits are unreasonably high and unattainable. Instead, more climate damage would be preferable to the economic disruption implied by thoroughgoing and rapid decarbonization.[44]

Among the institutions developing the strategy are Saudi Arabia's Ministry of Energy, Industry and Mineral Resources; Japan's Ministry of Economy, Trade and Industry; as well as the U.S. Chamber of Commerce, the European Union and African Union, and academics from think tanks and universities. At the time of writing, no official document had been released.[45]

The "pragmatic" climate strategy stresses the deficiencies of fossil fuel substitutes and how these energy sources have failed to gain traction in the developing world, where power demand growth continues to be met by energy-dense and low-cost fossil fuels, mainly coal. The narrative points out that climate policy must become cost-competitive for developing countries

[44] These strategies are outlined in Samantha Gross and Yuhji Matsuo, "Towards More Pragmatic Global Climate Goals and Policies," scholarly paper (Riyadh: KAPSARC, October 2017), http://eneken.ieej.or.jp/data/7608.pdf. Also see slides 17-20 in: Yukari Yamashita, "Climate Change and Economic Growth in Asia: What Are Realistic Goals?" (Powerpoint presentation, March 16, 2017), https://www.bakerinstitute.org/media/files/files/0587096b/Pragmatic_Approach_Baker_Institute_yamashita.pdf.

[45] In the interest of full disclosure, the author declares his involvement in the process

to adopt it and meet their economic aspirations, and that market mechanisms are needed to motivate advances in technology. It argues that renewables and electric vehicles are hampered by disadvantages around price, energy density and intermittency. Therefore, tradeoffs are needed among the three categories of climate spending:

- **Adaptation**: Investments and engineering techniques that reduce exposure to geographic and climactic changes;
- **Mitigation**: Reducing emissions including by reducing fossil fuel use;
- **Damage**: Economic losses from climate change.

Most of the tradeoffs lie in the mitigation-versus-damage balance. If strict mitigation measures are imposed before substitute technology is mature, the costs of mitigation could outweigh the costs of damage and adaptation, resulting in a larger-than-optimal expense. In Figure 6 below, Path 3 represents an "unbalanced" climate policy dominated by mitigation.

However, the pragmatists' "optimum" path (Path 2 in Fig. 6), which minimizes total cost, provides insufficient decarbonization to meet the 2°C carbon target. Average warming might reach 3°C and bring increased climate damage. But damage costs would—proponents argue—be more than offset by reductions in spending on mitigation. This finding also implies less harm to fossil fuel producers and to developing economies seeking low-cost energy services.

