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King Abdullah Petroleum Studies and Research Center

Commentary

Measuring to Manage: The Case for Improving CO_2 Monitoring and Reporting in Saudi Arabia

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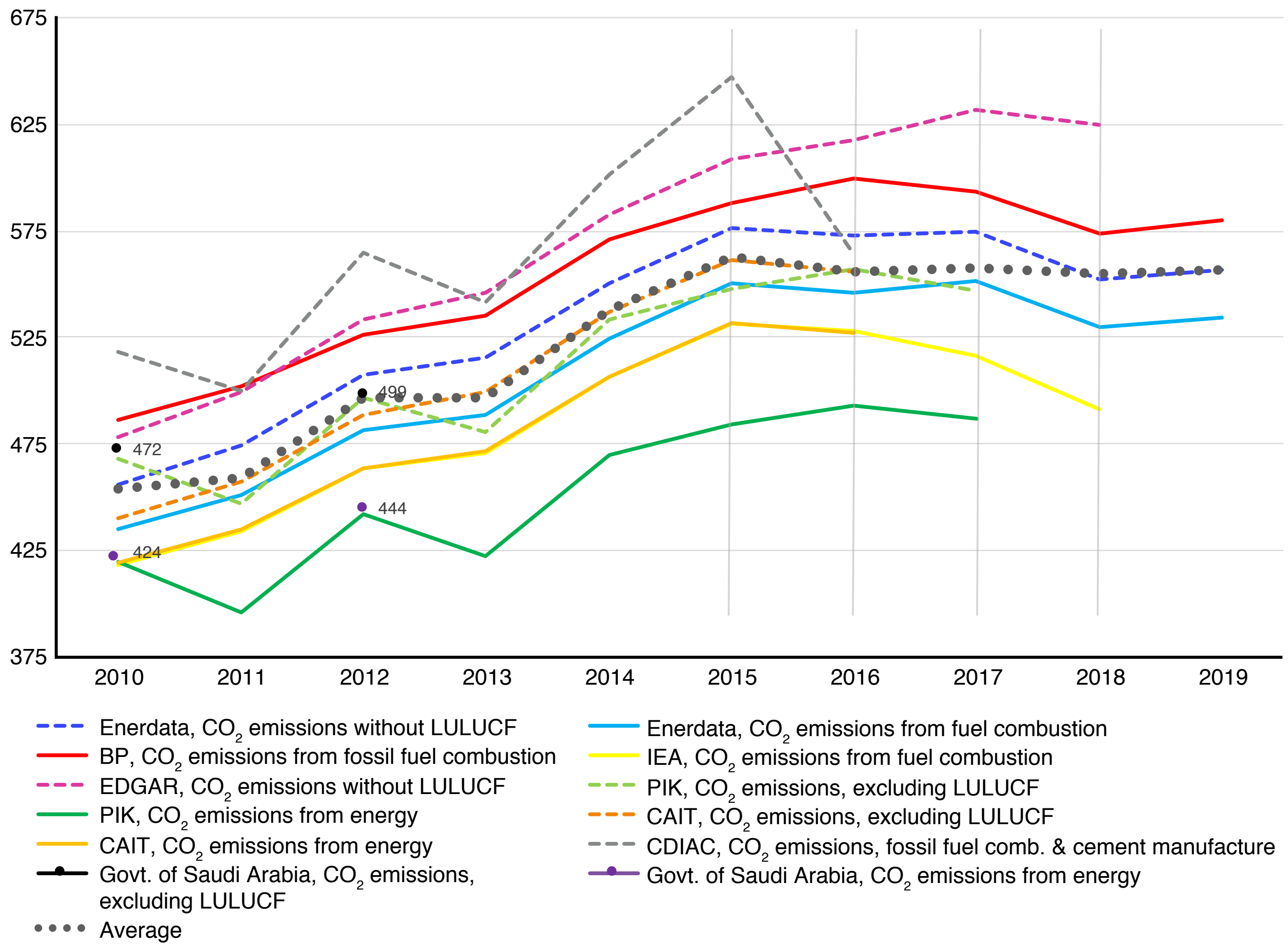
Robust domestic greenhouse gas monitoring and reporting systems can support domestic policymaking and help with gaining international recognition for Saudi Arabia's emissions management efforts.

What is the issue, and why is it important?

To support the transition to a circular carbon economy, there is an urgent need to develop robust domestic systems of carbon dioxide (CO_2) and greenhouse gas emissions (GHG) monitoring and reporting in the Kingdom. Such systems provide the essential evidence base for domestic climate policymaking. Developing them will also be crucial in helping Saudi Arabia achieve its reporting commitments under the Paris Agreement on climate change from 2024 onward and gain international recognition for its CO_2 mitigation efforts.

Carbon dioxide is the most abundant human-made GHG, which accounts for three quarters of global GHG emissions and an estimated 80% of Saudi Arabia's total GHG emissions, in CO_2 equivalent (Climate Watch 2020). Since 2016, Saudi Arabia's CO_2 emissions have stabilized after decades of rapid growth, which is a positive development. However, differences between data providers make it difficult to present clear evidence to policymakers, the public and the international community (Figure 1). These differences are quite common and arise because data providers use different sources, methodologies and assumptions (Appendices 1 and 2). For Saudi Arabia, the situation is made more challenging as it has not published regular, up-to-date official emissions inventories. The most recent report was published in 2018 and provides data only until 2012.

Figure 1. Estimates of Saudi Arabia's CO_2 emissions for 2010-2019.



Source: Authors, based on the databases described in Appendix 1. All data were retrieved from October to November 2020.
LULUCF refers to emissions from land use, land-use change and forestry.

Specifically, the two major emissions data-related challenges facing Saudi Arabia are as follows:

1. Lack of regularly published, official national GHG inventories

Many countries, including Saudi Arabia, do not publish annual or otherwise regular national GHG inventories (see Appendix 3). Saudi Arabia, for example, has developed and submitted four GHG inventories to the United Nations Framework Convention on Climate Change (UNFCCC). These inventories, for the years 1990, 2000, 2010 and 2012, were submitted between 2005 and 2018. This submission frequency is in line with the current general practice under the UNFCCC. However, more regular, up-to-date and detailed reporting will be needed to inform policymaking and fulfil international obligations under the Paris Agreement. From 2024 onward, in line with the Paris Agreement's Enhanced Transparency Framework, all parties are expected to submit a biennial transparency report every two years and a national communication containing an emissions inventory every four years (UNFCCC Secretariat 2020).

Saudi Arabia's latest emissions inventory is for the year 2012. More regular, up-to-date and detailed reporting will be needed to fulfil international obligations.

2. Differences in CO_2 and GHG emissions estimates from public and commercial data providers

Major international data providers' emissions estimates vary for most countries, including Saudi Arabia. These providers use different sources, methodologies and assumptions when constructing their CO_2 and energy balances. A related challenge is that some data providers only publish estimates after several years' delay. For example, as of December 2020, many major sources supplied data only through 2016. The International Energy Agency's (IEA) most recent data available to researchers on Saudi Arabia was for 2018. Detailed CO_2 emissions estimates for 2019 were only available via Enerdata, a subscription service. BP and the Emissions Database for Global Atmospheric Research (EDGAR) also provided less detailed 2019 data.

The lack of reliable data at a granular level can undermine the evidence base for policy planning. As observed by management scholar Peter Drucker (1954), only what gets measured, gets managed. As Saudi Arabia embarks on its Circular Carbon Economy National Program, understanding the drivers of past and current emissions trends will be crucial to help inform available policy options and possible future trajectories.

This KAPSARC Commentary makes the case for strengthened emissions monitoring and reporting in Saudi Arabia to support both data-driven domestic emissions management and international trust-building around the Kingdom's contribution to the Paris Agreement.

To illustrate related issues and make the case for improved emissions tracking systems, this commentary examines publicly available CO_2 emissions data for 2010-2019 in three areas of emissions accounting: aggregate, sectoral and fuel-specific CO_2 emissions. It highlights how differences in data providers' estimates can influence analyses of emissions trends and future projections, which, in turn, can lead to very different conclusions for policymaking. The commentary concludes with suggestions on what is needed to improve dialogue, data sharing and institutional capacity around Saudi Arabia's CO_2 and GHG reporting to support its circular carbon economy policies.

Analysis of available CO_2 data and related challenges

Based on its UNFCCC inventories, Saudi Arabia's total GHG emissions were 525 megatonnes of CO_2 equivalent ($MtCO_2e$) in 2010 and 548 $MtCO_2e$ in 2012.[1] In the 2012 inventory, CO_2 accounted for 91% of the reported GHG emissions, with methane and nitrous oxide comprising the remainder. This data is produced domestically by Saudi Arabia. Few international sources provide estimates of countries' total GHG emissions. The Potsdam Institute for Climate Impact Research (PIK) and the World Resources Institute's Climate Analysis Indicators Tool (CAIT) are among the best known. Most other data providers focus on CO_2 emissions, especially from fuel combustion, which are easier to estimate at a greater frequency.

These data are usually expressed at an aggregate level. They may include both combustion and non-combustion emissions (i.e., industrial process-related CO_2 emissions). Data may be reported at the sector level (e.g., industry, transport, power or households) and by fuel type (e.g., oil, gas or coal).

In addition, land use, land use change and forestry (LULUCF) are important CO_2 sources and sinks. Many different accounting approaches are applied to these emissions, which can lead to different estimates (see e.g., Krug [2018]). Natural sinks have a relatively minor role in Saudi Arabia's emissions profile; the UNFCCC 2012 inventory estimates land and forestry sinks to be -9 $MtCO_2$. Appendix 1 provides descriptions of key datasets.

Importantly, the scope of CO_2 data coverage varies across providers. Some report total CO_2 emissions, whereas others report CO_2 emissions from fossil fuel combustion, which is a narrower category. Others estimate only CO_2 emissions from the energy sector, an even narrower category. Providers also regularly make updates to improve the accuracy of data as new information is revealed. For example, this commentary uses data retrieved from Enerdata in October 2020. In December 2020, Enerdata revised its estimates of Saudi Arabia's CO_2 emissions in 2017-2019 downward.

Aggregate CO_2 emissions

Aggregate emissions data are particularly useful for studying trends over time and comparing countries. These data can vary significantly depending on the data provider. Nevertheless, some broad observations about Saudi Arabia can be drawn by comparing 10 CO_2 emissions datasets from seven providers spanning 2010-2019 (Figure 1):

- The data providers concur that Saudi Arabia's CO_2 emissions stabilized in 2016-2017 and significantly declined in 2017-2018.

- In absolute terms, the data differ significantly across providers. In 2016, the latest year for which data are available from all providers, the highest and lowest total CO_2 emissions estimates differ by 61 megatonnes (Mt). EDGAR's estimate is 11% higher than CAIT's. BP's estimate of energy-related CO_2 emissions is 14% higher than the IEA's. This variation among the different sources has remained consistent

[1] These totals exclude changes in land use and forestry. The inventories include CO_2, methane and nitrous oxide emissions but not hydrofluorocarbons, perfluorocarbons or sulfur hexafluoride.

since at least 1990 (the first year for which data for all datasets are available). The magnitudes and directions of changes in CO_2 emissions are also usually consistent, which points to the differences originating from the providers' sources and methodologies.

- PIK's estimates of total and energy sector CO_2 emissions largely align with Saudi Arabia's 2010 and 2012 inventories. PIK's PRIMAP-hist dataset uses countries' official inventories reported to the UNFCCC whenever they are available.

Similar differences are revealed by a comparison between estimates made by different providers for the same years for three UNFCCC Annex I (developed) and two other non-Annex I (developing) countries — Norway, Singapore, the United Arab Emirates, United Kingdom and United States (see Appendix 2). Overall, no patterns emerge to indicate that one data provider's estimates would be more accurate than others'. Furthermore, estimates by international providers vary even for countries that report regularly and have more stringent UNFCCC reporting requirements (i.e., Norway, the United Kingdom and the United States). This finding underscores the need for robust domestic data to guide policymaking.

Sectoral CO_2 emissions

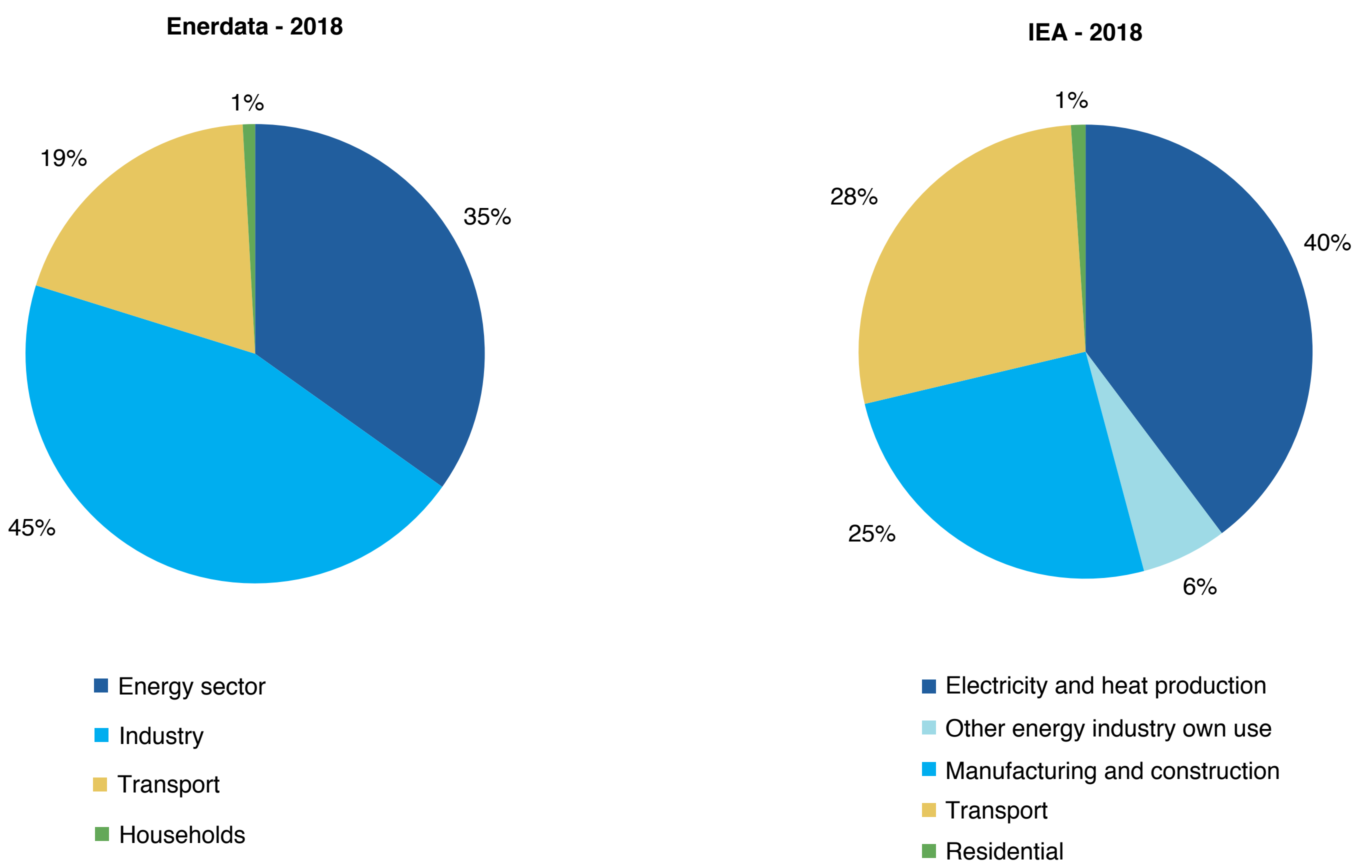
Sector-based emissions data describe CO_2 emissions from the economy's main energy-consuming sectors, such as electricity generation, industry (including petrochemicals, steel and cement), transport and households. It is also possible to attribute emissions from electricity to end-use sectors (e.g., commercial, residential and industrial uses). However, these types of analyses typically examine power sector emissions as a whole. Thus, only direct emissions, such as those from natural gas combustion in cooking or heating, are grouped under households or the residential sector.

This section focuses on data for Saudi Arabia from Enerdata and the IEA (retrieved in October 2020). These providers offer relatively long-term and recent data with a good level of detail. Although both providers ultimately draw on the same energy input source material, differences are often apparent, especially for more recent years. Differences in the timing of updates and methodological assumptions drive this variation. For example, Enerdata's estimates of total CO_2 emissions from fuel combustion in 2018 are 8% higher than the IEA's estimates.