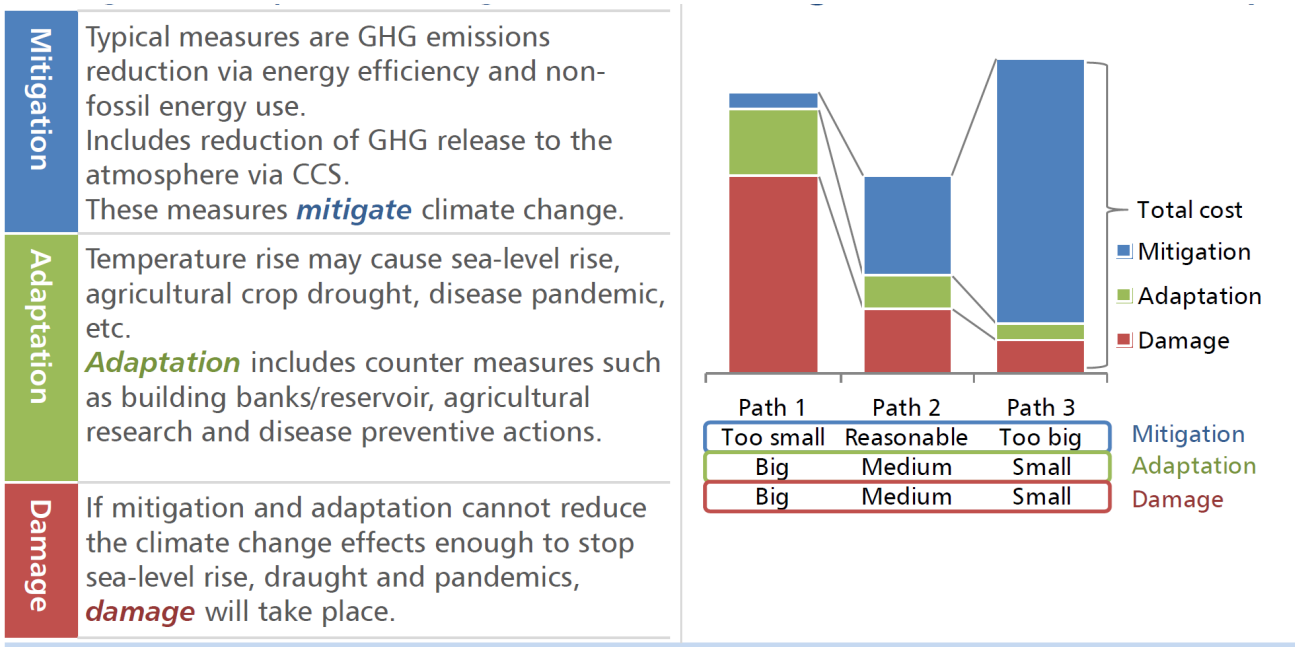

Figure 6: Comparison of cost paths with varying levels of spending on mitigation, adaptation and damage (Source: Institute for Energy Economics, Japan)

These raw estimates raise questions in regards to their accounting methods, which are based on modeling carbon taxes required to bring about sufficient reductions in demand. A very

rough comparison of *actual* climate mitigation and damage costs highlights potential weaknesses in the assumptions used. For instance, between 1980 and 2018, the United States sustained some $1.5 trillion in damage from 219 weather and climate disasters.[46] The portion of those damages attributed to climate change is unknown. By contrast, the US government spent a tenth of that amount, less than $150 billion, between 1993 and 2014 (a shorter period) on climate research, technology and assistance.[47]

More specifically, in 2017, the United States experienced a record $306 billion in damages from weather and climate disasters. (Fig. 7) That amount is five times the 2017 revenues of Saudi Aramco[48] and more than 70% of OPEC's 2016 oil export revenues.[49] If anthropogenic climate factors were responsible for 20% of the damage—due to intensified drought-induced wildfires and flooding from extreme rainfall—paying for that portion alone would require Saudi Aramco's *entire* 2017 revenues. Of course, 20% may be too large an estimate of the anthropogenic role, but the damages tallied are also incomplete and do not account for heat-related mortality, decreased crop yield, increased electricity demand, and other factors such as negative feedback loops from shrinking snow and ice cover, or methane releases from thawing permafrost.[50] (Fig. 8)

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[46] Adam B. Smith "2017 U.S. billion-dollar weather and climate disasters: a historic year in context," Climate.gov; Jan. 8, 2018; https://www.climate.gov/news-features/blogs/beyond-data/2017-us-billion-dollar-weather-and-climate-disasters-historic-year

[47] "Climate Change Funding and Management," US Government Accountability Office, 2015; https://www.gao.gov/key_issues/climate_change_funding_management/issue_summary

[48] The Saudi Aramco revenues estimate comes from a rough doubling of Saudi Aramco reported revenues of $33.8 billion in the first half of 2017. See: "The Aramco Accounts: Inside the World's Most Profitable Company," Bloomberg News. April 13, 2018. (https://www.bloomberg.com/news/articles/2018-04-13/the-aramco-accounts-inside-the-world-s-most-profitable-company) The US climate-related weather damages come from: Adam B. Smith "2017 U.S. billion-dollar weather and climate disasters: a historic year in context," Climate.gov; Jan. 8, 2018. (https://www.climate.gov/news-features/blogs/beyond-data/2017-us-billion-dollar-weather-and-climate-disasters-historic-year)

[49] The 13 OPEC member states earned a combined $433 billion in 2016. "OPEC Revenues Fact Sheet," US Energy Information Administration, May 15, 2017. https://www.eia.gov/beta/international/regions-topics.php?RegionTopicID=OPEC

[50] It is worth adding that no amount of mitigation spending in 2017 would have affected climate change-related disasters in 2017. Results could only be expected in future years. Effective mitigation requires GHG reductions outside the United States as well. Further, the future "payoff" in tempering climate change could be difficult to measure given natural climate variability, making current spending justifications difficult.