The two organizations also estimate the relative shares of emissions from each main sector significantly differently (Figure 2). These variations are largely due to differences in the categorizations of certain types of emissions. For example, Enerdata includes refining activities in the energy sector, whereas the IEA includes them in industry. Enerdata treats electricity generation by industrial autoproducers as part of industry, whereas the IEA includes it under electricity and heat production. Furthermore, as will be discussed below, differences with respect to transport-related emissions may be explained by assumptions regarding the ultimate consumers of diesel. In Saudi Arabia, diesel is used on a large scale for both transport and electricity generation.

Two major data providers estimate the relative shares of the energy, industry and transport sectors of total CO_2 emissions significantly differently.

Figure 2. Saudi Arabia's sectoral fuel combustion CO_2 emissions according to Enerdata and the IEA, 2018.

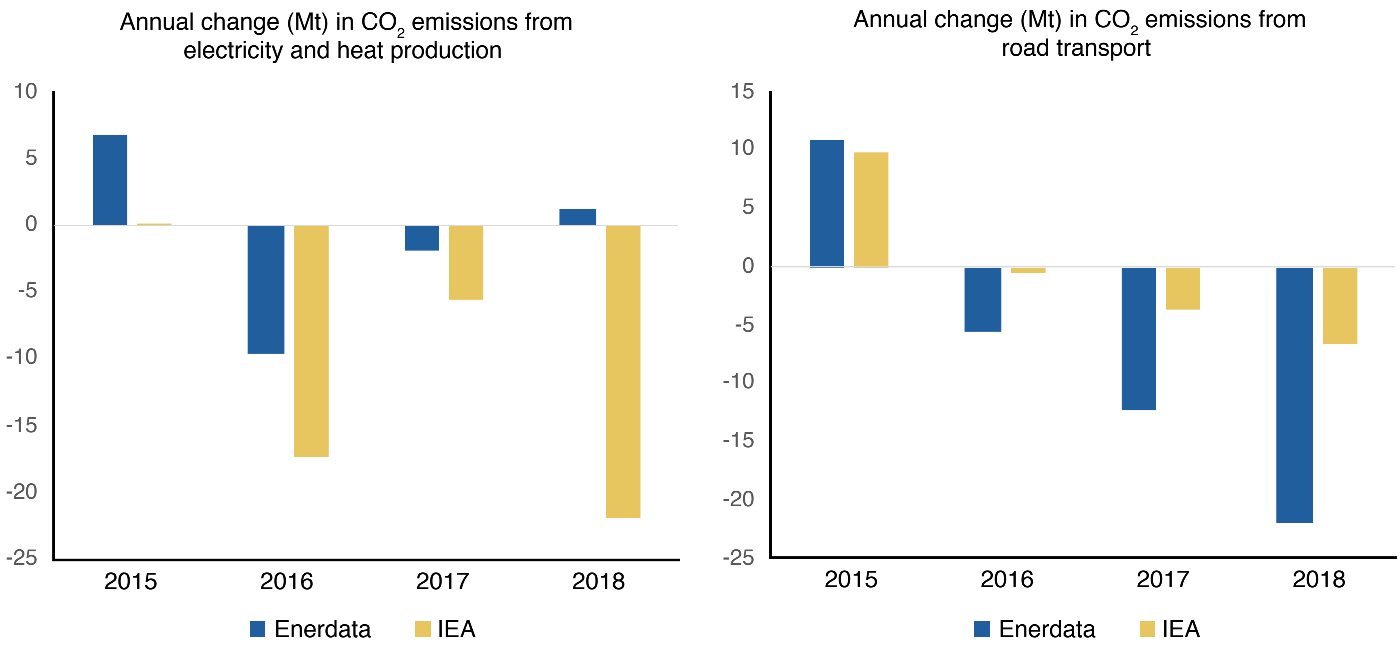


Source: Authors, based on Enerdata (2020) and IEA (2020a).

Additionally, Figure 3 illustrates some important differences in the estimates of changes in absolute sectoral emissions over time. First, for electricity and heat production (excluding autoproducers), IEA reports major emissions reductions in both 2016 (-17 Mt) and 2018 (-22 Mt). In contrast, Enerdata indicates a more moderate fall in 2016 (-10 Mt) and a small increase in 2018. Second, for road transport, the IEA shows a minor decrease in emissions in 2018 (-7 Mt). Enerdata, however, indicates major drops in both 2017 (-12 Mt) and 2018 (-22 Mt).

These discrepancies can be better understood by aggregating the absolute changes in the two sectors by provider and comparing them. When done so, the differences across the providers narrow to around 3-8 Mt per year for the period 2015-2018. This result suggests that the allocation of these emissions reductions across the transport and power generation sectors could explain the difference.

Figure 3. Annual changes in Saudi Arabia's CO_2 emissions from power generation and road transport, 2015-2018.



Source: Authors, based on Enerdata (2020) and IEA (2020a).

Fuel-specific CO_2 emissions

Many data providers also provide breakdowns of fossil fuel combustion-related CO_2 emissions by fuel type. This information is important for understanding the different dimensions of emissions changes, as different fuels have different CO_2 intensities. It can also shed light on the issue of the appropriate attribution of emissions across sectors, identified in the previous section. With this objective, this section examines CO_2 emissions from fuel use in the electricity and transport sectors. The major fuels used in Saudi Arabia are crude oil, natural gas, heavy fuel oil (HFO), diesel and gasoline.

Electricity (power) generation

Both the IEA and Enerdata suggest that natural gas use in the power sector has increased in recent years. According to the IEA, CO_2 emissions from oil combustion in the power sector fell by 66 Mt between 2015 and 2018. It attributes the decrease in oil combustion-related emissions to crude oil (-30 Mt), diesel (-27 Mt) and HFO (-9 Mt). The IEA also reports that emissions from natural gas increased by 22 Mt over the same period. In contrast, Enerdata reports that oil-related emissions in the power sector fell by only 13 Mt over the same period, whereas natural gas emissions increased by 3 Mt.

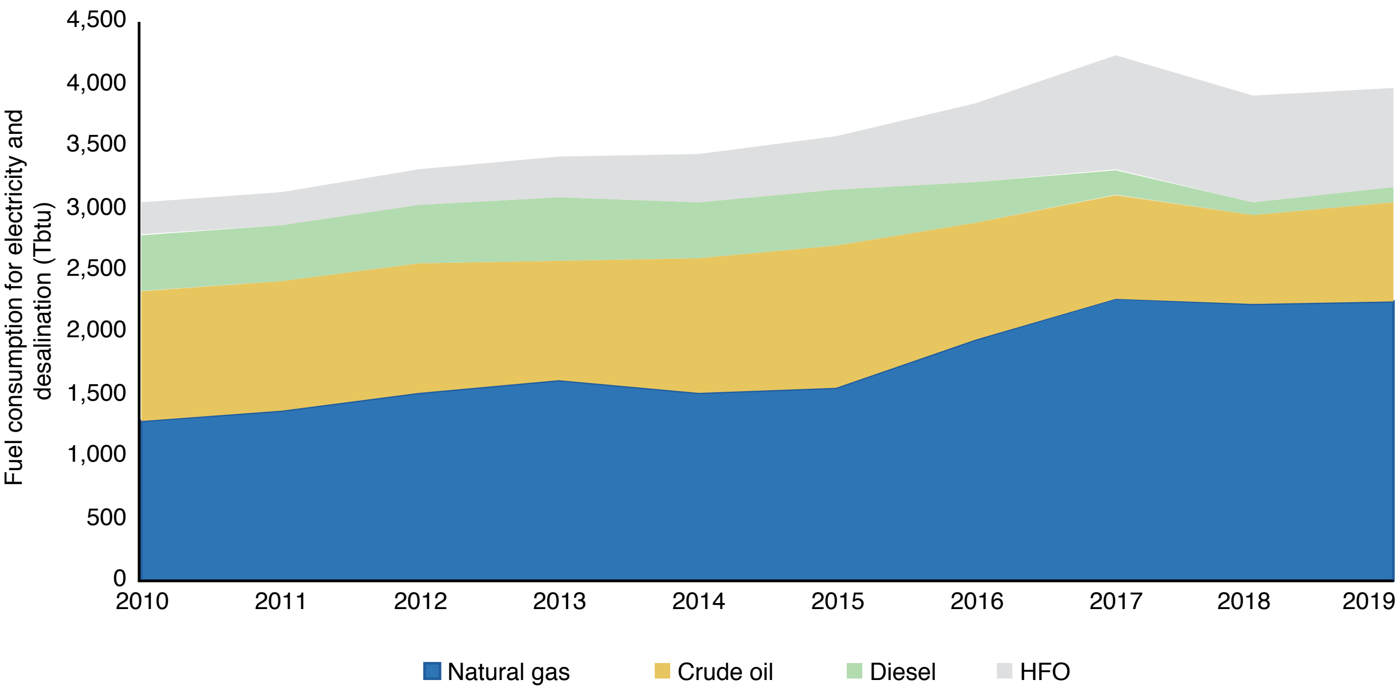
The two sources are more aligned regarding CO_2 emissions from autoproducers (i.e., industrial plants that produce their own electricity). According to the IEA, these emissions increased by 10 Mt between 2015 and 2018, driven by natural gas use (+14 Mt). Enerdata does not provide a breakdown of fuels used by autoproducers but estimates that their emissions increased by 13 Mt.

Saudi Arabia's Electricity and Cogeneration Regulatory Authority indicates a 97% increase in heavy fuel oil-related emissions in the power sector between 2015 and 2018, whereas the International Energy Agency suggests a 45% decline.

Data from Saudi Arabia's Electricity and Cogeneration Regulatory Authority (ECRA) also show significant switching from oil-based products to natural gas since 2015 (Figure 4). However, ECRA also suggests that HFO increased by 97% over the same period. In contrast, the IEA estimates a 45% decrease in HFO-related CO_2 emissions. More specifically, according to ECRA, the use of crude oil fell by 429 trillion British thermal units (Btu), or -38%, between 2015 and 2018. Diesel use fell by 343 trillion Btu, or -76%. Moreover, ECRA states that HFO consumption rose by 417 trillion Btu (+97%) and natural gas consumption by 670 trillion Btu (+43%). IEA data for the same period indicate decreases in crude oil (-45%) and diesel emissions (-77%) and an increase in natural gas-related CO_2 emissions (+60%). Thus, the IEA and ECRA find changes of approximately similar magnitudes for all fuel types except HFO.

This result suggests that the IEA may have allocated emissions related to HFO use to a different sector, such as industry. It may be used by autoproducers to generate electricity or to generate heat in industrial processes. Other data lend support to this hypothesis. For example, the IEA estimates that Saudi Arabia's HFO-related CO_2 emissions from manufacturing and construction increased by 26 Mt (+61%) between 2015 and 2018, partly replacing natural gas. Given the lack of domestic data on HFO or natural gas use in the industrial sector, however, it is difficult to draw conclusions with certainty.

Figure 4. Fuel use in power generation in Saudi Arabia, 2015-2019.



Source: Authors, based on ECRA (2016-2020).

The increase in HFO use in Saudi Arabia can be tied to the fall in global demand for high sulfur fuel oil (HSFO). Demand for HSFO fell ahead of the enforcement of the International Maritime Organization's (IMO) sulfur cap rule in 2020. The cap requires ships to use fuel oil with a maximum sulfur content of 0.5%, whereas HSFO has a sulfur content of 1%-3.5%. HFO surpassed crude oil as the primary oil-based fuel in the Saudi power sector in 2017. In 2018, Saudi Arabia became a net HFO importer (Shabaneh, Al Sadoon, and Al Mestneer 2019).

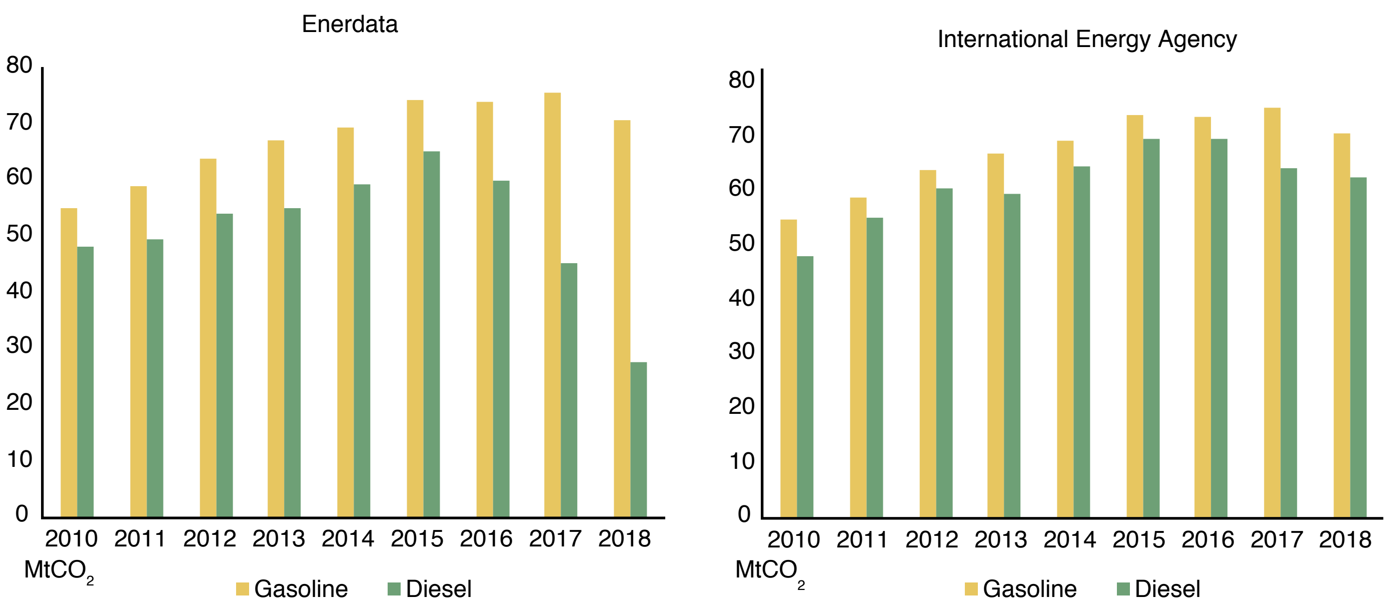
Data from the Joint Organisations Data Initiative (JODI) confirm that Saudi Arabia's total HFO use increased by 34% between 2015 and 2019. JODI's data are based on inputs from national authorities. Shabaneh, Al Sadoon, and Al Mestneer (2019) have noted that Saudi Arabia's HFO demand will continue to rise, with 7 gigawatts of HFO-fired power plants coming online in 2020 alone. They have suggested that Saudi Arabia could become one of the leading importers of HSFO displaced by the IMO regulation. Notably, HFO has the highest CO_2 content among all fossil fuels used in Saudi Arabia (IEA 2017).

Imports of high sulfur fuel oil displaced by international maritime emissions regulations could increase. This fuel has the highest CO_2 content among all fossil fuels used in Saudi Arabia.

Road transport

Enerdata and the IEA present significantly different estimates of fuel-specific CO_2 emissions in the road transport sector (see Figure 5). Enerdata suggests that these emissions fell by 40 Mt (-29%) between 2015 and 2018, driven by a large drop in diesel consumption (-37 Mt, -58%). The IEA, however, suggests that these emissions fell by only 11 Mt (-7%). It attributes this smaller decline to decreases in both diesel (-7.2 Mt) and gasoline (-3.5 Mt) consumption-related emissions.

Figure 5. Saudi Arabia's fuel-specific CO_2 emissions in road transport, 2010-2018.



Source: Authors, based on Enerdata (2020) and IEA (2020a).

Conclusions

In November 2020, King Salman bin Abdulaziz Al Saud announced the launch of Saudi Arabia's Circular Carbon Economy National Program, which will "consolidate and accelerate the current momentum toward sustainability and in a holistic manner" (G20 Saudi Arabia 2020). The circular carbon economy concept values all available emissions mitigation options across all sectors. Thus, it is intended to help countries manage their emissions holistically and promote more sustainable energy systems.

As Saudi Arabia continues to develop its Circular Carbon Economy National Program, measuring CO_2 and other GHG emissions becomes increasingly important.

As Saudi Arabia continues to develop this national program, measuring CO_2 and other GHG emissions becomes increasingly important. Circularity can only be achieved by managing all flows of carbon in the economy holistically, which requires full, detailed measurement. In other words, better emissions data enable more targeted and effective policy interventions.