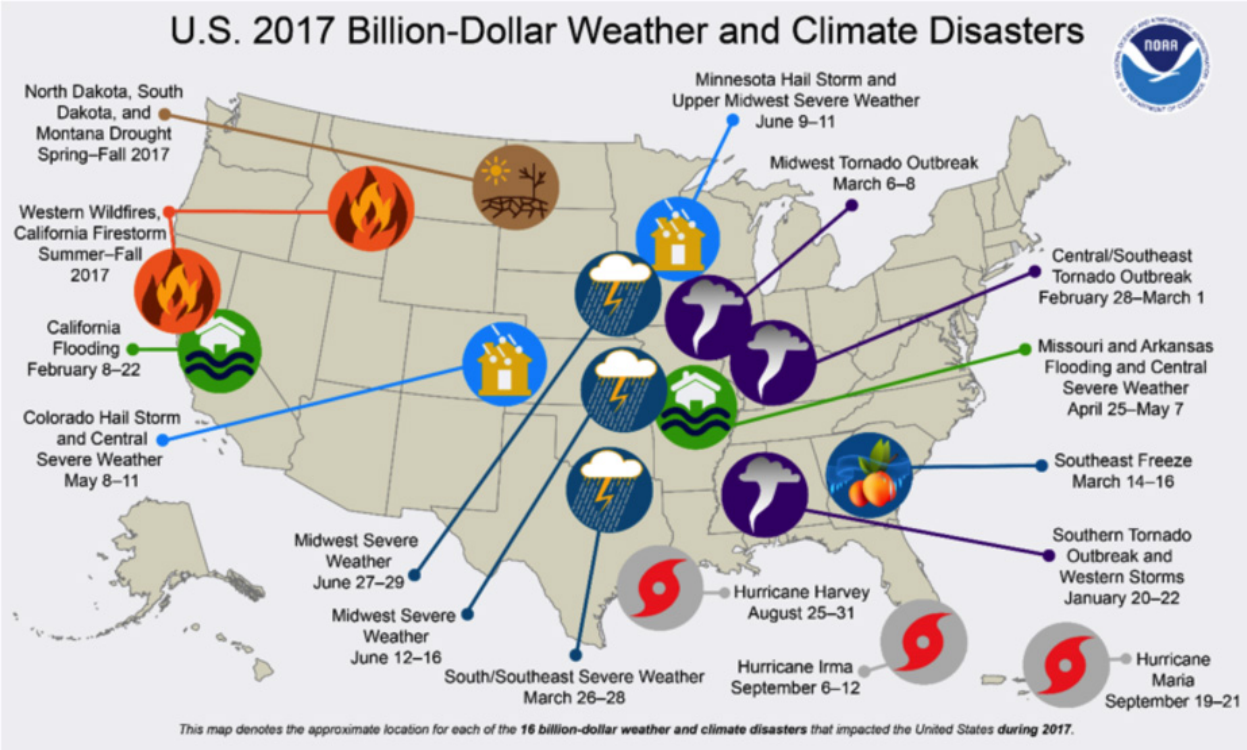

Figure 7: Source: National Oceanic and Atmospheric Administration 2018 https://www.climate.gov/sites/default/files/2017-disasters_map_lrg.jpg

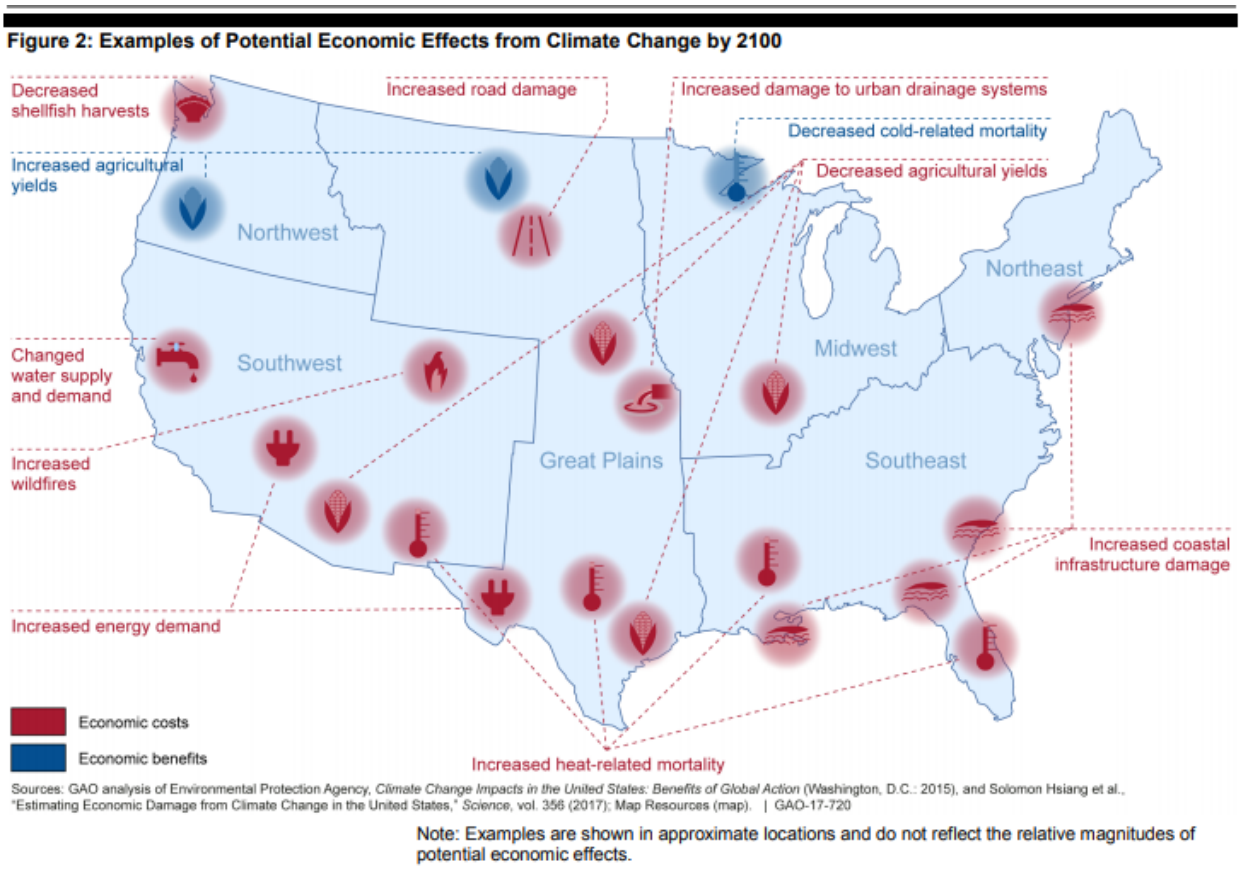

Figure 8: Source: "Climate Change: Information on Potential Economic Effects Could Help Guide Federal Efforts to Reduce Fiscal Exposure," US Government Accountability Office, Sept. 2017; https://www.gao.gov/assets/690/687466.pdf

In summary, the "throw in" strategy revolves around speculation that humanity will be better off by delaying strict mitigation because improved technology will emerge in the future and reduce GHG emissions without terminating the fossil fuel industry. Given that such technologies have neither been demonstrated nor deployed, the "throw in" strategy may be described as a multilateral version of Saudi Arabia's prior obstructionism approach.

CONCLUSION: A FOURTH STRATEGY

The three strategy types above outline near-term practices producer states might adopt to coexist with climate action, seeking not just to survive, but to recast their businesses in ways that provide competitive advantages.

Despite the increasing climate consciousness in Saudi Arabia and its improved relations with the global climate regime, some of the strategies outlined here are best described as *alterations* in the manner in which fossil fuels harm the Earth's climate, geography, inhabitants and their property. While improvements in upstream production techniques can assist at the margins, it is worth noting that the fossil fuel sector—oil, gas and coal—remains responsible for two-thirds of the ongoing GHG emissions that continue to accumulate in the atmosphere. To the extent

that strategies outlined here assist producers with marketing fuels that continue to be combusted in unabated fashion, they prolong damage to the Earth's climate, despite providing short-run economic benefits, particularly in developing countries.