The major fall in Saudi Arabia's 2018 emissions provides a useful example of where better data are needed. Although the fall was clearly caused by declining diesel consumption, the relative contributions of the power and transport sectors to the decline remain ambiguous. The relatively limited public data make detailed emissions analyses complicated. Thus, limited evidence is available to support policy discussions around energy consumption at the sectoral and sub-sectoral levels in Saudi Arabia. Understanding precisely where emissions are rising and falling is crucial for impactful policymaking.

In the power sector, an important issue that deserves greater attention is the current scaling up of HFO generation. Renewable energy and natural gas, along with continued energy efficiency improvements, are better substitutes for HFO in the electricity mix in terms of CO_2 emissions. Such an approach would also be closely aligned with the Kingdom's target of phasing down oil products in its power sector mix by 2030 (e.g., Shabaneh, Al Sadoon, and Al Mestneer [2019]).

In the transport sector, alternatives to oil products are still limited. Demand for electric vehicles is likely to grow more slowly in a fossil fuel-abundant country like Saudi Arabia than in many other countries. In the shorter term, the highest gains in terms of limiting emissions in transport will be achieved through end-use efficiency and other demand side-related measures. Such measures include vehicle fuel efficiency standards and alternatives to private vehicles, such as car sharing and public transport. Another option would be to promote the increased use of diesel fuel light-duty vehicles, which are more efficient than cars fueled by gasoline and, thus, emit less CO_2. Such a policy would create a shift from gasoline to diesel use, although the air quality issues associated with diesel use would need to be weighed in when considering this option.

Strengthened domestic emissions measurement, reporting and verification (MRV) systems allow countries to effectively measure their emissions and estimate related avoidance or reduction potential.

Overall, strengthening domestic emissions measurement, reporting and verification (MRV) capacity and systems provides many benefits. MRV systems allow countries to effectively measure their GHG emissions and estimate the potential emissions avoidance or reductions from projects and policies. They can help countries assess their possible support needs and the effectiveness of any support received (Kingdom of Saudi Arabia 2019). Robust MRV systems can also enable countries to publish more regular, high-quality emissions inventories and progress reports starting in 2024. In turn, these reports will support data-driven domestic emissions management and build trust around the implementation of the Paris Agreement.

Saudi Arabia's Designated National Authority (to the Kyoto Clean Development Mechanism) coordinates UNFCCC reporting efforts and the MRV of emissions. This authority operates under the supervision of the Minister of Energy. In recent years, it has been developing a domestic MRV system in coordination with a dedicated GHG inventory team and relevant domestic data providers, including ministries and other government agencies and industries. The government has highlighted several capacity-building priorities in this area. They include strengthening the capacity of the GHG inventory team and enhancing the capacity to track and quantify progress in mitigation (or "mitigation co-benefits of economic diversification") and adaptation (Kingdom of Saudi Arabia 2019).

Saudi Arabia, together with domestic data providers and knowledge partners, can take the following actions to improve its domestic GHG and CO_2 emissions MRV and management systems. These actions, which can also address many of the challenges identified in this commentary, are:

- **Dialogue:** Technical dialogues with international data providers may provide greater clarity on how country-specific estimates are created and where possible gaps exist. They can also be leveraged to build domestic capacity for emissions monitoring and reporting.

- **Data sharing:** International data providers' estimates will continue to be used as a basis for international comparisons and analyses. Periodically sharing national data with these providers may help improve the quality of their estimates.

- **Institutional capacity:** Saudi Arabia should continue to build domestic formal emissions monitoring and reporting capacity across the energy ecosystem and other key sectors. It can also draw from existing expertise in these institutions. Doing so could help generate up-to-date and more granular data for sectoral and aggregate inventories.

- **Knowledge development:** Regularly sharing up-to-date sectoral and fuel-based emissions data with domestic academic and research institutions may help in several ways. These institutions could support the development of accurate and more detailed analyses of emissions drivers and trends to support national energy and climate change policy planning and help design targeted policy interventions to manage emissions.

Together with an operational emissions MRV system, these measures can help provide an evidence base for operationalizing the circular carbon economy in the Kingdom and meeting its national goals under the Paris Agreement.

Engaging with international data providers, building institutional capacity, and enabling domestic knowledge partners to conduct emissions-related analysis can support the operationalization of the circular carbon economy in the Kingdom.

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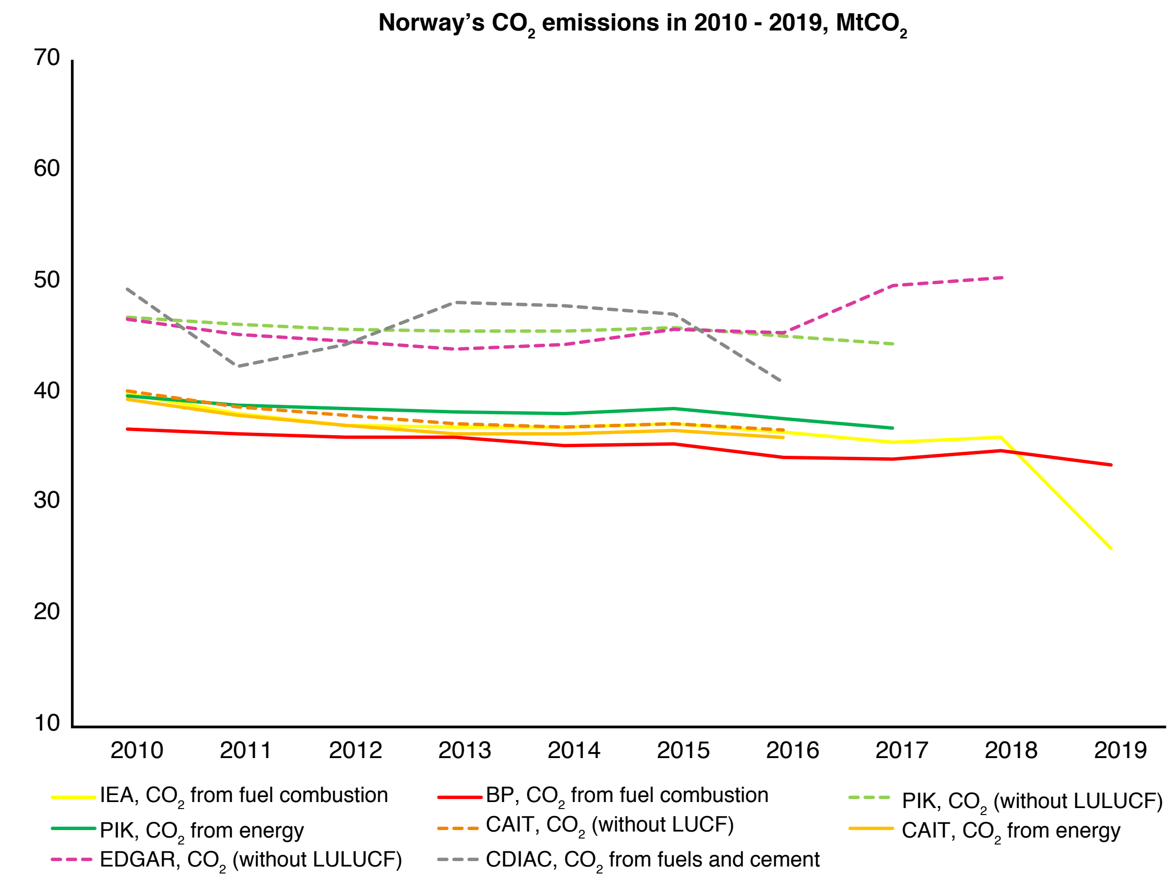
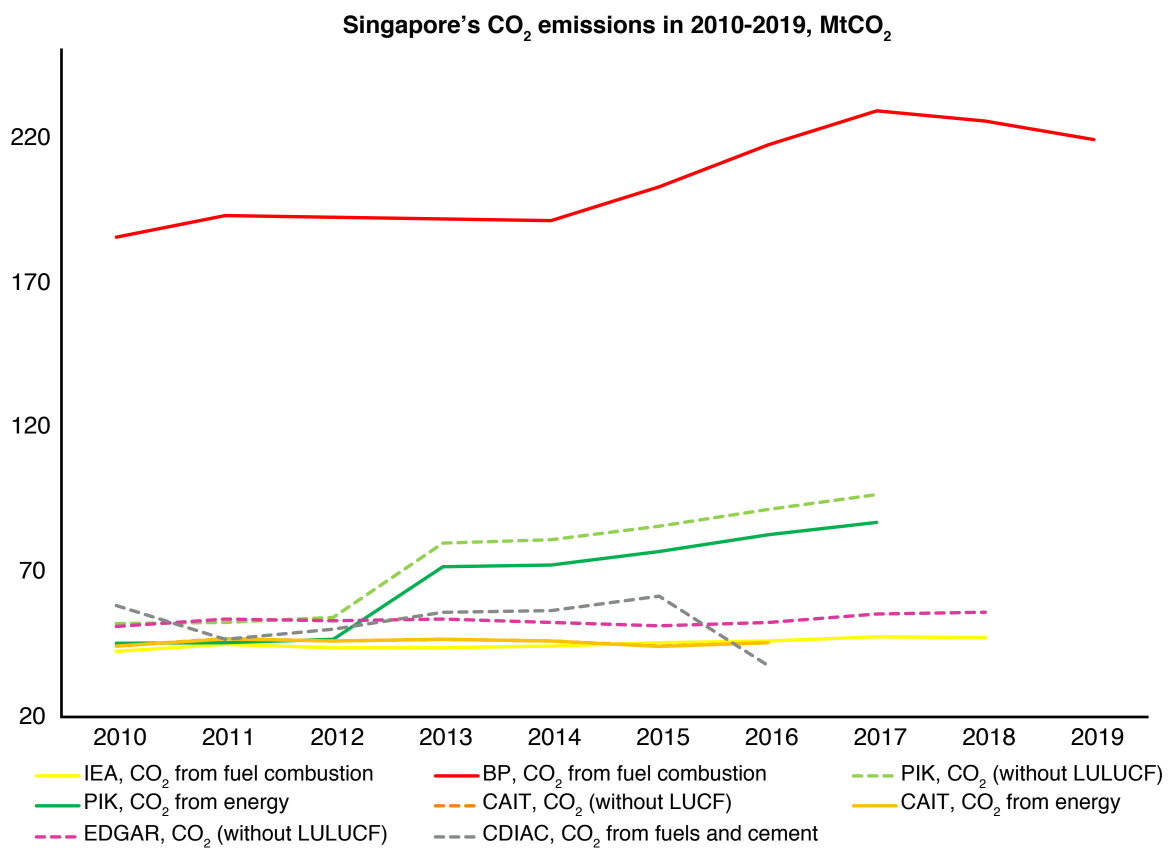
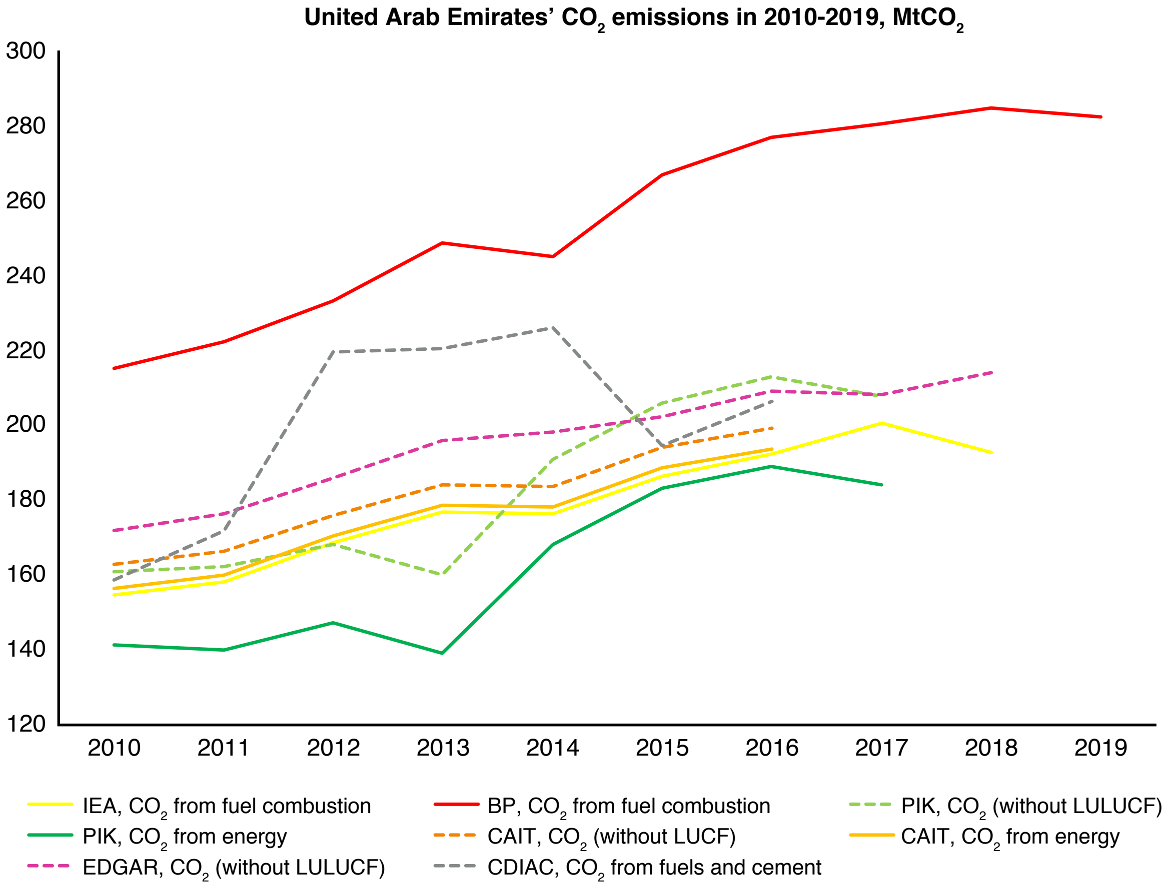
Appendix 1. Datasets Used in the Analysis.