A fourth strategy—briefly mentioned in the introduction—offers greater promise than the three above: Diversification beyond the oil and gas business. For companies, particularly shareholder-owned oil companies, diversification is part of the constant challenge of adjusting to evolving markets. When governments nationalized their oil concessions in the 1970s, the big Western oil companies created new opportunities elsewhere. Climate action is hastening the next major shift in the energy business.

For producer countries, nonoil diversification also makes sense. The more prudent of these states have actively begun creating new economic sectors that complement and eventually can replace those facing the risk of climate action. Ironically, a robust fossil fuel export sector is useful in funding investments aimed at diversifying away from fossil fuels. Some oil producers have taken steps in this direction. The United Arab Emirates—and Dubai in particular—have built diversified economies that are already unwinding lopsided dependence on oil exports and prices. Saudi Arabia has announced a similar effort. Structural barriers in the GCC labor markets add complexity to diversification.

Regardless, the oil market appears likely to grow more competitive as demand shifts into reverse in the OECD, and developing Asia becomes the main growth focus. How oil producing countries adapt in the long run remains in question.

A more chaotic oil market could be one result. Producers might seek a more bilateral route to marketing of oil, pairing with importers in an environment of enhanced competition. Hydrocarbon states which cannot compete may find themselves sidelined—either for geological (cost) reasons or above-ground political/institutional deficiencies, or even importer embargo.

Alternatively, producer countries could pursue a more cooperative path. Here, one might envision an enhanced role for OPEC in allocating producers with equitable shares of a shrinking global oil market in the best interests of exporters and the global climate. If that happened, OPEC's organizing principle might shift. Rather than managing the price of oil, it might allot member countries a share of the market based not just on a member state's oil output capacity, but on the climate credentials of the oil it produced. The preparations outlined in Saudi Arabia, the world's low-cost oil producer, would seem to place it in a strong position in either scenario.

BIBLIOGRAPHY

Aissaoui, Ali. "Saudi Arabia's Economic Diversification: Progress in the Context of the GCC and Challenges." In *Resources Blessed: Diversification and the Gulf Development Model*, edited by Giacomo Luciani, 1–24. Berlin: Gerlach Press, 2012.

Albassam, Bassam A. "Economic Diversification in Saudi Arabia: Myth or Reality?" *Resources Policy* 44 (2015): 112–17.

BP. "Statistical Review of World Energy 2018." Statistical report. London: BP, June 2018. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html.

Callen, Tim, Reda Cherif, Fuad Hasanov, Amgad Hegazy, and Padamja Khandelwal. *Economic Diversification in the GCC: Past, Present, and Future*. International Monetary Fund, 2014.

Dale, Spencer, and Bassam Fattouh. "Peak Oil Demand and Long-Run Oil Prices." Academic paper. Oxford: Oxford Institute for Energy Studies, January 2018. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/01/Peak-Oil-Demand-and-Long-Run-Oil-Prices-Insight-25.pdf.

Depledge, Joanna. "Striving for No: Saudi Arabia in the Climate Change Regime." *Global Environmental Politics* 8, no. 4 (2008): 9–35.

EDGAR. "Fossil CO2 & GHG Emissions of All World Countries, 2017." European Commission science database. Brussels: Emissions Database for Global Atmospheric Research, 2017. http://edgar.jrc.ec.europa.eu/overview.php?v=CO2andGHG1970-2016.

Golombek, Rolf, Alfonso A. Irarrazabal, and Lin Ma. "OPEC's Market Power: An Empirical Dominant Firm Model for the Oil Market." *Energy Economics* 70 (2018): 98–115. https://doi.org/10.1016/j.eneco.2017.11.009.

Gross, Samantha, and Yuhji Matsuo. "Towards More Pragmatic Global Climate Goals and Policies." Scholarly paper. Riyadh: KAPSARC, October 2017. http://eneken.ieej.or.jp/data/7608.pdf.