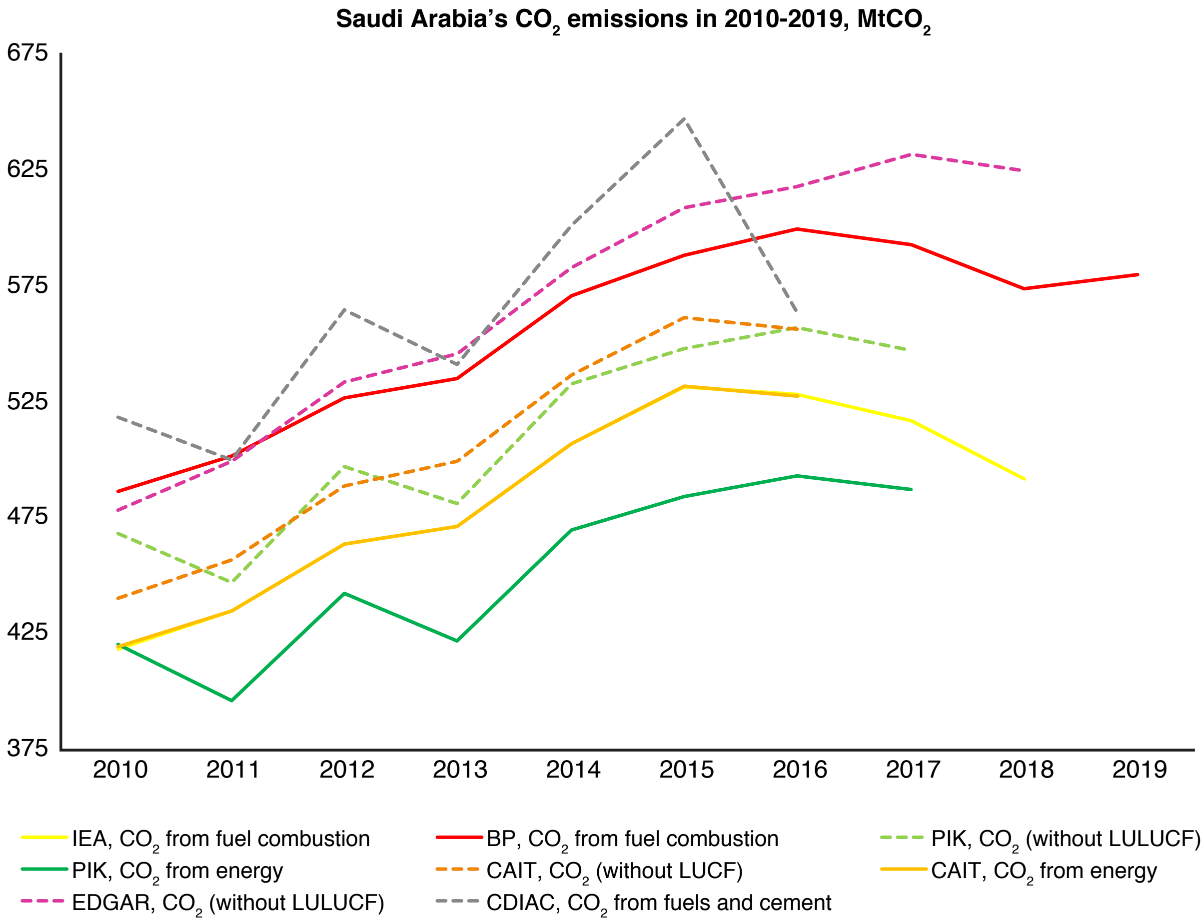
Provider	Description / methodology	GHG/CO_2 emissions data coverage	Availability (Dec. 2020)
BP	Based on “Default CO_2 Emissions Factors for Combustion,” listed by the Intergovernmental Panel on Climate Change (IPCC) in its Guidelines for National Greenhouse Gas Inventories (2006). Does not include sequestered carbon dioxide (CO_2), other sources of emissions or other greenhouse gas (GHG) emissions.	CO_2 from oil, gas and coal consumption for combustion-related activities	1965-2019
Climate Analysis Indicators Tool (CAIT), World Resources Institute	The most comprehensive dataset on Climate Watch. Emphasizes comparability of data across countries. Does not use countries’ official inventories reported to the United Nations Framework Convention on Climate Change (UNFCCC). Data sources: CDIAC, IEA, U.S. Environmental Protection Agency and Energy Information Administration and the Food and Agriculture Organization of the United Nations (FAO).	All GHGs. Main IPCC sectors, including energy sub-sectors	1990-2016
Carbon Dioxide Information Analysis Center (CDIAC)	Retrieved from World Bank Data. Provided by the U.S. Department of Energy. Calculates annual anthropogenic emissions from data on fossil fuel consumption (from the U.N. Statistics Division’s World Energy Data Set) and world cement manufacturing (from the U.S. Department of the Interior’s Geological Survey, USGS 2011). Estimates of global CO_2 emissions are probably accurate within 10% (as calculated from global average fuel chemistry and use). Country estimates may have larger error bounds.	CO_2 from the burning of fossil fuels and the manufacture of cement, including that used for the consumption of solid, liquid, and gas fuels and gas flaring	1960-2016
Emission Database for Global Atmospheric Research (EDGAR)	Produced by the European Commission, the Joint Research Centre and the Netherlands Environmental Assessment Agency. Emissions in CO_2_excl_short-cycle_org_C include all fossil CO_2 sources, such as fossil fuel combustion, non-metallic mineral processes (e.g., cement production), metal (ferrous and non-ferrous) production processes, urea production, agricultural liming and solvents use. Mainly based on the IEA’s energy balance statistics for energy-related sectors. Data for agriculture are mainly from the FAO.	Total CO_2 emissions, excluding land use, land use change and forestry (LULUCF); large-scale biomass burning with savannah burning; and forest fires	1970-2018
Enerdata	Enerdata obtains historical data from the IEA. Estimates for the most recent years are based on energy market data from regional organizations, specialized institutions and national sources and on IPCC emissions coefficients (Enerdata 2020).	Total CO_2 emissions, including sectors, subsectors and fuel types and excluding LULUCF	1970-2019
Government of Saudi Arabia	GHG emissions inventories submitted to the UNFCCC as part of National Communications (I-III) and a Biennial Update Report (I)	CO_2, CH4 and N_2O	1990, 2000, 2010, 2012
International Energy Agency (IEA)	Includes CO_2 emissions from fuel combustion in IPCC Source/Sink Category 1 A Fuel Combustion Activities. Also includes those that may be excluded from the Sectoral Approach and reallocated to IPCC Source/Sink Category 2 Industrial Processes and Product Use (IPPU) under the 2006 IPCC Guidelines. The IEA calculates CO_2 emissions using its own energy balances, which, in turn, are based on a variety of national and international sources. It uses the default methods and emissions factors of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IEA 2020b). Sources for the IEA’s energy balance data include Saudi Aramco, the Saudi Arabian Monetary Agency and Saudi Arabia’s Electricity and Cogeneration Regulatory Authority. They also include Saudi Arabia’s General Authority for Statistics, the Joint Organisations Data Initiative, OPEC and the International Renewable Energy Agency (IEA 2020c).	CO_2 emissions from fuel combustion, including energy and IPPU	1960-2018/2019
Potsdam Institute for Climate Impact Research	Provides the PRIMAP-hist dataset, available via Climate Watch. Based on countries’ official inventories reported to the UNFCCC. Missing data are filled in using other sources, including CDIAC, EDGAR and FAO.	All GHGs. Does not include land use change and forestry but covers all other main IPCC sectors.	1850-2017

Appendix 2. Comparison of CO_2 Emissions Estimates for Selected Countries.

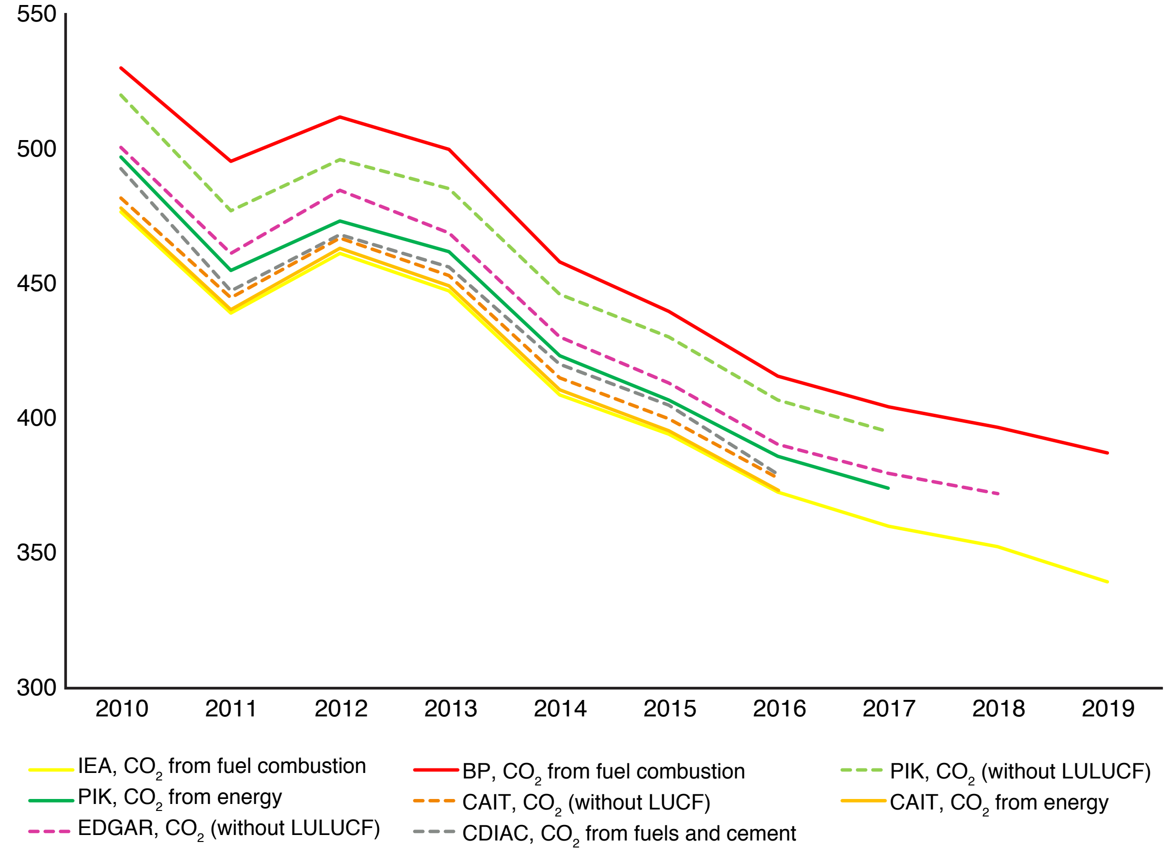




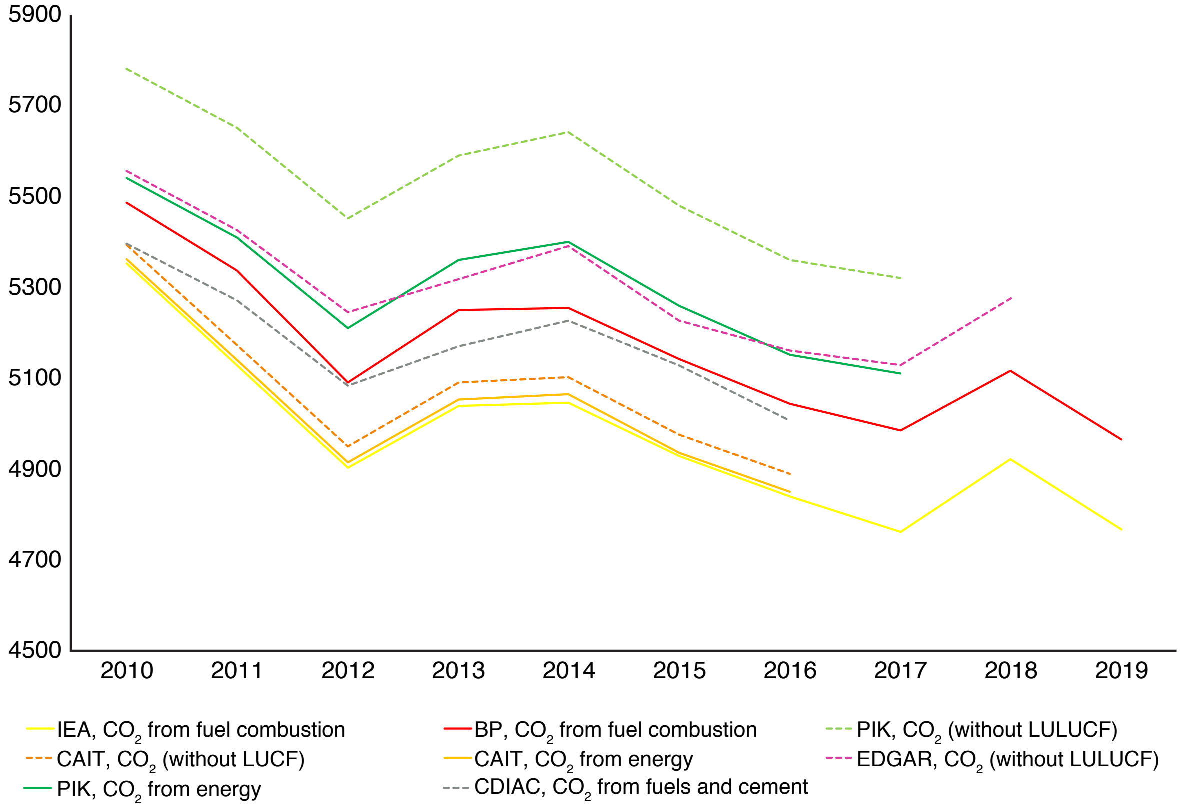

United Arab Emirates' CO_2 emissions in 2010-2019, $MtCO_2$
300
280
260
240
220
200
180
160
140
120
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
IEA, CO_2 from fuel combustion
BP, CO_2 from fuel combustion
PIK, CO_2 (without LULUCF)
PIK, CO_2 from energy
CAIT, CO_2 (without LUCF)
CAIT, CO_2 from energy
EDGAR, CO_2 (without LULUCF)
CDIAC, CO_2 from fuels and cement


Saudi Arabia's CO_2 emissions in 2010-2019, $MtCO_2$
675
625
575
525
475
425
375
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
IEA, CO_2 from fuel combustion
BP, CO_2 from fuel combustion
PIK, CO_2 (without LULUCF)
PIK, CO_2 from energy
CAIT, CO_2 (without LUCF)
CAIT, CO_2 from energy
EDGAR, CO_2 (without LULUCF)
CDIAC, CO_2 from fuels and cement

United Kingdom's CO_2 emissions in 2010-2019, $MtCO_2$



United States' CO_2 emissions in 2010-2019, $MtCO_2$



Source: Authors, based on the databases described in Appendix 1. All data retrieved on November 24, 2020.

Appendix 3. United Nations Framework Convention on Climate Change Reporting Obligations and Status.

International greenhouse gas (GHG) emissions monitoring, reporting and verification (MRV) arrangements aim to ensure transparency around emissions among countries and stakeholders, including through international expert reviews. Transparent and up-to-date emissions information helps build trust among countries as they seek to reduce emissions. It also underpins the development of aggregate estimates of global progress toward common goals. Transparency around emissions (and the support provided and received to reduce them) can also support policymaking by identifying gaps in implementation.

Under the UNFCCC (agreed in 1992 and in force since 1994), different GHG emissions reporting and review obligations apply to countries classified as Annex I (developed) and non-Annex I (developing countries). Annex I countries include OECD members (as of 1992) and economies in transition. Non-Annex I countries are all other countries.

Until recently, the UNFCCC transparency system was bifurcated so that different rules and review processes applied to each group. Annex I countries were required to report their emissions (through National Communications and GHG inventories) more frequently and in more detail. In addition, the Kyoto Protocol (agreed in 1997 and in force since 2005) required developed countries with emissions reduction commitments to submit supplementary information.

Under the UNFCCC, developed and developing countries have been required to submit biennial updates of their emissions inventories and mitigation actions (and related support) since 2014. These reports are known as Biennial Reports (BR) and Biennial Update Reports (BURs). In addition, countries are expected to submit National Communication (NC) reports every four years. In practice, developed countries have generally been able to meet these requirements, with exceptions when reporting on the provision of support to developing countries. In contrast, many developing countries have been "struggling with aspects of reporting" (ECBI 2019, 13). As of February 2021, only five non-Annex I countries had submitted all four BURs (13 had submitted three, 33 had submitted two and 63 had submitted one). By comparison, all but two Annex I countries had submitted all four BRs (UNFCCC 2021). Appendix Table 1 lists the UNFCCC reports submitted by the example countries included in Appendix 2.

Appendix Table 1. UNFCCC transparency reports submitted by six example countries.

	NCs and BRs/BURs submitted as of February 2021	Year of latest GHG inventory in a National Communication or BR/BUR
Annex I countries		
Norway	7 NCs and 4 BRs	2017 (and annual inventory for 2018)
United Kingdom	7 NCs and 4 BRs	2017 (and annual inventory for 2018)
United States	6 NCs and 2 BRs	2013 (and annual inventory for 2018)
Non-Annex I countries		
Saudi Arabia	3 NCs and 1 BUR	2012
Singapore	4 NCs and 4 BURs	2016
United Arab Emirates	4 NCs and 0 BURs	2014

The Paris Agreement (agreed in 2015 and in force since 2016) introduced the Enhanced Transparency Framework, a new system that builds on the existing arrangements. The major difference is that BRs and BURs will be superseded by Biennial Transparency Reports (BTRs). These new reports have common guidelines for all countries, with built-in flexibility for developing countries. The BTRs also provide a tool for reporting progress on countries' nationally determined contributions under the agreement. Some details of the guidelines remain under negotiation at the time of this writing. However, all parties to the agreement are expected to start submitting BTRs in 2024.

About the Project

Energy productivity is a paradigm for evaluating energy policy. It is increasingly being used by G20 governments and leading companies looking to maximize the value created from energy use. At the most basic level it involves using metrics, such as energy intensity, to measure and manage the relationship between economic growth and energy consumption. For Saudi Arabia, increasing the value created from each unit of energy consumed can help to achieve the Saudi Vision 2030 objectives, addressing climate change and making progress toward the United Nations' Sustainable Development Goals.

A common problem facing governments is that different elements of energy policy such as conventional power, renewable energy, energy efficiency and industrial strategy are often pursued in isolation or compete with each other for attention. Energy productivity can be also used as a strategic policy framework to help integrate such issues for better whole-of-government decisions. It does this by focusing attention on minimizing the costs of providing energy services while maximizing the benefits of energy consumption.

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The King Abdullah Petroleum Studies and Research Center (KAPSARC) is a non-profit global institution dedicated to independent research into energy economics, policy, technology and the environment across all types of energy. KAPSARC's mandate is to advance the understanding of energy challenges and opportunities facing the world today and tomorrow, through unbiased, independent, and high-caliber research for the benefit of society. KAPSARC is located in Riyadh, Saudi Arabia.

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