Heede, Richard. "Tracing Anthropogenic Carbon Dioxide and Methane Emissions to Fossil Fuel and Cement Producers, 1854–2010." *Climatic Change* 122, no. 1–2 (2014): 229–41.

Hvidt, Martin. "Economic Diversification in GCC Countries: Past Record and Future Trends." *Research Paper*, Kuwait Programme series, 2013.

Krane, Jim. "A Refined Approach: Saudi Arabia Moves beyond Crude." *Energy Policy* 82 (2015): 99–104.

———. "Rationalizing Energy Demand through End-User Prices in the GCC." *Oxford Energy Forum*, no. 102 (November 2015).

———. "Stability versus Sustainability: Energy Policy in the Gulf Monarchies." PhD dissertation, University of Cambridge, 2014. http://dx.doi.org/10.17863/CAM.5943.

Lattanzio, Richard K. "Canadian Oil Sands: Life-Cycle Assessments of Greenhouse Gas Emissions." US Government report. Washington: Congressional Research Service, March 10, 2014. https://fas.org/sgp/crs/misc/R42537.pdf.

Luciani, Giacomo. "Resources Blessed: Diversification and the Gulf Development Model." In *The Gulf Region: Economic Development and Diversification*, edited by Giacomo Luciani, Steffen Hertog, Eckart Woertz, and Richard Youngs. Berlin: Gerlach Press, 2012.

Masnadi, Mohammad S, Hassan M El-Houjeiri, Dominik Schunack, Yunpo Li, Samori O Roberts, Steven Przesmitzki, Adam R Brandt, and Michael Wang. "Well-to-Refinery Emissions and Net-Energy Analysis of China's Crude-Oil Supply." *Nature Energy* 3, no. 3 (2018): 220.

Mayer, Benoit, and Mikko Rajavuori. "National Fossil Fuel Companies and Climate Change Mitigation under International Law." *Syracuse J. Int'l L. & Com.* 44 (2016): 55.

Ministry of Energy, Industry & Mineral Resources of Saudi Arabia. "Saudi Arabia Takes Its Place as Global Citizen at COP 22." Government press release. Riyadh: Ministry of Energy, Industry & Mineral Resources of Saudi Arabia, 2017. https://docs.wixstatic.com/ugd/bc5fc9_455265c3bb8a41db987af3d3f72308cc.pdf.

Pal, Jeremy S., and Elfatih A. B. Eltahir. "Future Temperature in Southwest Asia Projected to Exceed a Threshold for Human Adaptability." *Nature Clim. Change* 6, no. 2 (February 2016): 197–200.

Sen, Anupama, and Bassam Fattouh. "Economic Diversification in the MENA in the Context of Peak Oil and the Energy Transition." In *Workshop on Sustainability in the GCC*. University of Cambridge, UK, 2018.

Smith, James B. "WHAT CONCERNS SAUDI ARABIA ABOUT THE FUTURE OF ENERGY AND CLIMATE CHANGE." Diplomatic cable. Riyadh: US State Department via WikiLeaks, February 21, 2010.

Van de Graaf, Thijs. "Battling for a Shrinking Market: Oil Producers, the Renewables Revolution, and the Risk of Stranded Assets." In *The Geopolitics of Renewables*, 97–121. Springer, 2018.

Van de Graaf, Thijs, and Aviel Verbruggen. "Saving OPEC: How Oil Producers Can Counteract the Global Decline in Demand." *Foreign Affairs*, December 22, 2014. https://www.foreignaffairs.com/articles/persian-gulf/2014-12-22/saving-opec.

———. "The Oil Endgame: Strategies of Oil Exporters in a Carbon-Constrained World." *Environmental Science & Policy* 54 (2015): 456–62.

Yamashita, Yukari. "Climate Change and Economic Growth in Asia: What Are Realistic Goals?" Powerpoint presentation presented at the Energy Security in Asia-Pacific: Current Trends and Future Developments, Baker Institute, Houston, March 16, 2017. https://www.bakerinstitute.org/media/files/files/0587096b/Pragmatic_Approach_Baker_Institute_yamashita.pdf.